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# Energy and Emissions Outcomes of Heat Pumps Installations

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# Agenda

- Heat pump technology and the Ontario market
- Energy and emissions in different building types
- Emissions from natural gas and electricity in Ontario
- Canada's carbon price through 2030
- Overview of the business case for heat pumps

# Heat pump technology

# What is a heat pump?

- A mechanical device in the building transfers heat between indoors and out.
- In heating mode, this device can take heat from the air, ground, or water outside and bring it inside to make the space warmer.
- In cooling mode, it can take heat from inside the building and move it outside to cool the space.

# Why choose a heat pump system?

Heat pumps offer several advantages over other traditional heating and cooling systems:

- Energy efficiency
- Versatility
- Environmental benefits
- Improved safety
- Improved comfort
- Longer lifespan
- Zone control

# Common commercial heat pump systems

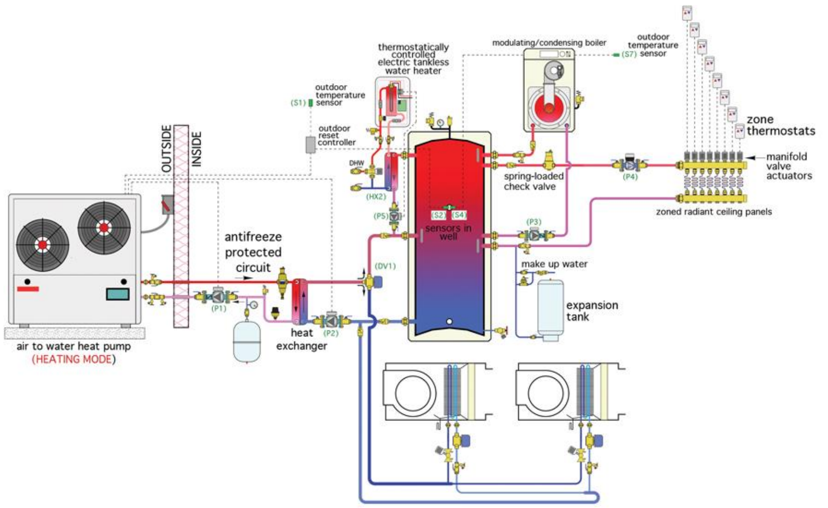
| |
|---|
| Single-Split Systems |
| Multi-Split Systems |
| Packaged Terminal Heat Pumps (PTHP) |
| Rooftop Terminal Units (RTU) |
| Variable Refrigerant Flow (VRF) |
| Hybrid Heat Pump Systems |

# Air to water heat pumps

Air-to-water and water-to-water heat pumps have been intentionally designed for sustainable buildings.

These heat pumps feature energy-efficient technology, such as electronic vapor injection (EVI) compressors, while using refrigerants with low global warming potential (GWP).

Up to 5 times more efficient than a boiler-chiller combination.



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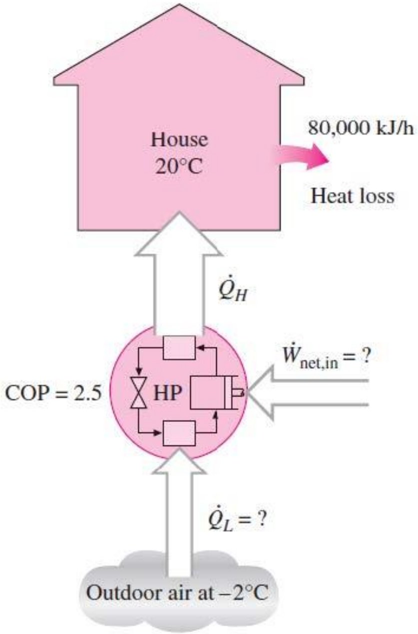
# Why heat pumps are more efficient

A heat pump is used to meet the heating requirements of a building and maintain it at 20°C.

On a day when the outdoor air temperature drops to -2°C, the building is estimated to lose heat at a rate of **80,000 kJ/hr** which is:

- **75,000 Btu/hr**
- **22 kW**
- **6.3 tons**



# Why heat pumps are more efficient (con't)

If the heat pump under these conditions has a COP of 2.5:

**Power Consumption** by heat pump:

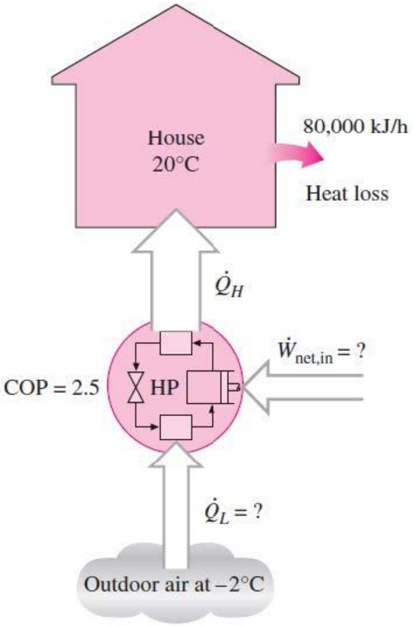
$$W_{net,in} = \frac{Q_H}{COP_{Heat\ Pump}} = \frac{80{,}000\ kJ/hr}{2.5} = 32{,}000\ kJ/hr$$

$$= \mathbf{8.9\ kW}$$

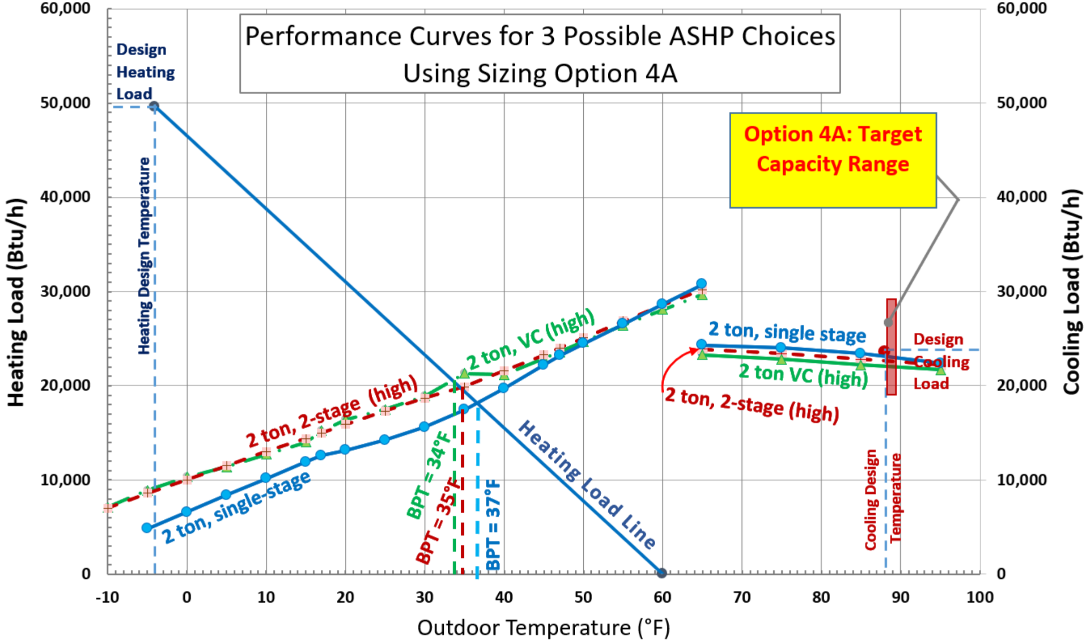
**Rate of heat transfer** from outdoor air:

$$Q_L = Q_H - W_{net,in} = (80{,}000 - 32{,}000)\ kJ/hr = 48{,}000\ kJ/hr$$

$$= \mathbf{13.3\ kW}$$



# Heat pump capacity




Source: Natural Resources Canada Air-source Heat Pump Sizing and Selection Guide.

# Heat pump capacity – sizing matters

**Oversized systems** – Using traditional rules of thumb or existing heating equipment capacities that might result in an oversized system.

**Undersized systems** - Heat Pump capacity is often chosen according to the summer heat gain to ensure humidity control. In climates like Ontario, this results in an undersized system that cannot meet heat load.

# The future is heat pumps

Heat pumps are typically two-to-five times more energy efficient than natural gas boilers.

Heat pumps heat and cool, eliminating the need for a separate cooling system.

Heat pumps can also address unique heating needs in industry and district heating.

Switching to heat pumps cuts emissions of greenhouse gases and helps improve air quality.

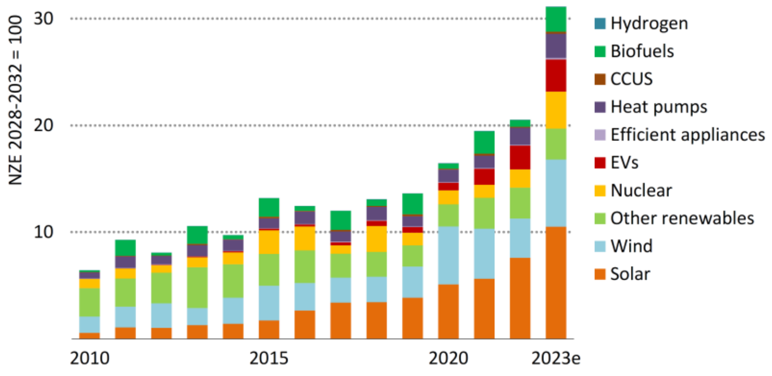
The expansion of heat pump manufacturing and installations to meet rising demand will create more jobs.

