# EMERGING ENERGY-EFFICIENT TECHNOLOGIES IN ONTARIO'S MANUFACTURING SECTOR

This fact sheet describes emerging[1] energy-efficient and decarbonization technologies in Ontario's manufacturing sector.

As of 2024, there are over 36,000 companies in the Ontario manufacturing sector,[2] employing over 775,000 Ontarians and supplying 11 percent of Ontario's GDP. Many of these companies have already made significant investments in what are now considered conventional energy-efficiency technologies such as variable frequency drives on fans and pumps, LED lighting fixtures and lighting controls, and high-efficiency HVAC systems and controls. These technologies and others are widely available and generally eligible for incentives through Save on Energy's Retrofit program.

As defined by Statistics Canada,[3] the manufacturing sector in Canada covers a huge range of industries. The seven most energy-intensive industries—pulp and paper, metals, refineries, chemicals, lumber, food and non-metallic minerals—represent about 90 percent of the total energy use in the sector.

**THIS FACT SHEET EXAMINES THREE EMERGING MANUFACTURING TECHNOLOGIES:**

1. Electrification of industrial process heating
2. Industrial heat pumps
3. The Industrial Internet of Things

For an overview of established energy-efficient technologies in the Ontario manufacturing sector, please refer to the Industrial Energy Efficiency Best Practices Guide.

[1] A technology is considered emerging if it is not widely adopted in Ontario.
[2] https://cme-mec.ca/manufacturing-matters-in-ontario-5-fast-facts
[3] https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2510002501

# 1. ELECTRIFICATION OF INDUSTRIAL PROCESS HEATING

## TECHNOLOGY DESCRIPTION

Industrial heating uses heat to transform materials by removing moisture, separating chemicals, creating steam, heat-treating metals, melting, drying, cooking and countless other applications. Industrial heating in North America currently relies primarily on fossil fuel sources, and accounts for about 10 percent of the entire North American greenhouse gas emissions footprint.

Many types of industrial processes conventionally heated with fossil fuels can be designed for, or converted to, electric heating.

In some cases, electric heating technologies have been commercially available for decades, but are only recently gaining market share due to a shift toward low-carbon energy. In other cases, the technology is feasible but is only now becoming commercialized at a larger scale. There are also several new electric heating technologies based on nanotechnology that can offer entirely new ways of heating materials. Recent government and utility initiatives in Canada, the U.S. and many other countries are providing incentives for industry to discover or re-discover electric heating options.

## 1. ELECTRIFICATION OF INDUSTRIAL PROCESS HEATING

Examples of commercially available electric heating technologies that have been gaining market share in recent years include:

| TECHNOLOGY | HOW IT WORKS | TEMPERATURE GENERATED | APPLICATIONS |
|---|---|---|---|
| **RESISTANCE HEATING** | Passes electric current through a material with high resistance, such as a metal wire. Heat is transferred to the material by conduction, convection and infrared radiation. | Up to 1,200 °C | • Water heating<br>• Boilers<br>• Electric ovens<br>• Immersion heaters<br>• Industrial stoves |
| **INDUCTION HEATING** | An alternating magnetic field is generated with electrical conductors, inducing an electric current and generating heat inside the target material itself (iron and its alloys work best). | Up to 2,500 °C | • Powder coating<br>• Melting of metals<br>• Industrial stoves<br>• Can also be used to heat metal strips or hardware on other materials without heating them (e.g., closures) |
| **INFRARED HEATING** | A form of resistance heating that uses reflectors to concentrate and direct infrared radiation to heat up a material from a distance without direct contact. The infrared radiation is absorbed by the material, which heats up. | Up to 1,000 °C | • Drying and curing paint, ink and adhesives<br>• Forming of plastic<br>• Glass manufacturing<br>• Textiles<br>• Targeting personnel heating needs in large spaces |
| **MICROWAVE HEATING** | Microwave radiation is used to penetrate materials and excite the molecules, producing heat. This technology is well suited to continuous flow process industries. | Up to 3,000 °C | • Heating of liquids and fuels<br>• Textiles<br>• Paper<br>• Insulation<br>• Food and beverage processing |
| **HEAT PUMPS** | These do not produce heat but can be used to recover, upgrade and move heat. | N/A | See section 2 for industrial applications for heat pumps. |

