BEST PRACTICES RESEARCH TO INFORM MUNICIPAL WATER UTILITY DECARBONISATION

Prepared by: Mohammad AmirRahmani
UBC Sustainability Scholar, 2024

Prepared for: Nazli Azimikor, Senior Engineer
Dam Safety, Water Services
Metro Vancouver
August 2024

Disclaimer

This report was produced as part of the UBC Sustainability Scholars Program, a partnership between the University of British Columbia and various local governments and organisations in support of providing graduate students with opportunities to do applied research on projects that advance sustainability and climate action across the region.
This project was conducted under the mentorship of Metro Vancouver staff. The opinions and recommendations in this report and any errors are those of the author and do not necessarily reflect the views of Metro Vancouver or the University of British Columbia.

Table of Contents

List of Figures

List of tables

Introduction

This study explores the strategies and approaches that leading municipalities worldwide are in using to transition their water utilities to a low-carbon future.

Cities like Prague, Glasgow, Amsterdam, and San Francisco exemplify the global effort to decarbonize drinking water utilities. This research will conduct a jurisdictional scan of regional and municipal water utilities leading the way in decarbonization. By analyzing case studies, policy frameworks, and technological advancements, the study aims to identify key success factors, challenges, and best practices that have enabled these cities to significantly reduce greenhouse gas emissions in their water supply and treatment systems. The findings will be compiled into an inventory of practices, a final report, and a presentation.

Toward GHG Reduction and Net-Zero in the Water Sector

The water sector is increasingly confronted with challenges such as rapid population growth, climate change, extreme weather events, frequent and intense floods and droughts, deteriorating water quality, and aging infrastructure. To address these issues, new paradigm are emerging that integrate energy management, greenhouse gas (GHG) reduction, resource recovery, and climate resilience into water management strategies.

The Intergovernmental Panel on Climate Change (IPCC) categorizes emissions into three scopes: Scope 1 includes direct GHG emissions from sources owned or controlled by the reporting organization; Scope 2 encompasses indirect emissions from the generation of purchased energy (such as electricity, heat, and steam), which are considered indirect due to their origin outside the entity's immediate operations; and Scope 3 covers all other indirect emissions not included in Scope 2, such as those from the production of materials, extraction of raw materials, disposal of waste products, rental of vehicles, and outsourcing of maintenance services (Zhang et al., 2021).

According to the International Energy Agency (IEA), in 2015, approximately 4% of the world's electricity was consumed to transport and treat water and wastewater – a figure expected to nearly double within 25 years (United Nations Environment Programme, 2017). Nearly 40% of energy for water infrastructure comes from fossil fuels (International Climate Initiative, 2020). Hence, Scope 2 and Scope 3 GHG reductions in the water sector are more significant than Scope 1. Water services' challenges toward decarbonization varies, however, their main source of GHGs is in Scope 2 and Scope 3, unlike Metro Vancouver.

Many countries, cities, and industries have pledged to meet the goals of the Paris Agreement (UN, 2016) and achieve net-zero emissions by 2050. However, the financial burden of becoming climate resilient along with transitioning to net zero, and ensuring the safe supply of water, presents a significant challenge for companies. This is further complicated by the limitations public companies face in adjusting service prices to offset capital deficiencies. Consequently, decarbonization in most cities is a complex task that necessitates a comprehensive and holistic approach. The water sector needs more than one solution to achieve carbon neutrality (Ren & Pagilla, 2022). A combination of approaches and collaboration among different stakeholders are needed. These solutions could include applying advanced technologies, implementing new policies and practices, and making behavioural changes.

Green House Gases in Water Utility

Scope 1 – Direct Emissions

Design and construction of new facilities

The construction of water infrastructure is a significant contributor to Scope 1 emissions. In the water sector, these emissions typically result from on-site fuel combustion in construction machinery and vehicles, as well as from the use of materials. The energy-intensive nature of construction, which often relies on diesel and other fossil fuels, directly contributes to the release of GHG emissions. Additionally, the production and use of construction materials, such as concrete and steel, are associated with substantial GHG emissions.

As the demand for water infrastructure grows with urban expansion and climate resilience initiatives, it is crucial to incorporate sustainable design and construction practices that minimize these direct emissions. This can be achieved by adopting low-emission construction technologies, using alternative fuels, and implementing energy-efficient systems within the utility operations.

Water supply and treatment

These emissions primarily arise from the combustion of fossil fuels used in operating pumps, generators, and other essential equipment. For instance, diesel or natural gas-powered pumps are often used to extract, transport, and transfer water from sources to treatment facilities and storage tanks. Maintenance activities that involve the use of service vehicles and equipment could also contribute to Scope 1 emissions, as these activities often depend on the use of gasoline or diesel.

Furthermore, the operational processes could have GHG emissions releases, such as backup generators during power outages, if they are using fossil fuels. Likewise, emergency generators, often fueled by diesel or natural gas, are essential for ensuring a continuous water supply but contribute directly to GHG emissions when in use. Transitioning to renewable energy sources, adopting energy-efficient technologies, and optimizing operational processes are crucial for reducing water supply systems' Scope 1 emission footprint.

Scope 2 – Indirect Emissions from Energy Purchased

Scope 2 emissions are the indirect GHG emissions from the electricity purchased to power various activities in transporting and treating water. Mitigating these emissions primarily involves transitioning to renewable energy sources such as wind, hydro, solar, geothermal, and biomass. Additionally, improving the efficiency of energy systems within water utilities plays a crucial role in reducing overall energy consumption, helping to reduce overall energy costs.

Pumping

To enhance efficiency in pumping systems, key strategies include upgrading to high-efficiency pumps, optimizing pump operation schedules, and incorporating variable frequency drives (VFDs). Regular maintenance and monitoring are essential to ensure pumps operate at peak performance, minimizing energy waste due to mechanical issues or inefficiencies. Moreover, integrating intelligent water management systems that leverage real-time data and analytics can further identify opportunities for energy savings and operational improvements.

Treatment process

In water treatment plants, Scope 2 emissions primarily arise from the electricity used to power various processes, including pumping, filtration, disinfection, and chemical dosing. If this electricity originates from fossil fuels, it becomes critical to improve the energy efficiency of these treatment operations and transition towards renewable energy sources to reduce Scope 2 emissions effectively.

Scope 3 – Other Indirect Emissions

Scope 3 emissions in the water cycle include all indirect sources of GHGs that fall outside of the scope 1 and scope 2. These emissions arise from upstream and downstream activities within the broader water treatment and supply chain. Key areas contributing to scope 3 emissions can include:

- Purchased/leased goods and services
- Transportation and distribution
- Generated waste

To achieve net-zero emissions and ensure comprehensive accountability, organizations must evaluate their entire supply chain. This involves assessing the full scope of their activities to understand and mitigate their total environmental impact. Water utility companies can collaborate with suppliers who actively manage and report their GHG emissions and by optimizing their procurement practices.

