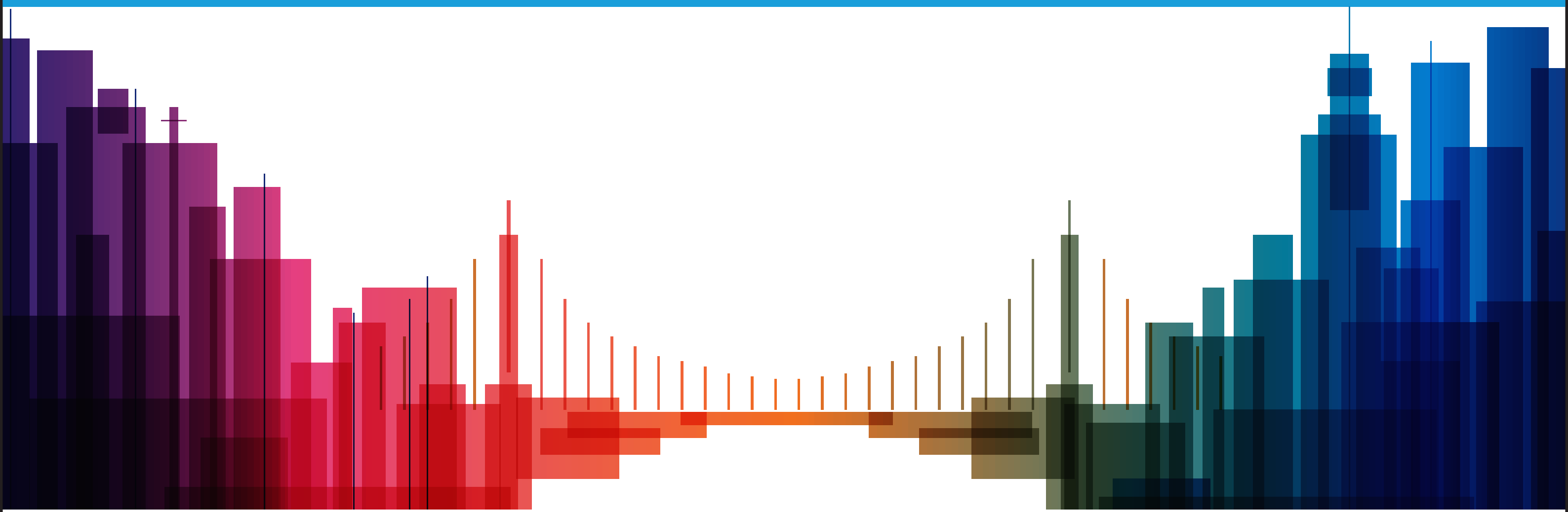
United 4 Smart Sustainable Cities

Energy efficiency in buildings

Case study of the U4SSC A guide to circular cities

June 2020

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Case study: Energy efficiency in buildings

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Foreword

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The case was reviewed by Okan Geray.

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CONTENTS

List of Figures and Tables

Figures

Tables

Deep lake water cooling: its origins and the next evolution

Author: Catherine Thorn

Introduction

Background

Toronto is Canada's largest city and continues to grow at a staggering rate (City Planning Division, 1). In January 2018, the city earned the unique title of having the highest crane count in Rider Levett Bucknall's crane index (RBL, 3), an indicator of high-rise construction activity in North American cities. This rapid growth comes with opportunities and challenges. Economic growth exerts more pressure on Toronto's already constrained electricity grid (Central Toronto Area Integrated Regional Resource Plan, 1) and makes it harder to reduce total greenhouse gas (GHG) emissions; however, it also provides Toronto with the scale and resources to invest in transformative strategies.

The Economist has highlighted Toronto as one of the ten most liveable cities in the world (The Economist Intelligence Unit, 10). To maintain its competitiveness, the city has embraced city building policies that will position Toronto at the forefront of macro energy trends: decarbonisation, decentralisation, and digitisation. Addressing climate change is a key priority for the city, and its climate change action plan, titled 'TransformTO', envisions 'a city that has achieved a low-carbon future while enhancing [its] local economy, reducing inequalities, and improving public health' (Scioli, 11).

Through TransformTO, the city has committed to reduce greenhouse gas (GHG) emissions by 65 per cent by 2030 and by 80 per cent by 2050 compared with 1990 levels (Scioli, 16). Since the 60 per cent of GHG emissions in Toronto is generated by buildings (The Atmospheric Fund, 7), the city has identified thermal energy networks as a critical strategy to meet its goals (Scioli, 32).

