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Enhancing water efficiency programming in the City of Calgary

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ABSTRACT

This paper presents the steps undertaken in a two-phase study to enhance the City of Calgary's (the City) water efficiency programming for indoor and outdoor industrial, commercial, and institutional (ICI) customers and outdoor residential customers. Study objectives included evaluating programs in other urban jurisdictions for suitability to Calgary, and developing short-, medium-, and long-term recommendations for water efficiency programming for the City. Phase I of the study included a literature review of Calgary's water consumption trends and explored over 150 water efficiency programs implemented across jurisdictions in North America, identifying a subset of 33 programs for further evaluation. Phase II evaluated program options through an integrated assessment, including gap, Strengths, Weaknesses, Opportunities, and Threats, and cost-benefit analysis. An implementation strategy was developed for seven water efficiency programs, grouped into complementary bundles of indoor and outdoor ICI and residential landscape transformation programs. The study also identified areas for further research, and key supporting elements or success factors for water efficiency programming in the City. This paper adds value to the discussion on approaches to select suitable indoor and outdoor ICI and outdoor residential water efficiency programs, and aids in informing the City's current and future strategic water planning and programs.

Key words: industrial commercial and institutional (ICI), outdoor water use, program assessment, urban water use, water conservation, water efficiency

HIGHLIGHTS

- Presents the steps undertaken and key insights from a study on enhancing the City of Calgary's water efficiency programming for indoor and outdoor industrial, commercial, and institutional customers and outdoor residential customers.
- Adds to the literature on evaluating and selecting water efficiency programs.
- Provides recommendations to inform Calgary's current and future strategic water planning and programs.

GRAPHICAL ABSTRACT

INTRODUCTION

Over the past 40 years, increased water use has been observed globally due to factors such as population growth, shifting consumption patterns, and socio-economic development (WWAP 2019). It is anticipated that without a significant change in consumption trends, there will be a 20–30% increase in global water demand by 2050 (Delgado *et al.* 2021). In urban settings, water scarcity is impacted by growing urbanization and exacerbated by climate change, which is increasingly a driver of uncertainty for water supply (He *et al.* 2021; Ray Biswas *et al.* 2023). Water scarcity has traditionally been mitigated through engineering and infrastructure; however, these investments are costly and require substantial human and material resources (McDonald *et al.* 2014; He *et al.* 2021). It has also been observed that geographical and financial constraints related to infrastructure may further exacerbate water scarcity, underscoring the necessity for strategic management of water sources (McDonald *et al.* 2014).

Urban centres globally are increasingly embracing integrated approaches to water resource management, which emphasize not only supply management but also demand management. Demand management focuses on using existing water resources more efficiently and sustainably through strategies that influence how water is being used. There are several benefits to incorporating demand management into water management planning, including reducing the environmental impacts to natural water systems from withdrawals and discharges and delaying or avoiding costly supply infrastructure (Brandes & Maas 2005).

The study was situated in Calgary, Alberta, Canada and was developed in collaboration with the City of Calgary (the City), which has an approved plan for conserving water resources, the *Water Efficiency Plan 30-in-30, by*

2033 (WEP). The WEP notes that, despite initial efforts, numerous opportunities exist to enhance water use efficiency and conservation for the City of Calgary (City of Calgary 2005). In particular, the study aimed to guide the City in channelling its efforts to indoor and outdoor industrial, commercial, and institutional (ICI) and outdoor residential water use programs that have the potential to decrease water demand while maintaining cost efficiency. It provides a valuable point of reference for water efficiency[1] and conservation planning, which may be applicable in other contexts and jurisdictions. It does so by offering insights into the process, obstacles faced, and knowledge gained through the investigation and selection of applicable water efficiency programs.

METHODS

The study was conducted between January 2020 and June 2021, and was developed in collaboration with the Citizen Programs Team in the City's Watershed Planning group. A City Water Resources advisory group was established to provide subject matter expert review and input throughout the process, which also included members from various teams in the Watershed Planning and Infrastructure Planning groups. The study was divided into two phases so the City could evaluate preliminary research outcomes and programs before further program assessment and final deliverables in the form of water conservation program implementation plans.