Objective and Methodology

This primary objective of this project is to thoroughly examine the strategies and approaches employed by municipalities worldwide that have successfully decarbonized their water utilities. By focusing on leading examples, this research aims to identify key drivers, challenges, and best practices that have enabled these cities to significantly reduce GHGs within their water supply and treatment systems.

The project will begin with a comprehensive jurisdictional scan of regional and municipal water utilities that are at the forefront of decarbonization efforts. This scan will involve compiling a list of relevant cities and summarizing their initiatives and outcomes. The selected utilities will encompass a diverse range of geographical, infrastructural, and regulatory contexts to ensure a comprehensive representation. This phase involved desktop research to gather data on each city's decarbonization strategies and practices.

Following the jurisdictional scan, a subset of jurisdictions with similar characteristics and challenges to Metro Vancouver will be identified for detailed case study analysis. This analysis will delve into the specific strategies, technologies, policies, and collaborative approaches employed by these utilities.

Jurisdictional Scan

In selecting cities for this research on decarbonizing municipal water utilities, a multi-faceted approach is used to ensure a comprehensive and diverse representation. Various sources were used, including academic literature that provided in-depth analyses and case studies on effective strategies and outcomes in different regions. Additionally, cities that are part of global networks such as the C40 Cities Climate Leadership Group, Net Zero Cities initiative, and the Carbon Neutral Cities Alliance were included, as these networks consist of cities committed to ambitious climate action goals. Figure 1 illustrates 46 selected cities on a global map, which were studied for the initial scan. The list of cities include Amsterdam, Athens, Austin, Barcelona, Berlin, Boston, Boulder, Chicago, Copenhagen, Glasgow, Heidelberg, Helsinki, Houston, Istanbul, Iowa, LA, Lisbon, London, Madrid, Melbourne, Miami, Milan, Minneapolis, Montreal, New Orleans, NYC, Oslo, Paris, Philadelphia, Phoenix, Portland, Rio de Janeiro, Prague, Rome, Rotterdam, Seattle, SF, Stockholm, Sydney, Tel Aviv, Tokyo, Toronto, Warsaw, Washington DC, Yokohama.

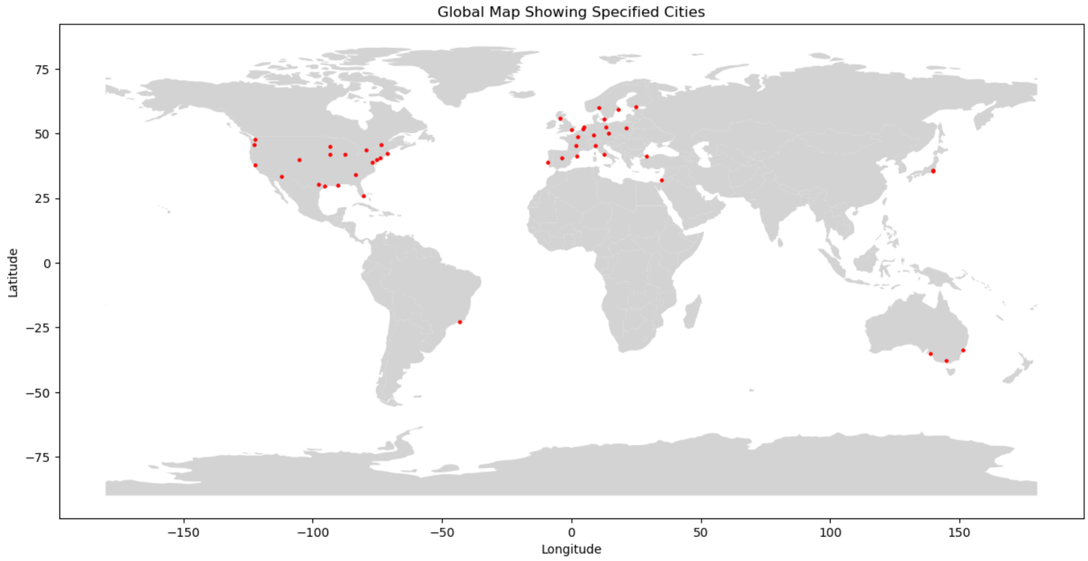

Figure 1 Diversity of initially selected cities on a global map

Initial Scan

The primary criterion for shortlisting cities in the first step was the availability of publicly accessible data. This criterion ensures that sufficient and reliable information is available for thorough analysis.

After scanning the public portals of these 46 selected cities and reviewing relevant literature, 14 cities were shortlisted. These cities are shown on a global map in Figure 2. The shortlisted cities are Adelaide, Amsterdam, Athens, Chicago, Glasgow, London, Madrid, Melbourne, Miami, Portland, Prague, San Francisco, Sydney, and Tokyo.

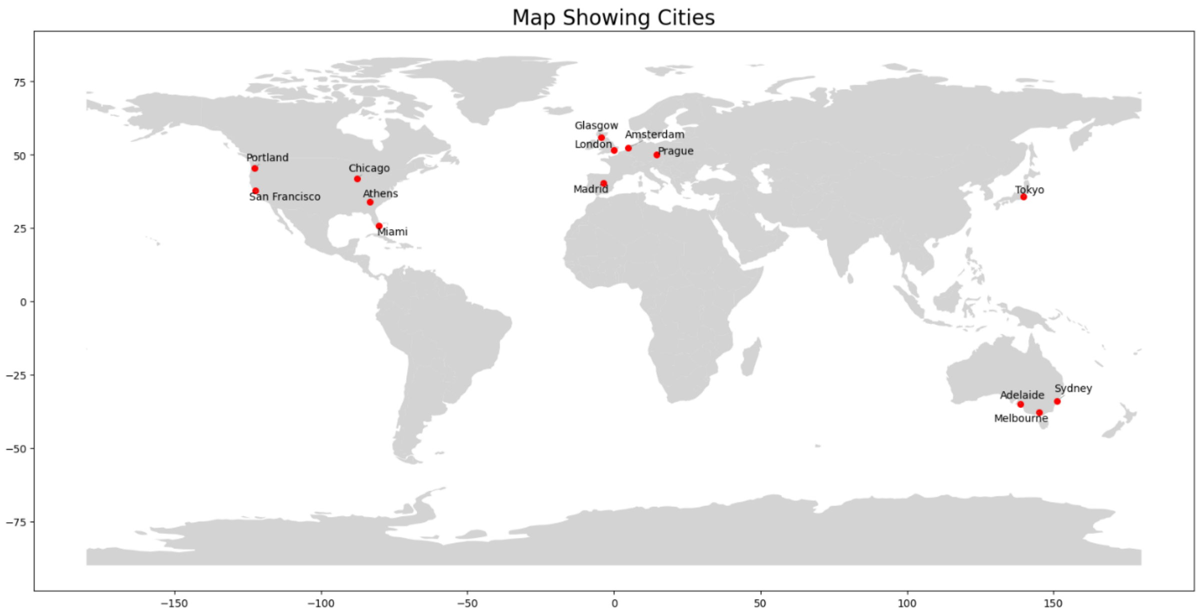

Figure 2 Shortlisted cities on a global map

Practices of Selected Cities

A comprehensive table has been compiled, detailing the best practices employed by the 14 selected cities in their efforts to decarbonize municipal water utilities. Table 1 provides an overview of the strategies and implementation approaches utilized by these cities.

