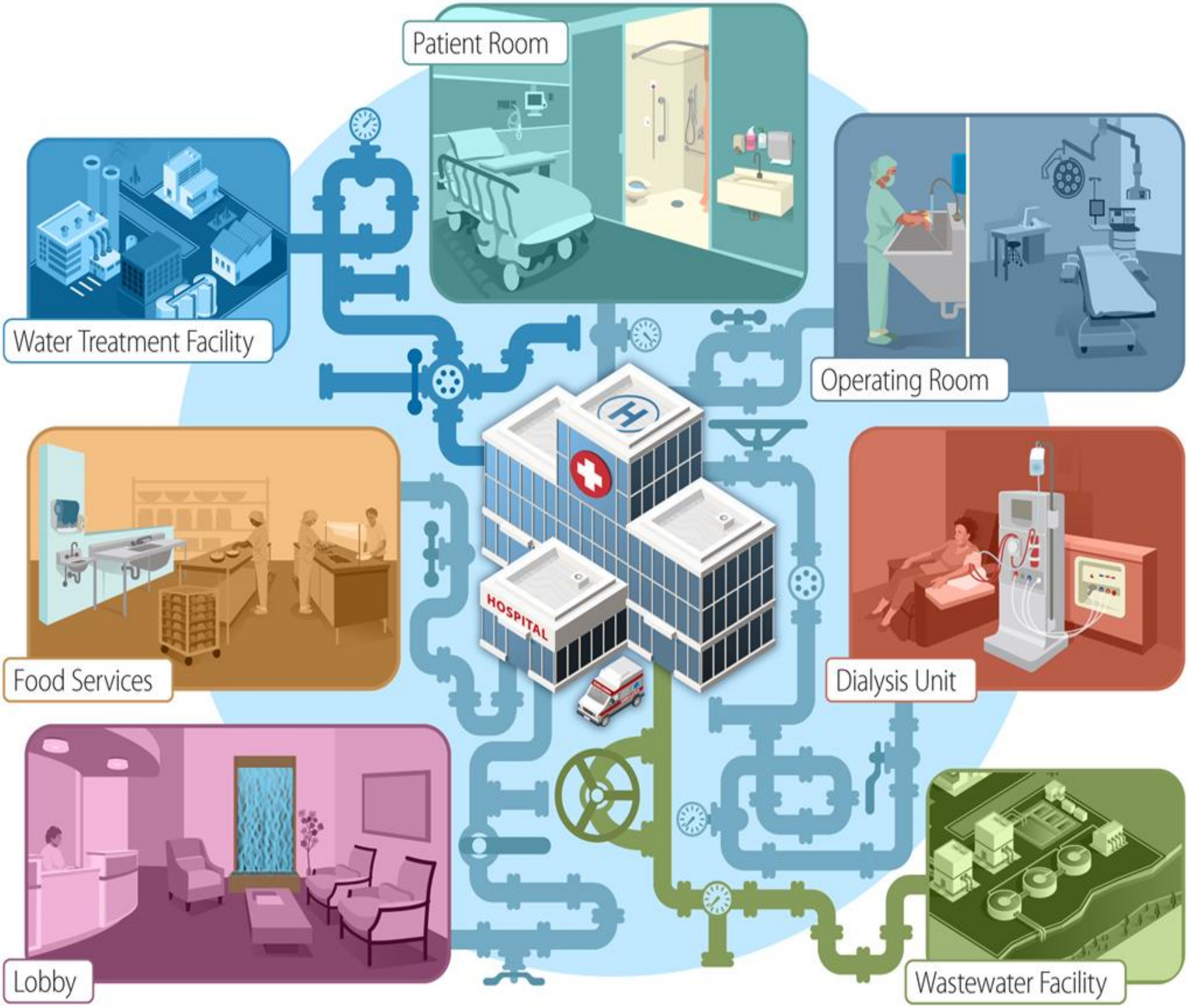

Water-Saving Opportunities in Lower Mainland Healthcare Facilities

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August 2021

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 organizations in support of providing graduate students with opportunities to do applied research on projects that advance sustainability across the region.

This project was conducted under the mentorship of the Provincial Health Services Authority (PHSA) staff. The opinions and recommendations in this report and any errors are those of the author and do not necessarily reflect the views of the PHSA or the University of British Columbia.

Acknowledgements

In the spirit of truth and reconciliation, the author acknowledges the past, present, and future generation of Indigenous peoples who have been living, working, and stewarding this landscape since time immemorial. The work for this project took place on the traditional territories of the Blackfoot Confederacy (Siksika, Kainai, Piikani), the Tsuut'ina, the Îyâxe Nakoda Nations, the Métis Nation (Region 3), and all people who make their homes in the Treaty 7 region of Southern Alberta. The mentorship and sponsorship for this project took place on the unceded ancestral lands of the xwməθkwəy̓əm (Musqueam), Skwxwú7mesh (Squamish), Stó:lō and Səl̓ílwətaʔ/Selilwitulh (Tsleil- Waututh) Nations.

The author would like to thank the following individuals for their contribution, feedback, and support throughout this project.

Ghazal Ebrahimi, Energy and Carbon Emissions Manager- Energy and Environmental Sustainability, Provincial Health Services Authority

Douglas Davila, Energy Specialist- Energy and Environmental Sustainability, Provincial Health Services Authority

All Lower Mainland health organizations stakeholders who took part in the interviewees and contributed by sharing their wealth of knowledge to make this research possible.

Cover image from Centers for Disease Control and Prevention[1]

[1] Image downloaded from: Centers for Disease Control and Prevention. (2019). *Reduce Risk from Water.* Healthcare-associated Infections. https://www.cdc.gov/hai/prevent/environment/water.html

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Executive Summary

The objective of this research project was to explore water-saving opportunities applicable to healthcare settings and identify innovative, yet feasible solutions at the Lower Mainland health organizations facilities. The findings from this research aim to support the Lower Mainland health organizations in meeting their 2030 water utilization reduction targets.

Water conservation is important for environmental sustainability, which is impacted by increasing demand for potable water, climate change, and urbanization. Healthcare facilities are large consumers of water and therefore have a significant role to play. Demonstrating action toward water conservation promotes environmental stewardship and provides benefits for healthcare facilities.

Qualitative methods were used to analyze the findings from literature reviews and semi-structured interviews held with Lower Mainland health organizations stakeholders. Common water-saving practices were shared with interviewees to identify challenges and opportunities for implementing water-saving initiatives at Lower Mainland health organizations.

The research findings were categorized by domestic and non-domestic water uses specific to healthcare facilities. Non-domestic uses were found to consume the most water in healthcare facilities, which was supported by the interview findings. Prior to implementing water-saving practices, the literature suggests developing a water management plan; these steps were synthesized and presented in the form of a PLAN-DO-CHECK-ACT Framework that is familiar to the Lower Mainland health organizations.

The research identified five categories of challenges. These are listed below from most to least commonly mentioned by the interviewees. Many of these challenges are interrelated; new opportunities require careful analysis during planning and implementation to overcome these barriers.

- Implementation: Competing prioritization of projects with limited funding and staff resources impacts implementation of new technology, operational changes, and monitoring programs.
- Operational: Water-saving interventions face barriers due to perceived risks to facilities operations and infection control; these may be influenced by educational barriers.
- Behavioral: Lack of awareness and educational barriers result in mindsets that view water conservation as a low priority and increase resistance to change.
- Monitoring: Limited water sub-metering and data collection and analysis methods were identified; however, water metering strategies must overcome implementation and behavioral challenges.
- Infrastructural: Variations in existing equipment, space availability, and other unique conditions require resource-intensive and site-specific feasibility assessments for water saving opportunities.

The research identified seven categories of opportunities to address the aforementioned challenges. These are listed below from most to least commonly mentioned by the interviewees.

- **Retrofits & Replacements**: Opportunities were identified in various areas including non-domestic uses (i.e., equipment, landscaping, housekeeping, heating and cooling processes, kitchen services) and domestic uses (i.e., faucets, toilets, showers, icemakers, etc.).
- **Education & Awareness**: Methods for educating staff can be improved by integrating water awareness into daily messaging to create a cultural shift in water conservation mindsets.
- **Water Metering**: Strategic implementation of water sub-metering and data management requires significant resources; re-framing this as a risk prevention method can increase stakeholder buy-in.
- **Water Management Planning**: Collaboration between stakeholder groups was identified as a key to improve water management planning and execution in healthcare facilities.
- **Operations & Maintenance**: Embedding water use monitoring and conservation practices into operations and maintenance processes presents low- to no-cost water-saving interventions.
- **Climate Resilience & Energy Synergies:** Recognizing the relationship between water conservation and climate adaptation in healthcare settings can help prioritize water-saving opportunities.
- **New Construction & Contracts**: Paying special attention to new construction and redevelopment projects is recommended as they often present suitable context for implementing design strategies that embrace water conservation.

Developing a water management plan is the primary recommendation for the Lower Mainland health organizations to overcome challenges and implement water-saving opportunities. These steps are summarized below:

- **Step 1- Assemble a Water Management Team:** This team would consist of diverse stakeholders across the Lower Mainland health organizations responsible for overseeing and implementing the water management program.
- **Step 2- Assess Facilities Water Use:** These efforts could include a water audit led by external consultants or managed through internal resources.
- **Step 3- Set Water-Saving Objectives and Goals**: The key is to develop measurable key performance indicators to monitor progress. Involving stakeholders external to the Water Management team can help identify and proactively mitigate operational barriers and improve awareness.
- **Step 4- Implement Water-Saving Projects**: Projects should be implemented based on priority of potential savings, costs, co-benefits and other metrics identified by stakeholders. Internal and external funding resources can be sought for implementation.
- **Step 5- Reporting and Analyzing Impacts**: Implementing a robust water metering and monitoring strategy can bolster reporting and analysis of completed water-saving projects.
- **Step 6- Make Improvements and Celebrate Successes**: Driving accountability by encouraging staff engagement through feedback mechanisms and internal recognition programs can insure continuous improvement of the water management plan.

The Lower Mainland health organizations can improve upon implementation of water saving opportunities by developing a robust water management plan as outlined in the steps above. This requires integrated stakeholder collaboration to meet sustainability targets and improve utilization of water resources.

Introduction

The purpose of this research project was to explore innovative water-saving opportunities applicable to healthcare settings and assess their feasibility for implementation at the four Lower Mainland health organizations. These organizations include Fraser Health (FH), Providence Health Care (PHC), Provincial Health Services Authority (PHSA), and Vancouver Coastal Health (VCH). The Energy Environment and Sustainability (EES) team that works across the four Lower Mainland health organizations is working to minimize water consumption in these facilities through the implementation of efficiency measures and water-conserving infrastructure as one of their key sustainability goals. To achieve this goal, the Lower Mainland health organizations have established water utilization targets to lower environmental impacts without compromising patient care or employee comfort. However, some of the Lower Mainland health organizations did not meet their 2020 water utilization targets due to a variety of reasons. This is a primary driver behind this research that seeks to answer: *what feasible water-saving opportunities can be implemented in healthcare facilities*? Secondary research questions seek to answer*: what challenges prevent water-saving opportunities from being implemented* and *what opportunities exist to overcome these challenges and ensure all Lower Mainland health organizations meet their 2030 water utilization targets*?

Background

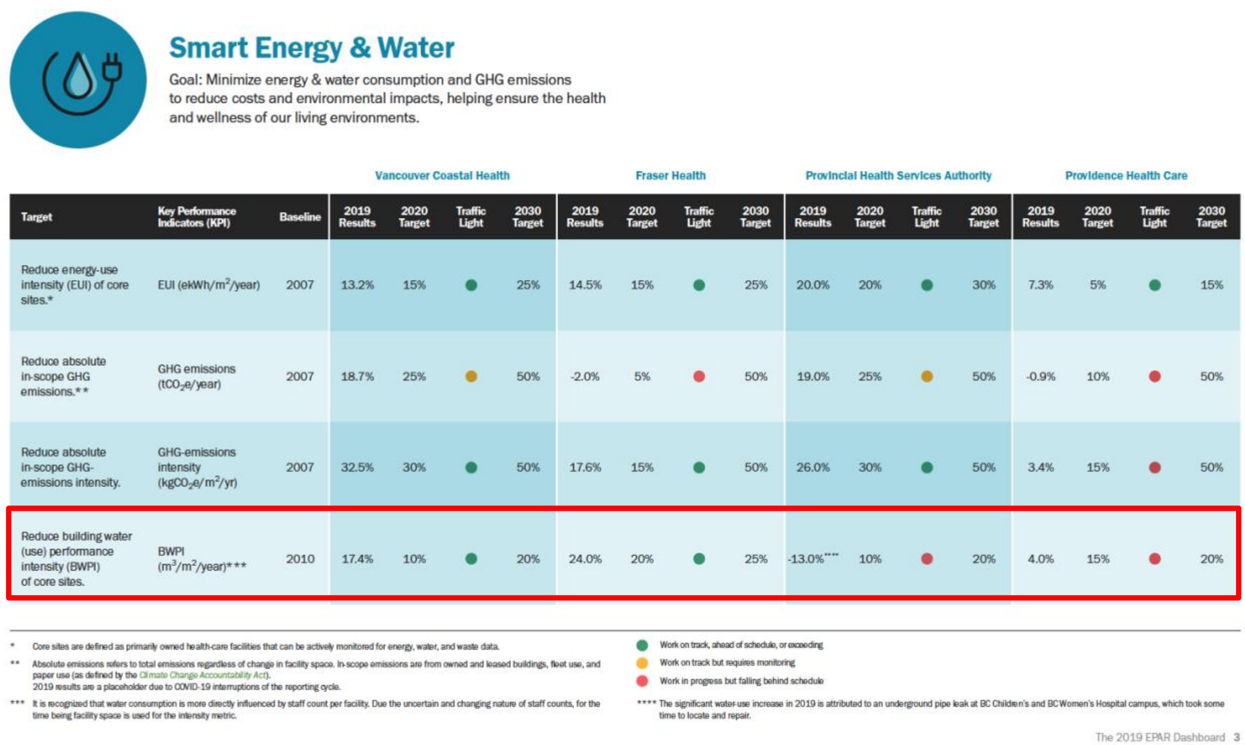
According to the Green Health Care (GHC) consortiums GHG+H20 Green Facility Toolkit[2], healthcare facilities are often one of the most intensive water users in a community (2021). The authors add that while Canada has an abundance of freshwater resources, regional water scarcity is a growing concern, especially as urban populations grow, climate change impacts intensify, and demand for water increases stress on sensitive aquatic ecosystems (GHC, 2021). Further, Canadians are the second-highest per capita consumers of water, lacking water system efficiency and water conservation behaviours (GHC, 2021). Therefore, reducing the unnecessary use of potable water is critical for environmental sustainability and human health, and healthcare facilities have a leading role to play in achieving this goal (GHC, 2021).

Water conservation is an important sustainability goal since treating and processing water requires substantial energy inputs, contributes to greenhouse gas (GHG) emissions, and has the potential to release wastewater contaminants into the environment (GHC, 2021). Therefore, decreasing water consumption has environmental benefits as it decreases the strain on municipal water supplies and reduces the energy needed to treat and deliver water (American Society for Healthcare Engineering, 2014). Additionally, there are benefits to healthcare facilities that implement water conservation practices, like lowering operating and energy costs, extending limited water supplies, increasing operational efficiency and infection control through the use of innovative technologies, and becoming more adaptable and resilient to climate change (GHC, 2021). However, the GHC acknowledges that the healthcare sector faces unique challenges in

[2] Green Health Care. (2021). *H20 Conservation.* GHG+H20 Green Facility Toolkit. https://greenhealthcare.ca/ghgwater/

conserving water (2021). For example, infection control requirements make the implementation of some common water-saving practices, like low-flow faucets, challenging or infeasible to implement (GHC, 2021). Further, some technologies are capital-intensive, resulting in implementation barriers due to the competing priorities and necessities of water consumption to deliver quality patient care (GHC, 2021). Despite this, acting on water conservation is critical for healthcare facilities and demonstrates action towards community and environmental stewardship, which is fundamental for promoting human health (GHC, 2021).

Figure 1 below shows a gap between 2019 water performance data and 2020 targets for some of the Lower Mainland health organizations (GreenCare, 2019). While delving into the reasons for this gap is beyond the scope of this report, the present study helps to identify challenges and opportunities to help Lower Mainland health organizations achieve their water performance targets.



Smart Energy & Water

Goal: Minimize energy & water consumption and GHG emissions to reduce costs and environmental impacts, helping ensure the health and wellness of our living environments.

			Vancouver Coastal Health				Fraser Health				Provincial Health Services Authority				Providence Health Care			
Target	Key Performance Indicators (KPI)	Baseline	2019 Results	2020 Target	Traffic Light	2030 Target	2019 Results	2020 Target	Traffic Light	2030 Target	2019 Results	2020 Target	Traffic Light	2030 Target	2019 Results	2020 Target	Traffic Light	2030 Target
Reduce energy-use intensity (EUI) of core sites.*	EUI (ekWh/m^2/year)	2007	13.2%	15%	● (green)	25%	14.5%	15%	● (green)	25%	20.0%	20%	● (green)	30%	7.3%	5%	● (green)	15%
Reduce absolute in-scope GHG emissions.**	GHG emissions (tCO_2e/year)	2007	18.7%	25%	● (yellow)	50%	-2.0%	5%	● (red)	50%	19.0%	25%	● (yellow)	50%	-0.9%	10%	● (red)	50%
Reduce absolute in-scope GHG-emissions intensity.	GHG-emissions intensity ($kgCO_2e/m^2$/yr)	2007	32.5%	30%	● (green)	50%	17.6%	15%	● (green)	50%	26.0%	30%	● (green)	50%	3.4%	15%	● (red)	50%
Reduce building water (use) performance intensity (BWPI) of core sites.	BWPI (m^3/m^2/year)***	2010	17.4%	10%	● (green)	20%	24.0%	20%	● (green)	25%	-13.0%****	10%	● (red)	20%	4.0%	15%	● (red)	20%

* Core sites are defined as primarily owned health-care facilities that can be actively monitored for energy, water, and waste data.

** Absolute emissions refers to total emissions regardless of change in facility space. In-scope emissions are from owned and leased buildings, fleet use, and paper use (as defined by the *Climate Change Accountability Act*).
2019 results are a placeholder due to COVID-19 interruptions of the reporting cycle.

*** It is recognized that water consumption is more directly influenced by staff count per facility. Due the uncertain and changing nature of staff counts, for the time being facility space is used for the intensity metric.

● (green) Work on track, ahead of schedule, or exceeding
● (yellow) Work on track but requires monitoring
● (red) Work in progress but falling behind schedule

**** The significant water-use increase in 2019 is attributed to an underground pipe leak at BC Children's and BC Women's Hospital campus, which took some time to locate and repair.

