TORONTO 2030 DISTRICT
SUMMARY REPORT

For: The Independent Electricity System
Operator (IESO) //

May 2023

THIS SUMMARY PRESENTS THE RESULTS AND CONCLUSIONS OF A FOUR-PART SERIES OF REPORTS PRODUCED BETWEEN 2020 AND 2022 BY THE TORONTO 2030 DISTRICT'S PATHWAYS PROJECT.

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Project Overview

This summary presents the results and conclusions of a four-part series of reports produced between 2020 and 2022 by the Toronto 2030 District's Pathways Project. Taken together, these reports explore credible pathways to achieving net-zero operational greenhouse gas (GHG) emissions for the built environment in the Toronto core by 2050.

Ultimately, the goal is that this project will help lay the foundation for practical implementation of its recommendations through pilot programs, experiments, new incentives and programs, and proposals for regulatory reform.

The Toronto 2030 District is part of a North American network of building districts and cities, the goal of which is to catalyze transformation in the built environment and the role it plays in mitigating and adapting to climate change. It is a public–private partnership that is committed to achieving a low-carbon future. Its members include property owners and managers, tenants, utility companies, government, service providers, and civil society actors.

Toronto 2030 District's vision is that:

Toronto will have net zero GHG emissions and be a healthy place for all to thrive.

Vibrant cultural, entertainment, business and residential communities will be

underpinned by a sophisticated clean infrastructure for essential resources and services.

The energy network will be clean, resilient and create minimal waste.

The District's first project was to create the Toronto 2030 Platform. The Platform was developed by the Canadian Urban Institute to track building performance and progress toward GHG reduction targets in the District. It displays energy use, water consumption, and transportation emissions data for the District by building type and block.

The second project was to search for a pathway or pathways to District decarbonization in the most economically feasible way. We started with a cost model for fuel switching, since this is both necessary and sufficient for decarbonization. Using that model, we explored ways to reduce costs and increase practicality.

This work is documented in four reports, each of which represents a distinct phase of the Pathways Project:

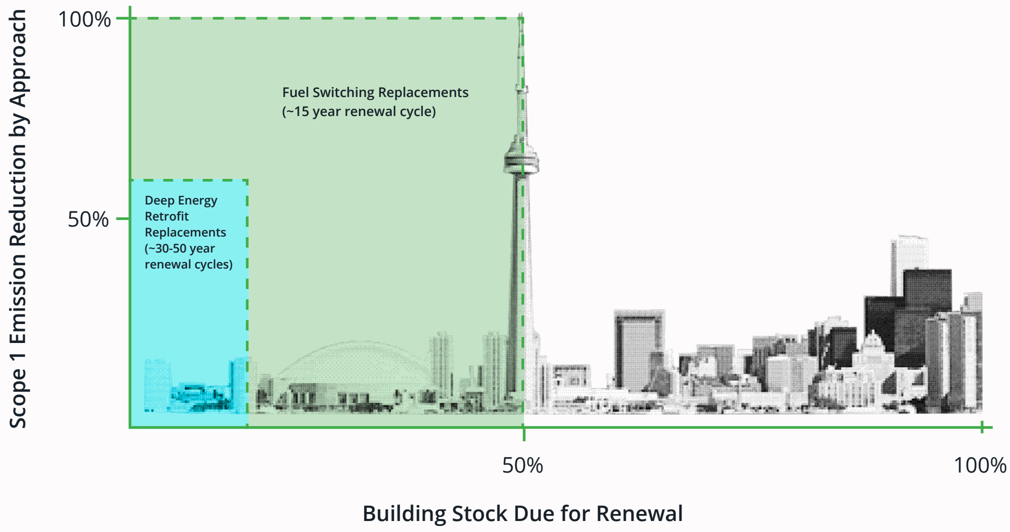
- **Phase one** is a high-level overview of the Toronto District—the city's downtown core—with a focus on the current state of the District's building and energy systems, and the challenge of moving the system to 100% net-zero GHG emissions. This phase is a foundation for the more detailed work that followed in the next three phases.
- **Phase two** examined the cost and viability of transitioning existing on-site combustion systems to emissions-free energy. It explored the feasibility of six options to replace natural gas heating systems: blue and green hydrogen boilers/furnaces, electric boilers, electric ground-source heat pumps, electric air-source heat pumps, and hybrid systems using renewable natural gas and electric heat pumps.
- **Phase three** looked at whether heating-load–related building retrofits can help reduce the cost of fuel switching and contribute to the pathway to net zero. The measures examined in this phase are consistent with the City of Toronto's definition of a deep energy retrofit.
- **Phase four** consolidated the project's findings. It also examined three additional technological solutions to assess potential contributions to reaching net zero in the Toronto District. As well, it discussed system-level policies and programs that need to be in place to help drive progress along the pathway.

Combined, the reports explore the ways in which Toronto District buildings can decarbonize, whether and how it is possible to help the electrical grid manage peak demands resulting from these decarbonization efforts, and the implications for building owners in terms of cost, feasibility, and more.