Source: World Energy Outlook Special Report, The Future of Heat Pumps

# Clean Technology Deployment Index

## Deployment of clean technologies has increased significantly since 2010.

Source: International Energy Agency, Net Zero Roadmap, A global Pathway to keep the 1.5°C Global in Reach, 2023






*Deployment of clean technologies has increased significantly since 2010*

- CCUS = Carbon Capture, Utilization and Storage.
- EVs = Electric Vehicles
- 2023e = estimated values for 2023 based on the latest available data by technology and project pipeline data.

# Temperature trends in Ontario

## Changes in climate data

Across Canada, residential buildings have historically been designed with heating systems only.

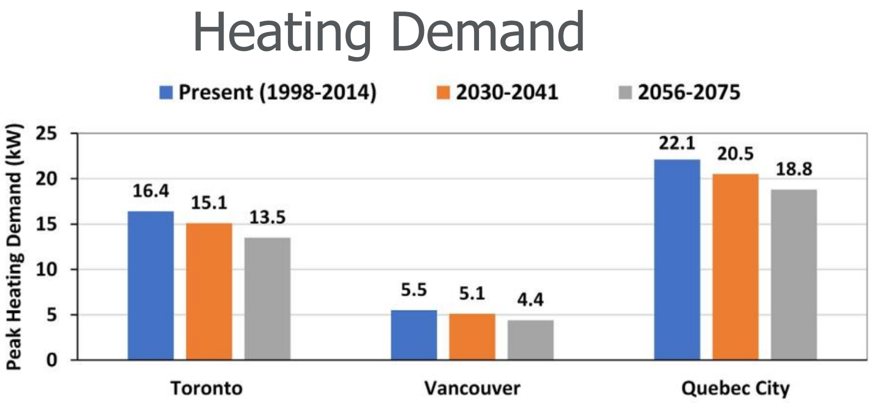
Analysis of historical temperature data from 1948-2016 shows an increase of average annual temperatures in Ontario of 1.7°C, and maximum summer temperatures of 1.1°C, increasing demand for cooling systems.

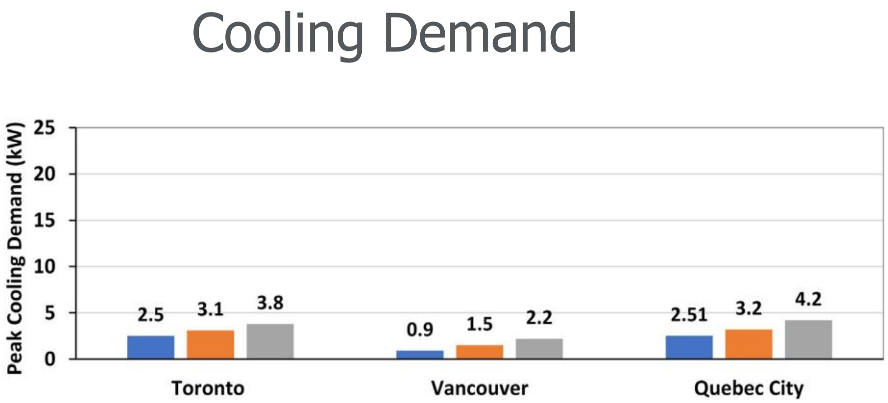
**Source: Natural Resources Canada, Canada's Climate Change Report, Chapter 4, 2019**

| REGION | CHANGE IN TEMPERATURE, °C | | | | |
|---|---|---|---|---|---|
| | Annual | Winter | Spring | Summer | Autumn |
| British Columbia | 1.9 | 3.7 | 1.9 | 1.4 | 0.7 |
| Prairies | 1.9 | 3.1 | 2.0 | 1.8 | 1.1 |
| Ontario | 1.3 | 2.0 | 1.5 | 1.1 | 1.0 |
| Quebec | 1.1 | 1.4 | 0.7 | 1.5 | 1.5 |
| Atlantic | 0.7 | 0.5 | 0.8 | 1.3 | 1.1 |
| Northern Canada | 2.3 | 4.3 | 2.0 | 1.6 | 2.3 |
| Canada | 1.7 | 3.3 | 1.7 | 1.5 | 1.7 |

*[a] Changes are represented by linear trends over the period. Estimates are derived from the gridded station data. There is a lack of data for northern Canada (see Figure 4.1).*

# Comparison of cooling and heating demand



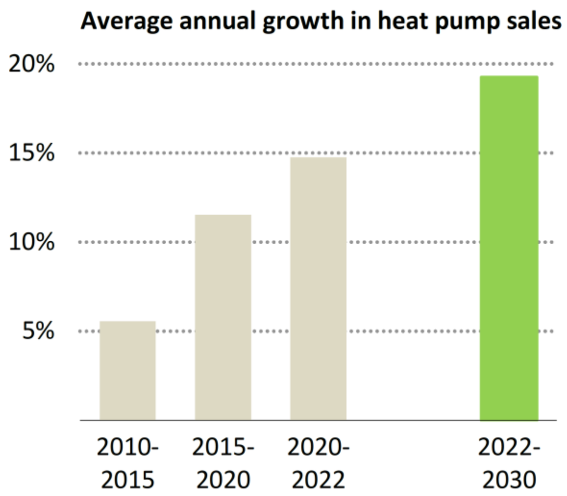



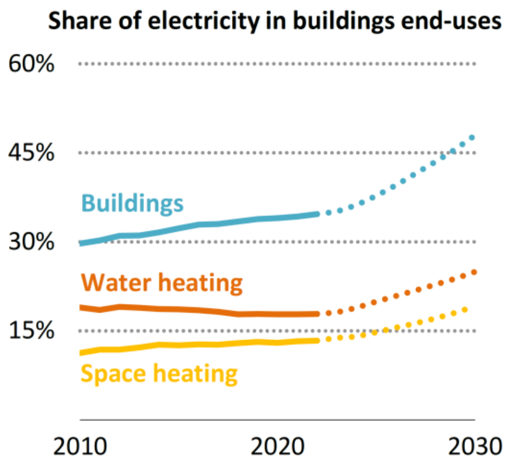

Toronto peak heating demand: 16.4 kW

Ottawa is in the same climate zone as Quebec City with a peak heating demand of 22.1 kW.

Source: The efficiency and GHG emissions of air source heat pumps under future climate scenarios across Canada, Energy and Building, 2022

# Global trends and projections in heat pump adoption

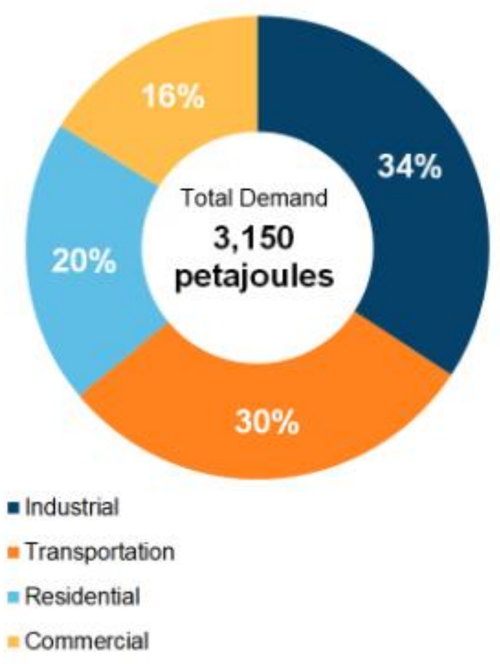


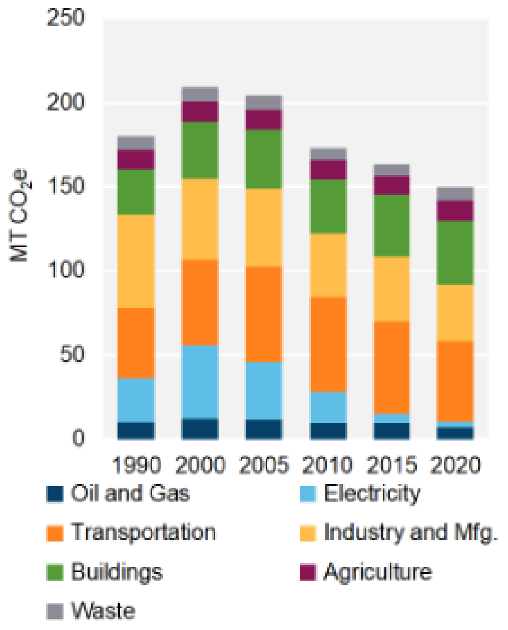




Source: International Energy Agency, Net Zero Roadmap, A global Pathway to keep the 1.5°C Global in Reach, 2023

# Energy and emissions

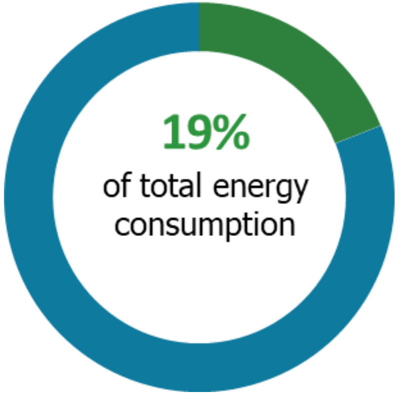
# End-use demand & GHG emissions by sector in Ontario

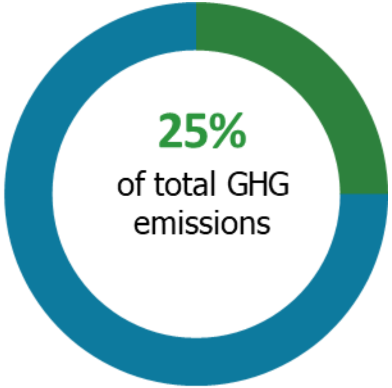



Source: Canada Energy Regulator, Provincial and Territorial Energy Profiles – Ontario