Table 1 List of practices and policies selected cities have taken toward net zero

City	Scope 1 Practices	Scope 2 Practices	Scope 3 Practices	Combined	References
Adelaide	• Transitioning to EV fleet	• Installing 37,000 solar panels		• Made changes in business strategies including "Proactive Environmental Leadership", which includes: 1. Climate change action with a reduce and reuse mindset 2. Waste reduce 3. Increased by-product reuse 4. Climate change resilience	(AECOM, 2024; Government of South Austraulia, 2024)
Amsterdam	• Side stream dosing of ozone in drinking water • Installing frequency-controlled pumps	• Dependent to the municipality's energy transition strategy • Installing 5 wind turbines		• Used an office's heat management system	(Van Der Hoek et al., 2016)
Athens	• Applying pump energy saving and efficiency increasing plans • Upgrading processes in treatment plants	• Installing 6 new hydro plants • Installing a new solar panel system • Exploit biogas in wastewater for electricity and thermal energy	• Constructing new WWTP to reuse water for irrigation, industry and hydrogen production • Recycling office waste	• Making office buildings bioclimatic	(EYDAP, 2024)
Chicago		• Installing solar panels • Utilization of biogas for energy and replacing that with natural gas • Energy saving program for all six treatment plans		• Carbon sequestration plans • Infrastructure upgrade plans	(Metropolitan Water Reclamation District of Greater Chicago, 2023)

City	Scope 1 Practices	Scope 2 Practices	Scope 3 Practices	Combined	References
Glasgow	• Transitioning to low carbon construction • Changing whole fleet to EV cars	• Operating all assets with renewable energy		• Carbon storage plans for carbon that cannot be avoided	(Scottish Water, 2024)
London	• Applying energy and fuel efficiency increase plans • Exploring low carbon process to replace existing process	• Investing on building a sustainable energy supply chain		• Including GHG of outsource activities • Considering carbon offsets, capture, storage and sequestration opportunities	(Thames Water, n.d.)
Madrid		• Installing microturbines on pipelines • Installing solar panels		• Shifting to cogeneration plants to improve energy and heat efficiency	(Canal de Isabel II, 2024)
Melbourne		• Transition to solar energy in head offices		• Their practices are mostly projected in water-energy nexus like Showering behaviour change, shower head replacement incentive, community engagement and education, building level water and heat saving	(Kenway et al., n.d.; Lam et al., 2018; Satur, 2023)

City	Scope 1 Practices	Scope 2 Practices	Scope 3 Practices	Combined	References
Miami	• Reducing transportation related fuel consumption, • Taking into account their air travel in GHG estimation and reducing it	• Expanding renewable energy generation • Convert waste to energy	• Reduce waste and water use	• Their practices are mostly projected in water-energy nexus like constructing ultra-low energy buildings. • Expand and protect green and blue spaces.	(Miami-Dade County, 2021)
Portland	• Increased efficiency of pumps • Replaced variable frequency pumps • Complied to green building policy of City of Portland • Transitioning to hybrid and EV fleets • LEED certified budlings	• Installing solar panels for warehouses		• Making roof of offices and buildings eco. • Digitally controlling heating, ventilation and cooling system for buildings	(Portland Water Bureau, 2020)
Prague	• Reducing process emissions • Taking into account employee's journey to work and planning for that • Taking into account business travel's and planning to be more sustainable about that		• Waste management plans • Considering sustainable companies in material and service procurement		

City	Scope 1 Practices	Scope 2 Practices	Scope 3 Practices	Combined	References
San Francisco	• Have innovation program for their water utilities			• Their plans mainly focus on reduction of water consumption • Implementing atmospheric water generation to test it for community garden's irrigation • Subsidize breweries which reuse process water • Subsidize integration of heat recovery onsite and water reuse • Water reuse program for domestic use	(San Francisco Environment Department, 2023)
Sydney		• Have co-digestion programs, turning food waste into renewable energy • Use of biogas from organic waste into energy • Use stormwater for cooling some systems	• Driving a decarbonisation of supply chain program	• Use of recycled water for industry	(Sydney Water, n.d.)
Tokyo	• Installing energy saving pumps • Switching to Zero Emission Vehicle (ZED) fleet	• Installing solar panels • Installing small hydropower • Procuring environmentally friendly energy	• Reducing waste and recycling programs • Going paperless in the department • Reducing plastic usage	• Water saving and greenery protection programs in water facilities	(Bureau of Waterworks, 2020)

City	Scope 1 Practices	Scope 2 Practices	Scope 3 Practices	Combined	References
				• Collaborate with local government and residents on GHG reduction • Distribute program's information and gather customer feedback • Encourage employees to attend forest preservation activities • International cooperation and information dissemination abroad • Rising awareness about GHG among staff • Collaborate with private companies on GHG reduction • Collaboration with universities on GHG reduction programs	

Characteristics and Drivers

Despite the absence of a global mandate (Ren & Pagilla, 2022) requiring water utilities to achieve net-zero emissions, many cities are making remarkable progress in this area. Table 2 details the characteristics of these proactive cities, including their local mandates and drivers, population sizes, and last disclosed GHG levels. This information highlights the diverse approaches and strong commitments of these cities as they work toward decarbonizing their water utilities and contributing to broader climate action goals.