## 1. ELECTRIFICATION OF INDUSTRIAL PROCESS HEATING

Examples of emerging technologies with early-stage industrial development and applications include:

| TECHNOLOGY | HOW IT WORKS | TEMPERATURE GENERATED | APPLICATIONS |
|---|---|---|---|
| **GRAPHENE HEATING** | Graphene is a pure carbon nanomaterial extracted from graphite that can be applied as an ultrathin film or even a paint. When an electric current passes through it, the resistance of the material generates heat. | Up to 2,000 °C | • Medical devices<br>• Specialized apparel<br>• Aerospace<br>• Construction materials<br>• Automotive<br>• Delicate or critical manufacturing processes |
| **CARBON NANOTUBE HEATING** | Carbon nanotubes operate similarly to graphene, but with additional structural and mechanical properties. This is an active subject of research and development. | Up to 3,000 °C | • Textile products (e.g., heating pads) used in industrial applications<br>• Heating moulds for plastic manufacturing |

### ADVANTAGES

All forms of electric heating have zero local emissions.

Heating can be targeted and controlled more precisely than most combustion sources.

Most electric heating has a much wider range of operation and very low turndown possibilities compared to fossil fuel systems.

Compact system design.

No special fresh air supply, exhaust or make-up air requirements.

No carbon monoxide or other combustion by-products.

Does not produce water vapour (humidity).

### CONSIDERATIONS

- Introducing large electric heating systems may significantly increase facility level electricity demand and may require enhanced demand response and global adjustment management practices.
- To optimize project economics, consider life cycle costs, organizational benefits and pursue available incentives.
- A large electric heating load may be affected by or cause changes to the facility's power factor.

## 1. ELECTRIFICATION OF INDUSTRIAL PROCESS HEATING

### ADVANTAGES

Greatly reduced fire risks.

No gas or liquid fuel storage, delivery or leaks; can be instantly shut off.

Most electric heating systems are 99 percent thermally efficient during operation (induction is 95 percent efficient due to inverter losses). Gas-fired heaters are typically around 80 percent thermally efficient, although more complex condensing systems can be over 95 percent efficient.

Typically much less complex than gas-fired systems, with high reliability and lower maintenance costs.

### CONSIDERATIONS

- A significant increase in electrical demand may require a service upgrade, larger transformer, upgraded distribution system devices and/or new wiring in the building.
- The North American market for high temperature electric heating is still developing and some solutions may not be widely available or come at higher costs.
- For large-scale deployment, there is a need to ensure sufficient capacity in the local electrical grid, especially for more remote or northern Ontario locations.

### ADOPTION

Electric heating can be applied to almost any industrial process and its adoption is being accelerated by the transition to low-carbon energy. Some examples include:

- **Chemical manufacturing:** chemical polymerization, distillation and reaction processes requiring precise temperature control and rapid heating rates.
- **Plastics manufacturing:** drying and heating of plastic resins.
- **Glass production:** melting, forming and annealing require high uniform temperatures, which can be achieved with infrared heating and possibly graphene or carbon nanotube heating.
- **Food processing:** melting, drying, baking, cooking and sterilization.
- **Pharmaceutical:** sterilization processes and tight temperature control of processing.
- **Automotive:** curing coatings, induction heating for powder coating and mould heating.
- **Metal casting:** melting of metals with induction furnaces.
- **Mining and steelmaking:** The largest electric heating applications (e.g., electric arc furnaces) in Ontario take place in these sectors. Please see the Emerging Energy Efficient Technologies in Mining and Emerging Energy Efficient Technologies in Steelmaking Fact Sheets for more information.

## 2. INDUSTRIAL HEAT PUMPS

### TECHNOLOGY DESCRIPTION

Heat pumps can provide both heating and cooling. Using the principles of thermodynamics, all heat pump systems move heat from one location to another by circulating and controlling the temperature and pressure of a carefully selected refrigerant fluid between a heat exchanger that receives external heat (evaporator) and a heat exchanger that releases heat (condenser) externally. Two everyday examples of simple (one-way) heat pumps are kitchen refrigerators and residential air conditioning.

The most common performance rating of a heat pump is the "coefficient of performance" (COP), calculated as:

$$\text{COP} = \frac{\textbf{Useful energy removed (cooling) or provided (heating)}}{\textbf{Energy input}}$$

Industrial heat pumps are usually customized for a particular process application. They can be as small as a residential air conditioning unit (10 kW) or larger than a bus (50 MW or more). Heat pump technology can deliver heat over 200 °C, but most commercial systems deliver heat at temperatures under 100 °C. As seen in Figure 1, commercially available heat pumps can be used in a variety of sectors for temperature needs under 150 °C.