# Energy and greenhouse gas (GHG) emissions in Ontario’s buildings sector

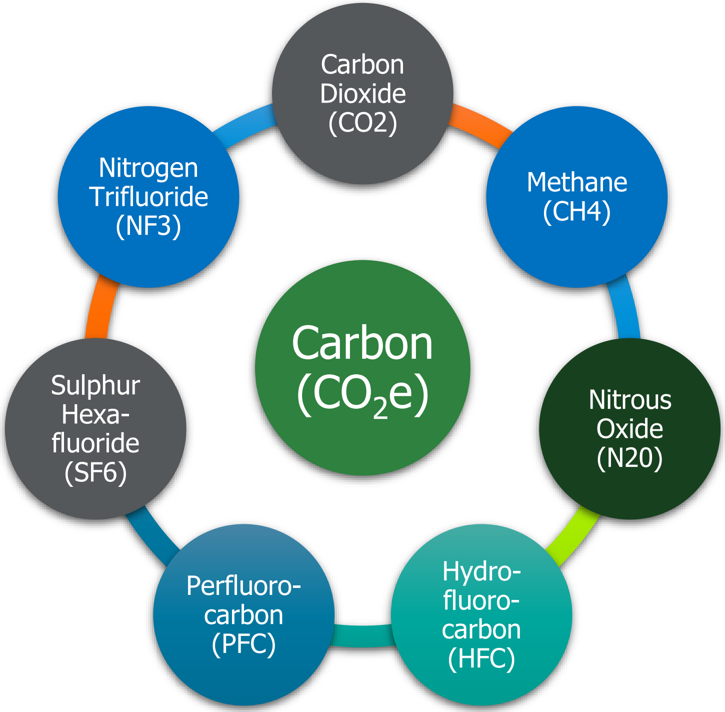



Sources : Canada Energy Regulator, Provincial and Territorial Energy Profiles (2019)

# What is equivalent carbon?

- "Carbon" includes all greenhouse gases.
- **Reported in a common unit for simple comparisons ($CO_2$ equivalent), taxes, credits.**
- Each of the GHGs has a unique atmospheric fingerprint.



# Emissions factors

| Fuel Source | Emission Factor (gram CO2e per unit) |
|---|---|
| Natural gas | 1,921 |
| Propane | 1515 |
| Light fuel oil | 2,753 |
| Electricity - Ontario | 30 |

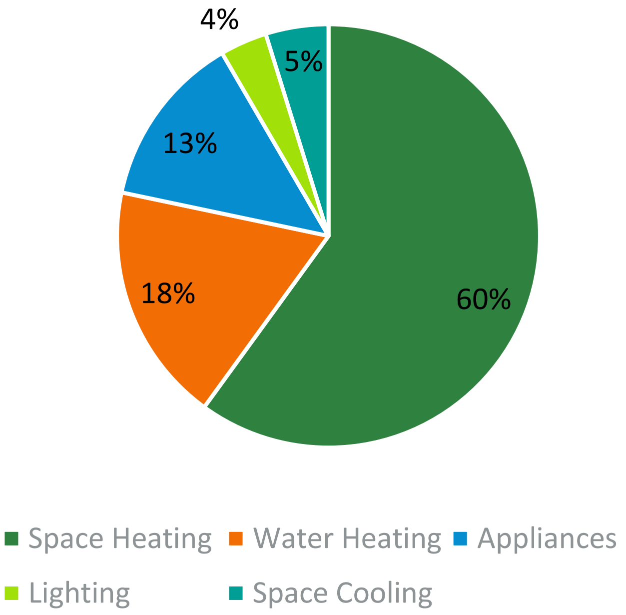
Source: National Inventory Report, Environment and Climate Change Canada, Tables 1.1, 3.1, 4.1, 5.1, 2024

# Residential energy use breakdown

How is energy consumed in a typical home?

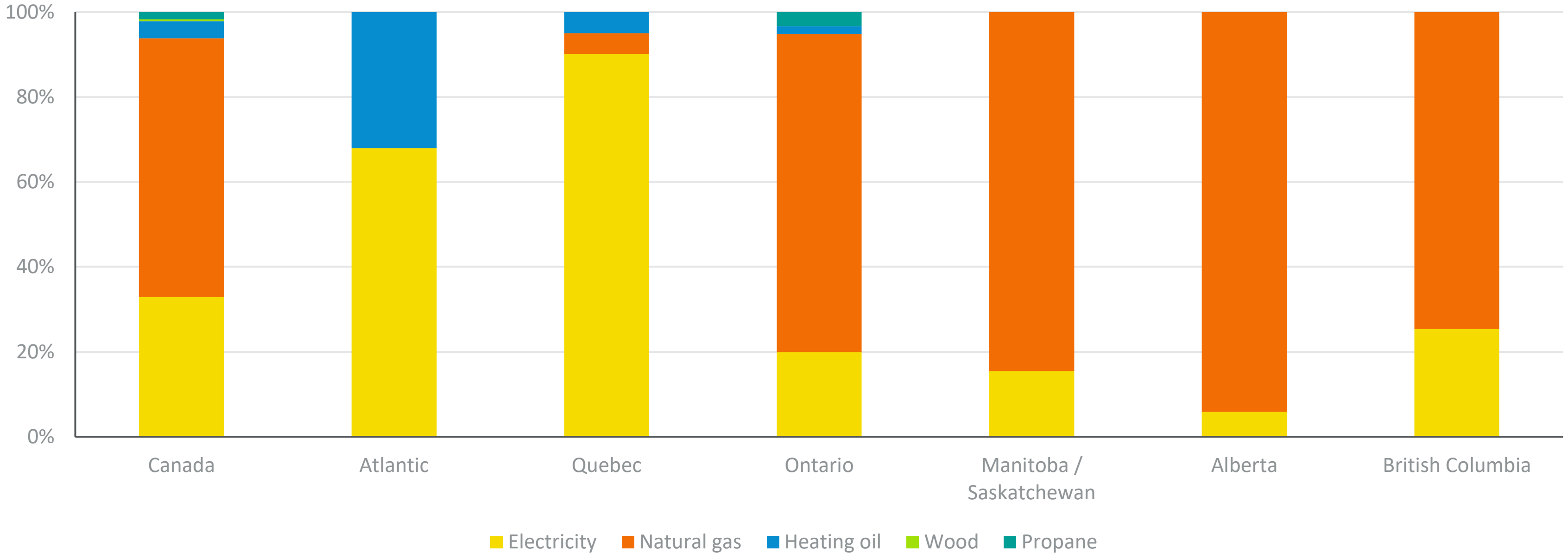
In Ontario, 44% of households heat with electricity, and 49% heat with natural gas, accounting for 93% of the market.

60% of residential energy use is typically dedicated to space heating.




*Source: Residential Sector Canada Table 2: Total Households Secondary Energy Use and GHG Emissions by End-Use | Natural Resources Canada*

# Regional residential heating system energy source




Source: Natural Resources Canada

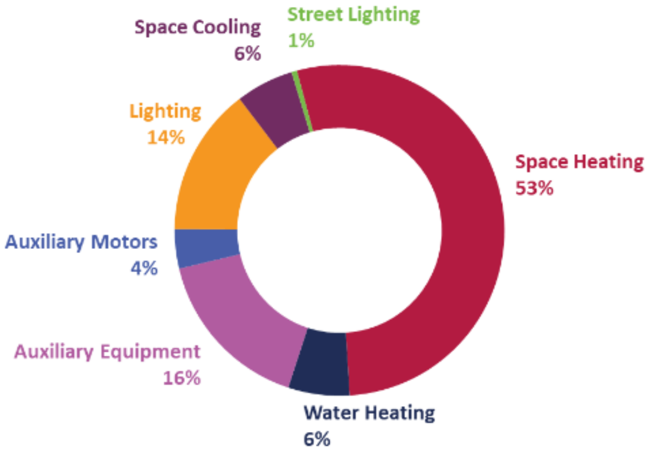
# Energy use in the commercial and institutional sector

Commercial and institutional buildings have more end uses than a single-family home.