Table 2 Characteristics of selected cities

City	Country	Signed Paris agreement	National mandate on decarbonisation	Local mandate/policy on decarbonisation	Population	GHG level of water utility (ktCO2e)	References
Vancouver	Canada	Yes	Net-Zero Emissions Accountability Act: Passed by 2021, net-zero by 2050	CleanBC Plan: Launched in December 2018, CleanBC is the province's climate action strategy designed to reduce greenhouse gas emissions while promoting clean economic growth. It outlines various measures across different sectors, including energy, buildings, transportation, and industry. The primary goal of CleanBC is to reduce greenhouse gas emissions by 40% below 2007 levels by 2030, 60% by 2040, and to achieve net-zero emissions by 2050.	2.7 million	2.05 in scope 2 (2021)	Shared data with the scholar and (CleanBC, n.d.; Government of Canada, 2021)
Adelaide	Australia	Yes	Net-Zero Emissions by 2050: In October 2021, the Australian government formally committed to achieving net-zero emissions by 2050. This commitment aligns Australia with global efforts to limit global warming to 1.5 degrees Celsius above pre-industrial levels.	The Act was amended in 2010 to set a target of reducing greenhouse gas emissions by at least 60% by 2050 compared to 1990 levels, and in 2020, South Australia committed to achieving net-zero emissions by 2050.	1.4 million		(Australian Government, 2022; Environment SA News, 2021)
Amsterdam	The Netherlands	Yes	Climate Act (Klimaatwet): The Climate Act, which came into force in 2019, legally commits the Netherlands to reducing CO2 emissions by 95% by 2050 compared to 1990 levels. It also sets an interim target of a 49% reduction by 2030.	The Regional Energy Strategy (RES) for North Holland outlines how the province plans to contribute to national climate targets. It includes strategies for increasing renewable energy generation, improving energy efficiency, and reducing greenhouse gas emissions. Amsterdam, as part of North Holland, has ambitious plans to become a zero-emission city	905,000	110 (1990), 48.175 (2013)	(City of Amsterdam, n.d.-a; Climate Laws of the World, 2019)

City	Country	Signed Paris agreement	National mandate on decarbonisation	Local mandate/policy on decarbonisation	Population	GHG level of water utility (ktCO2e)	References
				by 2030, banning petrol and diesel cars and promoting electric and shared mobility solutions.			
Athens	Greece	Yes	National Energy and Climate Plan (NECP): Greece's NECP, submitted to the European Commission, outlines the country's strategy for reducing greenhouse gas emissions by 55% by 2030 compared to 1990 levels, and achieving net-zero emissions by 2050. This plan includes specific targets and measures for various sectors, including energy, transport, industry, and agriculture.		664,000		(Greek National Energy and Climate Plan, 2022)
Chicago	USA	Yes	Executive Orders and Legislation: President Biden has issued several executive orders aimed at addressing climate change, including the rejoining of the Paris Agreement and setting the goal of achieving net-zero emissions by 2050.	The Illinois EPA developed the ICAP to outline strategies and actions to reduce greenhouse gas emissions and adapt to climate change impacts. The plan includes goals for energy efficiency, renewable energy, transportation, and resilience.	2.7 million		(Illinois EPA, 2024; U.S Department of State, 2021)
Glasgow	UK	Yes	The UK passed the Climate Change Act in 2008, which originally set an 80% reduction target in greenhouse gas emissions by 2050 compared to 1990 levels. In June 2019, this target was upgraded to a legally binding commitment to achieve net-zero emissions by 2050.	Emission Reduction Targets: The council has set a net zero target for 2030. Measures include improving energy efficiency in council buildings, reducing waste sent to landfills, and decarbonizing transport systems.	635,000	217 (2021-22)	(Glasgow City Council, 2024; Scottish Water, 2024; UK

City	Country	Signed Paris agreement	National mandate on decarbonisation	Local mandate/policy on decarbonisation	Population	GHG level of water utility (ktCO2e)	References
							Government, 2019)
London	UK	Yes	Same as Glasgow	Greater London has an ambitious plan to achieve net-zero carbon emissions by 2030. This plan, involves several strategies and initiatives aimed at significantly reducing greenhouse gas emissions.	9 million		(Element Energy, 2021)
Madrid	Spain	Yes	Climate Change and Energy Transition Law: Spain passed the Climate Change and Energy Transition Law in 2021, which sets ambitious targets for reducing greenhouse gas emissions. The law includes a target to achieve net-zero emissions by 2050 and an interim goal of reducing emissions by at least 23% by 2030 compared to 1990 levels.		3.3 million		(Santos, 2024)
Melbourne	Australia	Yes	Same as Adelaide	Victoria's climate change strategy is to become net-zero and climate resilient by 2050. And City of Melbourne's is leading to become net-zero a decade earlier, in 2040.	5 million		(Victoria State Government, 2021)
Miami	USA	Yes	Same as Chicago	2008's Florida Climate Change Action Plan does not set a target, and proposes recommendation to different sectors. Miami-Dade Country Climate Change Action Plan commits to	470,000		(Miami-Dade County, 2021)

City	Country	Signed Paris agreement	National mandate on decarbonisation	Local mandate/policy on decarbonisation	Population	GHG level of water utility (ktCO2e)	References
				reduction of GHG production to 80% below 2008			
Portland	USA	Yes	Same as Chicago	Oregon has set a target to achieve net-zero emissions by 2040. Portland's Climate Action Plan outlines ambitious goals to reduce GHG emissions and promote sustainability. The city aims to achieve net-zero carbon emissions by 2050.	665,000		(Oregan Legistlative Assembly, 2021)
Prague	The Czech Republic	Yes	National Energy and Climate Plan (NECP): The Czech Republic submitted its NECP to the European Commission as part of the EU's collective effort to meet climate targets. The plan outlines targets and measures for reducing greenhouse gas emissions, increasing renewable energy sources, and improving energy efficiency. The targets are designed to contribute to the EU's goal of achieving at least a 32% share of renewable energy in the EU's gross final energy consumption by 2030.	The Central Bohemian Region, like other regions, aligns with national climate policies and contributes to the overall targets through local initiatives and projects focused on sustainability and reducing emissions. Prague has developed a Climate Action Plan that outlines the city's goals for reducing greenhouse gas (GHG) emissions and cut GHGs by 45% before 2030.	1.3 million	205.880 (2021)	(Climate Change Laws of the World, 2019; PRAHA 2030, n.d.; Srb et al., 2023)
San Francisco	USA	Yes	Same as Chicago	Enacted in 2006, California Global Warming Solutions Act (AB 32) legislation set a target to reduce GHG emissions to 1990 levels by 2020. The state has since extended its climate goals under various regulations and initiatives. Also	815,000		(California Government, 2018; Executive Department,