Challenge and response

Beginning in the 1980s, concerns about depleting the atmosphere's ozone layer became a key issue for governments around the world, including the City of Toronto. At that time, the primary means of cooling buildings were chiller systems that used chlorofluorocarbon (CFC) refrigerants, which are chemicals that are particularly harmful to the ozone layer. Although CFC's have been phased out by regulations and replaced by less harmful substances, managing the environmental impacts of common refrigerants remains a challenge (Environment and Climate Change Canada, 1). While seeking solutions to reduce CFC's, a creative mechanical engineer, along with a group of environmentalists and politicians, developed the original concept for Deep Lake Water Cooling (DLWC), a system that would use cold water from the depths of Lake Ontario to supply cooling to buildings in the downtown core instead of refrigerant-driven chillers.

Meanwhile, in the 1990s, the City of Toronto experienced a water quality issue. Zebra mussels infested the city's potable water intake pipes from Lake Ontario, fouling the water and causing undesirable odours. To address the problem, the city considered installing carbon filters, which would have necessitated a large capital investment. Instead, the city decided to evaluate DLWC. Installing very deep raw water intake pipes could address the water quality issue caused by zebra mussels and provide a source of water that remains at a consistent, cold temperature year-round to support DLWC. Once the design and business case for DLWC was developed, the city established Enwave, the district energy company that developed and operates DLWC.

DLWC is an example of a circular city strategy that has provided, and continues to create, value for the City of Toronto and its citizens, and for the natural environment.