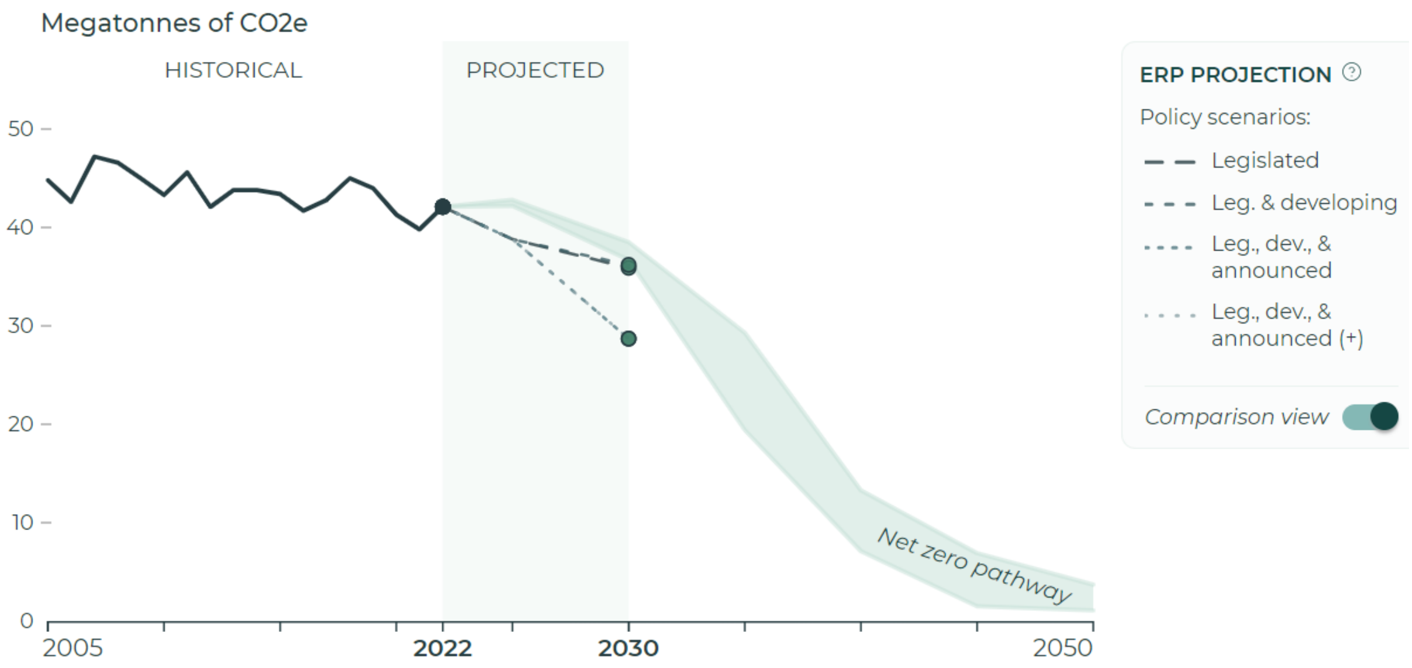
Heating is still the dominant end use, over 50%.

Natural gas is still the most common energy source used for heating; an even greater proportion than in residential buildings.

Distribution of commercial/institutional energy use by end use, 2018



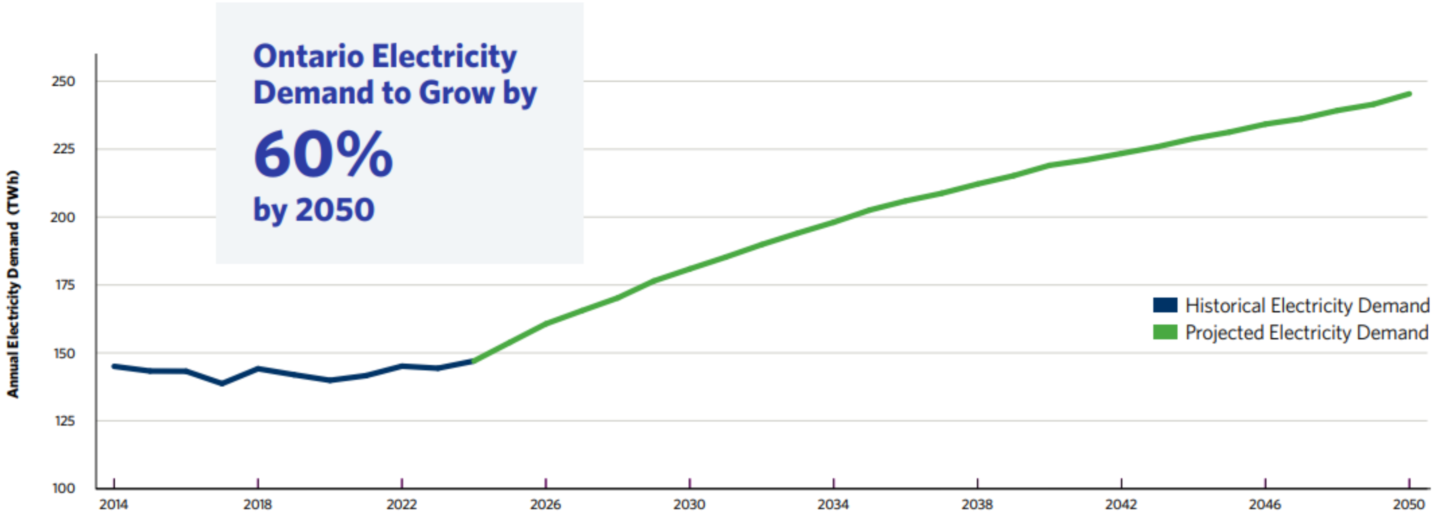
# Greenhouse gas emissions for commercial buildings




Source: Canadian Climate Institute

# Energy and demand forecasts

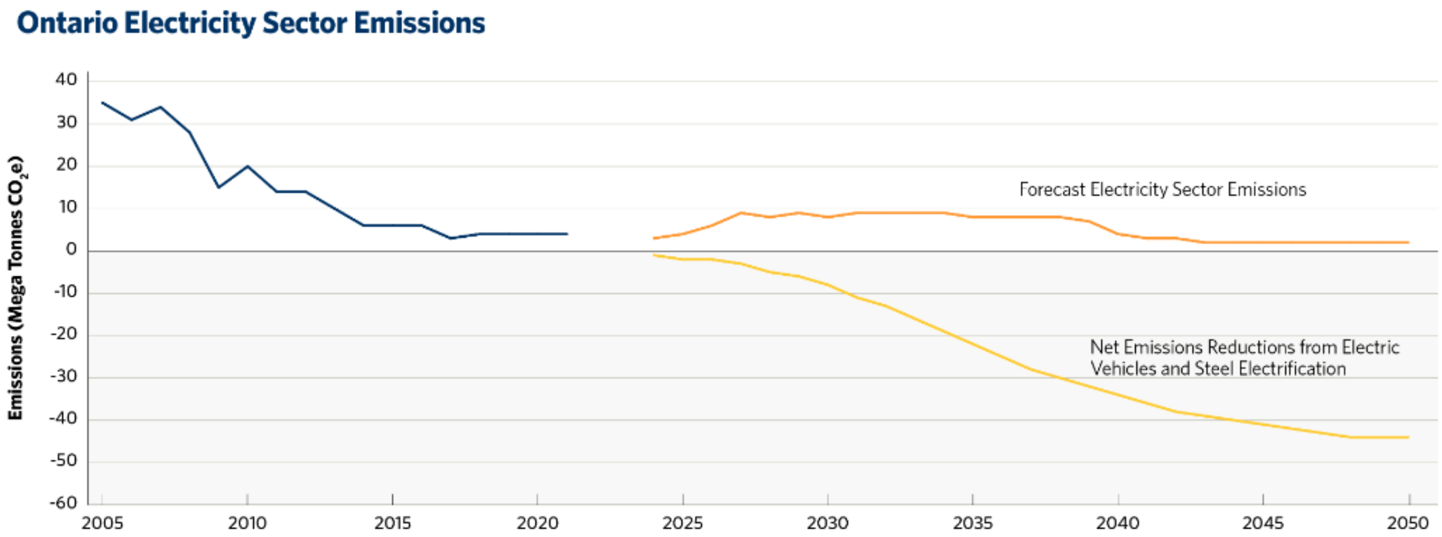
## 2024 Annual Planning Outlook and Emissions Update




https://www.ieso.ca/Powering-Tomorrow/2024/Six-Graphs-and-a-Map-2024-Annual-Planning-Outlook-and-Emissions-Update

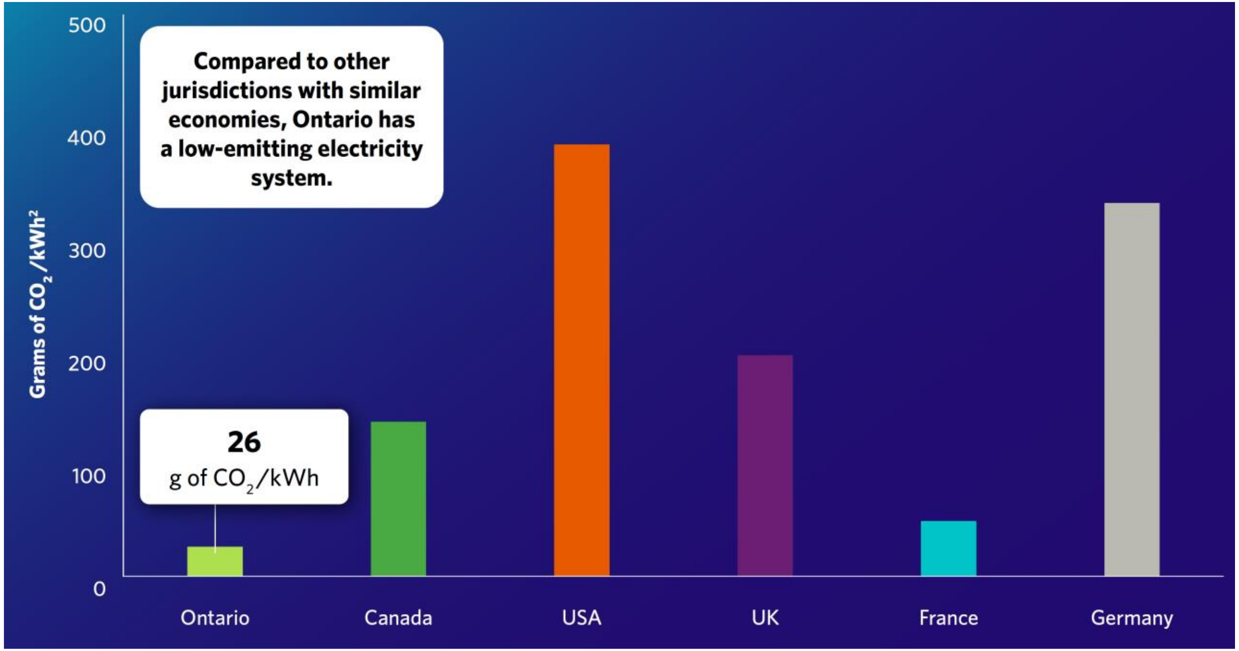
# Emissions forecasts

## IESO's Annual Planning Outlook (Spring 2024 Update)




https://www.ieso.ca/Powering-Tomorrow/2024/Six-Graphs-and-a-Map-2024-Annual-Planning-Outlook-and-Emissions-Update

# Comparing Ontario's electric grid emissions with nations




Source: IESO, Decarbonization and Ontario's Electricity System, assessing the impacts of phasing out natural gas generation by 2030, 2019



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# Supply mix overview

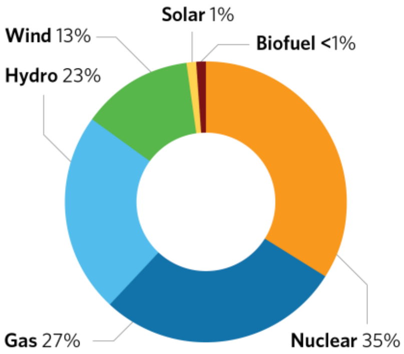
On average, only three per cent of Ontario's total greenhouse gas (GHG) emissions came from the Ontario electricity system.