The key findings from the project are that:

- Fuel switching is both **necessary and sufficient** to achieve net-zero 2050 goals—i.e., we cannot achieve our goals without fuel switching away from unabated natural gas. No other steps are necessary to eliminate GHG emissions from a building.
- Deep building retrofits can make a building more comfortable and appealing to tenants and can also reduce costs over time. However, building retrofits are **neither sufficient nor necessary** for achieving GHG reduction targets. Given the relative infrequency of deep retrofits, they are unlikely to contribute significantly to 2030 targets, although by 2050 they can provide value by reducing overall demand for energy.
- Solar and battery options are **neither sufficient nor necessary** for the achievement of emissions targets in buildings. In some cases, however, they can reduce costs to building owners or provide resilience.
- District heat networks produce emissions if their source of heat produces emissions. Toronto's systems use gas as a heat source, and therefore they are inconsistent with our climate goals and their use should not be expanded until their fuel is replaced with clean energy sources.

In 8 years, fuel switching alone at time of replacement can hit the 50% global emissions reduction target



Bold policy change is necessary, as the current policy framework is having little effect on buildings. Based on the work undertaken in the four phases, the Pathways Project encourages the following policy and program priorities:

- Implementing a net-zero framework over the next two to three years for Crown corporations, regulatory bodies, and key Ontario ministries. This process must begin with a Government of Ontario commitment to net zero by 2050;
- Enacting a sunset clause for the installation of new natural gas–based heating systems;
- Providing financial support for the installation of heat pumps;
- Using building codes and building-performance regulations to accelerate the process;
- Advocating for the phase-out of gas-fired boilers; and
- Supporting experimentation with clean gases without delaying current electrification efforts.

Phase One: Background—What is “the District”?

The Toronto District is the core of the City of Toronto and the financial and economic centre of the city. It comprises approximately 16 square kilometres and is bounded by the Don Valley Parkway to the east, Bathurst Street to the west, the railway lines (i.e., Dupont Street) to the north, and the lakefront to the south. The District had 238,000 residents in 2016, up by 41% from 2006, an increase that is greater than the city-wide rise of 9%.

Downtown Toronto was chosen because it contains every building type in the province except industry. We needed a “test bed” where we could verify real issues but that was small enough to be manageable. The study area includes single-family homes, apartment towers, “Main Street” retail, malls, small office buildings, office towers, schools, universities, hospitals, and government buildings.

Energy needs and consumption

Without intervention, the District’s electricity and natural gas demand are projected to keep rising this century due to Toronto’s growing population and role as an economic development powerhouse.

The District consumes roughly 20% of Toronto’s electricity and 12% of Toronto’s natural gas, although it contains only 3% of the city’s land area. In 2017, the District’s total energy consumption for buildings was 10,030 gigawatt-hours. Natural gas fuels purchased and combusted directly in buildings represented 48% of total energy consumption. Energy sources purchased by proportion are grid electricity (37%), deep lake–water cooling (DLWC) (electricity, 9%), district heating (natural gas, 5%), and water (electricity, about 1%).

These energy sources emit about 1.2 megatonnes of carbon dioxide per year. Of this total, natural gas for heating accounts for the largest share, at 74%, followed by natural gas–producing steam (16%) and electricity (10%).

The District is also home to nine data centres, which have power demands ranging from 2.4 to 10 megawatts.

Energy sources within the District

The District contains five multi-building energy systems, which meet its needs in various ways. Currently, these systems supply 14% of the District's energy needs:

1. The **University of Toronto's** district steam system and hot water system, which use natural gas to produce electricity and steam for 121 buildings on its downtown campus.
2. **Enwave Toronto's** energy system, which, in partnership with the City of Toronto, manages a district energy system covering approximately 2.5 million square metres and delivers services to more than 150 buildings in downtown Toronto. On the cooling side, the system is connected to the Island Water Treatment Plant and the DLWC; on the heating side, three boilers use natural gas to produce steam.
3. **Toronto Community Housing's** Regent Park community energy system, which supplies heat and cooling services to more than 800 residential units, commercial retail spaces, and City of Toronto buildings.
4. **Toronto Western Hospital's** heating system, which provides heating for the hospital through a decarbonized sewage energy-exchange system.
5. **Mirvish Village's** heating and cooling system, which will supply the energy needs of this new residential and commercial development in the Annex neighbourhood.[1]

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[1] Although Mirvish Village is on the perimeter of the District, it is a good example of a recently developed shared heating system, which is worth considering in our portfolio when looking at archetypes.

Phase Two: Replacing Natural Gas—What Can Be Done?

Phase two of the Toronto 2030 District's Pathways Project is its assessment of options for energy-supply decarbonization to replace end-use natural gas combustion in District buildings. The second report in the series examined solutions to replace 100% of existing natural gas, assessing the feasibility—both from a technological and cost perspective—of the available options. Many people cost individual energy measures, so we wanted to give owners a way to compare these to their own buildings. We therefore developed a cost-per-square-foot model.

The analysis is based on a database we built from metered data collected in 2017. Partners included Toronto Hydro, Enbridge Gas, Enwave, and the Municipal Property Assessment Corporation (MPAC). We collected information on full city blocks so as to not violate customer privacy, and we used MPAC data to approximate the composition of the blocks.

The designers on our team have experience designing buildings over the last 30 years and in interior fit-out, system replacement, and larger renovations in older buildings. Using this knowledge, we divided the occupancy into building typologies, usually based on building age. We assigned typical envelope and heating systems to those buildings and predicted energy use. We then cross-checked their energy use against energy use–intensity data published by the Ontario Association of Architects. Finally, we cross-checked the totals against the aggregate metered data from the platform study.

Through this analysis, we know that some of the more unique building types are miscategorized; however, they are a small portion of the total, and we know that every cubic meter of gas and kilowatt-hour of electricity have been accounted for. The result should be viewed as accurate by plus or minus 10%.