Phase I

The primary focus of Phase I was to research water conservation and efficiency programs in other jurisdictions and to conduct a preliminary screening of programs based on the City's water efficiency priorities. First, a review of Calgary's water consumption trends by type, time, and usage was completed to establish a background on existing water demand. Then, a comprehensive methodology was employed to identify leading North American water conservation jurisdictions and compile their ICI and outdoor water use programs into a structured database. The database underwent refinement and categorization, and weighted criteria were developed in alignment with the City's conservation priorities. The programs were then evaluated against these criteria and a subset of programs were identified for assessment in Phase II. This subset of programs was also assessed using a qualitative resilience lens.

Study area

Calgary is located in Alberta, Canada, to the east of the Rocky Mountains. It sources its water mainly from the Bow (60% of supply) and Elbow (40% of supply) rivers, which are situated in the South Saskatchewan River Basin (City of Calgary n.d. a). In addition to water provision for some municipal purposes and neighbouring regional customers, the City provides water to three core customer classes within Calgary, including single-family residential, multi-family residential, and ICI. Important risk factors for the City's current and future water supply and demand include climate, water licensing restrictions, and population growth.

Calgary has a semi-arid winter climate, characterized by short, hot summers and long, cold winters (City of Calgary 2018c). The city experiences chinook winds and resulting rapid weather fluctuations (City of Calgary 2018c). Calgary's precipitation is highly variable year to year; an average typical year saw the most precipitation in the month of June with 103.6 millimetres (mm), followed by July with 62.8 mm, and May with 52.8 mm. This monthly trend is also found in the historic monthly precipitation median (City of Calgary 2022). The tributaries in the South Saskatchewan River Basin are vulnerable to declining mountain runoff, which is of particular concern in Calgary where glacier melt from the Bow River basin typically accounts for 3% of the annual discharge (Bash & Marshall 2014). Calgary's water use has been shown to increase with temperatures above 10 °C (Chen *et al.* 2006) and 15 °C (Akuoko-Asibey *et al.* 1993), as well as during periods of low precipitation (Akuoko-Asibey *et al.* 1993). Both flood and drought are risks, as evidenced by major flood events in 2005 and 2013 and dry years in 2017 and 2018 (City of Calgary 2018b). Notably, in the summer of 2023, Calgary experienced drought conditions, which resulted in mandatory water restrictions applied to all homes and businesses to limit outdoor

[1] Note to the reader on terminology: Water efficiency entails using less water through the same consumer behaviours, while conservation reduces water used through behaviour change (Grace Communications Foundation 2020). Water efficiency has been defined as the 'minimization of the amount of water used to accomplish a function, task, or result' and water conservation has been defined as 'a beneficial reduction in water loss, waste, or use' (Grace Communications Foundation 2020). Historically, the City has not made a distinction between these two terms and as such the terms are used interchangeably in this paper.

water use (City of Calgary n.d. b). Climate change exacerbates these risks, with increased winter precipitation and extreme heat days (City of Calgary 2018b).

Under the *Alberta Water Act*, the province requires a water license for diversions of any ground or surface water (Government of Alberta 2023b). A 2018 report to the City noted that based on Calgary's existing licences, the City will face challenges in providing water for peak day demand as early as 2036 due to the projected population growth (City of Calgary 2018a). The City currently holds three water licences: two for the Bow River and one for the Elbow River (City of Calgary 2018a). Calgary is just one of several licence holders in the Bow and Elbow watersheds, including upstream hydroelectric dams and power plants, and downstream irrigation districts, who have higher priority licences which enable them to draw large volumes of water during peak water consumption periods (City of Calgary 2005). In 2006, a moratorium was imposed on new surface water licenses in the basin. This restricts Calgary's water supply to an approved allocation with yearly and peak day withdrawal limits. Typical river low-flow periods in late-summer and fall tend to coincide with the timing of highest peak day demands, which may be exacerbated by climate change and population growth, requiring more stringent limitations on peak day demand.

Calgary has experienced substantial population growth, with an increase of 3.08% in population year-over-year and 9.38% over the past 5 years (Government of Alberta 2023a). Despite this expansion, improved water treatment measures have helped prevent a corresponding increase in total annual water system demand, reflecting the trend of 'de-coupling' of water use and population growth generally experienced across North America in recent years (City of Calgary 2016; Heberger *et al.* 2016; CWN n.d.). However, as Calgary's population continues to rise and basic water efficiency measures become widespread, the City may need to pursue alternative measures to meet its water needs using the available supply.