In 2023,

- 87% renewable transmission output
- Ontario's renewable capacity
  - 73% renewable transmission connected
  - 91% renewable distribution connected


Source https://www.ieso.ca/en/Powering-Tomorrow/2021/Six-things-to-know-about-the-IESOs-study-on-phasing-out-gas-fired-generation-by-2030

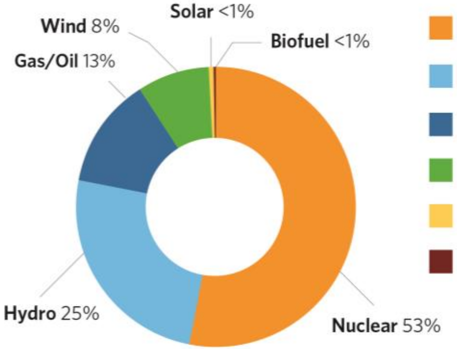
# Ontario capacity vs. output (grid-connected)




| | |
|---|---|
| **Nuclear** | 13,214 MW or 35% |
| **Gas/Oil** | 10,471 MW or 27% |
| **Hydro** | 8,862 MW or 23% |
| **Wind** | 4,943 MW or 13% |
| **Solar** | 478 MW or 1% |
| **Biofuel** | 296 MW or <1% |

Transmission-Connected Capacity as of June 20, 2024

Source: Reliability Outlook, An adequacy assessment of Ontario's electricity system, July 2024 to December 2025, IESO




| | 2023 Energy Output | 2022 Energy Output |
|---|---|---|
| **Nuclear** | 79.3 TWh or 53.2% | 78.8 TWh or 53.7% |
| **Hydro** | 37.4 TWh or 25.1% | 38.0 TWh or 25.9% |
| **Gas/Oil** | 19.1 TWh or 12.8% | 15.2 TWh or 10.4% |
| **Wind** | 12.2 TWh or 8.2% | 13.8 TWh or 9.4% |
| **Solar** | 0.7 TWh or <1% | 0.75 TWh or <1% |
| **Biofuel** | 0.4 TWh or <1% | 0.3 TWh or <1% |

Total Electricity Output by Source in 2023

Source: Year Eng Data, IESO

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# Ontario electrical grid - annual average emissions factor

**Annual Average Emissions Factor (annual AEF)**

The average annual amount of greenhouse gas emissions produced per unit of electricity consumed (gCO2e/kWh).

- Calculated by taking the total amount of annual emissions produced divided by the total amount of electricity consumed
- Typically used to calculate emissions from electricity consumption
- Can be used to calculate emissions changes from a fuel switching project

**Annual AEF ($gCO_2eq/kWh$):** The total emissions from electricity production in Ontario (gCO2eq) divided by the total electricity produced (kWh) in any given year.

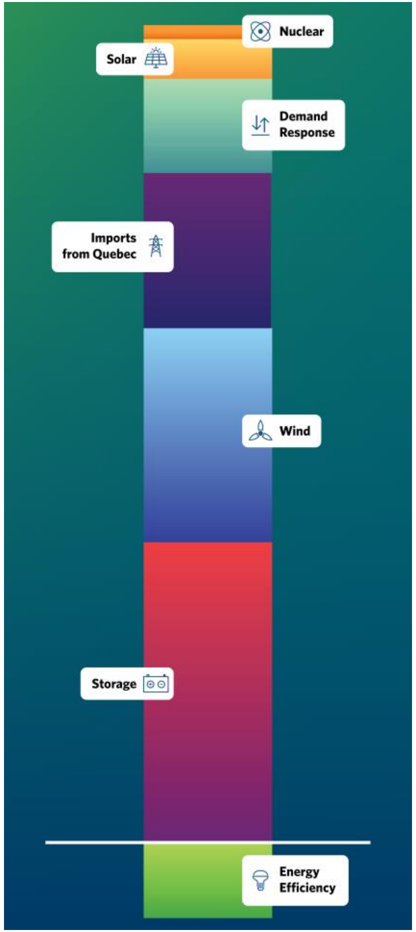
| | |
|---|---|
| 2023 | 67 |
| 2022 | 51 |
| 2021 | 44 |
| 2020 | 36 |
| 2019 | 29 |
| 2018 | 29 |
| 2017 | 18 |
| 2016 | 40 |
| 2015 | 46 |

TAF, June 2024, Ontario Electricity Emissions Factors and Guidelines., p.11

# 2030 gas phase-out scenario

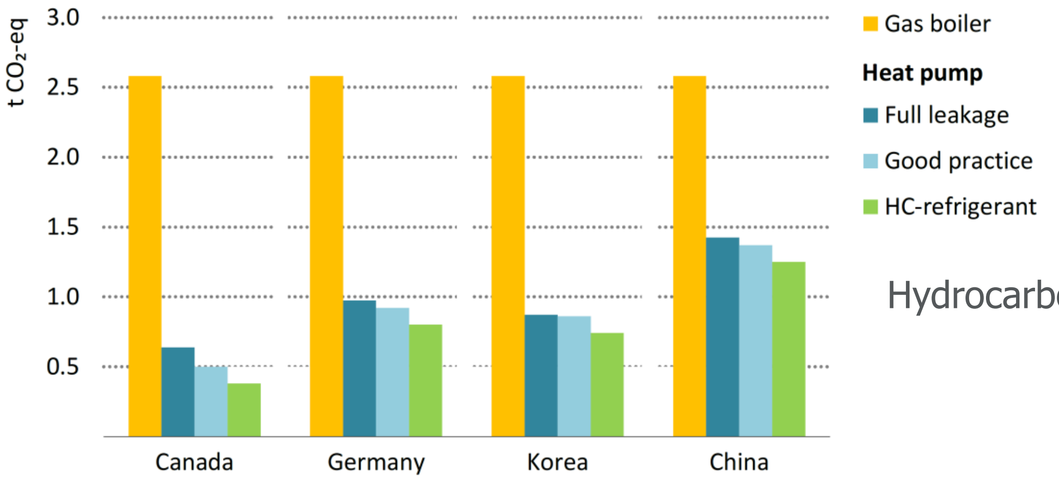
## Energy Efficiency

- Another 1,600 MW of energy savings, increased energy programs and policies.
- Ontarians achieved 1.5 TWh in energy savings and 186 MW of demand savings through Save on Energy programs in 2019 and 2020.
- IESO's 2021-2024 Conservation and Demand Management Framework is targeting 2.7 TWh of electricity savings and 440 MW of peak demand savings to help cost-effectively meet system needs.




Source: IESO, Decarbonization and Ontario's Electricity System, assessing the impacts of phasing out natural gas generation by 2030

# Total lifetime GHG emissions/MWh – Boiler vs Heat Pump




Hydrocarbon (HC)

Switching to a heat pump substantially decreases emissions regardless of climate conditions and electricity mix.

Source: World Energy Outlook Special Report, The Future of Heat Pumps

# Emission factor & life cycle cost

# Quantifying carbon emissions fulfils one of two purposes:

- Understand current or historical emissions (for example, a carbon inventory for an organization or city);
- Evaluate the carbon impacts of an actual or potential change (for example, a project, policy, or infrastructure decision).

Although the resource in question is the same (electricity), different electricity emissions factors should be used for different quantification purposes:

- To prepare an inventory
- To quantify impact
- To forecast

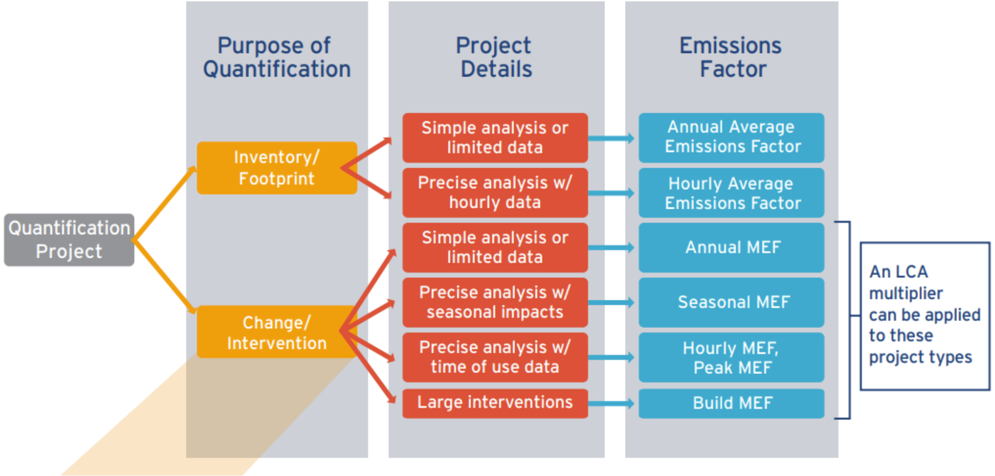
Source: A clearer view on Ontario's emissions, Updated electricity emissions factors and guidelines, TAF

# Emission factor guidelines

An Average Emissions Factor (AEF) quantifying current or historical emissions resulting from electricity consumption (such as for a building, company, or whole city).