The 2019 EPAR Dashboard 3

Figure 1. Lower Mainland health organizations Smart Energy & Water Utilization Targets

Although general water consumption processes are similar across the Lower Mainland health organizations facilities, there may be variances in the highest water-consuming areas and opportunities to implement feasible water-saving options. Therefore, this report provides a wide list of water-saving opportunities that could be considered by the individual Lower Mainland health organizations facilities. Acting upon any of these opportunities would require further site-specific audits to develop a feasible implementation plan.

Research Methods

The research methods for this report were split into three phases. In the first phase, a literature review was conducted to identify common water-saving practices developed by healthcare organizations across North America. Case studies on innovative technology implemented in these healthcare facilities were assessed and the findings were categorized based on domestic uses (i.e., handwashing, bathing, toilet flushing, drinking) and non-domestic uses (i.e., heating and cooling processes, medical equipment, kitchen services, housekeeping, and landscaping). The findings were further categorized based on healthcare-specific opportunities (i.e., domestic uses, non-domestic uses in processes and medical equipment) and general facility opportunities (i.e., non-domestic uses in housekeeping, kitchen, and landscaping services). Within these categories, water-saving practices were identified as hard measures (i.e., retrofits and replacements) or soft measures (i.e., operations and maintenance strategies, or educational training and organizational policies). This phase answered the primary research question by identifying different water-saving practices and innovative technology that could be applicable to Lower Mainland health organizations facilities. The findings from this phase, including case studies from healthcare facilities that have implemented the practices, are found in the Results (Literature Review) section, and further detailed in Appendix I.

Based on the literature review findings, five groups were selected to be interviewed: the Energy Environment and Sustainability (EES) team of the Lower Mainland health organizations, Facilities Maintenance and Operations (FMO), Business Initiatives and Support Services (BISS), the Green+Leaders (G+L)[3], and sustainability departments of another two health authorities in BC: Vancouver Island Health Authority (VIHA) and Interior Health Authority (IHA). These groups were contacted by email to seek interest in participation and were scheduled for 30–60-minute interviewees. Informal interviewees were held primarily through Skype audio calls; some interviews were held through Zoom video calls and telephone calls. Thirteen one-on-one interviews and eight focus group interviews with twenty-seven participants (2-7 individuals per group) were conducted for a total of 40 interviewees. Additionally, a survey was sent to the G+L's; twenty responses were collected. This phase answered the secondary research questions and verified the primary research data. Due to the informality of interviews, not all questions were answered by each participant. However, all interviewees were generally asked the following three questions:

1. What water-saving opportunities have been successfully implemented or are planned for implementation at your healthcare facilities?
2. What barriers may prevent water-saving opportunities from being implemented at your healthcare facilities?
3. What other opportunities may exist for water-saving at your healthcare facilities and how should they be prioritized?

[3] The Green+Leaders Program is open to all employees of the Lower Mainland health organizations who want to join a change-making community focused on sustainability issues. "Program participants receive leadership training and toolkits, plus access to fun and engaging events to connect with like-minded colleagues" (GreenCare, 2019).

The interview transcripts were analyzed and coded using qualitative methods to identify categories of challenges and categories of opportunities based on the interviewee responses. The frequency of response occurrence was counted based on the number of interviewees that referred to each challenge and opportunity category. This qualitative analysis allowed the researcher to identify the most common challenges and opportunities based on the frequency of responses. The findings from this phase are found in the Results (Interview and Survey Analysis) section.

The third phase of the research compared the findings from the literature review with the interview qualitative analysis to develop a summary and set of preliminary recommendations. These recommendations are meant to support the Lower Mainland health organizations facilities in developing a robust water management plan and creating a suitable context for implementing water-saving technologies and practices. The comparative analysis of the results and preliminary recommendations are found in the Discussion, along with limitations of the research methods and potential future research steps.

Results

Literature Review

The literature review assessed a wide database of resources from North American healthcare organizations to develop potential water-saving opportunities that could be implemented in Lower Mainland health organizations facilities. Detailed practices and case studies – from healthcare organizations that have successfully implemented these changes – are found in Appendix I . The research findings provided insights into typical high-water using areas within healthcare facilities that were targeted for analysis in Lower Mainland health organizations facilities.

One study highlighted that in the US, as much as 70% of a hospitals water consumption is from non-domestic uses, the remainder is consumed in domestic uses (Karliner & Guenther, 2011). While few reliable global consumption benchmarks are available in healthcare, the study noted that in general, health facilities can conserve water resources by closely metering water use, installing water-efficient fixtures and technologies, growing drought-resistant landscapes, and quickly repairing leaks (Karliner & Guenther, 2011). For an even greater impact on overall usage, hospitals in several countries are harvesting rainwater or recycling water for process uses (Karliner & Guenther, 2011).

Figure 2 below shows hospital consumption from two different resources. It is observed that the left (GHC, 2021) and right (EPA, 2015) graphs differ slightly. This highlights the necessity of a water audit to identify site-specific facility uses. Both data sources highlight that majority of water consumption in hospitals is from non-domestic uses.

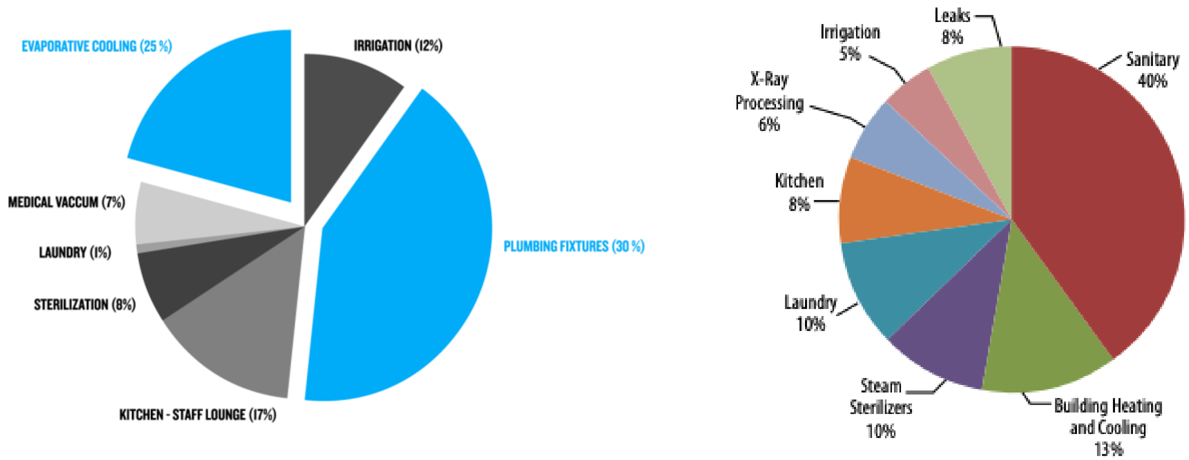


Figure 2: Healthcare Facility Water Consumption Breakout by Use

Water Saving Practices

The literature review findings presented in Tables 1-4 are categorized as healthcare-specific domestic and non-domestic uses and general non-domestic uses for institutional buildings. Sub-categories identify the highest water-using fixtures, processes, equipment, and services. The findings are further categorized based on hard measures (i.e., retrofits/replacements), and soft measures (i.e., operations/maintenance and education/policies). Findings for non-domestic uses in processes and equipment do not include practices for education/policies – aimed at improving general awareness of water conservation among service and clinical staff or patients and visitors – since these are typically operated by accountable trained users.

Table 1 below presents common practices for domestic use water-saving in healthcare facilities; sub-categories address the highest water-using fixtures and equipment. Multiple resources[4] were used for the development of Table 1. The findings are categorized based on hard measures (i.e., retrofits/replacements), and soft measures (i.e., operations/maintenance for trained users like the FMO, and education/policies for clinical staff, patients, and visitors).

[4] Resources from this section include multiple references: (Arya et. al., 2018), (Capital Engineering Consultants, 2014), (EPA WaterSense, 2012), (Green Health Care, 2021), (Healthcare Environment Resource Centre, 2015), (Ontario Agency for Health Protection and Promotion, 2018), (Pan American Health Organization, n.d.), (Petterwood & Shridhar, 2009), (Practice Green Health, 2016), (Rajini et al., 2015), (Southwest Florida Management District, 2018), (Walson & Bradford, 2017), and (Waterless Co. Inc., 2018).

Table 1: Water-Saving Practices for Healthcare-Specific Domestic Uses

SUB-CATEGORY	RETROFITS/ REPLACEMENTS	OPERATIONS/ MAINTENANCE	EDUCATION/ POLICIIES
Faucets	• Install flow straighteners, aerators, laminar flow faucets, low-flow fixtures, high-efficiency fixtures, metered faucets, foot-pedals, and/or automatic sensors	• Verify system pressures • Inspect for scale build-up • Check for and repair leaks • Adjust automatic sensors	• Post water conservation reminders at sinks • Train users to report leaks • Use taps-on/taps-off technique and alcohol-based hand rubs (ABHR) policies
Showers	• Retrofit multiple heads to operate individually • Install WaterSense models	• Verify system pressures • Check for and repair leaks • Inspect for scale build-up	• Provide user time trackers (i.e., clocks) in showers
Toilets	• Install dual-flush conversion or water displacement devices • Install low flow toilets; low-volume or waterless urinals • Use non-potable sources	• Verify system pressures • Inspect and replace worn parts and check for leaks • Ensure proper maintenance cleaning for non-flush urinals	• Train users to report leaks and other problems
Icemakers	• Install timers to produce during off-peak hours • Install air-cooled ENERGY STAR models	• Program machines to lowest possible rinse cycles • Clean machines and remove scale build-up	• Train users to report leaks
Drinking Fountains			• Train users to choose tap water over bottled water
Bed-pan Washers	• Install with dual-flush features		

Table 2 below presents common water-saving practices for healthcare facilities regarding non-domestic uses in heating and cooling processes; sub-categories address the highest water-using areas. Opportunities for education/policies are not identified since these processes are operated by trained FMO staff only. Multiple resources[5] were used to develop Table 2.

[5] Resources from this section include multiple references: (American Hospital Association, n.d.), (Arya et al., 2018), (Canada Green Building Council, 2021), (EPA WaterSense, 2012), (Healthcare Environment Resource Centre, 2015), (Massachusetts Water Resource Authority, n.d.), (Practice Green Health, 2016), (Practice Green Health, 2021), (Rajini et al., 2015), (Southwest Florida Water Management District, 2018), (Sullivan et al., 2010), (U.S. Department of Energy, 2011), and (Walson & Bradford, 2017).

Table 2: Water-Saving Opportunities for Healthcare-Specific Non-Domestic Uses in Processes

SUB-CATEGORY	RETROFITS/ REPLACEMENTS	OPERATIONS/ MAINTENANCE
Cooling Towers	• Use non-potable sources for make-up water • Recover condensate in closed loops • Change from open-loop to closed-loop • Use automatic chemical feed systems • Install conductivity and flow meters with automatic controls • Install delimiters to reduce drift and evaporation losses • Use pre-treatment systems	• Control blowdown water volume quantities • Maximize cycles of concentration and maintain chemicals program • Monitor flow and conductivity meter trends on make-up and blowdown lines • Optimize cooling efficiency and temperatures • Clean and maintain coils, heat exchangers, and condensers to prevent scale • Ensure tower fill valves close completely
Steam Boilers	• Recover steam condensate • Install expansion tanks to reduce tempering • Use automated chemical feed • Install flow meters on make-up water lines and condensate return lines with automatic blowdown and chemical feed systems • Use pre-treatment systems	• Improve make-up water quality and treatment • Control blowdown water and minimize make-up water use; maintain chemical program • Monitor make-up water meters to identify leaks and optimize performance • Enhance water heater efficiency • Inspect and maintain steam lines and boilers
Steam Traps	• Replace with maintenance-free units	• Develop steam trap inspection plan
Chilled water systems	• Automate controls to monitor the capacity of chillers and regulate cooling demand • Recirculate water through closed loops • Install pressure-reducing valves where system pressures are too high • Install water meters to identify leaks and optimize performance • Install heat pumps for energy/water-savings • Replace for air-cooled units	• Consider system component interaction to optimize efficiency and save water • Optimize controls for chiller efficiency • Reduce demand on chilled water systems • Ensure proper sizing of equipment • Monitor make-up water meter to identify leaks and optimize performance • Inspect chillers and remove scale build-up • Insulate pipes on chilled water loops
Water Purification	• Recycle brine or backwash from reverse osmosis or filter treatments • Consider different treatment systems that use less water and backflushing	• Use only when necessary • Use automatic controls to limit backwashes • Clean distillation systems as needed • Determine resin regeneration schedules

Table 3 below presents common water-saving practices for healthcare facilities regarding non-domestic uses in equipment; sub-categories address the highest water-using medical equipment. The water-saving practices are identified for retrofits/replacements and operations/maintenance strategies only; education/policies are not identified since this equipment is operated and maintained by trained clinical and FMO staff only.

Multiple resources[6] were used to develop Table 3.

Table 3: Water-Saving Opportunities for Healthcare-Specific Non-Domestic Uses in Equipment

SUB-CATEGORY	RETROFITS/ REPLACEMENTS	OPERATIONS/ MAINTENANCE
Single-pass cooling	• Use non-potable sources • Eliminate entirely and replace with air-cooled systems • Recirculate water to cooling systems • Use automatic controls to stop cooling water flow when not in use	• Identify all single-pass cooling systems • Use tempering device for water discharge temperature regulation • Use thermal recovery heat exchangers to preheat make-up water
Steam sterilizers	• Replace with thermostatically actuated valves to reduce tempering water volumes • Capture vacuum ejector water in uninsulated tanks for reuse in operations • Install steam condensate tempering systems • Use non-potable water sources for autoclave sterilizers • Install hydrogen peroxide gas plasma sterilizer units or electric liquid-ring vacuum pumps instead of vacuum/ejectors	• Adjust tempering water needle valve flow rates to reduce unnecessary drainage • Shut-off sterilizer when not in use • Use high-quality water to generate steam • Use full loads in sterilizers • Use controls to limit tempering water flows and perform backwash as needed (autoclaves) • Periodically check thermostatic actuated valves for proper functioning and less discharge • Change tempering needle valves annually
X-rays	• Use film water recycling units • Install automatic valves on film processing equipment to stop water if not in use • Replace with digital imaging	• Print in self-contained 'mini-lab or apply dry printing processes (like laser printing)
Dialysis Units	• Recirculate reject water through closed-loops for reuse in other operations • Reuse reject water by treating through reverse osmosis or filtration • Install water flow regulation devices • Replace with sorbent dialysate regeneration and online dialysate generation units	• Reduce discharge of high-conductivity and high-salinity reject water to the environment
Liquid-Ring Type Lubrication Systems	• Equip with full or partial recirculation and recovery systems • Replace with scavenging interface waste anesthetic gas pumps	• Check for use in vacuum pumps
Vacuum Pumps	• Recirculate water to chilled water systems and cooling towers with heat recovery	• Turn off pumps when not in use • Ensure setting to minimum manufacture specification to discharge less water • Periodically check for optimal efficiency

[6] Resources from this section include multiple references: (American Hospital Association, n.d.), (Canada Green Building Council, 2021), (EPA WaterSense, 2012), (Green Health Care, 2021), (Healthcare Environment Resource Centre, 2015), (McGain & Naylor, 2014), (Practice Green Health, 2016), (Southwest Florida Water Management District, 2018), (Sullivan et al., 2010), (Tarrass et al., 2010), and (Walson & Bradford, 2017).

	• Replace with non-lubricated air-cooled dry pumps or waterless vacuum pumps; avoid venturi vacuum systems in sterilizers	
Glassware Washers	• Install water recycling systems to reuse rinse cycle wastewater in the next load • Install systems with optimization rinse cycle controls for efficient cleaning	• Operate near or at minimum flow rate recommended by the manufacturer • Select fewest rinse cycles possible • Only run at full load capacity
Fume Hood Filtration/ Washdown Systems	• Replace fume hoods with gas-phase filtration; replace wet scrubbers with adsorbent dry filters and particle filtration • Install automatic shut-off valves to control flow in wash-down systems	• Calibrate blowdown process to a minimum • Do not exceed flow rates of specifications • Turn off water flow when not in use • Check liquid level controller and supply valve are functioning properly
Radiation Therapy Accelerators	• Retrofit to pump reject water to cooling towers for evaporative cooling	
Pumps	• Replace with more load efficient pumps • Replace pump valves with low-friction valves and variable-speed controls	• Check pressures aren't too high to cause leaks • Conduct leakage surveys
Compressors	• Eliminate single-pass cooling compressors (closed loop or air-cooled compressors) • Install automatic control systems to shut the system off when not in use	

Table 4 below presents common water-saving practices regarding general institutional non-domestic uses in housekeeping, kitchen, and landscaping services; sub-categories address the highest water-using services and equipment used in these services. The findings are categorized based on hard measures (i.e., retrofits/replacements), and soft measures (i.e., operations/maintenance for trained users, and education/policies for staff, patients, and visitors). Multiple resources[7] were used to develop Table 4.

[7] Resources from this section include multiple references: (American Hospital Association, n.d.), (Canada Green Building Council, 2021), (EPA WaterSense, 2012), (Green Health Care, 2021), (Healthcare Environment Resource Centre, 2015), (McGain & Naylor, 2014), (Practice Green Health, 2016), (Southwest Florida Water Management District, 2018), (Sullivan et al., 2010), (Tarrass et al., 2010), and (Walson & Bradford, 2017).