City	Country	Signed Paris agreement	National mandate on decarbonisation	Local mandate/policy on decarbonisation	Population	GHG level of water utility (ktCO2e)	References
				California has committed to achieving carbon neutrality by 2045 under Executive Order B-55-18. Francisco's Climate Action Plan sets a goal to achieve carbon neutrality by 2040.			State of Caifornia, 2018)
Sydney	Australia	Yes	Same as Adelaide	New South Wales has established a framework to address climate change, which includes goals for reducing GHG emissions, improving energy efficiency, and transitioning to renewable energy sources. The state has committed to achieving net-zero emissions by 2050. Sustainable Sydney 2030 plan outlines Sydney's vision for becoming a more sustainable city by 2030.	5.4 million		(NSW Climate and Energy Action, 2024; Sydney Water, n.d.)2024-09-05 11:01:00 AM
Tokyo	Japan	Yes	Long-Term Strategy under the Paris Agreement: Japan submitted its Long-Term Strategy under the Paris Agreement in 2020, which outlines its pathway towards achieving carbon neutrality by 2050. This strategy includes sector-specific targets and measures for achieving emission reductions.	Tokyo's Climate Action Plan aims to reduce greenhouse gas (GHG) emissions by 30% by 2030 compared to 2000 levels.	9.7 million	395.809 (2023)	(Bureau of Waterworks, Tokyo Metropolitan Government, 2024; The Government

City	Country	Signed Paris agreement	National mandate on decarbonisation	Local mandate/policy on decarbonisation	Population	GHG level of water utility (ktCO2e)	References
							of Japan, 2021)

Analysis and Comparison

Table 1 outlines a range of decarbonization practices across different cities, to mitigate Scope 1, Scope 2, and Scope 3 GHG emissions, as well as supporting processes.

Scope 1 Practices: Direct Emission Reductions

Scope 1 practices involve direct emission reductions from owned or controlled sources. For instance:

- Adelaide and Glasgow are transitioning to electric vehicle (EV) fleets to reduce emissions from transportation.
- Athens focuses on energy-saving initiatives in pump operations and upgrading treatment plants.
- London and Portland emphasize energy and fuel efficiency and the transition to hybrid fleets.
- Tokyo has installed energy-saving pumps and is switching to zero-emission delivery (ZED) fleets.

These initiatives reflect the cities' commitment to reducing direct emissions through improvements in vehicle efficiency and optimizing energy use in critical infrastructure.

Scope 2 Practices: Reducing Indirect Emissions

Scope 2 practices involve reducing indirect emissions from purchased electricity, steam, heating, and cooling. Cities are making significant investments in renewable energy:

- Adelaide, Athens, and Chicago are installing solar panels, with Athens also constructing hydro plants and utilizing biogas.
- Melbourne transitions to solar energy in head offices, while Portland installs solar panels for warehouses.
- Tokyo integrates solar panels and small hydropower systems.

These efforts signify a shift towards cleaner energy sources to power municipal operations.

Scope 3 Practices: Managing Indirect Emissions

Scope 3 practices include all other indirect emissions in a company's value chain. Examples include:

- Athens constructs new wastewater treatment plants to reuse water and recycle office waste.
- Miami expands renewable energy generation and converts waste to energy.
- Tokyo focuses on reducing waste, recycling, and going paperless within departments.

These strategies reflect efforts to manage emissions across the broader operational ecosystem.

Supporting Processes

Mixed practices target various emission scopes and general environmental resilience:

- Adelaide emphasizes proactive environmental leadership with a reduce-and-reuse mindset.
- Amsterdam utilizes office heat management systems, decreasing its dependence on municipal energy sources.
- Glasgow and London consider carbon storage and offsets for unavoidable emissions.
- Madrid shifts to cogeneration plants to improve energy and heat efficiency.
- Portland focuses on eco-roofs and digital HVAC control systems for buildings.
- Tokyo collaborates with local governments and communities on GHG reduction and engages in international cooperation.

Overall, Table 1 indicates that these cities are adopting a comprehensive approach to decarbonization, with efforts spanning direct emission reductions, renewable energy adoption, and extensive community and stakeholder engagement. Each city's practices reflect its unique context and priorities, contributing to the global objective of mitigating climate change.

In Australia, while **Adelaide** is supplying energy from a mix of renewable sources in addition to natural gas (Rahimi et al., 2023), both **Sydney** and **Melbourne** have cola in their energy mix (Gromek-Broc, 2023). It has been reflected in their strategies; **Melbourne** is taking strategies based on the energy-water nexus since they are also desalinating seawater for domestic use. Sydney focuses its plans on Scope 2. Because of the interaction of water and fossil fuel energy systems in **Sydney** and **Melbourne**, both cities prioritize saving water schemes. However, it can be concluded that Adelaide takes more comprehensive resolutions.

In Europe, **London** is independent of fossil energies (UK Electricity Production, 2024), and because of that, its actions are mostly in Scope 1 and Combined. They are working on their supply chain GHGs and studying carbon storage for the cases of unavoidable GHGs. The same approach can be seen in **Amsterdam** (City of Amsterdam, n.d.-b). They are not worried about Scope 2 GHGs, although they are investing in 5 wind turbines to reduce their costs along with their energy-saving plans in Scope 1. In **Athens**, while Greece is still using fossil fuels for energy production (Maniatis et al., 2023), it is seen that Athens's water department's focus is on reducing GHGs in Scope 2 and becoming energy independent. The same is true about Madrid; since the city has not been able to become net zero in energy, Canal de Isabel II's main concern is becoming energy-independent and reducing GHGs in Scope 2. Among all cities, **Glasgow** is similar to **Vancouver**. Almost all their energy comes from renewable sources, and they plan to become net zero earlier than 2050. Hence, their programs mainly focus on Scope 1 with drivers of saving costs and turning energy independent.

In the US, **Chicago's** plans are mainly related to Scope 2. Like some European cities, Chicago is investing in becoming energy-independent instead of focusing on Scope 1 emissions. **Portland** seems to have more progressive practice among US cities in study, and the reason could be that Oregon is also getting most of it energy from renewable sources (Oregan Government, n.d.).

Commitment to the Paris Agreement

All jurisdictions have committed to the Paris Agreement and have set targets for decarbonization at both national and local levels. There is notable variation in population sizes and reported GHG levels, highlighting diverse challenges and progress in decarbonization efforts. Most cities aim to achieve net-zero emissions by 2050, with some setting more ambitious targets for earlier dates, such as Vancouver (2040) and Glasgow (2030).

General Observations

Drivers

Policies

In Vancouver, both federal and provincial policies are driving the water sector towards achieving net-zero emissions. The federal government's commitment to the Paris Agreement influences national policies that encourage or require public sector companies, including water utilities, to adopt cleaner technologies and renewable energy sources. In British Columbia, the CleanBC plan sets ambitious targets for reducing emissions across all sectors, including water utilities. While CleanBC itself is not a regulation, it provides a framework that guides the development of policies and incentives aimed at reducing carbon emissions and promoting renewable energy adoption. Together, these initiatives are creating a strong policy environment that encourages the public sector in BC to work towards net-zero goals.