We then developed fuel-switching scenarios and envelope upgrades for each building typology and had them costed by supplier and by cost consultants. We used this data to develop square-footage costs for upgrading each building typology. We used 2021 costs as a baseline, which we later referenced when we evaluated market trends.

The report looks at three energy carriers: (1) renewable natural gas (RNG), (2) hydrogen, and (3) electrification. These three energy carriers were translated into six heating solutions: blue hydrogen boilers/furnaces, green hydrogen boilers/furnaces, electric resistance, electric ground-source heat pumps, electric air-source heat pumps, and hybrid systems using renewable natural gas and electric heat pumps. We assessed the six options for cost, ability to meet 2030 IPCC recommended targets, trend factors, and impact on the electricity grid.

Cost

Viewed by occupancy type, we can get a sense of the impact of fuel switching, at current capital improvement costs, on different types of buildings (see **Figure 1**). This is important, as different buildings have different business models. In a multi-unit building, for example, a 750-square-foot apartment would have, on average, an amortized capital and operating increase of $156/month if it was switched from natural gas heating to an air-source heat pump, which is a significant amount for many owners and renters. If amortized capital costs are excluded, the operating cost increase would be approximately $30/month for this size of apartment.

On the other hand, for a class A office with an average lease rate of $38 per square foot per year (which is the average in the District), an increase of $2 per square foot is more palatable. Members of the advisory committee felt that, for offices, these costs were too high to attract tenants willing to pay more for a low-carbon building, but if fuel switching was mandated for all landlords, the costs could be managed. Restaurants will face significant increases given that they are very high energy users compared with other occupancies. This points to a need to address the restaurant sector as a special case.

It is also important to consider the relative similarity of costs for heat pumps and blue hydrogen in single-family homes. Heat pump technology is more mature for this building type and there is more competition and greater innovation. This is not the case for larger heat pumps, however, although there is currently no technological reason why the price of larger heat pumps would not come down if demand accelerated.

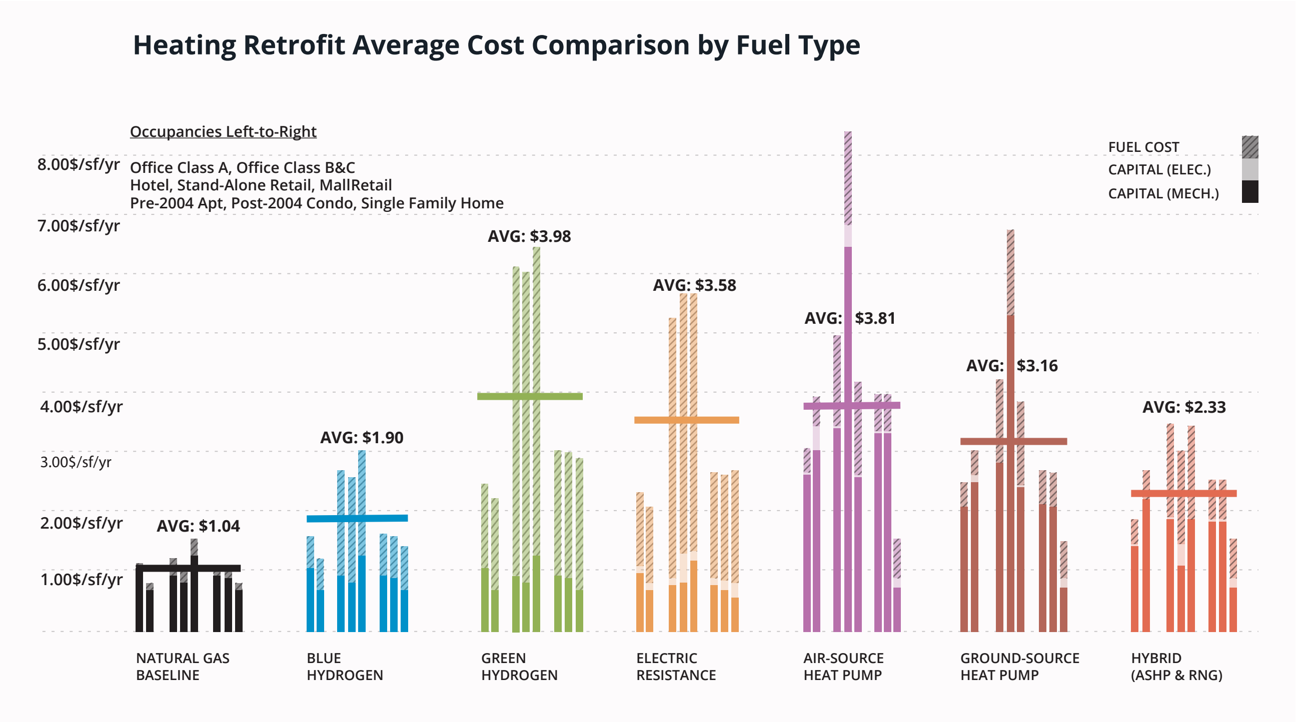

Figure 1 *Total cost comparison for fuel switching by occupancy and six fuel-switching alternatives (current actual costs or estimated current costs where markets do not yet exist)*

When we look at average costs by technological solution (excluding restaurants), other insights appear. Electric resistance heating has a lower cost than heat pumps, as operating costs are higher than for heat pumps but capital costs are lower. However, capital costs can be subsidized for early adopters and will decrease as demand increases—this is true of all technologies that have more developed markets. Operating costs are unlikely to come down; however, in the case of blue hydrogen, it is the industry that projects it will be inexpensive: data is estimated as no blue hydrogen system with functioning carbon capture and storage exists. In addition, the capital costs of blue hydrogen are lower because it is currently assumed that much of the existing heating mechanical equipment can be retrofitted for this new fuel source; however, operating costs are higher than for air-source heat pumps. By contrast, air-source heat pumps have a higher capital cost, as natural gas heating equipment will need to be replaced with air-source heat pump technology, but lower operating costs than blue hydrogen. Electric utility costs are likely to be more stable in the future once the energy grid has been developed to meet this new demand. (Heat pump and RNG costs are taken from current data.)