Table 4: Water-Saving Opportunities for General Facilities Non-Domestic Uses

SUB-CATEGORY	RETROFITS/ REPLACEMENTS	OPERATIONS/ MAINTENANCE	EDUCATION/ POLICIIES
Laundry	• Add ozonation and membrane technologies • Retrofit to recycle water from final rinse in next cycle • Install front-loading programmable ENERGY STAR • Install continuous-batch or tunnel washers with recycling • Install coin or card-operated	• Wash full loads only • Reprogram machines to minimize rinse cycles • Choose chemicals that require fewer rinse steps • Consult service providers for water-efficient operations and reclamation systems	• Encourage users to wash full loads only by providing laundry scale
Washer-Down Sprayers	• Install self-closing nozzles • Replace with water brooms or pressure washers	• Consider other tools (broom/dustpan; mops)	• Train users on appropriate uses (only use for floors and not countertops)
Mops/Cloths	• Add ozonated water cleaning systems • Relace with microfiber	• Use microfiber cloths • Recalibrate chemical dispensing systems • Change cleaning scheduled from periodic to as required	• Train users on appropriate uses and cleaning solution preparations
Dishwashers/ Kitchen Sinks	• Reuse rinse water as flush water in garbage disposals • Install load sensors in conveyor-type dishwashers • Install ENERGY STAR models • Replace to 8.3 L/min faucets	• Run dishwashers at full capacity and turn-off after use • Inspect to make sure fill valves close and repair leaks • Ensure maintenance and functioning of solenoid valves • Turn off continuous flow	• Educate staff to scrape dishes first and run dishwashers with full loads
Ovens	• Install boilerless combination ovens	• Program setting to control different cooking modes • Inspect for scale build-up, leaks, and broken parts	
Food Steamers	• Use ENERGY STAR models or boiler-less steamers		
Food/Garbage Disposals	• Install load sensors and automatic shut-off valves • Replace with water recycling food pulper and strainers	• Use cold water • Restrict flow rates, set timers, turn off during idles • Inspect blades and drains	• Train users to scrape food and compost instead of rinsing; prevent large objects or grease in drains
Pre-Rinse Spray Valves	• Install WaterSense models with high-efficiency valves and clamps	• Inspect for scale build-up, leaks, and broken parts • Ensure proper system pressure and ergonomics	
Water features	• Recirculate water or use non-potable sources • Install smaller pumps with lower pumping rates	• Check for leaks and damage • Consider co-benefits for wildlife and stormwater • Shut off water if possible	

Irrigation	• Use non-potable sources (rainwater, treated greywater) • Attach shut-off nozzles • Install water meters • Install automatic controls and weather sensors • Install high-efficiency/low-flow/smart irrigation systems • Install check valves • Use climate/drought-resistant/tolerant plants • Incorporate shade trees, reduce turfgrass/strip grass	• Use xeriscape planting and hydro-zoning techniques • Allow for brown grass during the dry season • Apply water in larger amounts but less frequently • Schedule irrigation based on the vegetation/climate needs • Avoid runoff by directing sprinklers to landscape • Keep area free of weeds • Require full (WaterSense) audit every 3 years • Adjust or repair sprinklers to ensure even distribution	• Ensure staff is familiar with water-efficient irrigation; WaterSense certification • Use multi-purpose landscaping policies to attract biodiversity, improve co-benefits and reduce maintenance costs • Evaluate site conditions (soil, sun/wind exposure, evaporation rates, moisture levels, etc.) prior to new landscaping installations
Stormwater management	• Direct roof drains to permeable surfaces • Utilize irrigation rain barrels • Replace impermeable with permeable surfaces • Install green roof systems		
Pools	• Install barriers or gutters to reduce evaporation/splashing • Install gauges to determine cleaning schedules • Install RO systems to reduce draining and cleaning needs	• Ensure temperatures and pH to reduce cleaning needs • Monitor use and check for and repair leaks • Reduce splashing by lowering water levels • Clean filter media as needed	

Additional information on alternative water sources that can be used to reduce potable water consumption in healthcare facilities is detailed in Appendix II. These findings may be most beneficial for new construction and redevelopment projects.

Water Management Plan

The research identified the necessity of a robust water management plan for healthcare facilities wishing to reduce water consumption. Water management plans can address water conservation by reducing water losses from leaks; increasing water efficiency of fixtures, equipment, systems, and processes; educating employees and occupants about water efficiency to encourage water-saving behaviors; and reusing onsite alternative water for hospital operations (EPA, WaterSense, 2012).

To implement the water-saving practices listed in Tables 1-4 above, it is highly recommended for a facility to first implement a water management plan. The research findings were compiled to develop Figure 3 below, which is presented in the form of a PLAN-DO-CHECK-ACT framework familiar to the Lower Mainland health organizations. These recommendations are based on the frameworks of several healthcare organizations and are summarized with key findings to support the Lower Mainland health organizations in developing their own water management plan. Detailed information on each of these steps is summarized in Appendix III; these resources can be further studied by Lower Mainland health organizations facilities wishing to customize the steps and learn more about water management planning.

Figure 3: Plan-Do-Check-Act Framework for Water Management Planning

Challenges

The analyses identified five categories of challenges in implementing water-saving opportunities based on the interviewee's responses; the frequency of responses resulted in the distribution shown in Figure 4 and Figure 5. The acronyms used to describe each stakeholder group in these figures and defined in Table 5 below. The categories are listed from most to least frequently occurring as implementation, operational, behavioral, monitoring, and infrastructural challenges; these are defined in Table 6 below.

Table 5: Explanation of Stakeholder Group Acronyms

STAKEHOLDER ACROYNYM	EXPLANATION
EES TEAM	Lower Mainland health organizations Energy Environment and Sustainability Team
FMO	Lower Mainland health organizations Facilities Maintenance and Operations
BISS	Lower Mainland health organizations Business Initiatives Support Services
BC HA	Other BC Health Authorities: Vancouver Island Health Authority (VIHA) and Interior Health Authority (IHA)
G+L	Lower Mainland health organizations Green + Leaders

Table 6: Category Definitions of Water-Saving Challenges

CHALLENGE CATEGORY	DESCRIPTION
IMPLEMENTATION	Competing prioritization of projects with limited funding and staff resources impacts implementation of new technology, operational changes, and monitoring programs.
OPERATIONAL	Water-saving interventions face barriers due to perceived risks to facilities operations and infection control; these may be influenced by educational barriers.
BEHAVIOURAL	Lack of awareness and educational barriers result in mindsets that view water conservation as a low priority and increase resistance to change.
MONITORING	Limited water sub-metering and data collection and analysis methods were identified; water metering strategies must overcome implementation and behavioral challenges.
INFRASTRUCTURAL	Variations in existing equipment, space availability, and other unique conditions require resource-intensive and site-specific feasibility assessments.

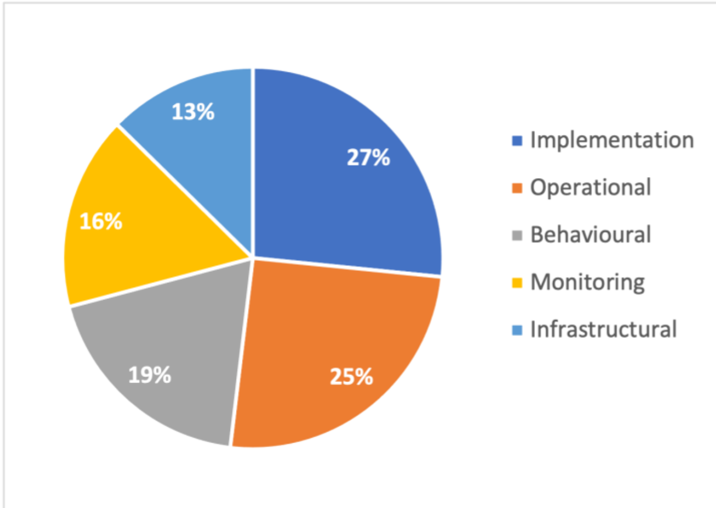


Figure 4: Percentage of Total Responses for each Challenge Category

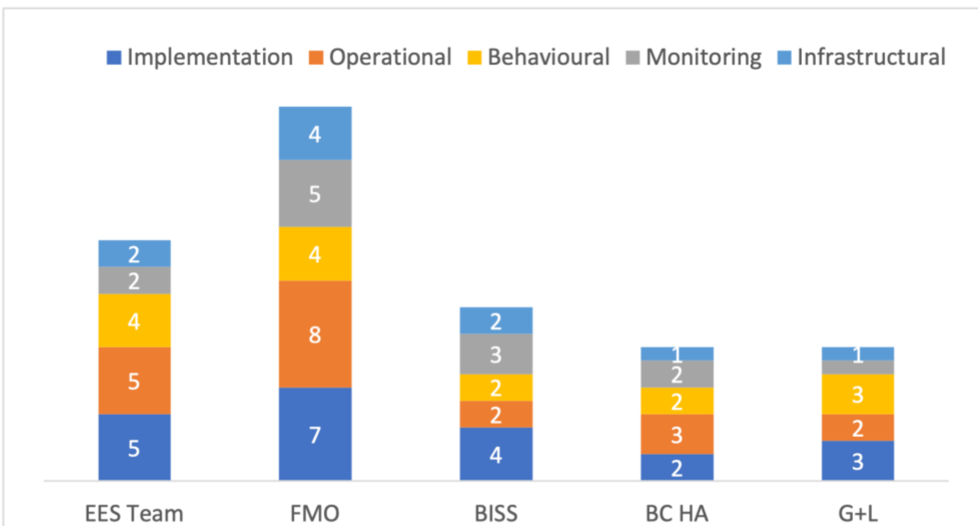


Figure 5: Number of Respondents per Stakeholder Group Referencing each Challenge Category

Implementation: Prioritization of Funding & Resources

Implementation challenges, due to the prioritization of limited funding and resources, were expressed by twenty-one out of forty (53%) interviewees. Five of the interviewees mentioned the BC government's mandated institutional goals for reducing greenhouse gas (GHG) emissions.

> *'...I personally have a great desire to save water, because I know it costs money, especially in the summer season. But I think it's suffering from the fact that it's not a direct contributor to climate change.' (FMO13)*

Due to this, there are more *incentives and funding available for energy-saving projects*, which also drives the priorities of staff resources and reduces the capacity for exploring other opportunities like water savings. This challenge is not unique to the Lower Mainland health organizations facilities, interviewees from two other BC Health Authorities noted capacity and resource constraints, both for new projects as well as for maintaining data management systems. Two interviewees mentioned previous audits that were conducted for improving water usage, however, few of these recommendations have been implemented. **Prioritization of funding and resources can be inferred as one of the primary barriers**.

Implementation of water-saving opportunities faces challenges due to costly replacements of ageing infrastructure with limited funding capacity. FMO1 stated that many water-saving projects haven't been implemented since *existing systems are old and it takes time and capital to replace them all*. Another direct example of a cost barrier was shared by BISS6 regarding dispensing systems, which can reduce water waste during cleaning solution preparation; the City of Vancouver was charging a significant amount of money to install a backflow system that prevented the project from being implemented. FMO14 shared that they ran into funding challenges when trying to retrofit their steam sterilizers; the cost to add a conditioning unit to recycle water was $12,000, and due to the cost, this project was not approved. EES3 highlighted projects like eliminating once-through-cooling equipment that has the potential to reduce water usage, but they are costly and with long payback periods, so it is **difficult to get these projects prioritized**.

> *'...If it's a question of spending money to improve the chillers or to save a few gallons of water, chillers will be more of a priority since they are so important for health care. We want to do these projects, but there are so many of them to prioritize.' (EES3)*

Funding allocations are determined by the prioritization of projects and available capital. BISS2 said that they are aware of the ENERGY STAR models that could replace older more resource-intensive equipment, like dishwashers. However, since most kitchen facilities use flight machines, due to the large capacities they handle, these *capital-intensive replacements exceed the department's internal funding* and would need to be **prioritized against other capital projects** by the health authority.

Operational: Infection Control and Operations Impact

Operational challenges arise when water-saving interventions impact procedures like infection control or cause unintended consequences on operations and maintenance performance. These challenges were referenced by twenty out of forty (50%) interviewees and are seen as the second most significant challenge preventing water-saving opportunities from being implemented in healthcare facilities. A common example was shared of restricting flow or using aerators on faucets, which can *increase the risk of Legionnaire's disease*. FMO14 added that low-flow fixtures can cause biofilms to grow in the drain; minimum flowrates are required to clean out the drains and prevent this from happening. EES4 summarized as follows:

> *'...Water is very important but doing water conservation is hard, we need it to sustain life. Conservation is great for the environment, but water usage is a priority for the health authority.' (EES4)*

From EES2's experience, they observed that the operating side of a system tends to be overlooked when introducing new changes. They added that while it may be easy to implement a water-saving opportunity on paper, there are many other aspects that need to be considered for commissioning. This is especially a challenge when it comes to new technology that staff have little previous experience with as it can cause unforeseen operational challenges and performance consequences. EES6 also identified a barrier regarding coordination with FMO stakeholders, noting that if a replacement makes the system **more complicated or costly to maintain** then there will be an immediate barrier with the FMO.

Several cases of unintended consequences from water-saving opportunities were highlighted by FMO stakeholders. FMO1 shared a project on waterless urinals that resulted in clogged and corroded drains and *created cleaning issues for housekeeping*. Similarly, low flow faucets caused calcium deposits in the drain that required housekeeping to use stronger cleaning chemicals, which increased the potential for other environmental hazards. While these are typical water-saving opportunities, FMO5 stated that they usually reject low-flow projects due to the operational impacts. BISS1 further added that water-saving devices, like low-flow faucets, may see pushback since they can *impact cleaning efficiency*, which is important for staff. Therefore, water-saving opportunities must carefully assess the **impacts to infection control standards as well as any operational impacts** upstream and downstream of the new equipment.

Another example of operational impacts was shared by EES4 when eliminating water-cooled systems for air-cooled systems. While this reduces water use, air-cooled systems are dependent on outside temperatures and are therefore more difficult to control. This has potential risk for areas like morgues or kitchens that can't risk losing operational control of cooling systems. Additionally, these modifications may have the consequence of increased energy usage. EES4 expressed that these changes have a **trade-off and balance point between water-saving and energy consumption** that needs to be assessed.

Other benefits of water-consuming activities should also be assessed prior to reducing water consumption. GL4 shared an example of the value of water consumption for irrigation at their facility:

> *'...Our garden is classified as a healing garden, and many of our patients utilize this space, especially over the pandemic when hospitals limited the number of visitors. Children at the end-of-life could still come to our facility with their parents, so our garden was a place for many families to have their last moments with their children before they passed away.' (GL4)*

GL4 added that keeping this garden as a special and beautiful place is of utmost importance for their staff and the health and wellbeing of their patients. Therefore, while water-saving strategies are necessary for long-term sustainability and environmental health, they need to be **balanced with impacts on energy consumption and quality patient care**.

Behavioral: Resistance to Change & Lack of Awareness

Behavioral challenges were mentioned by fifteen out of forty (38%) interviewees, largely due to a lack of awareness for water conservation practices and legacy mindsets that enhance resistance to change. For example, it is known that low flows pose a challenge for infection control procedures due to sanitation and legionella concerns. However, both EES1 and EES6 identified that there may be a lack of awareness about innovative technologies that can reduce water usage while still meeting all health standards. FMO11 shared that there is **resistance** in their facility to installing innovative water-saving sterilizers due to concerns over operational impacts and changes to standard ways of working; they added that the biggest pushback comes from clinical groups. FMO7 also identified these challenges in shifting from water-cooled to air-cooled compressors. While they agreed that air-cooled systems would use more energy due to the additional motors needed, they concluded that a **greater understanding** of the full picture is needed to assess this. For example, when considering the costs of treating municipal water, dumping into the sewer, managing chemicals, and monitoring for legionella concerns in water-cooled systems, the costs of switching to air-cooled systems may not be a limiting factor. Whereas, in **legacy methods** that only compare energy and water balances, the cost-benefit for installing air-cooled units may not be sufficient for stakeholder approval.

GL1 shared an example of cleaning dirty instruments, which uses a lot of water in clinical practice. They noted that the water waste is driven by legacy procedural operations and lack of awareness:

> *'…Several staff members have a practice of turning on the water and walking away. There isn't really any proper procedure in place and there could be a variety of reasons why people let it run: they don't want to wait for a few minutes while the water is filling in the basin; they walk away and forget about it; it's something that someone else showed them so they are just continuing to do it this way, or there are others that just may not be aware of this.' (GL1)*

BISS2 shared that the organization has many long-standing employees who drive institutional memory, which has benefits, but this can also make it **challenging to initiate procedural changes**. EES2 explained that they have seen many scenarios arise where an institution was trying to change a procedure but with little consideration for how to **address legacy practices and increase awareness of users** to accept the change as a necessary improvement prior to implementation.

> *'…While something may seem logical in terms of how it can save and how it works, you can't change the legacy of a company. They have been operating this way for 30 years and they are used to it working this way, and suddenly you try to change it without considering how to train them and how they are going to operate this. This is very important' (EES2)*

These types of scenarios can **enhance attitudes that are resistant to change**. This sentiment was shared by EES3 who expressed the operational difficulties with installing new equipment:

> *'…Many people are used to traditional cooling towers…and now you have introduced a new system that they need to learn how to deal with. A lot of people don't like this, they don't want to deal with (or learn) new technologies and new work procedures.' (EES3)*

Many of the interviewees shared the sentiment that water conservation mindsets are not present. There is still a preconception that in Canada, where water costs are low and water resources are in abundance, that conservation of water resources is not a priority. Therefore, to implement successful water-saving opportunities and procedural changes, these **mindsets need to be overcome** first and foremost.

However, challenges remain with how best to overcome these mindsets. When presenting the idea of sharing this information at team meetings or holding additional seminars, two of the G+L interviewees expressed this would be a problem for clinical staff who are very busy during their shifts. Attendance may require personal time that is not available to everyone, so the opportunity to talk about water savings or isn't always there. HA2 added that **behavioral changes are difficult** when everyone already has so much to think about. Therefore, overcoming legacy mindsets requires **increasing awareness of water conservation** as a priority in everyday healthcare practices without increasing the burden on staff resources.

Monitoring: Water Meters and Data Management

Monitoring challenges were mentioned by thirteen out of forty (33%) interviewees and were largely attributed to the **lack of water meters and difficulty in managing data systems**. FMO1 expressed that water savings are difficult to measure since there are only two main meters on the water line coming from the city and some buildings are off the same meter. They added that while meter readings are collected, they aren't being monitored or visually displayed to give perspective on trends in water usage, likely due to *limited staff resources for data management*. This makes it **challenging to understand high consumption** areas in the facility and to develop key performance metrics.

Several interviewees highlighted monitoring challenges in kitchen services, which is a high-water consuming area. BISS2 explained that since there are no power consumption meters or water meters in kitchen facilities, there are no mechanisms to **develop baselines or monitor improvements** even when retrofits or procedural changes are made. Further, this lack of data to quantify savings creates barriers to gaining stakeholder buy-in. Leaks in underground piping are another challenge, particularly for older facilities as highlighted by three interviewees. Given the **lack of water meters to monitor variations** in use, this makes leaks challenging to identify and prioritize for repairs.

While several interviewees stated that it is possible to add water meter specifications to new contracts, installing water meters alone is not enough. FMO13 and FMO16 added that it can be difficult to know where to install water meters due to the complexity of water systems and lack of system infrastructure that prevents connecting to existing building systems. EES3 further emphasized that since water meters are expensive to install, a strategy for determining where to install them and how the data will be managed is pertinent. This relates to the primary challenge of *prioritizing capital and staff resources* for monitoring and managing water meter data. HA3 shared a direct example relating to this:

> *'…We started to input the (water) billing information into the system, but you need to have resources to maintain that system. Just setting up the system itself took almost four months, and that hasn't been updated in three years. So, we'll have to restart the process, but we currently don't have the resources to do so. When you have someone working on this for only a few months (like interns), they can only start the process, but they can't finish it (or maintain it)'. (HA3)*

Another important consideration for water metering is stakeholder alignment. HA1 shared an example where meters were added to measure domestic hot water consumption, but the FMO made some changes and ended up taking out the meters. They highlighted that overcoming these barriers requires motivation and alignment for a metering plan to ensure the system is monitored and maintained. Given the importance of **measuring outcomes** as expressed by many of the interviewees, water metering presents a current challenge and a future opportunity to manage and improve water usage.

Infrastructural: Site Variability (Equipment, Space, Processes)

Ten out of forty (25%) interviewees referenced **challenges with infrastructure and site variability** resulting in different water-use practices, both across the Lower Mainland health organizations and within organizations. While standard operating procedures are used by most sites, the layout and equipment are different, which makes it difficult to implement a technology or practice that would work across all organizations. Infrastructure constraints are also present and *water-saving procedures may conflict with infection control standards* due to this.