Carbon Tax and Financial Incentives

Regulations on carbon pricing, including carbon taxes and cap-and-trade programs in Canada, have created financial motivations for the water sector to reduce its carbon footprint. The federal carbon tax increases the cost of using fossil fuels for individuals, businesses and public companies. As a result, water utilities are increasingly motivated to invest in energy-efficient technologies and renewable energy projects to lower their operational and development costs. Federal initiatives, such as the Low Carbon Economy Fund, and provincial incentives like Innovative Clean Energy (ICE) (Government of British Columbia, 2024), provide rebates and grants for renewable energy installations, making it financially viable for companies to transition to renewable energies.

Voluntary initiatives and Public Pressure

In the absence of regulatory mandates and incentives, voluntary initiatives aimed at improving public welfare and conserving nature can motivate some water companies to reduce their greenhouse gas (GHG) emissions. By taking this proactive approach, these companies can position themselves as leaders in innovation and climate action.

Additionally, public pressure serves as a significant driver for companies to adopt net-zero strategies. As consumers increasingly demand more sustainable practices, companies face increased scrutiny and potential reputational risks if they fail to act.

Strategies

Conserve Water

Conserving water at the municipal level can significantly reduce GHG emissions. When water usage decreases, the demand for water extraction, treatment, and distribution also declines. This reduction in demand leads to lower energy consumption, as water treatment and distribution are energy-intensive processes. Moreover, conserving water reduces the volume of wastewater generated, which not only lowers the energy required for treatment but also decreases the emissions of non-CO2 GHGs, such as methane and nitrous oxide, that can be produced during wastewater treatment.

Reduce Water Loss

Reducing water loss through strategies such as proactive leak prevention, rapid repair of existing leaks, and upgrading aging infrastructure can significantly impact GHG emissions levels. Water loss represents not only wasted water but also the unnecessary consumption of energy and materials used in the treatment and transmission and distribution processes. By minimizing water loss, water utilities can ensure that energy and resources are used more efficiently, leading to a lower carbon footprint.

Maximize Internal Energy Generation

The water sector has considerable potential to reduce its dependency on fossil fuels by generating energy internally from renewable sources such as solar, wind, hydro and biogas. Water utilities can harness this potential by installing solar panels at their facilities, constructing hydro or micro-hydro plants on gravity-fed pipelines, and generating power from wastewater biogas.

Improving Energy Efficiency

Improving the energy efficiency of water utility operations is another effective strategy for reducing GHG emissions. This can be achieved by optimizing pumping systems, upgrading energy-efficient equipment, and implementing smart technologies for monitoring and managing energy use. Energy-efficient practices reduce the energy required for water extraction, treatment, and distribution, resulting in lower GHG emissions.

Maintain Equipment

Regular equipment maintenance is essential for ensuring that water utility systems operate at peak efficiency, significantly reducing GHG emissions. Proper maintenance helps the system run more efficiently, consume less energy, and extend lifespan of the equipment. Preventive maintenance also identifies and addresses issues before they lead to equipment failures or inefficiencies, which would otherwise result in higher energy use and increased emissions.

Challenges and Opportunities

Challenges

Energy Dependency and Stability

Energy dependency is a significant challenge for the water sector in achieving net-zero. Water utilities rely on consistent and reliable energy sources for their operation. Transitioning from fossil fuels to renewable energy can be complex and risky due to the variability and intermittency of renewables like solar and wind power. This dependency necessitates substantial investments in advanced energy storage solutions and grid enhancements to ensure a stable energy supply, which can be technically challenging and financially burdensome.

Moreover, the shift to renewable energy often requires a substantial overhaul of existing systems and processes. Many water utilities have long-standing contracts with traditional energy providers and infrastructure designed for fossil fuels. Breaking these dependencies involves navigating regulatory approvals, negotiating new energy agreements, and potentially facing resistance from stakeholders accustomed to the status quo. Achieving energy independence might also entail substantial investments in self-sufficient energy systems, such as microgrids or on-site renewable generation, which many water companies may lack the financial resources to fund. The need for a stable and continuous energy supply makes it critical for water utilities to meticulously plan and execute the transition to renewable energy, balancing reliability with sustainability goals.

Capital Investments

Capital investment is a significant obstacle for water sector aiming at achieving net-zero. The upfront costs associated with installing renewable energy systems, such as solar panels, wind turbines, and energy-efficient technologies, are major. Many water utilities operate with constrained budgets, and securing the necessary funding for these capital-intensive projects can be challenging. Even with government grants and incentives, the financial burden of such large-scale investments can deter utilities from pursuing effective decarbonization strategies.

Beyond the initial capital, maintenance and operational costs present another challenge. Renewable energy systems require specialized knowledge and skills to maintain, which may necessitate additional training for staff or hiring new personnel, adding another layer of financial complexity. Utilities must also account for potential downtime and the integration of new technologies into existing systems, further increasing costs and complicating the financial planning.

Resistance to change

Implementing change in the water sector to achieve net-zero is challenging due to the complexity and scale of operations, as well as the associated obstacles. Water utilities have established procedures, technologies, and infrastructure that have been optimized over decades. Transitioning to new, more sustainable practices requires significant alterations to these systems, which can disrupt daily operations and require extensive retraining of staff. Resistance to change is natural, especially in an industry where reliability and consistency are critical.

Moreover, the process of change includes uncertainties. Utilities must navigate regulatory landscapes while managing the expectations and concerns of stakeholders, including customers, employees, and government authorities.

New Technology and Material

Technological limitations pose significant challenges to the water sector's transition to net-zero. Advanced renewable energy technologies and energy-efficient systems are still evolving, and their integration into existing water utility infrastructure can be complex. In addition, utilities may lack the necessary technical expertise or face a shortage of proven scalable solutions. This challenge can be seen in the application of nature-based solutions in water supply since their application might require new expertise.

Moreover, replacing material vendors to reach net-zero in Scope 3 presents considerable difficulties. Navigating supply chain complexities, managing potential cost increases, and avoiding operational disruptions add layers of complexity and uncertainty, further complicating the path to achieving net-zero emissions.

Future Carbon Outlook for the Water Supply of Metro Vancouver

Locating Metro Vancouver Water Services Among Other Cities

MVWS stands out among all the cities in Table 2 for its comprehensive and advanced approach to decarbonization and GHG reduction. Leveraging abundant renewable energy resources in BC, mainly hydro, MVWS has successfully integrated renewable energy into its operations, significantly reducing its GHG emissions. The province's CleanBC Plan, which targets a 40%

reduction in GHG emissions by 2030 and net-zero emissions by 2050, showcases its commitment to leading climate action. MVWS is already implementing many of the advanced practices seen in other cities, setting a net-zero benchmark.