In 2005, the City of Calgary introduced the WEP, with the aim of matching 2003 water withdrawal levels from the Bow and Elbow Rivers by 2033 (City of Calgary 2005). Calgary has several past and ongoing water efficiency programs guided by the WEP. Early initiatives focused on improvements to City-owned facilities and typically focused on residential customer or user-incentive-based programs (City of Calgary 2018d). The 2016 WEP update redirected Calgary's water efficiency programming focus on two key conservation sectors: indoor water use for ICI customers, and outdoor water use for single-family, multi-family, and ICI customers (City of Calgary 2016). The 2016 WEP update included a review of water efficiency programs adopted from 2003 to 2014. Table 1 illustrates the City's completed or ongoing water efficiency programs since 2003.

Calgary's water efficiency targets include maintaining peak day demand below 950 million litres (ML) and reaching a daily per capita demand of 350 litres per capita per day (LPCD) (City of Calgary 2005). While the City also has targets related to achieving universal metering of all residential customers by 31 December 2014, and quantifying, monitoring, and benchmarking non-revenue water in its distribution system, these were not considered in the scope of the study. Universal metering and the water utility bylaw are credited with significant water savings, contributing to a decline in LPCD since 2003 (City of Calgary 2020). While the 350 LPCD target was briefly reached in 2016, there was a subsequent increase in LPCD during the particularly hot and dry summers of 2017 and 2018 (City of Calgary 2019; City of Calgary 2024). Peak day demand remained relatively stable from 2003 to 2018, with increases in peak day demand in 2007, 2014, and 2017 (City of Calgary 2019). In 2021, a heat dome that took place in June and July saw system demand reach a high of 820 mega litres per day, compared with the 5-year average of 519 mega litres per day (City of Calgary 2024). Collectively, this illustrates the importance of continued efforts to reduce water use during summer months and peak periods as factors such as irrigation and cooling can contribute to increased water demands (City of Calgary 2024).

Review of North American conservation programs

North American jurisdictions were selected based on discussions with subject matter experts, review of conference materials and white and grey papers from leading water organizations, and a web-based keyword search. Each jurisdiction was screened for relevance of conservation programming to outdoor and ICI water use, regional representation, and availability of information on water conservation programming. Programs were selected through an initial evaluation of whether the program was active and suitable to Calgary's typical water use behaviours as well as climate. Of the initial 37 jurisdictions considered, 18 were selected for further review and inclusion in the study. Of these 18 jurisdictions, 7 are regional organizations or regional municipalities and 11 represent a town, municipality, or utility. Ten of the jurisdictions are in the United States and eight are in Canada. Additionally, seven informational interviews were completed with jurisdictions to fill in information gaps and provide additional information on select

Table 1 | The City of Calgary's ongoing or completed water efficiency programs, 2003–2020

Program/Initiative	Description	Years
Ongoing		
Improvements to City-owned Facilities	Lead by example by providing water efficiency measures at City-owned facilities.	2003–ongoing
Rain Barrel Sales	Sales of rain barrels by a partner organization.	2005–ongoing
Indoor Water Use Education Campaigns	Targeted advertising and education to high water users and/or leaks detected.	2006–ongoing
Water Utility Bylaw: Emergency Watering Restrictions	Inclusion of outdoor watering emergency water restrictions.	2006–ongoing
Water Utility Bylaw: Low-Flow Fixtures	Inclusion of low-flow fixture requirements.	2006–ongoing
Water Utility Bylaw: Once-Through Cooling Systems	Inclusion of prohibition of once-through cooling systems.	2006–ongoing
Low-Flush Toilet Rebates (Multi-Family Residential and Hotels)	Rebates to switch to low-flow toilets for multi-family residential customers.	2008–ongoing
YardSmart	Communications and education to reduce outdoor water use in spring/summer.	2012–ongoing
Completed		
Universal Metering	Meter installations in all residential and ICI.	2005–2014
Low-Flush Toilet Rebates (Single-Family Residential)	Rebates to switch to low-flow toilets for single-family residential.	2005–2016
Spray Valve Restaurant Replacements	Replace spray valves in restaurants with high efficiency valves.	2006–2009
Diggin' in Yard Transformations	Yard transformation program.	2013–2017
Healthy Homes	Primarily indoor water-use audits and educational campaign (workshops and demonstrations) on efficient water measures.	2010–2014
Beauty on a Budget	Outdoor watering workshops paired with yard makeovers.	2015–2016
Outdoor Watering Market Research	Conduct research on perceptions and beliefs of various customer segments on home landscaping, and test possible program concepts.	2017–2018
ICI Water Use Research	Conduct research with different ICI customers on their feedback and attitudes towards a Capacity Buyback Program.	2017–2018

programs. Programs were sorted into five high-level categories based on InfraGuide Best Management Practices (FCM-NRC 2004) and specific program characteristics. The categories included: (1) communication and education; (2) partnerships and collaboration; (3) targeted information provision; (4) financial incentives or disincentives; and (5) regulations. Over 150 programs were included in the initial database.[2]