BISS1 shared that within their facility, there is variation between kitchen facilities depending on when it was built and what the site-specific practices are. They provided a specific example pertaining to washing carts for patient food delivery; every site has different practices based on how the carts are used and what the infection control requirements are. While they agreed that this labour-intensive process presents an opportunity for modification and water savings, like adding a second set of carts to reduce washing, they also noted that **site-specific variability like different sanitation schedules, different equipment availability and labor availability, as well as space constraints** for storing carts, poses a challenge.

Site variability is also present when analyzing retrofits for equipment. EES4 shared that the Medical Device Reprocessing Department (MDRD) sterilizers present a significant water-saving opportunity; retrofitting to use less potable water by recycling water for heating rather than disposing it from once-through cooling. However, the difficulty of implementing this water-saving measure relates to limitations and restrictions of the required physical space for additional equipment and the proximity of the condensate's heat rejection and recovery line. FMO14 and FMO15 added that some once-through-cooling units can't be replaced due to their location in the building, making it difficult to run separate cooling systems or install new units.

Infrastructure constraints are also present when considering changes to facilities that impact contracts with service providers. One interviewee shared an example of this as follows:

> *'…Big companies are eager and on-side to partner on sustainability issues…however, this can be a challenge when the infrastructure is outdated. Even if they have good ideas for sustainability strategies, their service model may not work with the existing infrastructure. The infrastructure needs to be in place before they can implement sustainable ways of working.' (BISS4)*

Therefore, water-saving opportunities are dependent on a site-specific analysis to determine the feasibility of implementation. This ties in with the primary challenge of *prioritization of funding and resources* since this type of audit and analysis would require significant resource allocation.

Implementation of water-saving projects is heavily influenced by all challenges discussed. Therefore, any new opportunities must be carefully analyzed from the initial design concept to the implementation phase, including commissioning and hand over to operations. Details surrounding what the existing infrastructural constraints are; what the operational and/or infection control impacts will be; how the equipment will be monitored to track water-saving reductions; and how the message will be communicated to gain approval for funding allocations requires careful due diligence and stakeholder coordination and collaboration.

Opportunities

The analyses identified seven categories of water-saving opportunities based on the interviewee's responses. These categories are described in Table 7 below and listed from most to least frequently occurring as: retrofits and replacements; education and awareness; water metering strategies; operations and facilities maintenance; water management planning; climate resilience and energy synergies; new construction and contracts. Occurrence frequency was counted based on the number of interviewees that mentioned an opportunity category, resulting in the distribution of responses shown in Figures 6 and 7 below. Stakeholder acronyms presented in the figures follow the descriptions from Table 5.

Table 7: Category Definitions of Water-Saving Opportunities

OPPORTUNITIY CATEGORY	DESCRIPTION
RETROFITS & REPLACEMENTS	Opportunities were identified in various areas including non-domestic uses (i.e., equipment, landscaping, housekeeping, processes, kitchen services) and domestic uses (i.e., faucets, toilets, showers, icemakers, etc.).
EDUCATION & AWARENESS	Methods for educating staff can be improved by integrating water awareness into daily messaging to create a cultural shift in water conservation mindsets.
WATER METERING	Strategic implementation of water sub-metering and data management requires significant resources; re-framing this as a risk prevention rather than cost-saving strategy can increase stakeholder buy-in.
WATER MANAGEMENT PLANNING	Collaboration between stakeholder groups was identified as a key to improve water management planning and execution in healthcare facilities.
OPERATIONS & MAINTENANCE	Embedding water use monitoring and conservation practices into operations and maintenance processes presents low- to no-cost water-saving interventions.
CLIMATE RESILIENCE & ENERGY SYNERGIES	Recognizing the relationship between water conservation and climate adaptation in healthcare settings can help prioritize water-saving opportunities.
NEW CONSTRUCTION & CONTRACTS	Paying special attention to new construction and redevelopment projects is recommended as they often present suitable context for implementing design strategies that embrace water conservation.

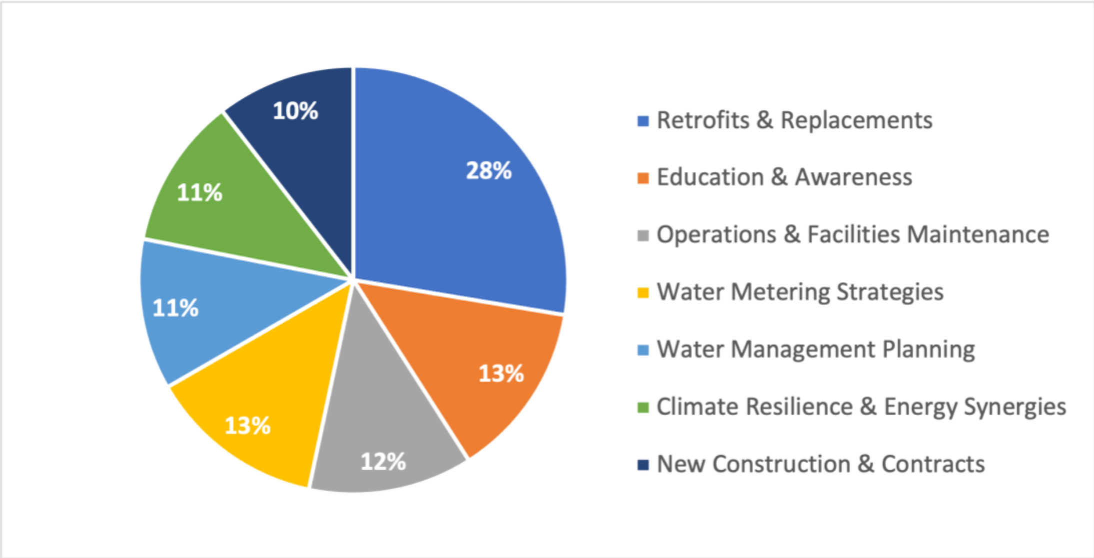


Figure 6. Percentage of Total Responses for each Opportunity Category

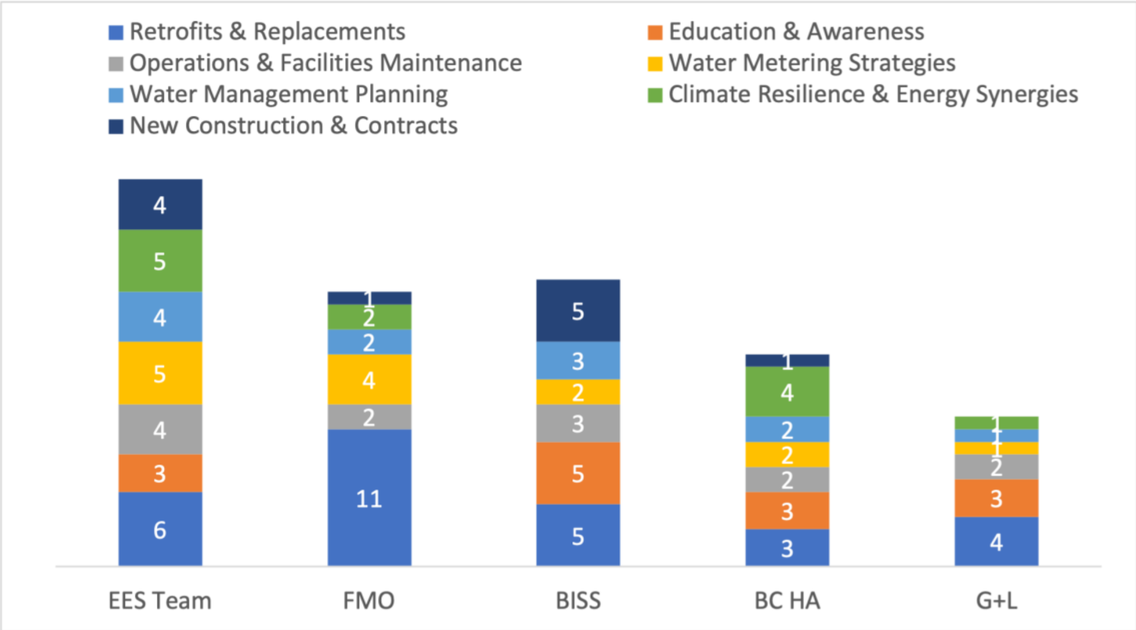


Figure 7. Number of Respondents per Stakeholder Group Referencing each Opportunity Category

Retrofits & Replacements

Opportunities for retrofits and replacements were mentioned by twenty-nine out of forty (73%) interviewees, thereby making it the most significant water-saving opportunity for Lower Mainland health organizations facilities. These were categorized based on the research findings as domestic and non-domestic uses of water; the latter being the most frequently referenced opportunity. Figure 8 shows the distribution of responses regarding retrofit and replacement opportunities for each water-use category. The following sections focus on the most frequently mentioned sub-category for retrofits and replacements as shown in Figure 9.

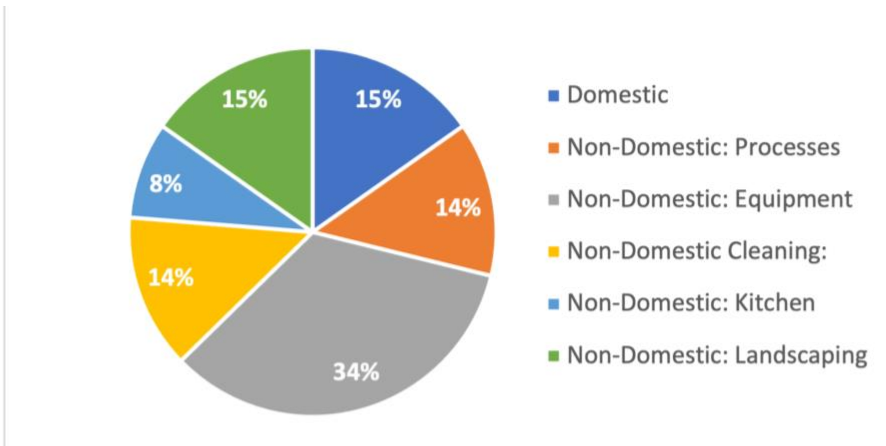


Figure 8. Percentage of Responses per Water-Use Category for Retrofits and Replacements

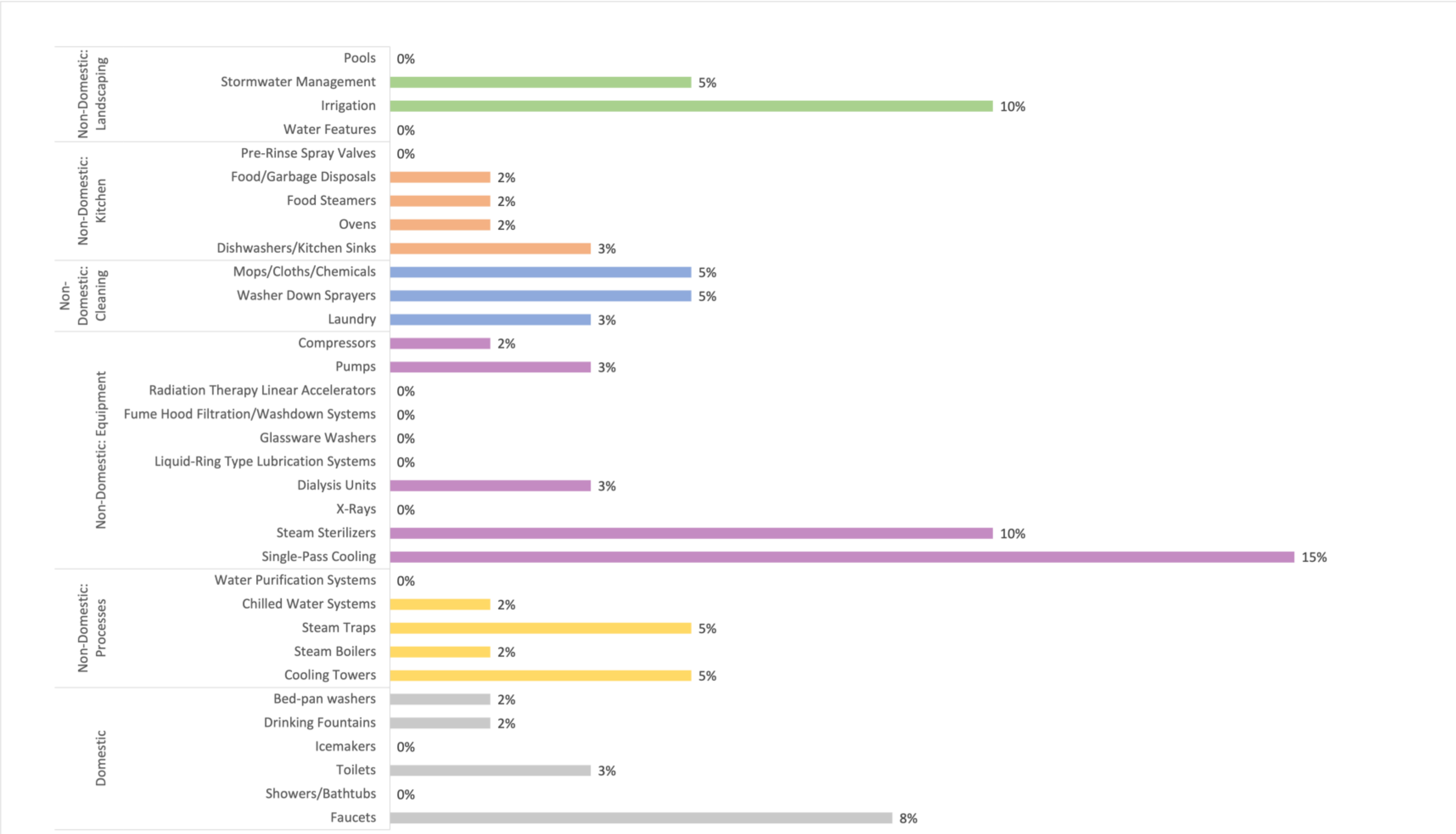


Figure 9. Percentage of Responses per Water-Use Sub-Category for Retrofits and Replacements

Non-Domestic Equipment:

The most frequently mentioned opportunity for retrofits and replacements, by twenty out of forty (50%) interviewees, was for non-domestic equipment; **single-pass cooling** (i.e., once-through water-cooled) equipment was the most frequently mentioned equipment sub-category. Single-pass cooling occurs in *steam sterilizers, dialysis units*, and *refrigeration compressors,* which use municipal treated (potable) water for cooling operations and disposes to the sewer after one use. While some Lower Mainland health organizations facilities have already implemented projects that replaced water-cooled compressors with air-cooled compressors, the interviewees identified that more opportunities remain[8].

> *'…These systems shouldn't be in our facilities anymore but every time we look, we still have this equipment in place. It's worth doing an audit to see where these systems are installed. (HA1)*

For eliminating single-pass cooling, **steam sterilizers** were identified as the most significant equipment opportunity. FMO13 plans to retrofit one of their facility's sterilizers to prove performance and gain clinical stakeholder buy-in before replicating these changes on the remaining two sterilizers. EES5 is taking a proactive approach; their facility has completed an audit to identify all single-pass cooling equipment, like MDRD sterilizers, and is developing a long-term plan to retrofit and replace these units. Retrofits include recirculating the condenser water or using drain heat recovery technology[9], that is well-established, low-maintenance, and simple to implement. EES5 shared that this technology can recover up to 15% of the hot drain water heat, which would reduce tempering water volumes. Other Lower Mainland health organizations facilities could conduct a similar audit to support a long-term replacement/retrofit plan.

While some interviewees shared concerns about the *trade-off between water versus energy consumption*, FMO7 shared a different approach for evaluating these opportunities. They explained that if the only comparison is between energy versus water consumption, then the cost-benefit may not be realized. However, there are other factors, like the cost of treating water and disposing of wastewater, which should be considered. Air-cooled systems have the added benefit of eliminating Legionella risks and associated resources for chemical treatment management. EES6 believed that the slight increase in energy usage is outweighed by the water-saving benefits. They added that if **efficient pumps** are installed in air-cooled systems, then both energy and water savings can be realized.

Dialysis units were identified as another water-saving opportunity. EES3 expressed that these systems can be retrofitted to use the reject water for irrigation purposes. HA1 shared that their facility is assessing ways to capture between 50-80% of the reverse osmosis water used in dialysis systems rather than sending it to

[8] Five interviewees noted that the City of Vancouver has made a bylaw mandating the removal of single-pass cooling equipment and that Metro Vancouver may follow suit. This would impact many of the Lower Mainland health organizations facilities and may increase potential for re-prioritization and funding incentives for these projects.

[9] One interview shared that their facility is assessing the use of RenewABILITY's drain heat recovery technology, more information on this technology can be found here: http://renewability.com/commercial/

the drain. This high-quality reject water can be retrofitted to a closed-loop system and used in operations like *cooling towers, steam boiler make-up water, or dialysis box flushing*. HA1 highlighted this as a significant opportunity for their facility, which currently drains 16,000 L of water per day from dialysis units.

Non-Domestic Landscaping:

Landscaping opportunities were identified by nine out of forty (23%) interviewees, with **irrigation systems** being referenced the most. While the 2013 audits [10]recommended water-saving irrigation technology for several facilities, few of these have been implemented to date and therefore remain as an opportunity for the Lower Mainland health organizations to consider. GL4's facility has made some improvements like installing **rain-detection sensors**; however, they believe more opportunities remain to assess technology like drip irrigation, flow-reducing spray heads, or spray head elimination to mitigate evaporation losses. FMO2 shared opportunities to improve their irrigation system, which uses potable water and does not have **weather sensors** nor **water meters** installed to monitor irrigation water consumption. FMO11 and FMO13 also agreed that irrigation at their facility could be improved by installing **automatic irrigation systems**.

Another opportunity that GL4 is investigating is the use of **rainwater cisterns** with automatic pumping capabilities. Cisterns were installed in the past, however, the ergonomics of collecting the water with buckets for manual watering proved difficult for senior citizen volunteer gardeners. HA3 expressed that rainwater collection for irrigation is a natural and low-cost option that they'd like to see implemented at their facilities. Another example for alternate water sources was shared by EES3 wherein dialysis units can be retrofitted to use the reject water for irrigation rather than dumping it into the drain. While greywater reclamation is another potential alternate water source, *onsite treatment can be cost and space-prohibitive*, so rainwater cisterns are likely more feasible. However, FMO15 shared from their experience that these systems are unique and require specialized operations strategies. Further, they *require significant maintenance* due to filtration requirements and are therefore more feasible for smaller facilities. FMO15 highlighted that there is more opportunity in new builds to install rainwater systems since sump pumps are typically installed beneath buildings and would result in costly retrofits.