Meeting the 2030 Targets

In order to meet the 2030 targets, work needs to begin now on decarbonizing buildings in the District. Over the next seven years, we need to move quickly to develop policy, build out the energy supply, and convert every current gas customer to a different energy source. Practically speaking, if the network is not in place now, as is the case for hydrogen, it cannot be relied on to meet 2030 targets. This means that electrification is the only viable option to contribute to 2030 targets (see **Figure 2**).

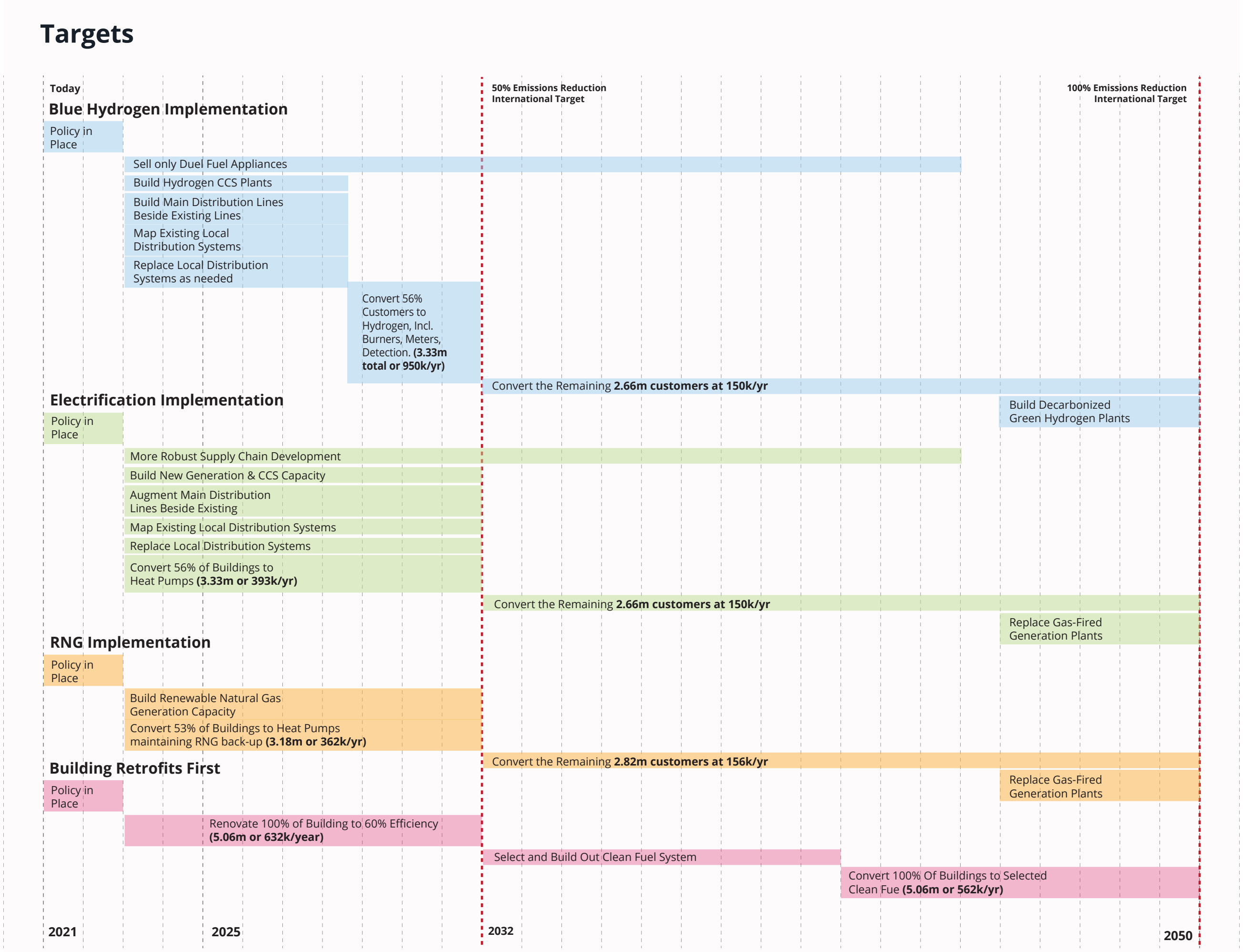

Figure 2 *Implementation scenario to meet international targets*

Trend factors

A consolidated review of the non-cost considerations is set out in **Figure 3**. (Green shading denotes moving in a positive direction; yellow shading denotes a neutral or an as-yet uncertain direction; and red shading denotes a negative direction.)