Promoting circularity

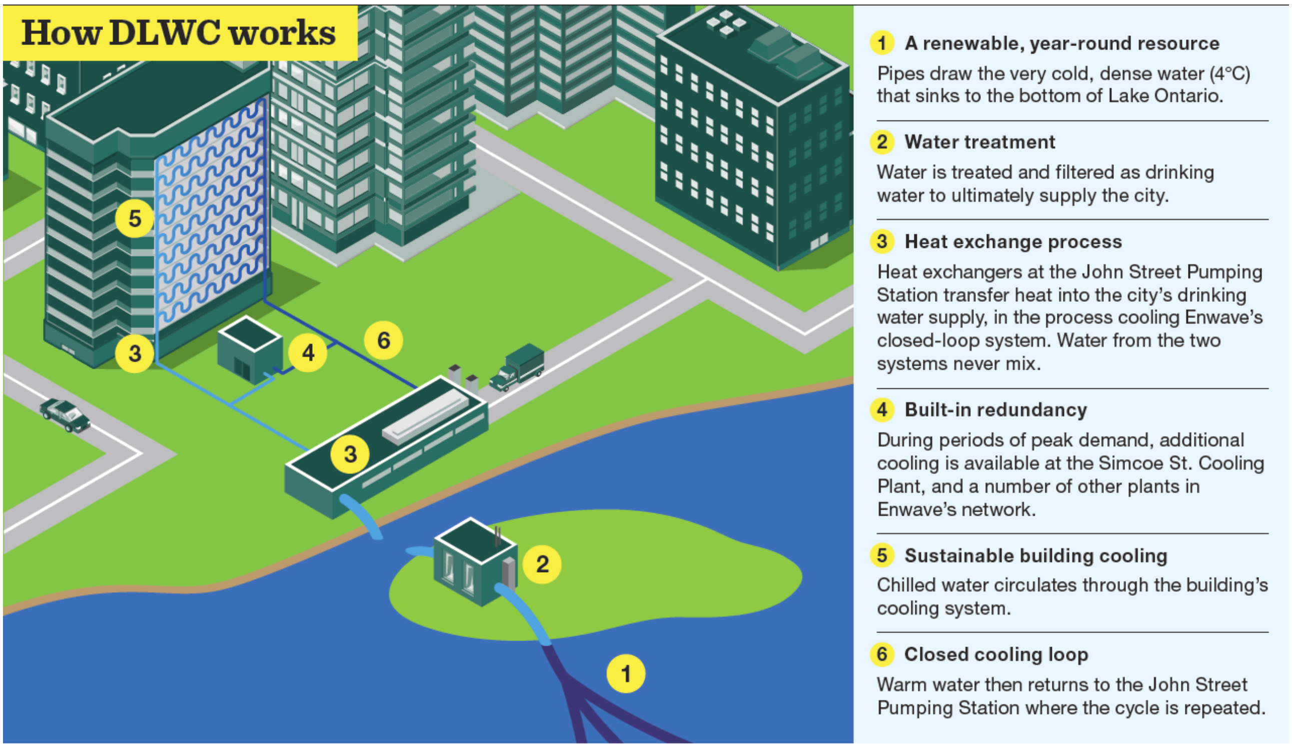
Vision and content

DLWC was initially set out to transform the way in which buildings are cooled, in order to reduce the environmental impact while providing value to the city and fostering economic development. Originally commissioned in 2004, DLWC has accomplished this objective. DLWC now serves over 70 buildings in downtown Toronto, displacing 1 391 kg of CFCs, 61 MW of peak electricity demand, 75 per cent of total cooling-related electricity consumption, and related GHG emissions. Looking forward, plans for DLWC continue to support the city's long-term goals. Through TransformTO, the city has identified that to achieve its GHG reduction targets by 2050, 75 per cent of its energy consumption will have to be derived from renewable or low-carbon sources and 30 per cent of all floor space will be connected to low-carbon thermal energy networks (Scioli, 2). The next evolution for DLWC will be the backbone for low-carbon heating, as well as for cooling.

How Deep Lake Water Cooling Works

Three DLWC intake pipes extend along the base of Lake Ontario to a depth of over 80 m below the surface, where the water remains at a temperature of about 4°C throughout the year. Once the water has been drawn from the lake and treated to make it potable, it is pumped through heat exchangers to cool it in Enwave's district system that supplies cooling to buildings throughout downtown. The potable water continues through the city's network to individual buildings where it is used, flushed down the drain and eventually makes its way back to the lake through the city's wastewater treatment systems.

Figure 1: DLWC Process (Source: Toronto Hydro)



The Next Evolution for DLWC

Three major initiatives are being planned that have the potential to expand the benefits of DLWC and capture additional value for Toronto:

- To install a fourth intake to expand renewable cooling capacity for DLWC.
- To add large-scale thermal storage tanks to increase renewable cooling utilization.
- To develop a district heat recovery system that uses rejected heat from buildings connected to DLWC to heat other buildings.

Fourth Intake

Installing a fourth intake into Lake Ontario has the potential to increase the capacity of DLWC significantly, while providing improvements to the city infrastructure such as control upgrades at the city's water filtration plant. To make this project a reality, a strong leadership commitment, a close working relationship between Enwave and Toronto Water, and a fiscally-responsible approach will be required. The city and Enwave will need to revise existing agreements to govern the use and upgrade of the existing, abandoned pipe infrastructure and the necessary rights of way to complete the project. Enough growth in demand must be secured to support investing in this new infrastructure.

Storage Tanks

Enwave Toronto recently signed an agreement with 'The Well', a mixed-use development in Toronto, where thermal storage tanks will be installed below the 7th level of underground parking, leveraging existing cooling infrastructure to take advantage of off-peak cooling capacity. These thermal storage tanks will be filled with chilled water from DLWC during the night, when cooling demand is lower and electricity is greener and cheaper, to support peak capacity during the day. Enwave's automated dispatch system will be used to determine optimal timing to fill and dispatch the thermal storage tanks given cost inputs, environmental metrics and load projections.

District Heat Recovery (DHR)

Many buildings connected to DLWC, such as data centres, require cooling year-round. These buildings reject a substantial amount of heat into the DLWC system, which can be recovered in the winter and upcycled through heat pumps to supply low-carbon heating to other buildings throughout downtown Toronto. Heat pumps use the same technology as refrigerators: they move heat from a low-temperature source (DLWC return pipe) to a high-temperature sink (the building to be heated). Heat pumps are powered by electricity and typically offer efficiencies approximately four to five times that of high-efficiency natural gas-fired boilers. Since electricity is currently substantially more expensive on a blended rate basis than natural gas, heat pumps will need to be strategically deployed to minimize electricity demand charges, in order to remain competitive in the market.

Table 1: Toronto's Strategic Approach to District Energy

Strategy	Partnership Approach
Description	The operations teams for DLWC and the city's potable water system work together in a close partnership to continually optimize operations.
Reason for Development	DLWC operations are highly integrated with the city's water operations. For example, city water flow rates affect the amount of cooling that can be produced at any given time; therefore, the DLWC operations team communicates projected water volumes needed to meet cooling demand to the city daily so that use of the city's water reservoir can be optimized to match water flows with DLWC demand.
Impact on District Energy	Using a partnership approach rather than operating in silos based on contract parameters has been critical to optimising holistic benefits to the city. For example, the DLWC system includes backup power that also supplies the city's potable water distribution pumps and gives those pumps priority that adds resiliency to the potable water system, as well as the DLWC system.
Strategy	**Toronto Hydro Incentive**
Description	Toronto Hydro, the local electricity utility in Toronto, developed a tailored incentive, paid in $ per kW of reduced electricity demand, for buildings to connect to DLWC.
Reason for Development	Toronto Hydro recognized that connecting buildings to DLWC reduces its electricity demand and related costs Toronto Hydro incurs for upgrading electricity infrastructure to support the ever-growing demand in downtown Toronto.
Impact on District Energy	The incentive provides buildings with a one-time payment when they connect to DLWC that can help support the business case for connection costs.