Creating a shortlist through screening, weighting, and a resilience lens

Drawing on and consolidating the program database, a chart was created with 96 unique water conservation programs presented by category and sub-category with brief descriptions. A decision matrix was used to evaluate and prioritize the program options, and nine criteria were developed and weighted in coordination with City stakeholders to best represent Calgary's context and the city's water conservation priorities: (1) local match; (2) quantity of water savings; (3) certainty of water savings; (4) scalability; (5) alignment (with existing programs, strategies, plans, and initiatives); (6) implementation feasibility for the City; (7) implementation feasibility for customers; (8) program targets new developments; and (9) program targets high water users.

Criteria were then scored on a scale between 0 and 2, with 2 being the highest or most appropriate match. A total score was calculated for each program by multiplying the program score for each criterion by the criterion weight and summing the weighted scores. Using the total score for each program, a point threshold was

[2] Note that the program count did not include less tangible programs generally related to communication, education, or partnerships.

established to determine which program would be included in Phase II. The threshold was based on the American Water Works Association (AWWA) Water Conservation Programs planning manual which suggests that a screening of potential conservation measures could yield 20–30 measures (AWWA 2006). By applying the threshold, a subset of top scoring programs was created. Program scores ranged from 0 to 45, with most programs receiving between 16 and 35 points. A threshold of 30 points was applied and a total of 33 programs were selected (35% of programs evaluated) for further review (see Supplementary Material for the selected programs and scoring).

The subset of programs was then assessed through a resilience lens, consisting of three overarching criteria, to ensure a balance of programs:

(1) Diversity of programs: Whether the selected programs target each sector (i.e., outdoor residential, multi-family, and ICI are all represented) and reflect a range of water conservation categories.
(2) Diversity of timeframes: Applicability for different timeframes (short-term, medium-term, and long-term implementation).
(3) Adaptability/flexibility to changing conditions (can be easily modified to reflect changing economic and environmental conditions and priorities).

Phase II

To further assess program suitability, the shortlisted programs (33 total) from Phase I were combined with existing City programs (14) and programs being researched or in the early implementation stage by the City (5) and were further analysed in Phase II. Key methods included Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis, gap analysis, and cost-benefit analysis (CBA). Implementation plans were then developed for the final list of suitable and applicable conservation programs for the City.

SWOT and gap analyses

An exercise to identify gaps in the City's existing water conservation programs, and entry points for further programming was conducted using SWOT and gap analyses. To support this exercise, a spreadsheet of Calgary's existing and historic water conservation programs was developed and reviewed in collaboration with the City. A SWOT template was filled out for each active program by drawing on insights gathered from program learnings, successes, and challenges identified by the City. The SWOT was conducted in consultation with the City's Citizen Programs Team, and was followed by a gap analysis of the current and desired future state of water conservation in the City.

The gap analysis was supported by insights gained in Phase I and the spreadsheet of existing programs, as well as the SWOT analysis. The gap analysis involved five main steps: (1) identify the desired future state of water conservation for the City; (2) determine the problem context and define the current state; (3) determine gaps by investigating the extent to which existing programming contributes to future objectives; (4) identify opportunities such as program focus areas or research initiatives; and (5) conduct a preliminary evaluation of the programs to assess suitability for the CBA.

Drawing on the findings from the SWOT and gap analyses, all programs under consideration were evaluated individually based on factors including potential contribution to identified gaps and program suitability for Calgary, to establish a shortlist of 35 programs. This included 16 new programs from the Phase I screening process, 14 existing City programs, and 5 City programs in research or early implementation stage. Figure 1 illustrates the process used to determine which shortlisted programs would be included in the CBA. The workflow considered factors such as: water and cost data; local data availability; whether the program was communication or education related; and if the program could be piloted or researched. This resulted in a final list of 11 programs for inclusion in the CBA, as well as three education and communication programs which would be considered for their costs with no water savings attributed.