A Marginal Emissions Factor (MEF) estimating the carbon impact of a change (e.g., an energy efficiency or renewable energy project).

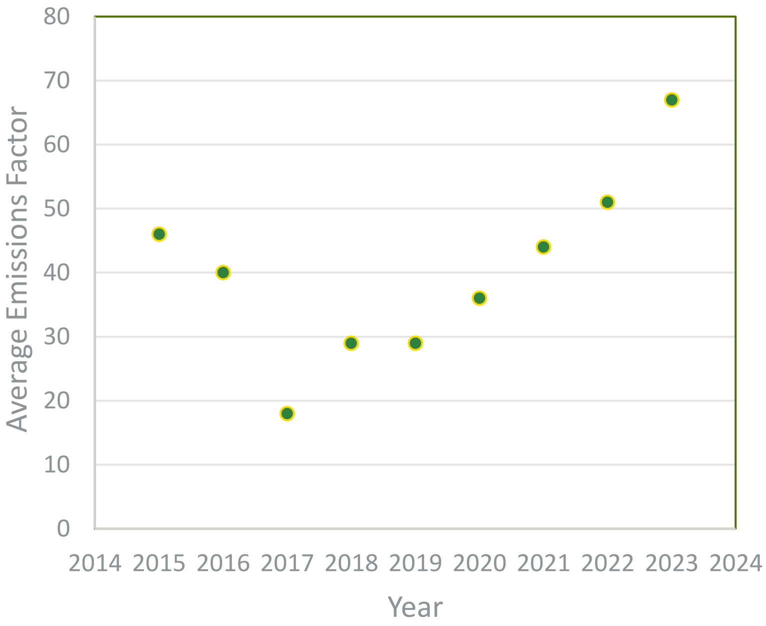
Estimating future carbon emissions either a Forecasted AEF or Forecasted MEF




Source: A clearer view on Ontario's emissions, Updated electricity emissions factors and guidelines, TAF

# Annual Average Emissions Factor in Ontario

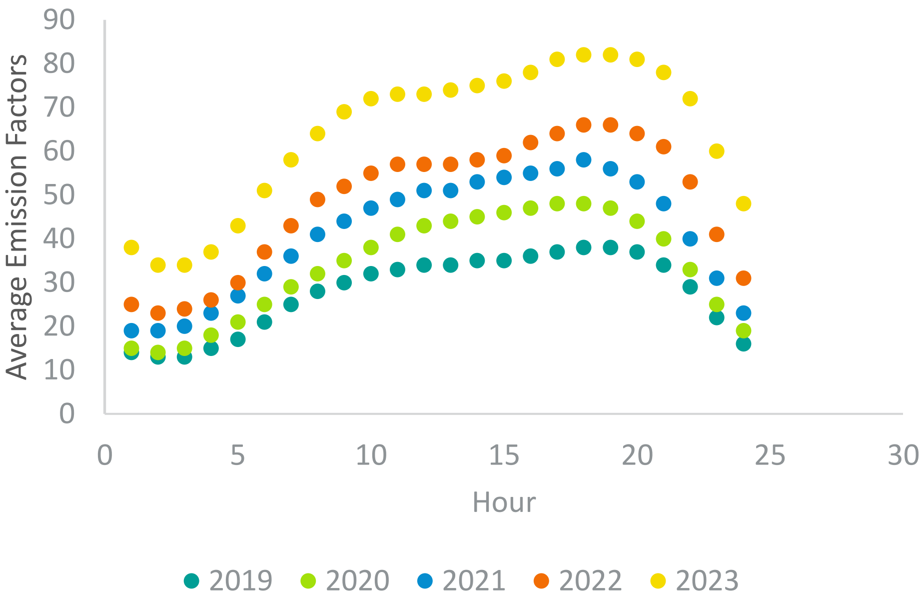
**Annual AEF ($gCO_2eq/kWh$):** The total emissions from electricity production in Ontario (gCO2eq) divided by the total electricity produced (kWh) in any given year.




Source: Ontario Electricity Emissions Factors and Guidelines , Accurate emissions factors are the backbone of climate action strategy, 2024, TAF

# Hourly average emissions factors

**Hourly AEF ($gCO_2eq/kWh$):** The total emissions from electricity production in Ontario divided by the total electricity produced in a specific hour of the day, averaged over the year.




Source: Ontario Electricity Emissions Factors and Guidelines , Accurate emissions factors are the backbone of climate action strategy, 2024, TAF



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# Marginal emissions factors

In Ontario, natural gas power plants are frequently used to respond to changes in demand because of their ability to increase and decrease production quickly.

Peak/off-peak marginal emissions factors (MEFs) represent the carbon impacts of changes in electricity consumption during peak and off-peak times, as defined by the IESO.

| Forecasted Peak/Off-Peak (gCO2eq/kWh) | | | |
|---|---|---|---|
| | | 2024 | 2030 |
| Summer | On Peak | 220 | 499 |
| | Mid Peak | 195 | 494 |
| | Off Peak | 95 | 359 |
| Shoulder | Mid Peak | 235 | 479 |
| | Off Peak | 107 | 387 |
| Winter | On Peak | 244 | 489 |
| | Mid Peak | 205 | 484 |
| | Off Peak | 100 | 434 |

Source: Ontario Electricity Emissions Factors and Guidelines , Accurate emissions factors are the backbone of climate action strategy, 2024, TAF

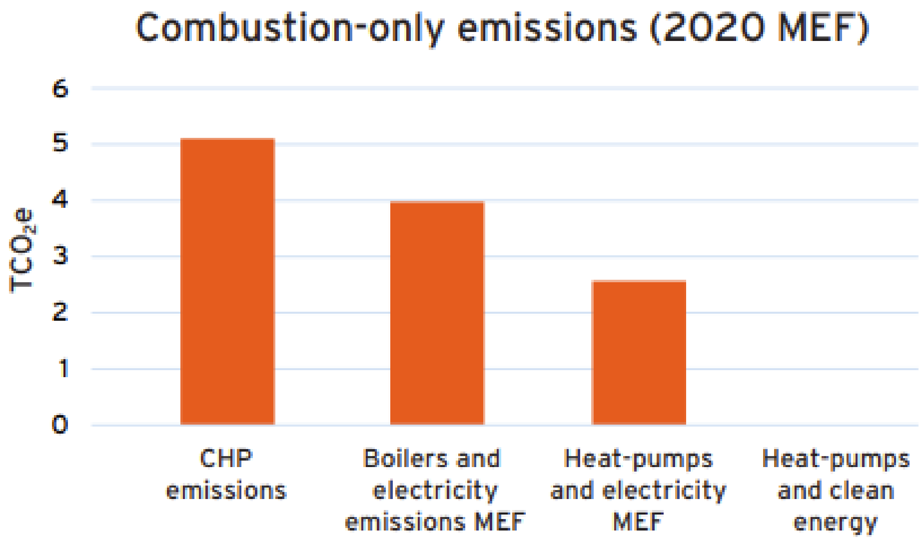
# Fuel switching to grid electricity life cycle assessment (LCA) (con’t)

**System 1:** Combined heat and power (CHP) generator with natural gas.

**System 2:** Traditional boilers and grid electricity.

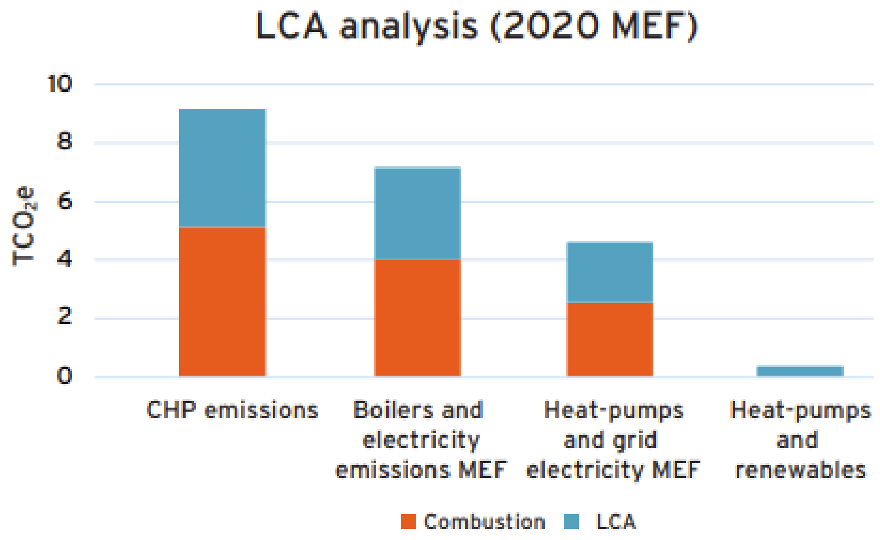
**System 3:** Heat pumps and grid electricity.