Table 2: Policy Impacts to DLWC, DHR and DE in Toronto

Policy	City of Toronto Energy Strategy
Description	The City of Toronto requires that developers applying for an Official Plan Amendment, Zoning By-Law Amendment, or Plan of Subdivision for a development with a total gross floor area of 20 000 m^2 or more submit an 'Energy Strategy' that evaluates opportunities to use sustainable energy, including low-carbon thermal energy networks.
Reason for Development	Requiring developers to prepare an Energy Strategy ensures developers consider low-carbon energy solutions that may not be part of their business-as-usual approach early in the planning process. This approach facilitates integrating renewable energy, energy sharing, enhanced resiliency, and more innovative solutions into community design from the start.
Impact on District Energy	The Energy Strategy has generated more interest from developers in holistic, innovative, low-carbon solutions, including DLWC, DHR, district-scale geothermal energy, and microgrids.
Policy	**Ontario Building Code**
Description	The Ontario Building Code establishes the design requirements for constructing a building in the province of Ontario.
Reason for Development	Its primary purpose is to ensure that buildings are safe, but it also includes minimum energy efficiency requirements.
Impact on District Energy	The Ontario Building Code references a modelling approach to evaluate energy efficiency that does not consider the impact of any energy supplied from a district system. A flaw in this approach is that a building with its own 90% efficient condensing boilers can be modelled as more efficient than the reference building, but buildings using 400% efficient geothermal heating from a district system are modelled the same as the reference building.
Policy	**Toronto Green Standard**
Description	The Toronto Green Standard sets minimum energy, carbon, and environmental requirements for buildings being developed in Toronto. It also establishes more ambitious voluntary targets which, if met, qualify developers for a substantial rebate on their development charges.
Reason for Development	The latest version of the Toronto Green Standard maps out a path to meet the TransformTO goal of achieving net zero carbon development by 2030. As part of this goal, it encourages using low-carbon thermal energy networks.
Impact on District Energy	While the building code establishes minimum requirements that many developers exceed anyway, the latest version of the Toronto Green Standard is much more ambitious and has pushed the market to a new level of energy performance. It also includes a carbon metric for the first time, which is creating additional interest in low-carbon solutions such as DHR.

Digitisation has been key in advancing the benefits of DLWC. In 2017, Enwave executed the first phase of a fully automated dispatch strategy that uses real-time data on weather, utility pricing, equipment availability and efficiency to optimize the use of its cooling and storage assets. Enwave also recently upgraded energy metering within connected buildings to improve remote troubleshooting, provide Wi-Fi connectivity and enable data trending. These advancements enable energy managers to gain a better understanding building energy efficiency and to improve it. The DLWC system also has 11 MW of backup generators that make it highly resilient to power outages and provide backup power to the city's potable water pumps.

Results

While the initial drivers for this project still hold true today, DLWC has generated significant additional benefits since its implementation. Realized and projected benefits from DLWC include the following:

- As part of the initial construction of DLWC, Enwave upgraded city infrastructure and provided backup power to the city's potable water distribution pumps.
- DLWC has displaced an estimated 1391 kg of CFCs.
- DLWC has displaced an estimated 61 MW of electricity demand. With future expansions planned, this avoided demand is expected to increase to a total of 74 MW. Displacing electricity demand eases the strain on the electricity grid in downtown Toronto, which is heavily burdened and projected to exceed capacity within the next few years due to Toronto's rapid growth.
- DLWC reduces cooling tower use, saving potable water consumption and related energy used in the treatment process.
- DLWC reduces buildings' electricity consumption for cooling by an average of 75 per cent compared with conventional chillers.
- DLWC has contributed to economic development in the city by retaining money spent on energy within the local economy and establishing a centre for innovation in district energy in Toronto. Over the past 10 years, more than 116 million Canadian dollars of capital has been invested in expansions of the DLWC distribution network.
- DHR has the potential to reduce GHG emissions by a projected 37 000 tCO_2e per year relative to that produced by conventional natural-gas fired boilers, provide a new model for low-carbon heating in Canada, and foster further economic development for the city.

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List of discussion partners/interviews

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