Cost-benefit analysis

To further support program selection for implementation strategy development, a CBA exercise was carried out using the Alliance for Water Efficiency's (AWE) Water Conservation Tracking Tool (WCTT), Version 3.0. The WCTT is an Excel spreadsheet that allows users to evaluate water savings, costs, and benefits.

Five of the six data input worksheets in the WCTT were used to run the CBA, including: (1) Common Assumptions, which is required to operate the tool with inputs such as customer classes, number of accounts, number of single- and multi-family dwellings; (2) Specify Demands, with inputs such as the baseline demand forecast per

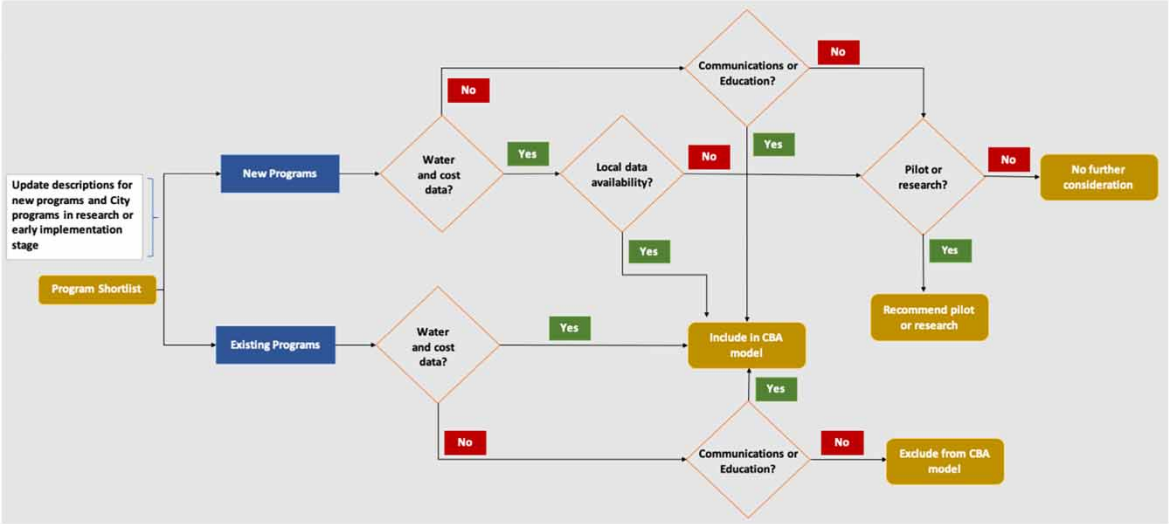

Figure 1 | Program assessment workflow.

customer class, system loss forecast, peak demand season dates, and peak demand as percent of annual demand per customer class; (3) Enter Utility Avoided Costs, which is used to estimate avoided costs related to water supply, wastewater, and system capacity, including variable operation and maintenance costs, water system delivery capacity requirements, new capacity and increment costs, and other avoided costs; (4) Define Conservation Activities, which has 23 optional activity inputs including unit water savings, utility costs, participant costs, participant non-water benefits, and related plumbing codes; and (5) Enter Annual Activity for program or participation in activities, as well as annual overhead costs for all programs.

An extensive data gathering exercise was conducted to meet the requirements of the WCTT, with data sourced from various departments of the City, literature, water conservation manuals, as well as programs in other jurisdictions. Inputs for existing programs were based on data collected from the City and the City's modelling tool, the Water Demand Forecast Model (WDFM). WDFM data was used for baseline demand scenarios. For prospective programs, calculations of costs and benefits were based on service area data, where available; however, several assumptions were made regarding individual program data inputs and their costs and savings in Calgary's context. Limitations and assumptions made at each stage were recorded and shared with the City.

Program benefits considered included water and wastewater savings, where applicable. Co-benefits, such as environmental benefits and social/community benefits, and benefits to the customer were not considered at an individual program level. Program costs to the City – such as marketing costs, contractor costs, and rebate and incentive costs – were considered for each program as fixed and/or variable costs. Additionally, an annual overhead cost was estimated. Staff time costs were not included in the CBA; however, staff time was considered separately in terms of potential full-time equivalent staff required to support the programs. With a few exceptions, costs to the customer were also not considered.

Of the 11 programs included in the CBA, 9 were newly identified and 2 were programs already under implementation by the City. The three new residential communication and education programs were assessed qualitatively based on estimated costs and potential contribution to other programs. Preliminary results from the CBA exercise were shared with the City who reviewed these alongside the qualitative assessments and selected preferred programs to move forward to implementation plan development.