Adoptable Practices

Supply Chain and Material and Services Procurement

Adopting decarbonization practices in supply chain and material and services procurement is essential for reducing overall GHG emissions. This involves sourcing materials that have a lower carbon footprint and ensuring that suppliers adhere to environmentally friendly practices. By prioritizing procurement from suppliers who use sustainable methods, MVWS can significantly cut down indirect GHG emissions. This practice not only supports the local economy but also encourages suppliers to adopt greener technologies and processes, creating a ripple effect throughout the industry.

Moreover, public companies and their departments can implement policies that mandate the use of recycled or sustainably sourced materials in public projects. Integrating sustainability and GHG production criteria into procurement processes ensures that environmental considerations play roles in decision-making. This can lead to innovative solutions, such as the use of green building materials, energy-efficient products, and technologies that reduce waste. By setting strict environmental standards, public sector service companies can drive significant advancements in sustainable supply chains.

MVWS's reliance on soda ash for water treatment, which is primarily produced only in the US and Turkey, is an example that can pose a significant challenge if these suppliers do not comply with net-zero strategies. To align with its decarbonization goals, MVWS could consider several approaches to mitigate it. One option is to explore alternative materials that serve the same purpose but have a lower carbon footprint. Another strategy could involve investing in new technologies that reduce or eliminate the need for soda ash altogether. Additionally, MVWS could implement carbon capture and storage (CCS) programs to offset the GHG emissions associated with soda ash usage. By taking proactive measures, MVWS can ensure that its operations remain consistent with its net-zero objectives, even when faced with supply chain constraints.

Going Fully ZEV

Transitioning to zero-emission vehicles (ZEVs) is a transformative step towards achieving net-zero emissions. By replacing traditional internal combustion engine vehicles with electric or hydrogen-powered alternatives, cities can significantly reduce air pollution and GHG emissions. This transition can include not only water service vehicles but also incentivizing employees to switch to ZEVs. Metro Vancouver has already made most of its fleet electric, setting a strong example in transition to net-zero and needs to support the shift to ZEVs for the remaining vehicles, including heavy trucks. It is also beneficial to consider employees' travel to work, and business travels in GHG calculations, ensuring a comprehensive approach to reducing emissions across all aspects of municipal operations.

Taking Into Account GHG in the Decision-Making of Projects

Incorporating GHG considerations into the decision-making process and design of projects can be a very proactive move from MVWS. This practice ensures that the potential carbon footprint of projects is evaluated and minimized from the planning stage. By integrating GHG assessments, MVWS can identify the most effective strategies for reducing emissions and promoting sustainability.

Carbon Storage

Carbon storage is a critical strategy for offsetting GHG emissions that cannot be fully eliminated. Given that many of MVWS's facilities are located outside the city, it is essential to implement carbon capture and storage technologies tailored to these specific contexts. One suitable approach is direct air capture (DAC), which involves capturing CO2 directly from the ambient air. This technology can be particularly advantageous for remote facilities with large land areas, where DAC units can be installed without significant space constraints. The captured CO2 can then be transported and stored in geological formations, such as deep saline aquifers, which are often found in various locations across British Columbia. When replacing backup and emergency diesel generators is impossible, carbon capture can help offset their GHGs.

Water Consumption Saving Schemes

If MVWS aims to keep its development plans smaller and reduce GHG production, a critical strategy involves implementing comprehensive water-saving schemes. MVWS can significantly reduce water consumption by promoting water-efficient technologies, such as low-flow fixtures, smart irrigation systems, and greywater recycling. These technologies minimize the amount of water that needs to be treated and distributed. Encouraging widespread adoption of these technologies can significantly impact MVWS's overall environmental footprint in the future.

Education and Stakeholder Engagement

In addition to technological solutions, public education and engagement programs are essential to encourage residents and businesses to adopt water-saving practices and change their consumption behaviour. MVWS can organize workshops, community outreach events, and educational campaigns to raise awareness about the importance of water conservation and its contribution to battle and mitigate climate change. Providing incentives for reducing water use, such as rebates for installing water-efficient appliances or discounts on utility bills, can further motivate the community to participate in these initiatives.

References

AECOM. (2024, August 1). *Designing a renewable-energy and storage system to power SA Water's Adelaide Desalination Plant*. https://aecom.com/projects/designing-a-renewable-energy-and-storage-system-to-power-sa-waters-adelaide-desalination-plant/

Australian Government. (2022). *Australian Government Climate Change commitments, policies and programs*.

Bureau of Waterworks. (2020). *Tokyo Metropolitan Government Environmental Five-Year Plan 2020-2024*. https://www.waterworks.metro.tokyo.lg.jp/eng/waterprofessionals/energy.html

Bureau of Waterworks, Tokyo Metropolitan Government. (2024, July 10). *Environmental Report 2023*. https://www.waterworks.metro.tokyo.lg.jp/files/items/30207/File/report2023.pdf

California Government. (2018). *AB 32 Global Warming Solutions Act of 2006*. https://ww2.arb.ca.gov/resources/fact-sheets/ab-32-global-warming-solutions-act-2006

Canal de Isabel II. (2024). *Clean Renewable Energies*. https://www.canaldeisabelsegunda.es/en/medio-ambiente

City of Amsterdam. (n.d.-a). *Policy: Climate neutrality*. Retrieved August 8, 2024, from https://www.amsterdam.nl/en/policy/sustainability/policy-climate-neutrality/

City of Amsterdam. (n.d.-b). *Policy: Renewable energy*. Retrieved August 8, 2024, from net-Zero Emissions by 2050: In October 2021, the Australian government

CleanBC. (n.d.). *Roadmap to 2030*.

Climate Change Laws of the World. (2019). *National Energy and Climate Plan of the Czech Republic*.

Climate Laws of the World. (2019). *Climate Act (Klimaatwet)*. https://climate-laws.org/document/climate-act_4bc4

Element Energy. (2021). *Analysis of a Net ZZero 2030 Target for Greater London*.

Environment SA News. (2021). *SA's new target to cut emissions ahead of COP26*. https://www.environment.sa.gov.au/news-hub/news/articles/2021/10/south-australia-cop26-emissions-target

Executive Department, State of Caifornia. (2018). *EXECUTIVE ORDER B-55-18 TO ACHIEVE CARBON NEUTRALITY*.