Multi-factor Analysis

	Blue Hydrogen	Green Hydrogen	Electric Resistance	Cold Climate (Air-Source Heat Pump)	Ground-Source Heat Pump	Hybrid Air-Source Heat Pump/ Renewable Natural Gas
Cost/square foot /year (capital plus operating)	🟩 1.90	🟥 3.98	🟥 3.58	🟥 3.81	🟥 3.16	🟨 2.33
Potential for fuel cost change	🟨 —	🟩 ↓↓	🟥 ↑	🟨 —	🟨 —	🟥 ↑
Emissions	🟥 10%	🟩 0	🟩 0	🟩 0	🟩 0	🟩 0
Potential for end-use cost change	🟨 —	🟨 —	🟨 —	🟩 ↓↓↓	🟩 ↓	🟩 ↓
Supply chain maturity	🟥 Low	🟥 Low	🟩 High	🟨 Med	🟨 Med	🟥 Low
Required system expansion	🟥 High	🟥 High	🟥 High	🟨 Med	🟨 Med	🟨 Med

Figure 3 *Multi-factor analysis—scale of the challenges*

While blue hydrogen appears to be competitive from a cost perspective, there are a number of barriers to it becoming a feasible solution for building heat, including (1) that there is currently no supply chain for the manufacture, distribution, and consumption of blue hydrogen in Ontario at scale; (2) it is not 100% carbon free; and (3) there are unresolved safety concerns related to the storage, transportation, and use of hydrogen for building heat.

The hybrid solution combines RNG and electrification, and takes advantage of the fact that "standard" heat pumps, which operate to about –10° Celsius, are much less expensive than cold-climate heat pumps. Thus, heating could be electrified using the standard pumps, and the existing gas system could be used as backup during peak demand days. Barriers to this solution include access to sufficient RNG to meet peak heating needs and convincing customers to pay for a system year-round that they only use a few times per year when the temperature is lower than -10˚C.

An electric heat pump strategy relies on a mature electricity industry and on largely clean energy, and its costs are likely to come down as demand for heat pumps increases and the technology advances. The challenges relate to whether the electricity system can meet these growing demands and manage new winter peaks.

Grid impacts

We evaluated the seasonal impacts of electricity consumption for each heating technology. As shown in **Figure 4**, analysis for the District suggests that peak demand may increase by 1.4 (standard heat pumps) to 3.45 times (electric resistance) of current demand.

Overall, data from Figure 4 shows that the impacts on energy consumption and peak demands will depend on the technology being used and severity of cold weather events. This will be key to assessing the required investments in upgrading the transmission and distribution system to meet load and peak demands.