**System 4:** Heat pumps and renewable generation.




Source: A clearer view on Ontario's emissions, Updated electricity emissions factors and guidelines, TAF

# Fuel switching to grid electricity life cycle assessment (LCA)




Source: A clearer view on Ontario's emissions, Updated electricity emissions factors and guidelines, TAF

# Estimating energy and emissions impacts

**Example 1 : Estimate the impact of changes in electricity consumption from fuel switching.**

A building electrification feasibility study assessed the impacts of replacing the existing gas boilers with a high efficiency electric heat pump system. Estimated impacts are as follows:

Decrease in natural gas consumption from the gas boilers:

**30,000 $m^3$/year**

Increase in electricity consumption the heat pump system:

**150,000 kWh/year**

Electrifying the building heating system will save 47.9 $tCO_2e$/year:

**(150,000 kWh/year x 67 $gCO_2eq$/kWh x 0.000001) $tCO_2eq/gCO_2eq$) – (30,000 $m^3$/year x 1932 $gCO_2eq/m^3$ x 0.000001)**

**= -47.9 $tCO_2eq$/year**

Source: Ontario Electricity Emissions Factors and Guidelines , Accurate emissions factors are the backbone of climate action strategy, 2024, TAF

# Annual Average Emissions Factor in Ontario (con't)

**Example 2 : Estimate the electricity emissions generated by a low-rise multifamily building in 2023.**

Multiply the total electricity consumption of the building over the entire year (kWh) by the AEF value for the given year. If the total consumption of electricity in the building is estimated to be 880,000 kWh/year, the total generation emissions are 59 $tCO_2eq$:

**880,000 kWh x 67 $gCO_2eq$ per kWh**

**=58,960,000 $gCO_2eq$ (approx. 59 $tCO_2eq$)**

Source: Ontario Electricity Emissions Factors and Guidelines , Accurate emissions factors are the backbone of climate action strategy, 2024, TAF

# Forecasted emissions factors - large residential building

| Scenario | Building Energy Consumption (kWh) | | Total Building Emissions ($tCO_2e$) 2023-2041 |
|---|---|---|---|
| | Electricity Consumption (kWh) | Natural Gas Consumption ($m^3$) | With AEF = 150 $gCO_2eq/kWh$ |
| **Baseline Performance:** Natural gas boilers, hydronic baseboard heaters | 1,600,000 | 323,810 | 14,297 |
| **Option 1 Fuel Switching:** Improved lighting and appliances, heat pumps for space heating and hot water, double-glazed windows | 3,300,000 | 9,524 | 5,317 |
| **Option 2 Comprehensive** Retrofit: Improved lighting and appliances, heat pumps for space heating and hot water, over cladding, triple-glazed windows, solar panels | 2,950,000 | -------- | 4,441 |

Source: Ontario Electricity Emissions Factors and Guidelines , Accurate emissions factors are the backbone of climate action strategy, 2024, TAF

# Canada - Federal Carbon Pricing System

The Federal Greenhouse Gas Pollution Pricing Act (GHGPPA) passed in 2018 establishes a set of minimum national standards for carbon pricing to help meet Canada's emission reduction targets under the Paris Agreement. The act has two carbon pricing mechanisms:

1. "Fuel Charges" (a form of 'consumer' carbon tax)
2. the "Output Based Pricing System" (OBPS - a form of ETS)

Provinces and Territories must support these standards unless they have an acceptable alternative carbon pricing system. In Ontario, the OBPS is superseded by the "Emissions Performance Standards" (EPS).

# Putting a price on emissions – Federal “fuel charge”

- Applies to 21 fossil fuels: including coal, coke, oil, gasoline, light fuel oil (e.g., diesel), natural gas, propane etc.
- Charges on fossil fuels are administered by the Canada Revenue Agency (CRA) and are applied to fossil fuel producers and distributors
- These charges are then passed on to the fuel consumers and are set to increase by 15$/year on every April 1 until 2030
- Approximately 90% of the Fuel Charge proceeds go back to individuals and families through the quarterly “Canada Carbon Rebate” (formerly known as “Climate Action Incentive” payments)

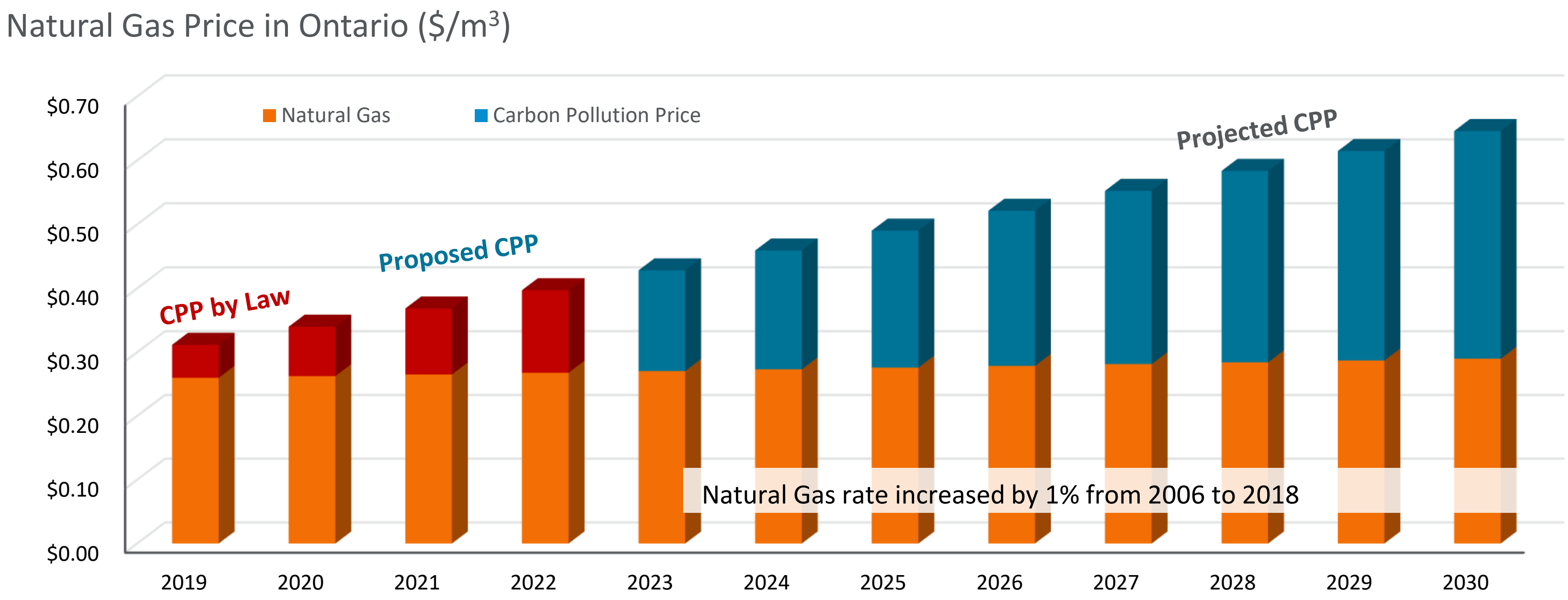

**Source:** https://www.canada.ca/en/environment-climate-change/services/climate-change/pricing-pollution-how-it-will-work/carbon-pollution-pricing-federal-benchmark-information/federal-benchmark-2023-2030.html

# Fuel charge applied to common fuels

| Rates (in $CAD) of the federal fuel charge on select fuels from 2021-2030 (starting April 1 of every year) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type** | **Unit $/per** | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 |
| **$CO_2e$** | tonne | 40 | 50 | 65 | 80 | 95 | 110 | 125 | 140 | 155 | 170 |
| **Gasoline** | litre | 0.0884 | 0.1105 | 0.1431 | 0.1761 | 0.2091 | 0.2422 | 0.2752 | 0.3082 | 0.3412 | 0.3743 |
| **Diesel** | litre | 0.1073 | 0.1341 | 0.1738 | 0.2139 | 0.2540 | 0.2941 | 0.3342 | 0.3743 | 0.4144 | 0.4545 |
| **Propane** | litre | 0.0619 | 0.0774 | 0.1006 | 0.1238 | 0.1470 | 0.1703 | 0.1935 | 0.2167 | 0.2399 | 0.2631 |
| **Natural gas** | cubic metre | 0.0783 | 0.0979 | 0.1239 | 0.1525 | 0.1811 | 0.2097 | 0.2383 | 0.2669 | 0.2954 | 0.3240 |

Sources: https://www.canada.ca/en/environment-climate-change/services/climate-change/pricing-pollution-how-it-will-work/carbon-pollution-pricing-federal-benchmark-information/federal-benchmark-2023-2030.html
https://www.canada.ca/en/revenue-agency/services/forms-publications/publications/fcrates/fuel-charge-rates.html#fcrts