To conclude the study, a final implementation strategy report was developed, including program implementation plans for the selected programs, which involved tailoring programs to Calgary's context and researching design and implementation options. Resources used to support program design and plans included utility reports and program examples, white papers, literature, and water organization web pages and publications. In addition, research and pilot studies that could fill data gaps and other identified limitations were also considered and presented where applicable. Complementary programs were grouped together and referred to as 'bundles', which involved researching the co-benefits of programs with varying priority areas relevant to the Calgary region. Additionally, alignment between programs and other City initiatives was mapped, with relevant success factors identified as supporting elements for individual program designs.

RESULTS

Resulting water conservation programs

The study resulted in the selection of seven new programs for which an implementation strategy was developed. The selected programs are listed in Table 2, Column B alongside the City's existing programs in Column A. These include five of the programs that were assessed in the CBA and two of the communication and education programs that were assessed qualitatively.

Table 2 | Existing and new water conservation programs by target sector

Target sector	A. Existing water conservation programs	B. New water conservation programs
Industrial, Commercial, Institutional (ICI)	**Indoor**	
	Water Utility Bylaw: Low-Flow Fixtures	Custom ICI Audit/Incentive
	Water Utility Bylaw: Once-Through Cooling Systems	
	Low-Flush Toilet Rebates	
	Outdoor	
	Water Utility Bylaw: Outdoor Watering Restrictions	Irrigation/Landscape Consultation
	Water Managed Sites Certification	Landscape Professional Training
	Indoor and Outdoor	
	Improvements to City-owned Facilities	
Single-family Residential	**Indoor**	
	High Consumption/Leak Education Campaign	
	Water Utility Bylaw: Low-Flow Fixtures	
	Outdoor	
	Water Utility Bylaw: Outdoor Watering Restrictions	All-in-one Garden Box
	Rain Barrel Sales	Rebate for Turf Removal/Water Smart Landscape Conversion
	YardSmart	Homebuilder Demonstration Garden
	Peak Day/Outdoor Watering Campaign	Turf Restrictions on New Development
	Water Managed Sites Certification	
	Design Your Yard	
	Indoor and Outdoor	
	Homeowner Water Guides	
Multi-family Residential	**Indoor**	
	Water Utility Bylaw: Low-Flow Fixtures	
	Low-Flush Toilet Rebates	
	Outdoor	
	Water Utility Bylaw: Outdoor Watering Restrictions	
	Indoor and Outdoor	
	Homeowner Water Guides	
General Public	Public Booths and Events	
	Water Tours	

Program bundles

Discussions with the City's Citizen Projects Team over the course of the study revealed an interest in the development of program 'bundles' – complementary groupings of programs that could result in shared program resources. It is expected that programs in each bundle will complement the City's ongoing initiatives, building on research that has been done and aligning with stated City priorities such as stormwater and drought management and climate resiliency. For example, costs related to marketing and implementation could be shared, and

bundled programs could present more cohesively in marketing and communications materials to the public. Two such bundles resulted from the final program selection, which are listed in Table 3.

Table 3 | Program bundles and descriptions

Program bundle	Program name	Program description
Bundle 1. Indoor and Outdoor ICI Water Use	Custom ICI Audit/Incentive	The audit portion of the program focuses on indoor water use. Multiple program streams are available. For each stream, an incentive is offered based on anticipated water savings.
	Irrigation/Landscape Consultation	Subsidized irrigation and landscape consultations to ICI customers. Consultations are led by landscape professionals who have completed the City-run Landscape Professional Training and assess irrigation systems, the landscape, and plants.
	Landscape Professional Training	The City of Calgary offers annual training for landscape professionals to become certified to complete irrigation and landscape consultations on behalf of the City.
Bundle 2. Residential Landscape Transformation	All-in-one Garden Box	An All-in-one Garden Box (kit) is offered to encourage residents to replace a portion of their lawn with resilient landscaping. The kit includes all components for lawn replacement (plants, soil, compost, design, educational material, etc.) and can be customized for factors such as square footage.
	Rebate for Turf Removal/Water Smart Landscape Conversion	The City of Calgary offers a rebate for the removal of existing turf grass and conversion of landscape to water smart landscape for single-family residential customers.
	Homebuilder Demonstration Garden	The City of Calgary partners with homebuilders and landscape architects to create water-wise demonstration gardens for new developments, potentially showcasing applications of All-in-one Garden Box installations.
	Turf Restrictions on New Development	The City of Calgary introduces new regulation that restricts the installation of turf in new developments. Landscapes can consist of a maximum of 50% turf in front yards and 50% turf in backyards. Non-turf landscapes must incorporate low water use plants and resilient landscaping practices and may incorporate stormwater retention features.