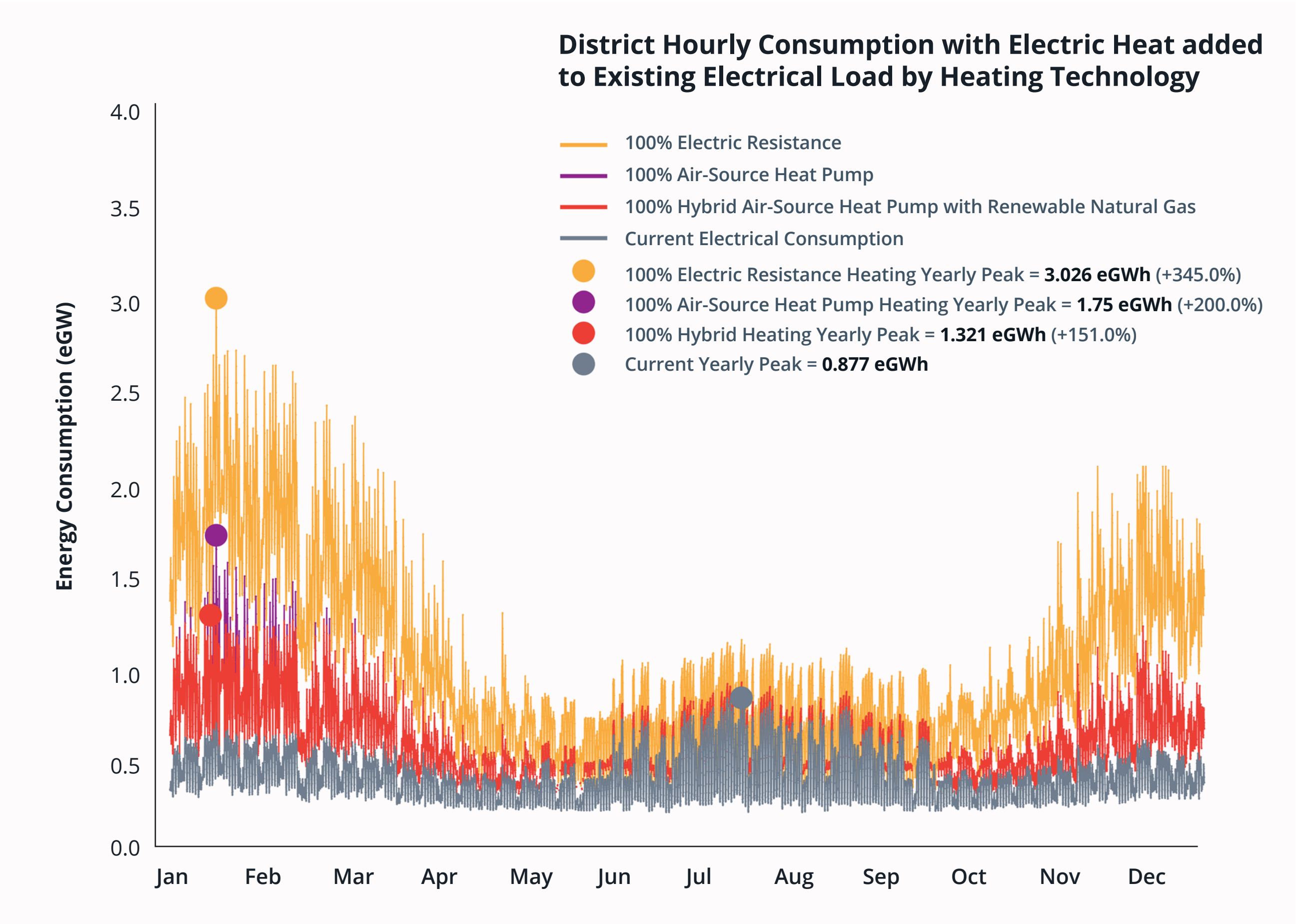

Figure 4 *District hourly consumption with electric heating added to existing electrical load by heating technology*

The analysis demonstrated that electrification is the most technology-ready option to replace 100% of natural gas demand in the District. Heat pumps are the preferred electrical solution due to their efficiency; if complete electrification were based on electric resistance heating, peak capacity would have to be increased by 350%. The current capital cost of heat pumps, particularly in the commercial sector, is a barrier to adoption. Scaling up heat pump applications and improving technologies will likely improve the economics within a relatively short time frame.

Blue hydrogen was the cheapest of the options examined; however, this assessment was based on estimated costs, as a blue hydrogen supply chain does not yet exist in Ontario. Green hydrogen, although the better option from a low-carbon perspective, is the most expensive option and is therefore not considered viable. Even with a carbon tax of $170 per tonne, the low-end estimate for green hydrogen is currently more than four times the cost of natural gas. To be viable, hydrogen requires a large-scale energy system transition that includes government, sector, and customer coordination. An incremental transition to hydrogen for buildings in the District is unlikely to be viable. In addition, significant safety issues need to be addressed before hydrogen can be used in buildings.

RNG will not be available in sufficient quantities to replace current natural gas demand in buildings, although it might be available to provide peak heat in hybrid systems. However, the RNG supply chain does not yet exist at scale, and the business model for hybrid RNG systems has not yet been developed.

Conclusions

Natural gas currently meets about two-thirds of the province’s residential space- and water-heating needs and 50% of the commercial sector’s needs. Given its predominance, moving away from the combustion of natural gas in buildings has significant challenges, in part owing to the many advantages of this energy source, including its cost-effectiveness, ability to deliver energy on demand, and the fact that it is a mature and established industry.

However, the District will not achieve its net-zero goals if a large, system-wide transformation does not begin soon. Electrification is considered the most viable option today. Given the benefits of gas, mandatory, economy-wide policy will be necessary to drive the needed change.

Phase Three: Building Retrofits—Do They Matter?

The third report in the Pathways Project examined whether investment in heat-load–related building retrofits would reduce the overall cost of decarbonization from the building owner's perspective. Contrary to our expectations, when upgrades are completed solely for heat load reduction and the costs are not partly paid for by normal end-of-life allowances, they are not cost-effective.

The analysis looked at whether four kinds of measures—curtain wall upgrades, window retrofits, roof improvements, and the use of energy recovery ventilators (ERVs)—can reduce the cost of fuel switching in buildings. These measures have the greatest potential for energy reductions—approximately 60%—which is the level at which efficiency can have a major impact on energy systems and (in a not-yet fully decarbonized system) GHG reductions.

Most effective upgrades

The curtain wall upgrade is the most effective measure, with an energy heating demand reduction of 28%, followed by the installation of an ERV, at 24%. Roof upgrades have a peak reduction of 2%. Overall, these three measures could reduce heating peak demand by 54%.

For peak demand reduction in multi-unit residential buildings, window retrofitting is the most effective measure (18%), followed by ERV installation (13%) and wall upgrades (11%). Roof improvements have the lowest impact (3%). Overall, these four measures could generate a maximum reduction of 45%. In single-family houses, these measures provide the highest level of reduction, at 85%.