# Natural gas rate in Ontario



# Heating systems

Combustion Heating

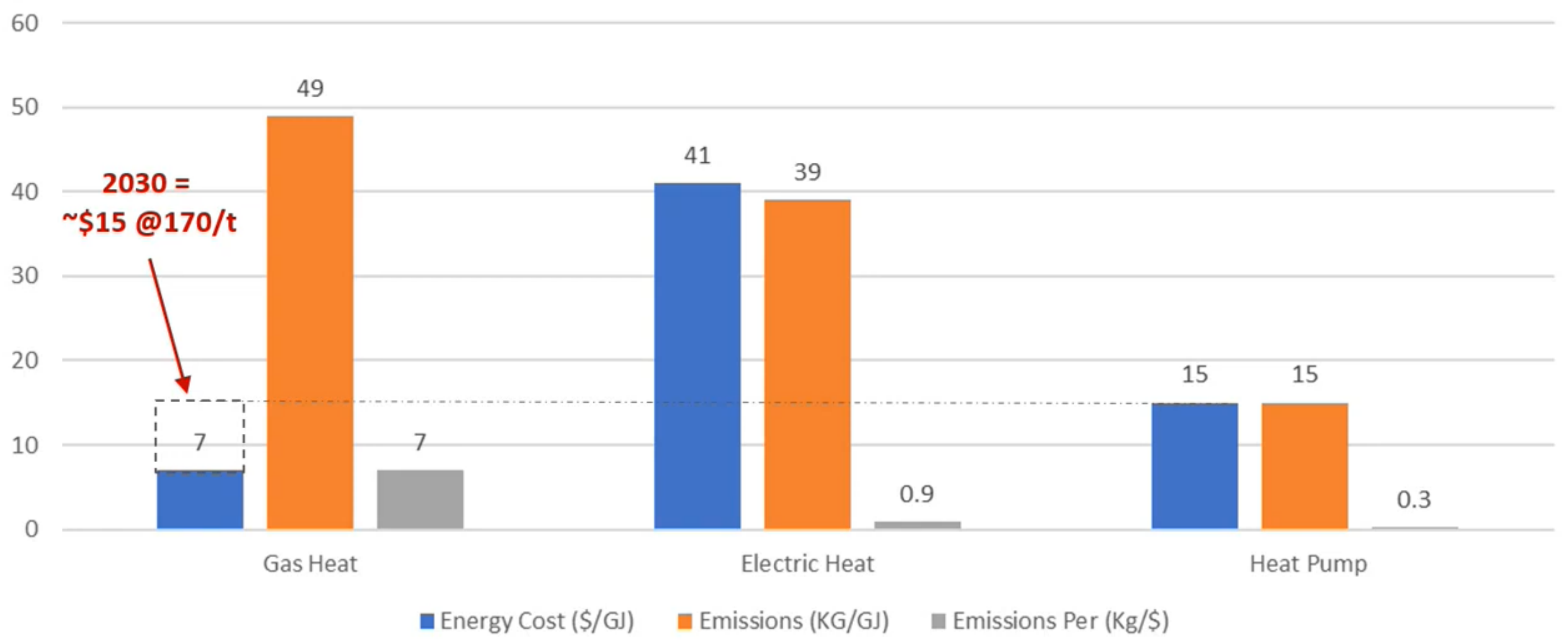
Resistance Heating

Heat Pump Heating/Cooling

| Efficiency | 80% – 98% | Close to 100% | 250 - 400% or 2.5 - 4.0 Coefficient of Performance (COP) |
|---|---|---|---|
| Energy Cost | \$0.45/m$^3$ | \$0.15/kWh | \$10/GJ - \$20/GJ |
| Energy Cost | \$15/GJ<br>(\$20.5/GJ by 2030 @\$170/t) | \$41/GJ | \$10/GJ - \$20/GJ |
| Emissions | 49 kg $CO_{2eq}$/GJ | 8 kg $CO_{2eq}$/GJ (Margin) | 2 – 4 kg $CO_{2eq}$/GJ |

All values are approximate for illustrative purposes

# Heating systems cont'd



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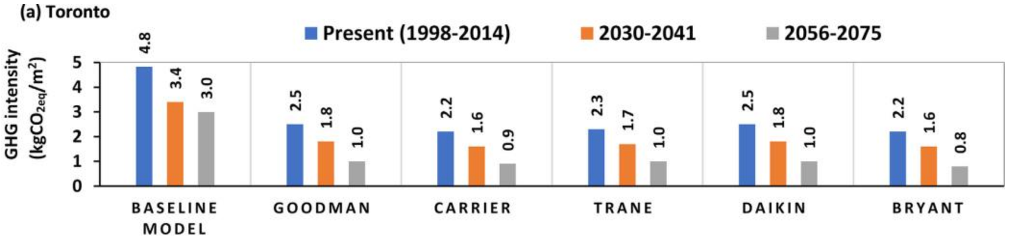
# GHG emissions intensity of ASHP for Toronto, Ottawa




Ottawa is in the same climate zone as


Source: The efficiency and GHG emissions of air source heat pumps under future climate scenarios across Canada, Energy and Building, 2022

# Lifecycle cost analysis

Lifecycle Cost =

Feasibility Study + Development + Engineering + Capital Cost +

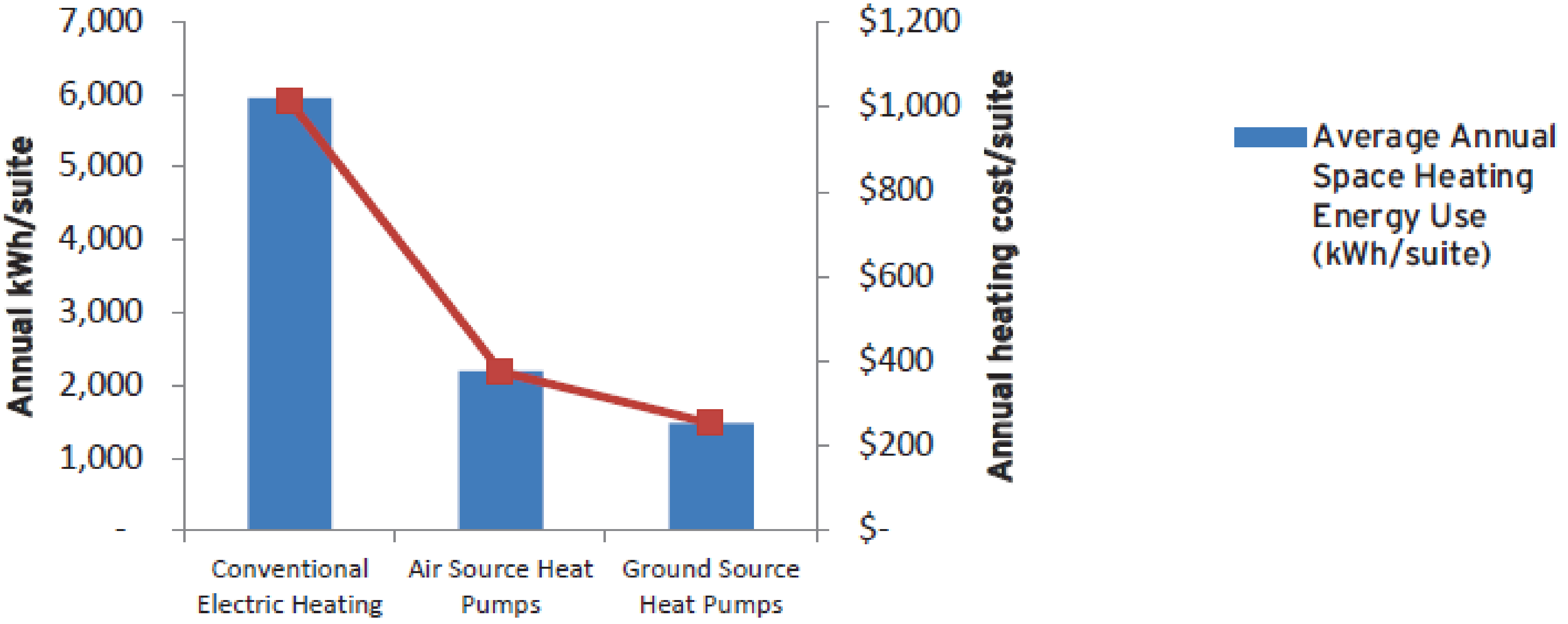
Operation & Maintenance + Fuel Costs

https://heatpumpcalculator.ca/

# Lifecycle cost analysis – variables to consider

- Feasibility, Design and Engineering
- Floor Area
- Heating and Cooling Load
- Inclusion of Domestic Hot Water in the Load
- Fuel rate
- Seasonal Efficiency and Coefficient of Performance
- Equipment Cost
- O&M

# Case study




TAF: Harvesting heat with heat pumps_ a guide to retrofitting electrically-heated multi-family dwellings in Ontario with heat pumps

# Questions?

# Save on Energy 2024 Energy Management Excellence Awards

Join us in celebrating the accomplishments and innovations of Ontario's energy leaders who are helping to drive a more sustainable future.


You won't want to miss this inspiring day filled with learning and networking opportunities.

**Tuesday, October 29**
**8:00 a.m. to 4:00 p.m.**
**International Centre, Mississauga**

**Register now!**

Spots are limited.

# Save on Energy's Capability Building Program

- Save on Energy's Capability Building program helps increase awareness of energy-efficiency opportunities, enhance knowledge and develop skills in organizations and communities across Ontario so they can undertake energy-efficiency actions and participate in Save on Energy programs
- The program includes tools such as workshops, webinars, training courses, coaching, peer learning and information resources including guides and videos

Learn more at https://saveonenergy.ca/Training-and-Support
Register at www.saveonenergytraining.ca



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# Post-webinar support

One-on-one coaching: tailored support for managing energy resources effectively

Post-webinar support intake form

Coaching sessions conducted virtually: phone, video calls, and email

Designed for organizations, new or old, seeking guidance.

# Stay connected with tools and resources

- Virtual one-on-one coaching: post-webinar support intake form for tailored support for organizations to manage energy resources effectively.
- Monthly bulletin: sign up to receive monthly training updates on all Save on Energy training and support new tools and resources.
- Live training calendar: visit this page to easily register for upcoming events and workshops.
- Training and support webpage: visit this page to access all training and support materials.

# Thank you!

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