Non-Domestic Processes:

Non-domestic processes present opportunities for hardware upgrades as highlighted by eight out of forty (20%) interviewees. These include *cooling towers, steam traps, steam boilers, chilled water systems, and water purification systems*; listed from most to least frequently mentioned by interviewees. Replacing **steam traps** with maintenance-free technology can reduce steam loss and are a simple, cost-effective water-saving measure with the added benefit of improving energy efficiency. **Cooling towers** present another opportunity for water-saving. Several interviewees highlighted that retrofitting open-loop cooling towers to closed-loop systems are an opportunity to save water. Similar opportunities exist for **steam boilers** that were

[10] In 2013, several water audits were performed for various sites within the Lower Mainland health organizations facilities. These identified opportunities for reducing water consumption, primarily in irrigation services and once-through-cooling equipment.

identified by three interviewees; retrofitting to closed-loop systems that extract heat from hot boiler make-up water saves energy and reduces sewer disposal volumes and water needed for tempering.

Non-Domestic Cleaning:

Retrofits and replacements for cleaning activities were identified by eight out of forty (20%) interviewees. One facility is working on a project to reduce water use in **laundry services** by implementing an innovation known as 'Lux Technology', which uses ozone and UV light injection to increase disinfection properties and thereby decrease wash water volumes. EES2 shared that this project is being propelled by a successful trial of this technology at another healthcare facility and could be evaluated as an opportunity for other facilities.

Other high water-consuming activities identified by the interviewees were **outdoor cleaning and equipment** washing. BISS7 noted that self-closing nozzles should be installed on pressure washers to prevent unnecessary drips and water waste. **Cart washing** in kitchen services is a labour- and resource-intensive activity that BISS1 identified as an opportunity. A one-time investment of purchasing two sets of carts or Interlock Z-Carts for facilities with space restrictions would reduce the need for sanitation and water use.

While most facilities use microfiber cloths, green chemicals, and dilution systems, an opportunity was identified for some of the *long-term care facilities* that are not implementing these tools. **Dilution systems** result in water savings by automatically dispensing cleaning chemicals to mitigate human error during solution preparation; BISS6 expressed that those errors result in unnecessary water use since new solutions must be prepared. BISS6 added that long-term care facilities use string-mops, which require buckets to be changed out after every four rooms. Replacing these with **flat mops** would reduce unnecessary water usage.

Non-Domestic Kitchen:

Opportunities to reduce water use in kitchen facilities were highlighted by five out of forty (13%) interviewees. Although most of these opportunities relate to contract service agreements discussed later in the report, replacement and retrofit opportunities were identified. BISS2 noted that **ageing dishwashers** present replacement opportunities to ENERGY STAR models[11]. Additionally, some of the long-term care facilities utilize food steamers and have food disposal troughs that use water for one rinse cycle before draining. Feasibility assessments for these opportunities could benefit from collaboration and shared learnings with other facilities that have already implemented these changes. For example, BISS4 shared that most **food steamers** have been replaced with combination ovens that are more efficient and use less steam. BISS1 and BISS4 shared that **food disposal troughs** have been retrofitted with water recycling capabilities or replaced with food pulpers and composting programs.

[11] ENERGY STAR is an EPA-backed symbol for energy efficiency. ENERGY STAR models can indirectly reduce water use by improving energy consumption, for example in dishwashers, ovens, icemakers, etc. (ENERGY STAR, 2021).

Domestic:

Opportunities to reduce domestic water use through retrofits and replacements were mentioned by nine out of forty (23%) interviewees. The main opportunity for domestic water use, as identified by three G+L interviewees, is the addition of **foot pedals** or **automatic motion sensors on high-flow faucets**, primarily found in clinical sinks and dirty utility rooms. This technology also reduces contamination risk, which is valuable for infection control. While **low-flow toilets** reduce water, they create challenges for operations as discussed previously. FMO8's facility is evaluating the installation of automatic flush valves for septic systems that could overcome this issue and realize benefits from intended water savings. Another example was shared by BISS5 of the Vancouver Convention Centre that recycles and reuses water for flushing rather than sending it to the drain, which could be considered for new construction and redevelopments. FMO13 shared that while clinical sinks may be more *difficult to replace with low flow fixtures due to infection control restrictions*, these changes could be implemented for public washrooms. They suggested the development of a Lower Mainland health organization policy to install **EPA WaterSense fixtures**[12]during any renovations or equipment replacements (subject to flowrate requirements).

Education & Awareness

Following retrofits and replacements, fourteen out of forty (35%) interviewees referenced opportunities to improve staff education and awareness. Interviewees generally agreed that **educating staff** on the value of water conservation could help overcome legacy mindsets that view water-saving as a low priority in British Columbia, where water resources are seemingly abundant and water costs are low.

GL1 shared that during the pandemic, Infection Control regulations removed all signage, but as restrictions ease and signage returns, there is an opportunity to incorporate **information on water conservation**. Other approaches were shared by HA2 who is developing a video to raise awareness for water reuse and energy synergies. Later this year, they'll also be starting a campaign to target behaviors for efficient laundry utilization. Since methods like dedicated sustainability events can be challenging to coordinate and participate in, HA4 proposed the following opportunity.

> *'…There needs to be dedicated resources that make it easy for people in the organization to engage in these conversations. Rather than it being a one-time initiative, it could be embedded into our daily work…integrated engagement can promote a cultural shift to change the way we think about our relationship to water.' (HA3)*

[12] WaterSense labeled products are those which meet the Environmental Protection Agency's (EPA) specification for water efficiency and performance, and are backed by independent, third-party certification. Products with a WaterSense label: perform as well or better than less efficient counterpart; are 20% more water efficient than average products in that category; realize water savings on a national level; provide measurable water savings results; and achieve water efficiency through several technological options. (EPA, 2021)

HA3 agreed with this sentiment and added that *messages only work when heard multiple times*. They shared the health authority's success in creating a safety culture; a similar approach of **integrating water conservation into regular communications** could be beneficial. GL3 shared their perspective:

> *'…If you are changing something that people are used to and they see it as interfering with their day-to-day activities, then you will get more resistance. Whereas, if you come to them with an approach that requires little individual input then things will go a lot smoother. Showing data and facts about how the change can help the environment makes people more eager to participate too.' (GL3)*

BISS2 agreed that **increased education and visibility of outcomes** is key for staff-buy in of behavioral changes. They added that the health authority has leverage to influence **monthly training seminars** conducted by service providers if opportunities are identified. EES6 observed that kitchen staff sometimes leave the faucets running to defrost food, which results in water waste and could be improved through **training and education on the proper uses of water**.

Other interviewees suggested partnering with the Green+Leaders (G+L) to approach **behavioral changes** in water-use practices. For example, **water-conservation awareness** could be incorporated into the G+L sustainability toolkits and become a future three-month focus area. BISS3 added that many of the service providers are part of the G+L network; these connections could be leveraged to increase awareness.

An important step for staff awareness and participation was highlighted by GL1; **management encouragement** was key to their personal involvement with the G+L. They added that when management designates roles like conducting audits and other awareness initiatives to staff, it creates trust and gets more people talking about sustainability. GL1 shared that they were selected to roll out a recycling initiative that was successful due to their innovative approach of incorporating games to engage with staff. A similar approach could be taken with water conservation.

Water Metering Strategies

The opportunity to install water meters and improve water consumption monitoring practices was identified by fourteen out of forty (35%) interviewees. EES4 stressed the value of water meters to support water management and the implementation of new practices and technologies:

> *'…Water meters are one way to develop a water management plan, because if you cannot measure it, you cannot manage it'. (EES4)*

BISS2 shared this sentiment adding that if water meters were in place, it would **quantify savings** and create more **visibility of outcomes** to encourage different operational practices and behaviors:

> *'…Water metering is the most important for us as it would really help to monitor outcomes, especially when we change a practice. Meters would help the business case too; if we are going to spend more on a piece of equipment but can show that we will save more on water and/or power, that will be beneficial.' (BISS2)*

Interviewees agreed that monitoring, graphing, and visually displaying water meter readings would give perspectives on trends in water use could support the health authority in reducing water consumption.

Leak identification was highlighted by EES1 and EES6 as an additional benefit of water submetering; *unidentified building leaks can consume large volumes of water and pose risks* to facilities management and operations. EES1 stated that **re-framing metering as risk prevention** rather than a cost-saving strategy would increase stakeholder buy-in. Further, **monthly monitoring** at the site level would likely catch variations in water use and prioritize repairs without waiting on quarterly data from the city. EES5 shared another low-cost intervention; leak detection and alarming systems could be installed on city water meters. Several FMO stakeholders also supported water metering, adding that it would make the most sense for large facilities or when retrofitting equipment like steam sterilizers to **measure outcomes** of these initiatives.

Interviewees stressed that a **strategy is needed for water meter installations** to overcome monitoring and data management challenges previously discussed. While new construction provides an easier opportunity to install water meters, EES4 explained that methods to assess installation locations for existing facilities could follow the health authority's energy sub-metering plan. For example, focusing on systems that use more than 10% of a facility's total water use. HA1 shared findings from a water audit at their facility; data was collected using temporary strap-on meters where feasible or estimated from equipment and fixture flow rates. This audit identified the highest water users as *cooling towers, thermal plants, renal dialysis units, and food services*. These areas could be prioritized for sub-metering in other facilities by utilizing internal resources or hiring a third-party consultant. These strategies also relate to the recommendations for a water management plan discussed next.

Water Management Planning

Thirteen out of forty (33%) interviewees referred to opportunities that would support the development of a water management plan. The first step in developing a water management plan is the **assembly of a water management team**, which interviewees saw as an opportunity to leverage partnerships with other departments. BISS1 suggested partnering with the Sustainable Food Operations Committee that is conducting audits on food waste in kitchen services and could potentially include water objectives into these initiatives. BISS8 stressed the importance of including Infection Control and Service Providers whose experience would help identify feasible water-saving opportunities. Other interviewees highlighted that the Green+Leaders could be approached to seek interest in furthering water-conservation goals. EES6 added that prioritizing water-saving could support funding a Water Coordinator position within the EES team.

The second step of a water management plan is **assessing facility water use**. While this has been done in some areas, like once-through-cooling systems, an opportunity remains to complete a robust assessment across all organizations. Two interviewees shared the approach of developing a preliminary checklist or survey for FMO and BISS stakeholders that are most familiar with facility equipment. This information would help develop a baseline of operational water use and identify opportunities for equipment upgrades. HA1 shared another benefit; water tracking initiatives can raise awareness and motivation from various stakeholder groups within the organization. While water audits are resource-intensive, FMO7 believed that it's worthwhile to prevent unnecessary water use.

Setting water reduction objectives and goals is the third step in a water management plan. EES6 stated that a generic water management plan with correct monitoring measures would support the development of action plans and resource allocation. Assembling a water management team with representatives from each interviewed stakeholder group would also support realistic target setting with fewer operational barriers. Two BISS stakeholders shared they are considering ways to connect the EES team with Service Providers in discussions on new equipment purchases. FMO stakeholders should also be involved in these discussions to share their perspectives on evaluation metrics for new projects. FMO5 highlighted that reliability, consistency, performance, and reduced labour-intensive operations and maintenance requirements are important key performance indicators for new projects. FMO13 shared that these goals could be realized by implementing a site-wide policy to install EPA WaterSense models for any new replacement.

Focusing on these initial steps would support the remaining phases (i.e., **implementing, reporting and analyzing,** and **improving**) of the water management plan. FMO13 shared that it would be most supportive to look at successful interventions from other healthcare facilities to share lessons learned about implementations that were not successful and how to modify them. They concluded the following:

> *'… I think that the key is to keep the team engaged with feedback mechanisms of the metrics (like reducing GHG bills or steam bills) to see how successful the interventions are. It's also great to celebrate the successes as this helps with team motivation and engagement.' (FMO13)*

Operations & Facilities Maintenance

While changes to operations and maintenance strategies were not referenced as frequently as retrofit and replacement opportunities, thirteen out of forty (33%) interviewees identified potential areas of improvement. The operations and maintenance references made by these thirteen interviewees were categorized as per domestic and non-domestic uses, as shown in Figure 13. Operations and maintenance opportunities referenced by interviewees from most to least commonly occurring were non-domestic uses (processes, cleaning, landscaping, and equipment) and domestic uses.

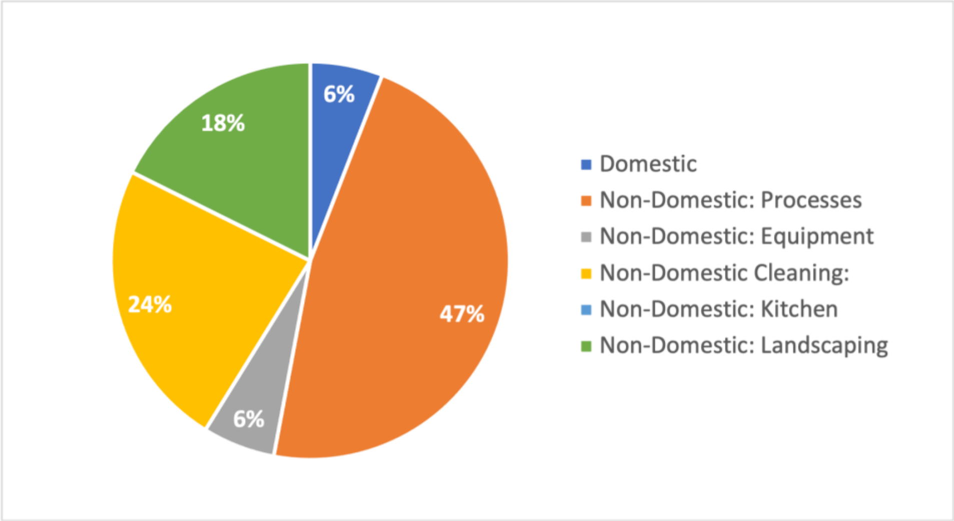


Figure 10. Percentage of Responses per Water-Use Category for Operations and Maintenance

Non-Domestic Uses:

For non-domestic uses in heating and cooling processes, the most referenced opportunity was in **water purification systems** and **steam traps**, followed by **chilled water systems** and **cooling towers**. Three interviewees noted that steam traps are often not well maintained and present an opportunity for water savings. FMO9 identified a specific opportunity for water purification:

> *'…For buildings with high lead content, we run an automatic flush valve to make the water safe for consumption. We could correct this by having chemical treatment rather than flushing or re-piping.' (FMO9)*

This example shows that water savings can be *realized without costly retrofits and replacements*. HA1 highlighted the value of **assessing water treatment systems** that require regular filter maintenance and consume water in back-flushing operations. At their facility, legacy filters were installed in storage containers to prevent the risk of Legionnaire's disease. However, their team identified that these filters were no longer necessary due to improvements in municipal water supply quality. They concluded that it's good practice to periodically check water quality and determine the necessity of water filters since this can save on maintenance costs and reduce water usage.

BISS9 shared a successful utilization program that improved operations and maintenance practices in **laundry services** across Lower Mainland health organizations facilities. This continuous improvement program required close collaboration with facility leadership to observe, monitor, and measure outcomes of operational changes; BISS9 shared that it has resulted in decreasing laundry volumes since 2011 across Lower Mainland health organizations facilities.

FMO14 shared how their facility has eliminated irrigation requirements by cutting back on plants, planting mostly lavender and other low-water native species, and letting the grass go golden in the summers. GL4 has been focusing efforts on **improving irrigation water utilization**; due to the garden size, they see this as the greatest water-saving opportunity. GL4 is having discussions with the Master Gardeners to determine minimal watering requirements and assess the use of drought-resistant plants in one irrigation zone before applying to the remaining zones. They stressed the importance of **continuous upkeep of the operations and maintenance program**; these efforts identified legacy sprinklers that have since been removed.

> *'…If we stay on top of our operations and maintenance program, it is manageable for our small team. We need to constantly monitor plant growth and adjust spray nozzles. Sometimes, the plants overgrow the sprinkler heads, rendering irrigation useless as adjacent plants don't get watered. If we were to ignore the system for six months, then it would become a lot more challenging for our team to manage.' (GL4)*

While the outcomes are still being measured for these initiatives, GL4 believes this is going to be their biggest win. They plan to set greater water reduction targets once minimum plant watering requirements are determined. GL4 concluded that irrigation operations and maintenance can be improved by utilizing programmed controls, fine-tuning plant water volumes, favoring drought-resistant species, and continuously monitoring for leaks and repairs. Other Lower Mainland health organizations could assess and implement these strategies at their facilities.

Domestic Uses:

Leak reporting and repairs were the most referenced operations and maintenance opportunities for domestic uses. A positive finding is that most facilities have some **leak detection programs** in place. GL2 shared that their unit's safety committee conducts monthly audits to identify leaks and FMO4 added that managers are regularly reminded to **report leaks** in faucets and running equipment. However, two interviewees noted that some *leak repairs were prolonged due to the prioritization of resources* for major capital development projects. Therefore, robust leak detection programs and repair prioritization could be further improved by the Lower Mainland health organizations to reduce unnecessary water use.

Climate Resilience & Energy Synergies

Opportunities to implement water-saving initiatives that enhance benefits like climate resilience and GHG emission reductions were highlighted by twelve out of forty (30%) interviewees. HA1 shared that in addition to cost-benefit analyses, their facility prioritizes new opportunities based on the **number of co-benefits** that can be achieved. HA3 noted that projects are selected based on several criteria with different assigned weighting factors; water projects that **improve upon multiple criteria** have a higher likelihood of funding.

Climate resilience is a co-benefit that HA3 and HA4 would like to see prioritized in project evaluations. They provided examples of *hospital vulnerability assessments that raised water awareness*. In case of a flooding event, a hospital's reliance on municipal water supply could be at risk. Further, contaminated water could be introduced into the facility. Assessing the use of storage tanks and trucks, which could be compromised during an extreme flooding event, further raised the profile of water supply risks. While emergency management planning may not stem from a water conservation perspective, HA3 added that these exercises can show the value of water-saving practices. Adding climate resilience into the assessment could also increase stakeholder buy-in for water conservation projects:

> *'…Bringing more awareness to the climate risk standpoint and linking water conservation to climate resiliency could help increase the priority of water-saving projects and make water use more efficient. If we were to bring in a water conservation initiative strictly for cost or water savings, it might not get as much traction. It would help if we can bring focus to the risk of droughts or flooding and how that would impact water quality at healthcare facilities.' (HA3)*

Energy-saving projects can also **indirectly benefit water savings**. Several interviewees referenced opportunities to use heat-recovery pumps in closed loops systems. EES1 and EES2 added that merging water-saving studies into ongoing energy-saving projects would allow the health authority to use external funding and government incentives for these initiatives. This would be a more efficient use of internal staff and external consultant resources rather than performing and funding separate studies.