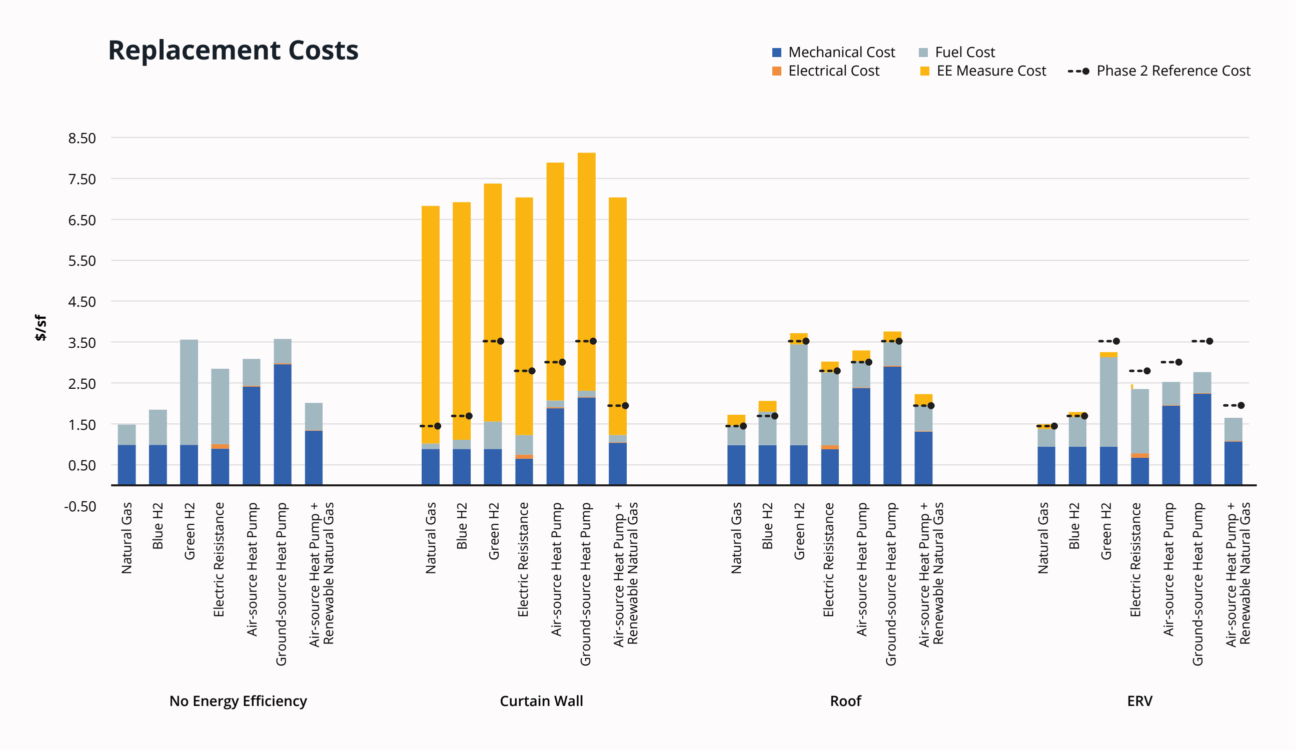

Figure 5 *Energy-efficiency replacement costs—Class A office*

Cost considerations

Overall, the cost analysis of these retrofit measures shows little potential for cost savings when building owners replace building components before their end-of-life for the sole purpose of reducing energy demand. **Figure 5** demonstrates that, in all cases, with the exception of ERVs, these investments make decarbonization more expensive.

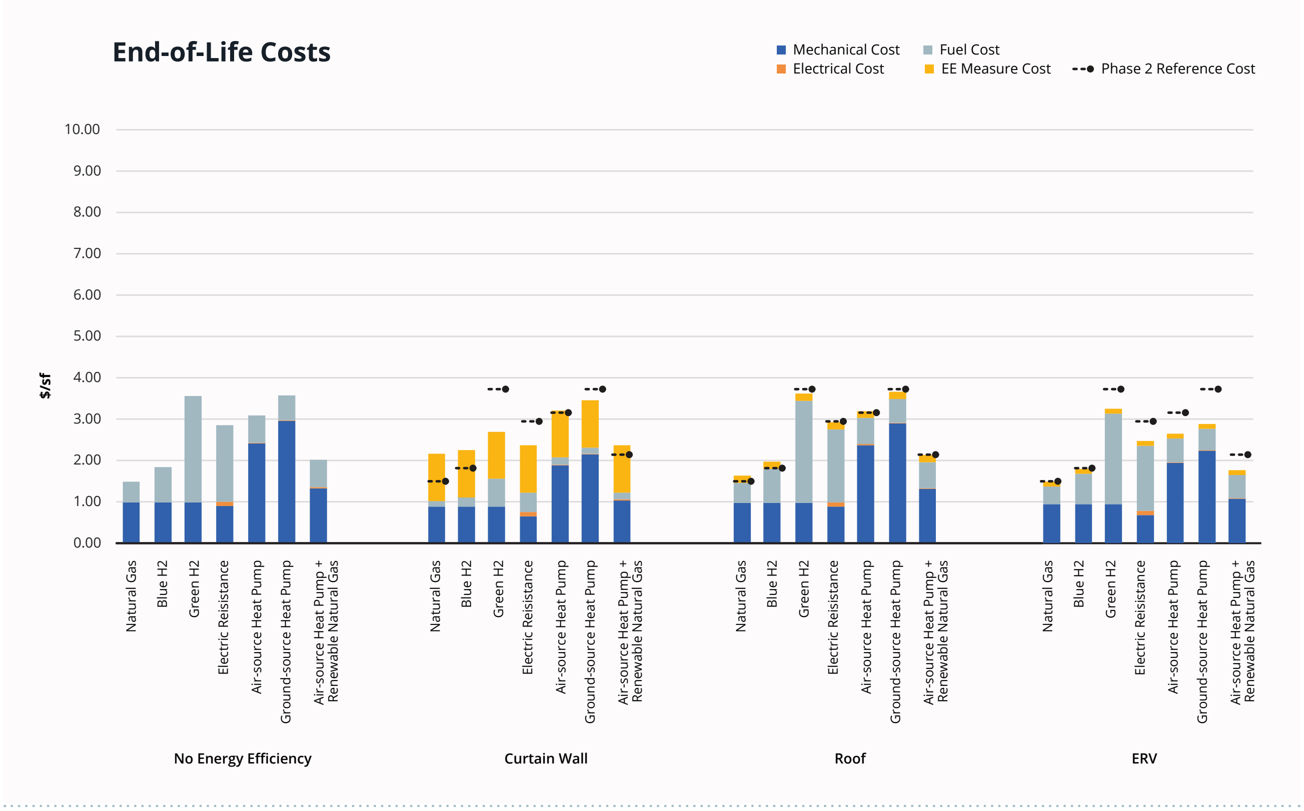

Figure 6 *Energy-efficiency end-of-life costs—Class A office*

Replacing building elements at end-of-life has a neutral-to-positive business case in most situations (see **Figure 6**). However, the proportion of buildings to which this would apply is unclear. In the case of building envelope elements, for most buildings in the District, end-of-life may not occur until after 2050.