DISCUSSION AND RECOMMENDATIONS

Limitations

Two key limitations were encountered over the course of the study. Limitations in data availability were encountered throughout the process and data collection was largely guided by available research along with informational inputs provided by the City at various stages. The program selection process was largely an internal desktop exercise that did not involve or include research into customer perceptions or other 'on-the-ground' research in Calgary. Additional research was suggested to validate considerations such as customer interest/buy-in; CBA inputs including incentive levels, water savings, and participation; and other program design elements. A lack of supporting data also resulted in some innovative programs being screened out early in the selection process. Furthermore, an emphasis on having a strong quantitative rationale for the inclusion of programs resulted in newer and more novel programs being out favoured for more established programs with proven outcomes.

The CBA did not include alternative water demand scenarios such as demands under increased population growth or climate change impacts (e.g., high temperature or low precipitation scenarios). The inclusion of such scenarios could provide further guidance for different levels of conservation program activity. The CBA tool inputs also included variable operations and maintenance costs from the city but did not include environmental savings. Moreover, the CBA focused on quantifiable aspects of water savings and did not capture indirect or potential spillover effects from programs.

Key insights

Several insights into water efficiency program planning and implementation in Calgary were gained during the study, with possible relevance for other jurisdictions. These relate broadly to two areas: approaching water efficiency programming through an integrated lens and pursuing data-driven decision-making supported by robust data gathering and analysis.

An integrated approach to water efficiency programming involves considering programs individually and collectively, as well as in the wider context of their application. This allows the value of programs which are not easily quantifiable to be accounted for (e.g., through considering program success factors). Considering co-benefits can also illustrate the relevance of water efficiency programming to other city departments, industry partners, or the wider community.

Co-benefits

Co-benefits, or beneficial aspects of the programs in addition to water conservation, were not included in the individual program assessments or the CBA. However, additional general co-benefits arose throughout the study that are applicable to each program bundle, which were identified as (i) climate change resiliency; (ii) stormwater management; (iii) drought management; and (iv) social, economic, and environmental benefits. These were highlighted given their relevance to other areas of the City's work.

Climate change resiliency was a co-benefit identified throughout the study. Selected programs have the potential to target likely drivers of summer water use by, for example, encouraging transitions to climate-resilient landscaping. This also has implications for drought management. Outdoor water use is understood to be a driver of peak day demand in Calgary; the Residential Landscape Transformation program bundle builds on the City's existing efforts to encourage water-wise landscaping through the transformation of lawns to low water use landscapes, including the incorporation of climate appropriate plants that can withstand drought conditions. This program bundle also has direct implications for stormwater management, given the inclusion of stormwater retention features. Both the Residential Landscape Transformation and Indoor and Outdoor ICI Water Use program bundles have the potential to contribute to drought resilience through increased water conservation during peak periods. The bundles also offer social, economic, and environmental co-benefits, by emphasizing communication, education, and fostering partnerships, which in turn could strengthen relationships between industry and community organizations. For example, through the Irrigation/Landscape Consultation program in the Indoor and Outdoor ICI Water Use program bundle, the City can educate customers about water conservation and landscape transformations; landscape transformation has also been noted to have the potential to reduce utility bills and enhance property values (California Water Efficiency Partnership 2020).

Implementation plans

The results of the study included seven new program implementation plans that were submitted to the City targeting indoor and outdoor ICI water use and outdoor single-family residential water use (program bundles 1 and 2). Each implementation plan was designed based on the possibility that the program would be implemented as a standalone program with a noted exception where two programs were designed for potential joint implementation: Irrigation/Landscape Consultation and Landscape Professional Training. The final implementation plans presented information to the City such as specific timeline (e.g., 5 years, 10 years), estimated costs of running the program, additional resources required, implementation tasks, program priorities, as well as monitoring and evaluation metrics. Additionally, certain programs called for the implementation of pilot programs to ensure factors such as water savings, customer interest, and appropriate allocation of resources, whereas other programs were recommended for full implementation.