New Construction & Contracts

Eleven out of forty (28%) interviewees believed that the best opportunity for water-saving projects is in **new construction and in new or renewed service contracts**. EES4 expressed this view since new construction standards incorporate water-saving equipment like the (MDRD) sterilizers that reduce the use of city water for cooling and condensate. EES5 conducted extensive studies on eliminating once-through-cooling at their facility and found that these initiatives are most cost-effective for re-developments or new construction, likely due to the *complexity and capital intensity of retrofitting old systems*. BISS5 shared an example of the Vancouver Convention Centre that recycles and reuses water for flushing operations to reduce water use by approximately 40%; this opportunity could be **explored for new construction and major redevelopment** projects. FMO15 shared that other water-saving opportunities like rainwater collection would also be best to consider for new construction since sumps are typically placed below buildings due to space constraints. EES1 summarized this opportunity as follows:

> *'…New construction should be explored more for water savings since there is ongoing work to consolidate standards for energy sustainability and climate risks. Consultants are being asked to investigate water-saving opportunities but that is a process that can be further refined. All buildings are designated to meet LEED Gold standards and water reduction strategies are being evaluated, but there may be an opportunity to improve on water consumption targets and make water reduction credits mandatory.' (EES1)*

Water-saving opportunities can also be leveraged in **new contracts and contract renewals** with service providers. BISS stakeholders highlighted opportunities to partner with the major patient and retail foodservice providers to incorporate more inclusive water-saving performance metrics in their sustainability plans. EES1 and EES6 highlighted that since water and energy use are included in current lease agreements, retail outlets and franchise operations that lease building space from the health authority do not pay for their own water and energy bills. This may result in service providers feeling *less accountable for consumption of resources.* EES4 also raised this concern as they observed their facilities water use decrease during periods when retail outlets were shut down due to strikes or renovations. While interviewees agreed that existing contracts are more difficult to update, there may be an opportunity for new contracts wherein service providers are made responsible for paying water and energy bills separately from the health authority; this would require the installation of sub-meters at these locations.

Survey Analysis

In addition to the interviews, a survey was sent to the Green+Leaders. Twenty individuals from this group participated in the survey; frequency of responses was counted by the same methods applied in the interview analysis. The key question evaluated was: *which processes identify an opportunity to reduce water consumption either through technology, process changes, and/or education?*

Thirteen references were made for hard measures like retrofits and replacements. This was followed by opportunities to improve education and training (7 references) then operations and maintenance strategies (5 references). Novel opportunities that were not mentioned during the interviewees are listed as follows:

- Improve plumbing, particularly in older facilities where staff may need to run the water for a longer period to reach comfortable temperatures and deliver quality patient care.
- Ensure the dishwashers are fully loaded each cycle.
- Educate staff to only fill tub as needed.

- Educate staff to re-hang clean clothing instead of throwing to the floor for washing.
- Install automatic shut-off sensors or foot pedals in clinical rooms

Discussion

A comparative analysis was performed of the research findings from the literature review to the interview and survey analysis findings. This analysis synthesized the findings based on the different steps of the water management plan to develop a set of preliminary recommendations for the Lower Mainland health organizations healthcare facilities. Some organizations may be at different stages of the water management plan and as such should review the steps based on their unique situations to obtain recommendations pertinent to their facilities.

PLAN Step 1 – Assemble a Water Management Team

The Lower Mainland health organizations have made some progress toward assembling a Water Management Team through the creation of the EES team in 2010. The EES team has established four key focus areas to ensure a collaborative energy and environmental sustainability approach is taken across the Lower Mainland health organizations facilities; one of these focus areas is Smart Energy & Water Use (GreenCare, 2019). The target goal is to minimize water consumption of core sites[13] measured by the key performance indicator 'Building Water Performance Intensity' (BWPI)[14] in m^3/m^2/year (GreenCare, 2019). The Lower Mainland health organizations have set 2020 and 2030 BWPI reduction targets relative to 2007 or 2010 baseline water consumption measurements: VCH (10% by 2020, 20% by 2030); FH (20% by 2020; 25% by 2030); PHSA (10% by 2020, 20% by 2030); PHC (15% by 2020; 20% by 2030).

The 2019 Environmental Performance Accountability Report (EPAR) shows a gap between 2019 water performance data and 2020 targets for some of the Lower Mainland health organizations. These organizations could be supported by a Water Management Team to consolidate efforts and meet 2030 water-saving targets. Having designated Water Coordinators – like the Energy Coordinators – within the EES team could be considered by the Lower Mainland health organizations to drive accountability. Further, close collaboration between Water and Energy Coordinators could bolster the prioritization and resource allocation for water-saving initiatives by combining work scopes with energy-saving initiatives.

Interviewees highlighted that more stakeholders should be brought into water conservation discussions, which is supported by the literature findings. The Lower Mainland health organizations Water Management Team could include stakeholders like Infection Control, BISS and facility Services Providers (i.e., Housekeeping, Patient Food, Retail Food, and Laundry), the Sustainable Food Operations Committee, and

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[13] Core sites are defined by the Lower Mainland health organizations as "primarily owned health-care facilities that can be actively monitored for energy, water, and waste data" (GreenCare, 2019).

14 The Lower Mainland health organizations recognizes that water consumption is influenced by staff count per facility. Due to the uncertain and changing nature of staff counts, the facility space (i.e., BWPI) is used as the performance metric (GreenCare, 2019).

the Green+Leaders. FMO stakeholders should be considered as key members of the Water Management Team due to their familiarity with the infrastructure and major mechanical systems.

Developing a strong Water Management Team will support the Lower Mainland health organizations to overcome operational and behavioral challenges. Gaining insights from different stakeholder groups can help identify and proactively mitigate operational impacts from water-saving measures. Developing a Water Management team can increase water conservation awareness among staff. Participating in the decision-making process will drive accountability amongst stakeholders and overcome barriers of change-resistance. These efforts may lead to an increase in the health authority's prioritization of water-saving initiatives.

PLAN Step 2 – Assess Facilities Water Use

While the Lower Mainland health organizations facilities have a base level of understanding about water consumption, unknowns in the water system remain due to complexity in site variability, presence of unidentified leaks from ageing infrastructure, and lack of water submetering practices. Conducting a water audit to identify facilities water use is an important action for overcoming these challenges. This information would support measurable outcomes to gain stakeholder buy-in for proposed changes to operations and maintenance strategies, educational awareness campaigns, and organizational policy changes. Further, quantifying water use would support the development of a business case for new water-saving opportunities and overcome the implementation challenges in prioritization of funding and resources.

Water metering and data management was identified as a challenge by at least one interviewee from each stakeholder group. Many interviewees expressed interest for submetering strategies, particularly in kitchen services, irrigation services, and for replacements of high water-using equipment like steam sterilizers. The Lower Mainland health organizations could start by mapping all water meters at the facilities. Next, larger facilities could be prioritized for metering equipment or processes that use more than 10% of the total facility water consumption. Temporary strap-on meters could be used to collect information and verify estimated water use with internal resources. Stakeholder alignment is key for developing a metering strategy; this includes meter installation and resource allocation for data management and monitoring.

If water meter installations are infeasible, then the Lower Mainland health organizations may consider alternative approaches for assessing facilities water use. For example, facilities could conduct internal audits through site-visits, collect data from water bills and meter readings from the previous 1-3 years, and assess equipment and fixtures nameplates to estimate water consumption based on healthcare operations and maintenance procedures. Interviews with equipment operators and building managers would further support the inventory process to verify end water uses and identify other opportunity areas. A survey could also be developed and sent to FMO teams who are familiar with equipment fixture rates and operations and maintenance requirements that consume high volumes of water. A survey is beneficial as it would allow stakeholders to collect the data and allocate resources internally. Example of survey questions were shared by BISS stakeholders as follows:

- What equipment is installed and available at your facility (list specifications)?
- Is your facility using pressure washers?
- Are staff required to scrape dishes and compost first?
- How frequently are carts washed (i.e., before and after meal delivery)?
- How much space is available for additional equipment (i.e., extra set of carts)?
- If ENERGY STAR or WaterSense models are available but are not being used, what is preventing them from being installed?
- If steamers or other items are still required, can they be upgraded to a more water-efficient type?
- Can the energy source of the ovens be changed if considering a boilerless combination type?
- Would the recommended retrofits/upgrades work at your facility?
- Would the staff be on-board to these changes, or would it disrupt standard ways of working?

Alternatively, a third-party consulting firm could be hired to collect this data if it becomes too resource intensive for facilities to do internally.

The primary challenge of this step is overcoming barriers of prioritization of funding and resources, including continuous data management. This could be overcome by reframing water metering and auditing as a risk prevention rather than a cost-saving strategy to increase stakeholder buy-in; monitoring water use will increase the potential to identify leaks that can pose risks to facilities and maintenance operations. Monitoring will also help measure outcomes and identify opportunities that can be shared with stakeholders to increase buy-in and awareness for the necessity of water conservation practices. Further, correct monitoring measures would support the development of actions plans and resource allocations as interviewees identified. Facility assessment would also identify the significance of infrastructural challenges and allow facilities to learn from one another in cases where infrastructure constraints are similar.

PLAN Step 3 – Set goals and objective for a water reduction action plan

While the EES has set general objectives and targets for water reduction, site-specific goals are needed to ensure these targets are met. Installation of water meters and development of monitoring strategies can support the Lower Mainland health organizations to develop innovative key performance metrics for evaluating projects and measuring goal progression. To develop the action plan and support realistic target settings, stakeholders outside of the Water Management Team should be consulted, including clinical staff and equipment operators . Involving stakeholders in this phase will help overcome operational challenges and increase staff awareness to overcome legacy mindsets resistant to change. Once projects are selected, they can be prioritized as per the Lower Mainland health organizations goals; simple implementations and focus on large water-using areas may be considered first. Further, interviewees highlighted the value of implementing projects with co-benefits like improving climate resilience or reducing energy consumption to increase the prioritization of water-saving initiatives.

To support the Lower Mainland health organizations in prioritizing projects, a comparative analysis was performed between the research findings and opportunities identified by interviewees and survey responders. These were split into different levels as described below. Each of the opportunities is analyzed as per the domestic and non-domestic use categories that were presented in Tables 1-4. Only Level 1 and Level 2 opportunities are discussed in detail. Level 3 opportunities are found in Appendix IV. It is recommended for Lower Mainland health organizations stakeholders to review all opportunity levels to determine the feasibility of implementation in specific facilities. Further prioritization will rely on completing the water audit to identify where the greatest water savings can be realized.

Level 1: High Consensus

High consensus opportunities include those mentioned by the interviewees and survey responders that also align with the water-saving practices identified from the literature review. Other opportunities include those identified by the interviewees based on their experience with healthcare facilities. These can be evaluated on a site-specific basis and prioritized by the Lower Mainland health organizations.

Level 2: Medium Consensus

Medium consensus opportunities include the water-saving practices identified from the literature review which interviewees believed would be difficult to implement due to the challenges identified as per the qualitative analysis categories. These opportunities would require further investigation by the Lower Mainland health organizations to determine feasibility of implementation.

Level 3: Low Consensus

Low consensus opportunities include the water-saving practices identified in the literature review that were not identified by the interviewees. It is possible that these opportunities exist or are already being implemented but were not mentioned by interviewees due to limited time or limited familiarity with the specific water-saving practice. It is recommended for stakeholders to evaluate these opportunities in Appendix IV to determine feasibility for implementation or confirm if they are already being implemented.

Domestic Uses

Level 1: High Consensus

The following high consensus opportunities were identified for domestic uses:

- Install WaterSense fixtures (EPA, 2012), metered faucets (EPA, 2012; SFWMD, 2018), foot pedals (PGH, 2016; GHC, 2021), and automatic motion sensors (PGH, 2016; EPA, 2012), particularly in clinical sinks, dirty utility sinks, and public washrooms.
    - If replacements are infeasible, then other low-intervention educational methods can be used to prevent unnecessary water loss, like posting reminders to turn faucets off when not in use (EPA, 2012; Rajini et al., 2015).
- Leak identification is ongoing and should continue to be prioritized for repairs by the FMO.
- Replace icemakers with ENERGY STAR air-cooled models (PGH, 2016; EPA, 2012); some facilities have already implemented these changes and can support other facilities in making these changes.
- For facilities planning to replace macerators with bedpan washers, specifications should be reviewed to determine if dual-flush features (PGH, 2016) are available.

Level 2: Medium Consensus

Medium consensus opportunities were identified for domestic uses; these would need to overcome barriers of legacy mindsets, operational impacts, and prioritization of funding and resources by the health authority. These opportunities include:

- Install laminar-flow (PGH, 2016; EPA, 2012) or low-flow fixtures (Walson & Bradford, 2017) following careful site-specific analysis and coordination with infection control guidelines.
- Consider non-potable water sources for toilet flushing (PGH, 2016), particularly for new construction and development projects.
- Interviewees suggest installing automatic flush valves to add water volumes to sewer systems to overcome operational impacts with low-flow toilets.

Non-Domestic Use: Processes

Level 1: High Consensus

The following high consensus opportunities were identified for non-domestic use processes:

- Modification of open-loop systems to closed-loop systems in processes like cooling towers and steam boilers (Walson & Bradford, 2017).
- Recover non-potable condensate in expansion tanks for reuse in heating and cooling processes and other operations to reduce potable water make-up and water-tempering demands (EPA, 2012; SFWMD, 2018; Sullivan et al., 2010; Walson & Bradford, 2017).
- Install maintenance-free steam traps and implement inspection plans (HERC, 2105) as a simple, low-cost, and indirect water-saving intervention.
- Assess opportunities that result in co-benefits like energy savings by using technology like heat-recovery pumps in cooling systems (EPA, 2012).
- Analyze component interaction and efficiency within chilled water systems (EPA, 2012); some facilities are already considering this and could support other facilities in starting this assessment.
- Install water meters to support monitoring and identification of further process optimization opportunities; prioritize systems that would benefit from automated controls or other operational and maintenance strategy improvements (EPA, 2012).
- Analyze the necessity of water purification systems and consider alternative treatment systems that use less water or eliminate maintenance operations like backflushing (EPA, 2012). For example, facilities may consider chemical treatment to reduce flushing procedures and ensure water quality.

Level 2: Medium Consensus

The following medium consensus opportunities were identified for non-domestic use processes:

- Evaluate cooling tower efficiency and improve operations through maximizing cycles of concentration (EPA, 2012; Sullivan et al., 2010), installing delimiters to reduce evaporation (EPA, 2012; Walson & Bradford, 2017), and improving chemical treatment management (MWRA, n.d.).

    - Interviewees viewed these methods as less beneficial than replacement with air-cooled systems, which eliminate water use and treatment; for facilities that do not have the option of installing air-cooled systems, these operational strategies could be considered.

Non-Domestic Use: Equipment

Level 1: High Consensus

The following high consensus opportunities were identified for non-domestic use in equipment:

- Eliminate all single-pass cooling; while many facilities have made progress on this, more opportunities remain, particularly for MDRD steam sterilizers that are high water users. Elimination strategies may include:
    - Replacing equipment like compressors with air-cooled systems (EPA, 2012; AHA, n.d.).
    - Retrofitting existing systems to closed-loop circuits that recirculate and reuse this non-potable water in other operations (PGH, 2016; EPA, 2012) and enhance co-benefits like heat-recovery through condensate temping systems or pumps (PGH, 2016).
    - Dialysis units can be retrofitted to recycle and treat reject water through reverse osmosis for use in irrigation (PGH, 2016; Tarrass et al., 2010; AHA, n.d.).
- Assess pump performance: ensure appropriate pressures to reduce the potential for leaks (AHA, n.d.; Sullivan et al., 2010); install variable frequency drives (VFDs) and low-friction valves to improve pump performance and reduce unnecessary water use (EPA, 2012).

Level 2: Medium Consensus

While none of the equipment opportunities were proven to be infeasible, barriers of prioritization of funding and resources may restrict equipment modifications. To overcome this barrier and improve implementation of high-consensus opportunities listed, interviewees suggested the following ideas:

- Focus on the co-benefits of these projects, like improving facility climate resiliency or energy savings, to bolster prioritization and funding allocation.
- Consider high-consensus opportunities primarily in new construction and renovation projects.
- Update Request for Proposals (RFPs) with metrics that ensure new equipment purchases are evaluated based on water-saving potential.

Non-Domestic Use: General

Level 1: High Consensus

The following high consensus opportunities were identified for general non-domestic uses (i.e., cleaning, kitchen, and landscaping services):

Cleaning Services

- Consult third-party laundry service providers to verify water-efficient operations (EPA, 2012).
    - While some service providers use tunnel washers and are likely encouraging water-efficient operations, these services could be assessed for opportunities like water reclamation retrofits and chemicals use resulting in fewer rinse cycles (PGH, 2016; EPA, 2012).
- For in-house laundry services, facilities could investigate the following:
    - Installing front-loading ENERGY STAR models that can be reprogrammed to eliminate additional rinse cycles (PGH, 2016; EPA, 2012; HERC, 2015).
    - Retrofitting systems to treat and reuse water in subsequent rinse cycles through UV lamps and ozonation and membrane technologies (PGH, 2016; Blight & Dingwell, 2017).
        - One facility is already investigating ozone and UV light injection to improve disinfection and reduce water use and can share learnings with other facilities.
    - Utilization improvement programs should continue and seek to remind users to wash full loads by providing laundry scales (EPA, 2012; SFWMD, 2018).
- While most facilities are using more efficient pressure washers rather than washer-down sprayers, other opportunities include installing self-closing nozzles to reduce drips and leaks and training staff on the appropriate uses of these tools (EPA, 2012).
- Replace all cloths with microfiber (PGH, 2016; Arya et al., 2018; PHO, 2018) and replace string mops with flat mops to reduce water consumption, particularly in long-term care facilities.
- Install chemical dispensing systems in long-term care facilities with appropriate recalibration schedules set by the manufacturers (PGH, 2016).
    - If chemical dispensing systems cannot be installed then appropriate training is needed for users preparing chemical solutions to prevent errors (EPA, 2012; SFWMD, 2018).
- Evaluate cleaning schedules for equipment – like wheelchairs and food delivery carts – to determine minimum sanitation requirements (SFWMD, 2018) or evaluate purchases of extra sets of equipment to reduce additional cleaning cycles.

Kitchen Services

- Install load sensors in conveyor-type dishwashers (EPA, 2012); some facilities have already installed these and could be used as a baseline for other facilities.
- Implement monthly training seminars for service staff that educate on water-saving procedures like ensuring correct oven settings for different cooking modes to minimize water and energy use (EPA, 2012); running dishwashers at full capacity, turning dishwashers off when not in use, and scraping dishes prior to loading in dishwashers (EPA, 2012; SFWMD, 2018; HERC, 2015).
- Replace food steamers with ENERGY STAR or boilerless models (PGH, 2016); some facilities have already made these changes and can share learnings with other facilities.
- Implement composting programs and replace food/garbage disposals with food pulper and strainer systems that recycle water (EPA, 2012; Walson & Bradford, 2017); some facilities have already made these changes, but opportunities remain in long-term care facilities.