When completed alongside significant renovations, deep retrofits can support decarbonization. This work can also achieve other goals, such as increased comfort, increased asset value, and a reduction of peak load on the grid, all of which increase the dollar value of the investment. As these end-of-life renewals occur every 30 years or so, they will not significantly contribute to our 2030 goals, but could be of material benefit for the 2050 goals.

Phase Four:
System-Level Solutions

The final report in the Pathways Project summed up the project's findings to date and examined three additional technological solutions to see if they would contribute to cost-effective building decarbonization in the Toronto District: building-mounted solar panels; behind-the-meter storage systems, which can be used as backup energy storage in buildings; and the expansion of district heating.

Our findings showed that these technologies are not necessary to achieve cost-effective decarbonization; however, they can provide other general benefits such as additional grid capacity, backup energy generation, supporting peak demand days, and financial benefits through the exploitation of time-of-use pricing. The current costs of these technologies would need to come down in order to make them economically attractive from a decarbonization perspective.

Solar

We looked at local independence, resilience, peak shifting, and cost for solar energy systems. Photovoltaic (PV) systems on buildings in the District can provide returns on investment between 5% and 11% if there is protected access to sun and installation is simple, particularly on very large, flat roofs and on single-family houses.

However, the generation potential of these installations, even if maximized, will only contribute a fraction of the total energy required in the District and will have an even lower contribution to generation during winter electrical peaks caused by electrification of the District's heating systems.

PV systems alone are therefore not sufficient to provide building energy resilience during power outages. When combined with batteries, PV systems can, however, provide buildings with some access to electricity even during long outages, which are rare but costly if, for example, many people must be moved from their homes.

Batteries

Energy storage located in buildings has the potential to provide emergency backup energy for critical services or peak shifting, but cannot reliably do both due to the unpredictable nature of emergencies.

Emergency backup battery systems benefit the building owner. Peak shifting mostly benefits the grid operator; however, it would require the creation of policy to nudge owners in that direction. Simple building heating controls are very cost-effective but offer the smallest benefits. The current cost of batteries is the main impediment to deploying them for any significant benefit.

The analysis of these additional solutions concluded that they were not necessary components to a decarbonization pathway. Building-mounted solar, even when coupled with battery electricity storage, will not meet today's—let alone future—electrical loads using current technology.

District heat

Although district heating systems are already heavily used in the District, accounting for more than 10% of all heating, currently, 98% of all installed capacity is fossil fuel based, which means that switching from a building-based solution to district energy will not decarbonize a building in the near term. Once district heating systems are decarbonized, however, their expansion could become an option for building owners.

The way forward

This analysis found that the most urgent action required to achieve the 2030 and 2050 carbon emissions targets is to focus on switching from fossil fuel to non-emitting energy for heat at the building level. The only technology option currently available to achieve the scale of reduction in the time frame required is electrification, although hybrid systems that also use RNG could become available once an RNG supply chain is in place.

Electric options (particularly heat pumps) can be deployed immediately. The analysis showed that in each case, fuel-switching costs were significant ($2 to $4 per square foot per-year increase) at today's prices, but that these costs will come down as the market for clean energy heating equipment develops. However, the electricity grid will need to expand to ensure that the growing demand can be met reliably. The analysis also demonstrated that most building owners would be able to bear these costs if their competitors faced the same costs.

The importance of policy and programs

Fuel switching at the scale and pace needed to reach 2030 and 2050 carbon emissions targets will not happen without the introduction of government policy and programs. It is therefore crucial that governments start developing a policy framework that can guide overall system conversion over the coming decades. This will require further research, involvement of key system stakeholders in consultations, and public discussion of the options to replace natural gas in building heating.

The Pathway Project's findings related to policy and programs therefore stress the importance of:

- Implementing a net-zero carbon framework over the next two to three years for Crown corporations, regulatory bodies, and key Ontario ministries. This process must begin with a Government of Ontario commitment to net zero by 2050;
- Enacting a sunset clause for the installation of new natural gas–based heating systems;
- Providing financial support for the installation of heat pumps;
- Using building codes and building-performance regulations to accelerate the process;
- Advocating for the phase-out of gas-fired boilers; and
- Supporting experimentation with clean gases without delaying current electrification efforts.

The province also needs to develop policy, regulatory systems, codes, and standards; build these new energy systems, including their generation, distribution, manufacturing, and supply chains; convert 3.8 million natural gas customers; and fully decarbonize the electricity grid and energy system.

The goal of the Pathways Project is that, ultimately, its findings and recommendations will lead to practical implementation through pilot programs, experiments, programs, and proposals to achieve net-zero operational GHG emissions for the built environment in the Toronto core by 2050.

TORONTO
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The Toronto 2030 District is a private sector–led initiative supporting District-wide reductions in building-related energy, water, and transportation emissions across Toronto's downtown core. Sponsored by Building Owners and Managers Association (BOMA) Toronto, the Ontario Association of Architects, and Sustainable Buildings Canada, the Toronto 2030 District seeks to convene key stakeholders in the local building sector in support of a more effective culture of building conservation across all building types in the District.

If you would like to learn more about Toronto 2030 District's Pathways Project or collaborate with us, please contact:

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