Success factors

An important feature of each implementation strategy was the inclusion of relevant success factors. Carried forward from Phase I, success factors represent supportive elements for which water savings were not identified but that have proven key to effective program implementation in other jurisdictions. These were identified as:

(1) *Data-Driven Decisions:* Accessibility and proactive or targeted use of water consumption data.
(2) *Communication, Education, and Outreach:* Programs that help inform citizens about water conservation and instill an ethic of water conservation in the community.

(3) *Enforcement:* The existence of regulations that target or affect specific water uses alongside enforcement mechanisms.
(4) *Partnerships:* Partnerships between the water provider/utility and other organizations or stakeholder groups.

A final insight from the study included the importance of data-driven decision-making supported by robust data gathering and analysis in order to demonstrate value for investment and to target programming effectively. Successful programming was found in jurisdictions that collected data to support the development of a program rationale or to adapt and refine an existing program. Accordingly, a streamlined process for water consumption data review and analysis is important to enable targeted programming.

Future recommendations

While several recommendations were identified over the course of the study, a final set of recommendations including further research and pilot studies was identified to best support the implementation strategy and selected water conservation programs.

Implementation strategy

The implementation strategy and individual plans were not intended to take the place of a water conservation plan or act as a comprehensive guide to program implementation, and further research is needed to support program implementation. The development of a comprehensive workplan, including a detailed timeline and employee roles for each project stage, is recommended for a further stage of program analysis. Public participation, such as through focus groups, public workshops, or other forms of engagement may also contribute to program development and help ensure the acceptance of programs by the Calgary population.

Research and pilot study

Supplementary research and pilot studies are expected to support the successful implementation of the selected programs. Research is recommended to evaluate and validate factors such as customer interest and buy-in, incentive levels, water savings, participation, and other program design elements. Accordingly, it is suggested that the City conducts further 'on-the-ground' research. It would also be beneficial to conduct supplementary research and analysis on residential and ICI outdoor water use. For example, preliminary analysis to identify the City's high outdoor water users in the ICI category could target metered irrigation customers. Program planning can also be further supported by the use of tools such as Geographic Information Systems (GIS), which could provide an analysis of residential lots, in order to determine landscape cover types.

A pilot study should be undertaken to verify the actual savings potential for the City and to establish more reliable water estimates for typical water use per square foot for landscapes in Calgary. Results could inform the following selected programs: All-in-one Garden Box, Rebate for Turf Removal/Water Smart Landscape Conversion, Turf Restrictions on New Developments, and Homebuilder Demonstration Garden. Additionally, several programs were identified in Phase I that put water use data directly in the hands of the user, allowing for early leak detection, increased customer interaction, and engagement of customers in water conservation. Water budgets establish an amount of water appropriate for a customer type; water budgets for indoor residential users may consider variables such as number of people in the household and average daily water use, whereas water budgets for outdoor users may establish a typical water use per area of irrigable landscape. Water use reports or online portals help customers compare or benchmark their use to other customers with similar profiles and set up alerts for high water use and potential leaks. While water budgets were not included in the final program selection, it is recommended that the City identifies a customer class to pilot the development of a water budget or benchmark.

CONCLUSION

Globally, water demands impacted by population growth and changing consumption patterns are expected to increase by 20–30% by 2050 (Delgado *et al.* 2021). Urban areas face increased water scarcity due to urbanization and climate change, necessitating water management (McDonald *et al.* 2014; He *et al.* 2021). In 2016, Calgary's WEP update shifted the City's focus towards conservation in the outdoor water use sector, as well as indoor ICI water use. The two-phase collaborative study discussed in this article aimed to identify and develop a path forward for water conservation programs in line with the City's water efficiency goals. Insights emerged related to the value of pursuing an integrated approach to water efficiency programming – one that considers co-benefits

and other success factors such as data-driven decision-making, communication, education and outreach, enforcement, as well as partnerships. Recommendations suggest further research and pilot studies for program validation. The study contributed a comprehensive foundation for advancing water conservation strategies and programs in the City of Calgary while acknowledging potential areas for further exploration. The findings and recommendations from this study may be used to inform current and future strategic water planning and programs for the City of Calgary; for example, the recently released Drought Resiliency Plan (2024) targeted at reducing water demand, protecting water supply, drought preparedness, ensuring healthy landscapes, and building strong relationships with water users. The findings presented in this study may also be insightful for other jurisdictions undertaking water efficiency and conservation planning.

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DATA AVAILABILITY STATEMENT

Data cannot be made publicly available; readers should contact the corresponding author for details.

CONFLICT OF INTEREST

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