Landscaping Services

- Water meter installations are highly recommended to measure consumption (EPA, 2012).
- Install smart irrigation systems with automated controls and weather (CGBC, 2021; PGH, 2016; Arya et al., 2018; EPA, 2012; SFWMD, 2018); these recommendations were also made in the 2013 Water Audit recommendations and could be re-visited by the Lower Mainland health organizations.
- Other operational strategies are being implemented by some facilities and could become a landscaping policy for all Lower Mainland health organizations. These include:
    - Xeriscape planting methods (GHC, 2021; PAHO & WHOGHC, n.d.; SFWMD, 2018)
    - Hydro-zoning techniques (EPA, 2012)
    - Letting the grass go brown during dry periods (EPA, 2012)
    - Scheduling irrigation based on specific vegetation and climate needs (Arya et al., 2018; EPA, 2012; SFWMD, 2018; Rajini et al., 2015)
    - Planting drought-resistant species like native plants (Karliner & Guenther, 2011; CGBC, 2021; PGH, 2021 & 2016; SFWMD, 2018; Rajini et. al., 2015)
    - Incorporating shade trees (EPA, 2012)
    - Adjusting or repairing sprinklers to ensure even distribution and appropriate trajectories (EPA, 2012; HERC, 2015).
- Using non-potable sources for irrigation like dialysis unit reject water or rainwater collected through cisterns (Karliner & Guenther, 2011; PGH, 2021; GHC, 2021); these would have to be assessed on a site-specific basis as some infrastructural constraints may be present.

Level 2: Medium Consensus

The following medium consensus opportunities were identified for general non-domestic uses (kitchen and landscaping services only):

Kitchen Services

- Install ENERGY STAR models (PGH, 2016; EPA, 2012)
    - These opportunities need to overcome the cost of implementation and prioritization of other projects by the health authority.
- Install boilerless combination ovens (PGH, 2016; EPA, 2012)
    - These opportunities would have to be assessed by FMO stakeholders due to prioritization of funding and resources and infrastructural challenges like site variability and accessibility to alternate energy sources; the best opportunity for implementing these water-saving methods is therefore in new construction and renovations.

Landscaping Services

- Use non-potable sources like treated greywater for irrigation; this can be completed onsite using reverse osmosis treatment (PGH, 2016; PAHO & WHOGHC, n.d.)

    - The primary challenge is overcoming the cost of retrofits for older facilities and storage space for onsite treatment.
- Installing rainwater cisterns for outdoor irrigation are recommended (Arya et. al, 2018) but are likely more feasible for smaller facilities or in new construction projects.

DO Step 4 – Implement reduction projects and practices

The implementation of projects may vary between facilities based on resource and infrastructure constraints. The key to successful implementation is stakeholder communication and coordination to ensure that resources are available to meet approved timelines. The action plan should be implemented based on the prioritization of projects, with timeline contingencies incorporated to account for changing priorities.

It would benefit the Lower Mainland health organizations to have an overarching policy for all fixture replacements and new equipment purchases, like installing only EPA WaterSense or ENERGY STAR models; these specifications can be incorporated directly into new purchasing agreements. New construction projects should consider consolidation of standards for energy sustainability and climate risks. Stakeholders like Supply Chain and Projects and Planning should be consulted to ensure that these models or other equally rated competitor products can be purchased. Service contracts can also be modified during renewal or new contract developments to incorporate water-saving performance metrics. Additionally, Contract Managers may consider revisions to new and renewed contracts that would make service providers accountable for paying separate water and energy bills to increase awareness of water consumption and support behavioral and operational changes. If pursued, this would require installation of submeters and should be considered in the water metering strategy.

CHECK Step 5 – Reporting and Analyzing Impacts

To ensure successful reporting and analyzing of implemented water-saving opportunities, a strategy for monitoring must be developed; it is beneficial to include this strategy during the goals and action plan setting. Monthly monitoring can be conducted through water submetering data analysis or by assigning individuals to be accountable for tracking, monitoring, and reporting on water-efficiency measures. This will ensure accountability and that targets are on track. Internal auditing can ensure that behavioral or operational and maintenance strategies are being followed accordingly.

The Lower Mainland health organizations should review the action plan annually, with detailed audits performed every 3 years. The ENERGY STAR Portfolio Manager could be used to analyze impacts since the Lower Mainland health organizations already access this database for energy performance tracking. Reporting and analyzing of water-saving performance should be shared with other facilities to create an environment of collaboration and shared learning. Additionally, collaborations with external healthcare organizations and reviewing the case studies in Appendix I can support learning from previous successes and failures of water-saving projects.

ACT Step 6 – Improve upon areas and celebrate successes

Interviewees identified that the key to successful water management planning and opportunity implementation is to keep the team engaged through feedback mechanisms that evaluate the success of implemented interventions and identify areas for improvement. These mechanisms can be as simple as placing water conservation suggestion boxes in prominent areas to encourage staff to provide feedback. Interviewees suggested incorporating water conservation discussions into regular team meetings, like the monthly EES team meetings, to drive accountability and engagement of staff. Celebrating team successes also helps with motivation and engagement of staff. Internal and external recognition can award teams for contributions toward achieving the set water management goals. Since the Lower Mainland health organizations are part of the Green Health Care consortium, they can share successes with these external organizations to increase awareness and gain support for new initiatives from interested stakeholders.

Research Limitations

Several limitations were identified in the research methods that are addressed. First, the method of counting interviewee responses for each challenge and opportunity category was subject to error. Interviewees were counted as an occurrence if they mentioned a challenge or opportunity category at least once, yet the emphasis placed on each response was not assessed. Some interviewees discussed the challenge or opportunity categories more than once; if this was considered it may have changed the distribution of responses to result in different primary challenges and opportunities.

Second, the focus group interview analysis was subject to similar limitations that may have caused errors in the data. In group settings, interviewees may not have voiced their opinions when they agreed with a statement made by another, and thus were not counted as an occurrence. Therefore, the frequency of responses may have been undercounted, resulting in a different prioritization of the major challenges and opportunities. Another challenge with the focus groups arose with the communication medium of audio calls rather than video calls. Video or in-person interviews would have allowed the interviewers to read body language and facial expressions and make inferences on the group consensus of challenges and opportunities identified; these non-verbal cues could have been counted in the frequency of responses.

Another limitation is that only one researcher completed the qualitative analysis. For a more robust processes, the transcripts should have been coded and evaluated by more than one researcher to ensure the correct categorization of challenges and opportunities. Further research on this topic may wish to re-evaluate the transcripts to identify new categories or modify category labels.

Short timelines were another limitation to the research. While the project was initially meant to develop a comparative analysis of different technologies and cost-benefits to implementing them, this was not completed. Further research may assess the identified technologies and opportunities and develop a unique business case for implementation at each Lower Mainland health organizations facility. Additionally, future research may consider site audits and more interviews with clinical staff and FMO staff, well acquainted with the equipment, to provide greater insights into site-specific challenges and opportunities to verify the research findings.

Conclusion

This research project explored innovative water-saving opportunities and assessed their applicability at Lower Mainland health organizations facilities. The literature review identified common water-saving practices developed by external healthcare organizations and reviewed these findings with Lower Mainland and other BC health stakeholders during semi-structured interviews. Qualitative analysis methods provided insights into the challenges that prevent implementation of water-saving initiatives as well as opportunities that exist to overcome these challenges and improve feasibility of implementing water-saving practices.

The top three challenges that influence feasibility of water-saving initiatives in healthcare facilities were identified as **implementational** (prioritization of funding and resources), **operational** (perceived risks to facilities operations and infection control), and **behavioral** (lack of awareness and educational barriers that reduce willingness for water conservation). These challenges are closely interrelated and influence other identified challenges; therefore, they should be addressed in an integrated manner.

The top three opportunities for reducing water consumption in healthcare facilities were identified as **retrofits and replacements** (primarily for non-domestic uses in equipment), **education and awareness** (communicating water conservation to overcome perceived risks), and **water metering** (strategic installation and data management to prioritize high-water users). Other opportunities like focusing on co-benefits obtained from water conservation (i.e., climate resilience and emissions reduction) and prioritizing water-saving metrics in new construction and contract renewals can help overcome implementational challenges by increasing stakeholder buy-in for these initiatives.

The most important finding from this research that can support the Lower Mainland health organizations in meeting their 2030 water utilization targets is the recommendation to develop a robust **water management plan**. First, the health authority should assemble dedicated water management team that includes diverse stakeholders familiar with facilities operations and management, clinical practices, and infection control guidelines. Stakeholder collaboration will promote innovative solutions and proactively mitigate potential operational impacts. Emphasizing water conservation in regular communications will help overcome educational barriers and increase prioritization of these initiatives. The water management team can coordinate resources for water audits and water metering strategies to verify high-water using areas and identify leaks. Completing this assessment can support the Lower Mainland health organizations in setting realistic water reduction targets with improved key performance indicators. Projects may be selected and prioritized based on the high consensus opportunities identified in this research: eliminating single-pass cooling equipment (steam sterilizers, dialysis units), retrofitting cooling towers to closed-loops with heat recovery pumps, installing weather-sensing irrigation systems and rainwater cisterns, retrofitting ageing kitchen equipment (ENERGY STAR models) and cleaning equipment (laundry systems with ozonation and recycling). Other low-cost interventions like modification of operations and maintenance strategies can also be considered. Water-saving initiatives should develop long-term monitoring plans to measure effectiveness and ensure feedback mechanisms for continuous improvement. Successes should be celebrated with internal and external stakeholders to drive engagement for future opportunities.

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Appendices

Appendix I – Examples of Water-Savings Implemented at Healthcare Facilities

Water-Saving Practices for Healthcare-Specific Domestic Uses

Case studies were identified that show the successful implementation of the water-saving practices listed in Table 1. For example, Bridgepoint Hospital in Ontario installed low-flow fixtures in washrooms and successfully reduced water use by 32% (Canada Green Building Council, 2021). Strathcona Hospital in Alberta replaced 9.5 L/min faucets with 3.8 L/min faucets and added automatic occupant sensors to reduce potable water demand by 47% (Alberta Health Services, n.d.). A hospital in the US retrofitted toilets with low-flush valves, saving more than 5 million gallons of water and resulting in $45,000 of annual savings and an estimated payback of 18 months (Waterless Co. Inc., 2018). The Niagara Health System's St. Catherine's Hospital in Ontario realized a reduction in water use of nearly 35% through water-efficient plumbing fixtures (Canada Green Building Council, 2021). Kingston General Hospital in Ontario reduced water use by 25% by installing flow moderators in hand-washing sinks and by improving toilet flush valves (Green Health Care, 2021).

Water-Saving Practices for Healthcare-Specific Non-Domestic Uses in Processes

Case studies were identified that show the successful implementation of the water-saving practices listed in Table 2. At one facility, water from three water-cooled compressors was captured and pumped into cooling towers, resulting in an approximate savings of 36,000 gallons of water per year (Hoppszallern et al., 2015). The Three U.S. Veterans Administration Medical Centre conducted an integrated energy audit for steam trap performance that repaired or replaced malfunctioning units to achieve an estimated 50-75% steam loss reduction (American Hospital Association, n.d.). Institutional buildings were also assessed for water-saving opportunities since the size and building occupancy capacity has similarities with hospitals. The University of British Columbia replaced their gas-fired steam district energy system to an efficient hot water district energy system that improved energy efficiency by 25% and uses 2000 times less water than the steam system it replaced, resulting in 270 million liters of water saved per year (UBC Energy & Water Services, 2019). UBC Energy & Water Services also installed the hot water system in a closed-loop with leak detection technology to prevent water losses (2019). Further, continuous auditing and retrofit opportunities for heating and cooling processes have conserved more than 170 million litres of water per year (UBC Energy & Water Services, 2019). The Toronto Rehabs University Centre saved 2,365 meters cubed of water annually by retrofitting two walk-in freezers and two walk-in refrigerators to closed-loop circuits (Green Health Care, 2021).

Water-Saving Practices for Healthcare-Specific Non-Domestic Uses in Equipment

Case studies were identified that show the successful implementation of the water-saving practices listed in Table 3. Massachusetts Hospital eliminated once-through cooling in the morgue; replacing it with air-cooled systems resulted in 2.1 million gallons of water saved per year. This hospital also incorporated retrofit systems to recirculate cooling water to the sterilizers and save an additional 4 million gallons of water per year. Further, by recirculating cooling water in vacuum pumps and removing unnecessary units, further net annual savings of 8.5 million gallons of water was realized (Massachusetts Water Resources Authority, n.d.). Another U.S. hospital modified refrigeration systems to closed-loop; recirculating this water reduced consumption by about 3 million gallons per year and the facility saved more than $20,000 in annual water and sewer costs (Waterless Co. Inc, 2018). Stanford Health Care in Palo Alto, California installed closed-loop water systems to recirculate condensate from sterilizers rather than tempering and draining, this technology saved 12 million gallons of water annually (Ferenc, 2016). Another hospital reduced water consumption by 17,600 gallons annually by installing automatic stop valves on film processing equipment (Waterless Co. Inc., 2018).

Water-Saving Practices for General Facilities Non-Domestic Uses in Cleaning

Case studies were identified that show the successful implementation of the water-saving practices listed in Table 4. The Nova Scotia Health Authority retrofitted a large tunnel washer and five washer-extractors that previously sent wastewater to the drain; now they reclaim and treat this wastewater with UV lamps, ozone modules, and filter media (Practice Green Health, 2016; Blight & Dingwell, 2017). The recycling system is equipped with internal sensors that record water temperature, flow rates, and total dissolved solids (TDS) for improved monitoring (Practice Green Health, 2016; Blight & Dingwell, 2017). This also reduced the demand for steam to heat incoming makeup water, which saved monthly natural gas bills (Practice Green Health, 2016; Blight & Dingwell, 2017). Another hospital installed rinse water reuse systems in laundry machines to save 2 million gallons of water annually (Waterless Co. Inc., 2018).

Water-Saving Practices for General Facilities Non-Domestic Uses in Landscaping

The Bridgepoint Hospital in California reduced potable water use for irrigation by more than 50% by installing environmentally friendly features such as smart irrigation systems connected to local weather stations and reintroducing native plants to the hospital landscaping. The Niagara Health System's St. Catherine's Hospital in Ontario implemented similar strategies with high-efficiency irrigation technology and drought-tolerant plants to reduce potable water use by more than 50% (Canada Green Building Council, 2021). Providence St. Peter's Hospital in Washington introduced native drought-resistant plants and installed water sensors and drip irrigation with an expected reduction in irrigation runtime by 75% (Practice Green Health, 2016). At several Californian healthcare facilities, in-ground sprinkler systems were replaced with drip irrigation, which uses 20-50% less water, and turfgrass was replaced with native and drought-resistant landscaping (Ferenc, 2016). The Santa Rosa Regional Hospital in California is expected to reduce water use by 50% by diverting stormwater from roofs to bioswales and onsite catch basins that will allow rainwater to infiltrate slowly into the soil (Ferenc, 2016). Another U.S. facility launched an irrigation initiative after realizing they were using twice the water per acre as two other nearby facilities; by fixing leaks and installing weather-based controllers, the facility reduced irrigation water use by 1.5 million gallons in the three-month irrigation season alone (Hoppszallern et al., 2015). The Packard Children's Hospital in California is designed to use 38% less water than the average Northern California hospital. The hospital installed two 55-gallon cisterns buried beneath the front driveway that will capture rainwater in the winter from building roofs, condensate from air handling units, and the water discarded from dialysis treatment (Bonvissuto, 2017).

Appendix II – Alternative Sources for Water Supply in Healthcare Facilities

As identified by Karliner & Guenther, hospitals can have a greater impact on reducing water-consumption by using alternative sources instead of potable water (2011). EPA WaterSense has developed guidelines for alternative sources that are listed in Table 8 below (2012). In addition to the opportunities listed in Tables 1-4, these methods could be considered by the Lower Mainland health organizations to further reduce potable water consumption.

Table 8: Alternative Sources for Water Supply in Healthcare Facilities

SOURCE	HOW TO COLLECT	HOW TO USE	WHAT TO CONSIDER
Rainwater / Stormwater	• Collected from impervious surfaces and distributed to onsite features like berms, swales, and rain gardens or diverted to storage tanks and pumped to other areas.	• Rainwater from rooftops is generally high quality and can be used to supplement or replace irrigation water with little treatment or filtering.	• Rainwater collected from ground has more variable quality since it can pick up pollutants from the landscape and may require treatment.
Treated Gray Water	• Collect wastewater from lavatory sinks, laundries, and bathing; does not typically include wastewater from toilets, urinals, or kitchens.	• Graywater water can be collected and treated on or off-site; the lowest level of treatment is typically sufficient for subsurface irrigation. • More intensive treatment needed if including toilet and urinal flushing or for above-ground irrigation uses.	• Requires careful site-specific analysis of health and safety requirements; should be used within 24 hours since it can foster bacteria and pathogens. • If should not be applied on plants intended for human consumption or sprayed in ways that it can be inhaled.
Condensate from Air Conditioning	• Condensate typically captured in a drip pan (to prevent damaging equipment) can be repurposed to discharge for other uses.	• Generally high quality and free of minerals and total dissolved solids (TDS); safe for use in cooling tower make-up water with biocide control or in subsurface irrigation.	• Condensate can grow bacteria when removed from the air; filter and disinfect if potential for patients to inhale • Condensate depends on cooling load, relative humidity, and make-up air volumes.
Reverse Osmosis System Reject Water	• RO systems have residual streams that remain after water purification (20-25%); this reject water is less pure than the source water entering the system but may still be repurposed for other uses.	• If sanitary conditions are maintained for storage and transfer, reject water can be used in areas requiring higher water quality like toilet and urinal flushing, cooling tower make-up, above-ground irrigation, or water features.	• If used for irrigation, only apply to plants with high salinity tolerances, due to elevated levels of TDS • If used for cooling tower makeup water, ensure TDS concentration meets cooling tower set points.
Cooling Equipment Blowdown	• Can be collected from single-pass cooling equipment; as water evaporates from cooling equipment, the concentration of TDS builds up, therefore remaining water must be blowdown and replaced with make-up water that can be repurposed for other uses.	• Single-pass cooling equipment reject water can be reused in cooling processes or subsurface irrigation • Could be treated through nanofiltration or RO to make it suitable for other uses.	• TDS content is significantly high and may contain other bacteria or chemicals; should not be used where it can be inhaled by patients. • If cooling equipment is very efficient, the TDS content could be too high for use in irrigation; facility managers should carefully assess impact.

Tables 9 and 10 below were taken from the EPA WaterSense Guide (EPA, 2012) and provide further information for the Lower Mainland health organizations to consider if these alternate sources were to be repurposed for uses in healthcare facilities operations.

Table 9: Water Quality Considerations for Onsite Alternative Sources

Possible Sources	Level of Water Quality Concern					
	Sediment	Total Dissolved Solids (TDS)	Hardness	Organic Biological Oxygen Demand (BOD)	Pathogens (A)	Other Considerations
Rainwater	Low/ Medium	Low	Low	Low	Low	None
Stormwater	High	Depends	Low	Medium	Medium	Pesticides and fertilizers
Air Handling Condensate	Low	Low	Low	Low	Medium	May contain copper when coil cleaned
Cooling Tower Blowdown	Medium	High	High	Medium	Medium	Cooling tower treatment chemicals
Reverse Osmosis and Nanofiltration Reject Water	Low	High	High	Low	Low	High salt content
Gray Water	High	Medium	Medium	High	High	Detergents and bleach
Foundation Drain Water	Low	Depends	Depends	Medium	Medium	Similar to stormwater

Note: The use of single-pass cooling water is also a possible source of clean onsite water, but facility managers should first consider eliminating single-pass cooling because of its major water-wasting potential. For that reason, it is not included in the list.