EYDAP. (2024, June 24). *CLIMATE CHANGE*. https://www.eydap.gr/en/SocialResponsibility/Enviroment/ClimChange/

Glasgow City Council. (2024). *Glasgow's Climate Plan*. https://www.glasgow.gov.uk/climateplan

Government of British Columbia. (2024). *Innovative Clean Energy (ICE) Fund*. https://www2.gov.bc.ca/gov/content/industry/electricity-alternative-energy/innovative-clean-energy-solutions/innovative-clean-energy-ice-fund

Government of Canada. (2021). *Canadian Net-Zero Emissions Accountability Act*. https://laws-lois.justice.gc.ca/eng/acts/c-19.3/fulltext.html

Government of South Australia. (2024, July 1). *Our Strategy 2020-25 Delivering trusted water services for a sustainable and healthy South Australia*. https://www.sawater.com.au/__data/assets/pdf_file/0007/581875/Our-Strategy-2020-2025_Updated-branding_May-2024.pdf

Greek National Energy and Climate Plan. (2022). https://www.iea.org/policies/12750-greek-national-energy-and-climate-plan

Gromek-Broc, K. (Ed.). (2023). *Regional Approaches to the Energy Transition: A Multidisciplinary Perspective*. Springer International Publishing. https://doi.org/10.1007/978-3-031-19358-3

Illiniois EPA. (2024). *State of Illinois Priority Cliamte Action Plan*.

International Climate Initiative. (2020, March 3). Water companies on the way to CO2 neutrality. *International Climate Initiative*. https://www.international-climate-initiative.com/en/iki-media/news/water_companies_on_the_way_to_co2_neutrality/

Kenway, S., Pamminger, F., Skinner, R., Bors, J., Smith, L., Bergmann, D., Lauren, N., Hanasz, P., Radion, A., Eadie, M., Olsen, K., Lam, K. L., & Liang, X. (n.d.). *UTILITIES MOVING BEYOND SCOPE 1 AND 2 GREENHOUSE GAS EMISSIONS FOR CUSTOMER BENEFITS AND AFFORDABLE NET ZERO CITIES*.

Lam, K. L., Lant, P. A., & Kenway, S. J. (2018). Energy implications of the millennium drought on urban water cycles in Southeast Australian cities. *Water Supply*, *18*(1), 214–221. https://doi.org/10.2166/ws.2017.110

Maniatis, Y., Doukas, H., & Karagiannis, E. (2023). *A Greek Green Deal: Building energy democracy and fighting energy poverty*.

Metropolitan Water Reclamation District of Greater Chicago. (2023). *Climate Action Plan*.

Miami-Dade County. (2021). *Climate Action Strategy*.

NSW Climate and Energy Action. (2024). *The Climate Change (Net Zero Future) Act 2023*. https://www.energy.nsw.gov.au/nsw-plans-and-progress/government-strategies-and-frameworks/climate-change-net-zero-future-act-2023

Oregan Government. (n.d.). *How Oregon Uses Energy*. Retrieved August 8, 2024, from https://www.oregon.gov/energy/energy-oregon/Pages/How-Oregon-Uses-Energy.aspx#:~:text=Hydroelectric%20power%20makes%20up%20the,by%20coal%20and%20natural%20gas.

Oregan Legistlative Assembly. (2021). *Clean Energy Targets, House Bill 2021*.

Portland Water Bureau. (2020). *Carbon Foot Print Report*.

PRAHA 2030. (n.d.). *Prague 2030 Climate Plan*. https://klima.praha.eu/en/the-climate-plan-at-a-glance.html

Rahimi, I., Nikoo, M. R., & Gandomi, A. H. (2023). Techno-economic analysis for using hybrid wind and solar energies in Australia. *Energy Strategy Reviews*, *47*, 101092. https://doi.org/10.1016/j.esr.2023.101092

Ren, Z. J., & Pagilla, K. (2022). Pathways to Water Sector Decarbonization, Carbon Capture and Utilization. *Carbon Capture*.

San Francisco Environment Department. (2023). *San Francisco's Climate Action Plan Water Supply Addendum*.

Santos, J. (2024). *Spain's Integrated National Energy and Climate Plan*. https://www.climatescorecard.org/2024/02/spains-integrated-national-energy-and-climate-plan/#:~:text=The%2023%25%20reduction%20proposed%20in,improving%20energy%20efficiency%20to%2044%25.

Satur, P. (2023). *Net Zero Water Cycle Enabling Environment Research: Phase Two Report*. Monash University.

Scottish Water. (2024). *Scottish Water Net Zero Emissions Routemap*. https://scottishwaternetzero.co.uk/

Srb, M., Grešíková, M., Salová, N., Sýkora, P., Štrupl, J., Xia, R., Huml, O., Prokop, P., Hájková, M., Harasymchuk, I., Kočí, V., & Beneš, O. (2023). Prague Water Net Zero Strategy 2025: Methodology and roadmap. *Water Supply*, *23*(5), 1859–1873. https://doi.org/10.2166/ws.2023.098

Sydney Water. (n.d.). *Out path to net zero and beyond*.

Thames Water. (n.d.). *Our Journey ro net zero carbon and beyond*. https://www.thameswater.co.uk/about-us/environment/managing-our-carbon-emissions

The Government of Japan. (2021). *The Long-Term Strategy under the Paris Agreement*.

UK Electricity Production. (2024). *London Electricity Production*. https://electricityproduction.uk/in/london/

UK Government. (2019). *UK becomes first major economy to pass net zero emissions law*. https://www.gov.uk/government/news/uk-becomes-first-major-economy-to-pass-net-zero-emissions-law

UN. (2016). *List of Parties that signed the Paris Agreement on 22 April*. https://www.un.org/sustainabledevelopment/blog/2016/04/parisagreementsingatures/

United Nations Environment Programme. (2017). *The Emissions Gap Report 2017: A UN Environment Synthesis Report*. UN. https://doi.org/10.18356/1cf881fb-en

U.S Department of State. (2021). *The United States Officially Rejoins the Paris Agreement*. https://www.state.gov/the-united-states-officially-rejoins-the-paris-agreement/#:~:text=On%20January%2020%2C%20on%20his,becomes%20a%20Party%20again%20today.

Van Der Hoek, J. P., Mol, S., Janse, T., Klaversma, E., & Kappelhof, J. (2016). Selection and prioritization of mitigation measures to realize climate neutral operation of a water cycle company. *Journal of Water and Climate Change*, *7*(1), 29–38. https://doi.org/10.2166/wcc.2015.026

Victoria State Government. (2021). *Victoria's Climate Change Strategy*.

Zhang, Q., Smith, K., Zhao, X., Jin, X., Wang, S., Shen, J., & Ren, Z. J. (2021). Greenhouse gas emissions associated with urban water infrastructure: What we have learnt from China's practice. *WIREs Water*, *8*(4), e1529. https://doi.org/10.1002/wat2.1529