*Key:
Low: Low level of concern
Medium: Medium level of concern; may need additional treatment depending on end use
High: High concentrations possible and additional treatment likely
Depends: Dependent upon local conditions
(A): Disinfection for pathogens is recommended for all water used indoors for toilet flushing or other uses

Table 10. Types of Treatment for Alternate Sources Based on Intended Use

Possible Sources	Filtration	Sedimentation	Disinfection	Biological Treatment	Other Treatment Considerations
Rainwater	Depends	Depends	Depends	No	May be used for irrigation without additional treatment
Stormwater	Yes	Depends	Depends	Depends	For non-potable use only
Air Handling Condensate	No	No	Yes	No	Segregate coil cleaning water
Cooling Tower Blowdown	Depends	Depends	No	No	Consider TDS monitoring
Reverse Osmosis and Nanofiltration Reject Water	No	No	No	No	Consider TDS monitoring
Gray Water	No	Depends	No	Depends	Biologically unstable for long periods of storage unless treated; subsurface drip irrigation requires the least treatment
Foundation Drain Water	Depends	No	Depends	No	May be hard if in alkaline soils

*Key
Yes: Level of treatment likely needed
No: Level of treatment not likely needed
Depends: Treatment depends upon ultimate use

The steps described in the following sections are summarized from various resources and presented in a PLAN-DO-CHECK-ACT framework in Figure 13.

PLAN Step 1: Assemble a Water Management Team

The first step in developing a robust water management plan is to assemble a water management team. Arya et al. suggests getting management, clinicians, and administrative staff on board for successful progression with subsequent planning steps (2018). The team should include a champion responsible for overseeing and implementing the programs, team members familiar with regulatory compliance, and facility or building managers knowledgeable of the infrastructure and major mechanical systems (EPA, 2012). Having this team assembled will supports the development of water conservation policies; this provides a framework for incorporating water efficiency into long-term facility operation, establishing, and achieving water management goals, and allocating resources to achieve them (EPA, 2012).

PLAN Step 2: Assess Facilities Water Use

Practice Green Health states that accurate tracking, measuring, and baselining of water use can help hospitals understand their water consumption and opportunities for improvement (2021). The EPA WaterSense guidelines highlight the criticality of understanding how water is used within a facility; water assessments provide a comprehensive account of all known water uses and allows the water management team to establish a baseline from which progress and program success can be measured (EPA, 2012).

As shown in Figure 2, healthcare facility water use can vary due to differences in infrastructure, equipment, and processes. Therefore, before appropriate water utilization targets can be set, a greater understanding of water consumption is necessary to support the facility in identifying high-priority opportunities.

There are several methods that can address this step; these are summarized to support the Lower Mainland health organizations healthcare facilities in completing their own water audits (EPA, 2012; US Department of Energy, 2021).

a. Collect existing data from water bills, equipment and fixture nameplates, spatial plans, and auditing records from the previous 1-3 years.
b. Conduct facility site-visits, interview operations and maintenance staff, and develop surveys to inventory major-water using fixtures equipment and processes.
c. Review the data to identify potential leaks and areas for potential water submetering and monitoring of high-use areas based on the inventory.
d. Assess utility costs for potable water and disposal an identify opportunity areas for water-efficiency technology and processes.

Water metering strategies can support the facility in assessing water use. Once the inventory is developed and daily water use is estimated from the equipment, the highest water using areas can be prioritized for meter installation. Temporary strap on meters can also be used to verify the water baseline and end uses.

PLAN Step 3: Set goals and objectives for a water reduction action plan

Once baseline facility water use is known and high-water using areas are identified, the Water Management Team can identify water-saving objectives. Key stakeholders outside of the Water Management Team should be consulted based on site-specific familiarity with buildings, equipment, infrastructure, and processes. Including employees from different parts of the organization will obtain a range of perspective and promote a sense of ownership (EPA, 2012). Defining clear objectives supports the process of developing attainable goals with clear timelines for implementation. Key performance indicators should be developed to monitor the progression of the goals. Successful goal setting will drive the plan and fuel continuous improvement.

Once goals and objectives are set an action plan can be developed. The action plan should predict if water goals can be met by implementing cost-effective water-efficiency measures; it should also include education and outreach efforts for building occupants to help reduce water use (US Department of Energy, 2021). The action plan can be created as a new document or incorporated into an existing document. Projects can be selected from the water saving practices identified in the research. The EPA WaterSense guide summarizes the key sub-steps for developing an action plan as follows (2012):

a. Identify projects and calculate costs and potential savings
    i. Consider targeting the largest uses of water for the most significant savings.
    ii. Consider codes and standards that may incentivize the use of certain fixtures or equipment.
    iii. Once all opportunities are identified, develop a list of potential projects to prioritize and estimate individual project costs and potential savings.
b. Identify funding sources
    i. Consider leasing equipment from equipment vendors to trial them first.
    ii. Look for rebates and incentive programs from the local water utility.
    iii. Consider private financing or look for provincial financing programs.
c. Calculate simple payback to support project prioritization
    i. Determine the total project cost and subtract funding/rebate sources from the budget.
    ii. Estimate water savings from the project.
    iii. Identify cost of water and wastewater and potential energy impacts.
    iv. Evaluate different competitor products on the market
d. Prioritize projects
    i. Fix equipment that is malfunctioning or leaking to target the most urgent issues first.
    ii. Start with simple projects to create initial positive results and gain stakeholder acceptance.
    iii. Evaluate opportunities for low- to no-cost operations and maintenance changes that may be more cost-effective than retrofits and replacements.
    iv. Prioritize remaining projects based on the facility goals and consider:
        i. Shortest to longest simple payback period
        ii. Highest to lowest potential of water savings
        iii. Most visibility to least visibility (i.e., landscaping before processes)
        iv. Greatest to least environmental impact (water and energy savings)

DO Step 4: Implement reduction projects and practices

The key step to a successful implementation is ensuring that the necessary resources (i.e., time, money, personnel) are available to complete the projects in the action plan (EPA, 2012). Projects should be implemented in order of priority. Stakeholder communication and coordination is necessary to ensure that key components of the action plan have support and are implemented successfully. Encouraging staff involvement can help develop new ideas and monitor the success of the action plan. Flexibility is also important since priorities and resources may change so contingencies should be incorporated into the implementation process and work scopes (EPA, 2012). New construction and renovations should be implemented based on the action plan developed in step 3. The US Department of Energy adds that facilities should "consider developing equipment specifications that target water-efficient products, so they are automatically purchased for retrofits, renovations, and new construction" (2021).

CHECK Step 5: Report and Analyze Impacts

A key element of a water management plan is regular review and auditing to ensure measures are implemented and that goals are realistic and are being accomplished (US Department of Energy, 2021). Reporting and analyzing of impacts can help track trends and identify emerging issues. Further, facilities can be compared to one another to share practices and ensure return on investment for projects (Practice Green Health, 2021). Assigning individuals to be responsible for tracking, monitoring, and reporting on water-efficiency measures can promote accountability. Behaviors of staff and operational and maintenance strategies should also be monitored to identify efficacy. Action plans should be reviewed annually, and goals should be revised as they are achieved; a detailed reassessment of the facility should occur on a 3–4-year basis to update water balances and identify new water management goals and water-saving opportunities (EPA, 2012). Green Health Care suggests using the ENERGY STAR Portfolio Manager that has capability to track progress and compare water use over time (2021).

ACT Step 6: Improve upon areas and celebrate successes

The final component of the water management plan is to improve upon the plan and celebrate successes. Water conservation suggestion boxes can be placed in prominent areas to encourage staff to give feedback on improvement opportunities (Southwest Florida Management District, 2015). Making water conservation a regular part of team meetings will further drive accountability and engagement of staff (Southwest Florida Management District, 2015). Celebrating successes is key to continuous staff engagement and motivation. The EPA WaterSense suggests the following strategies for recognizing achievement (EPA, 2012):

a. Establish an internal recognition program to award personnel/teams that provided significant contributions toward achieving water management goals.
b. Respond to employee and staff suggestions and reports of issues to encourage participation.
c. Explore opportunities for external recognition (i.e., ENERGY STAR, LEED).
d. Report progress publicly to interested stakeholders to gain support for initiatives and recognition.
e. Report progress to facility staff and building occupants in a newsletter.

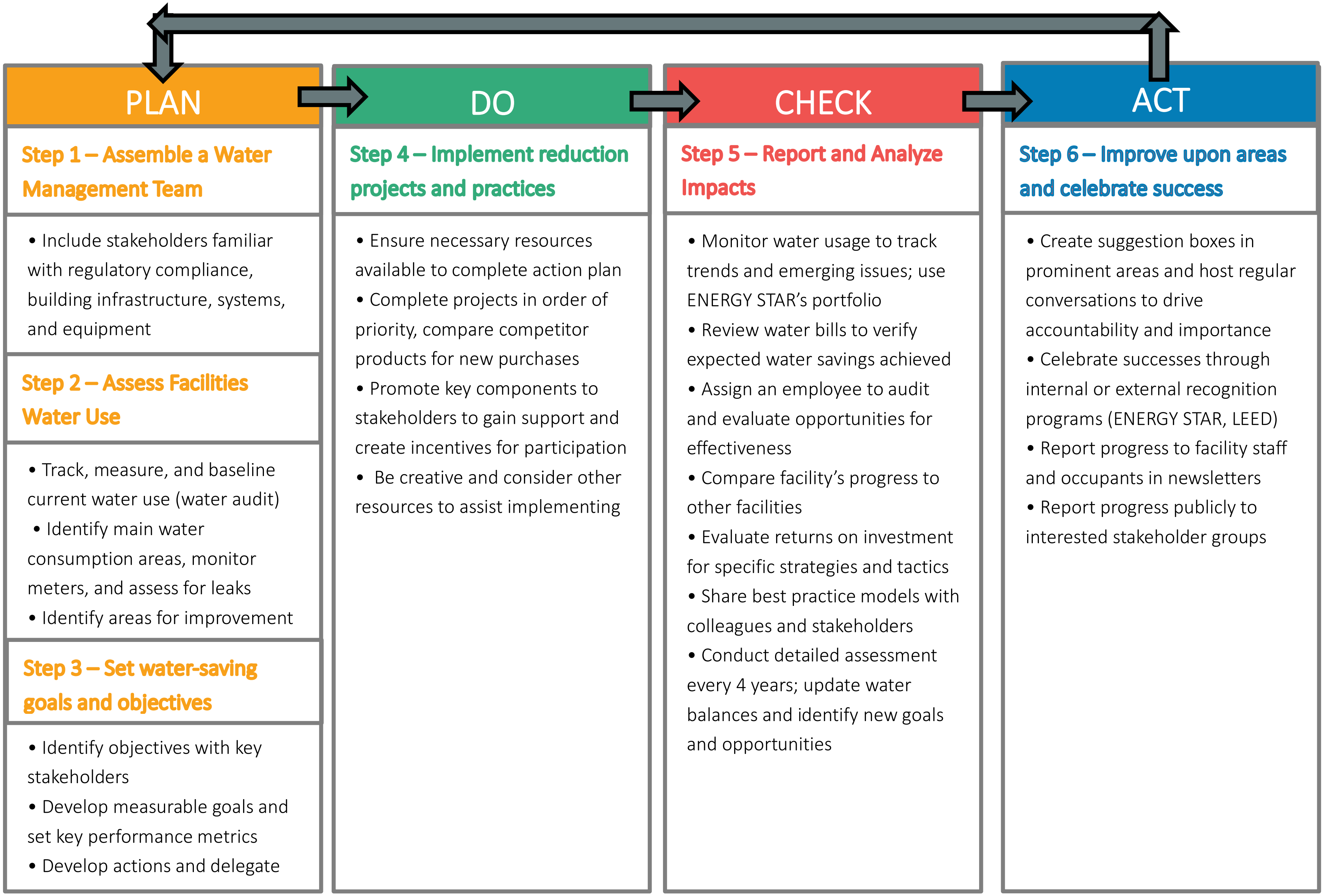

Figure 11: Water Management Plan Flowchart

Low consensus opportunities include the water-saving practices identified in the literature review that were not identified by the interviewees. It is possible that these opportunities exist or are already being implemented but were not mentioned by interviewees due to limited time or limited familiarity with the specific water-saving practice. It is recommended for stakeholders to evaluate these opportunities to determine their feasibility for implementation or confirm if they are already being implemented.

Domestic Uses

Level 3: Low Consensus

Other domestic use opportunities were identified in the literature and could be considered by the Lower Mainland health organizations. For faucets, these include installing flow straighteners (SFWMD, 2018), adjusting automatic sensors, and removing scale build-up to ensure functionality (EPA, 2012). In cases where low-flow toilets cause issues, dual flush conversion (EPA, 2012; PGH, 2016) or water displacement devices (SFWMD, 2018; HERC, 2015) could be evaluated instead. Showers were not mentioned by interviewees but may present water-saving opportunities like installing WaterSense models, retrofitting multiple heads to operate individually, inspecting for scale build-up, and providing shower time-trackers for users (EPA, 2012). Other opportunities for icemakers include installing timers to produce during off-peak hours, programming machines to the lowest possible rinse cycles, and cleaning machines to remove scale build-up (EPA, 2012).

Non-Domestic Use: Processes

Level 3: Low Consensus

If air-cooled systems are not installed, then other opportunities for cooling towers and steam boilers can be evaluated. This includes automating chemical feeds (EPA, 2012; Sullivan et al., 2010), improving water treatment (EPA, 2012), controlling blowdown water volumes (PGH, 2016; EPA, 2012; Sullivan et al., 2010), cleaning and maintaining coils to prevent scale, and ensuring tower fill valves close completely (EPA, 2012). Chilled water systems could be improved by installing pressure-reducing valves where system pressures are too high (HERC, 2015), insulting pipes on water loops to reduce cooling loads, and regularly inspecting chillers to remove scale build-up (EPA, 2012). Further, if no alternate water treatments can be implemented, then high water-using treatment systems can be retrofitted to recycle backwash water (SFWMD, 2018).

Non-Domestic Use: Equipment

Level 3: Low Consensus

Other opportunities were identified in the research for single-pass cooling equipment, like automating controls to stop the flow of water when the equipment is not in use (EPA, 2012; AHA, n.d.). Sterilizers could be retrofitted with thermostatically actuated valves to control tempering water flow (EPA, 2012; HERC, 2015) or vacuum ejector retrofits to capture reject water for reuse (EPA, 2012; HERC, 2015). X-rays were not mentioned in interviews; it is inferred that most units have been replaced with digital imaging that use less water than conventional film production (EPA, 2012), however, this should be verified by facilities.

Other opportunities for dialysis units that were not mentioned by interviewees include installing flow regulation devices or replacing them with sorbent dialysate regeneration or online dialysate generation (Tarrass et al., 2010). Liquid ring-type lubrication systems typically exist in vacuum pumps and should be identified through a site-wide audit; they can be replaced with scavenging interface waste anesthetic gas pumps (PGH, 2016), non-lubricated air-cooled dry pumps or waterless vacuum pumps (EPA, 2012). These can also be retrofitted with full or partial reject water recovery systems (PGH, 2016; EPA, 2012).

Other site-specific laboratory equipment like glassware washers should be evaluated at facilities to determine opportunities to recycle and reuse water in the next rinse cycle, optimize rinse cycles at minimum recommended flow rates, and only run systems when they are at full load capacity (EPA, 2012). If used, then fume hood wet scrubbers can be replaced with gas-phase filtration systems, adsorbent dry filters, or particle filtration (EPA, 2012). Washdown systems can be installed with automatic shut-off valves, calibrated to reduce blowdown volumes, and turned off when not in use (EPA, 2012). Radiation therapy linear accelerators also have the potential to be retrofitted to use reject water in cooling towers (HERC, 2015).

Non-Domestic Use: General

Level 3: Low Consensus

Other opportunities were identified in the literature that the Lower Mainland health organizations could consider for improving non-domestic uses. In-house laundry machines could be investigated to install coin or card-operated options with capabilities to recycle water from the final rinse to the first rinse in the next load cycle (EPA, 2012). Rather than using pressure washers, other tools like brooms and dustpans, mops and squeegees, or water brooms could be evaluated for operational efficiency and water savings (EPA, 2012).

Other opportunities that were not explicitly suggested by interviewees but should be evaluated by the Lower Mainland health organizations include replacing kitchen sink faucets with WaterSense models at 8.3L/min flow rates (PGH, 2016), inspecting dishwashers for leaks, and ensuring fill valves and solenoid valves are functioning (EPA, 2012; Karliner & Gunther, 2011), and turning off continuous flows for beverage island cleaning (HERC, 2015). If food/garbage disposals cannot be phased out, another option is to install automatic shut-off valves, use cold water, restrict flow rates, install timers, or reuse rinse water from dishwashers as disposal flush water (SFWMD, 2018). Additionally, users should be trained to monitor performance, prevent drains from being clogged with debris, and turn off water to disposal systems during idle periods (EPA, 2012). Pre-rinse spray valves should be assessed by the FMO; opportunities for this equipment include installing WaterSense models with high-efficiency valves and clamps, inspecting regularly for scale build-up and leaks, and ensuring ergonomics for ease of use and performance (EPA, 2012).

Landscaping water features were only mentioned by one stakeholder. If these are in place, facilities should determine the necessity of these features and whether they can be shut off permanently or temporarily (EPA, 2012; Rajini et al., 2015). Other water feature opportunities include installing smaller pumps with lower pumping rates (EPA, 2012), recirculating water or using non-potable sources (PGH, 2016; EPA, 2012), regularly checking for leaks and damage (EPA, 2012), and implementing co-benefits for wildlife and stormwater management (EPA, 2012). Other irrigation improvements include ensuring WaterSense audits are completed on a three-year basis (EPA, 2012), installing check valves and shut-off nozzles to prevent backflow and leaks (EPA, 2012; SFWMD, 2018), and modifying irrigation schedules to apply larger amounts of water but less frequently (EPA, 2012; Rajini et al., 2015). Further, landscapes should be kept free of weeds to make more water available for plants (EPA, 2012). Additionally, turfgrass and strip grass can be removed or avoided as these are more difficult to water (EPA, 2012). Stormwater management can be improved by replacing impermeable surfaces with permeable surfaces and directing roof drains to these areas (Arya et al., 2018; PAHO & WHOGHC, n.d.). Additionally, green roof systems can be installed for additional co-benefits of biodiversity and reducing the urban heat island effect (Karliner & Guenther, 2011; Arya et al., 2018). Pools were not mentioned frequently by interviewees, likely since few facilities have them. For those that do, they could consider water-saving options: installing gauges to determine need's basis cleaning schedules; installing reverse osmosis systems; maintaining proper chemicals balance to reduce draining and cleaning requirements; installing gutters or reducing pool levels to prevent splashing losses; and installing water meters to identify and repair leaks (EPA, 2012).