## 2. INDUSTRIAL HEAT PUMPS

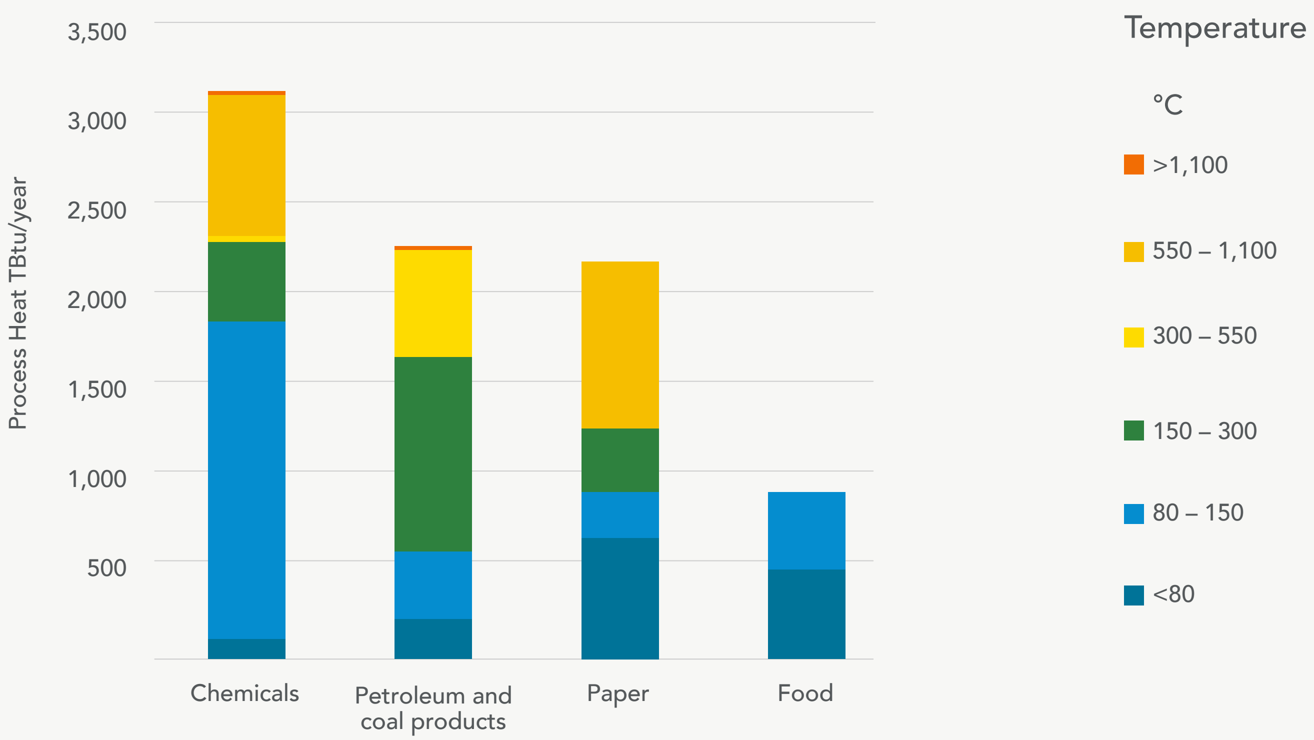


Figure 1: From ACEEE – Building the Industrial Heat Pumps Domestic Market, Andrew Hoffmeister, Neal Elliott, Paul Scheihing, Hellen Chen, 10/16/23.

Refrigerants are carefully selected for various properties, including performance, safety and environmental factors. The boiling point of the refrigerant at system pressures is critical since it must change from liquid to gas in the evaporator stage and from gas to liquid in the condensing stage.

## 2. INDUSTRIAL HEAT PUMPS

Examples of commercially available industrial heat pumps include:

| TECHNOLOGY | HOW IT WORKS | POWER SOURCE | COP |
|---|---|---|---|
| ELECTRIC HEAT PUMP | Uses compressors and valves to control the temperature and pressure of the refrigerant in what is known as the vapour compression cycle. | Electricity | 2.5 – 3.0 |
| GAS-ENGINE HEAT PUMP | Uses a natural gas-fired engine to power a compressor in a similar vapour compression cycle to electric heat pumps. | Gas | 1.5 – 2.0 |
| ABSORPTION HEAT PUMP | Uses the heat produced from burning natural gas or other high-quality waste heat to pressurize the refrigerant in what is known as the absorption cycle. | Gas/waste heat and electricity | 1.5 – 2.5 |
| HEAT TRANSFORMER HEAT PUMP | Uses low-grade heat to operate an absorption cycle. Heat transformer heat pumps have a low COP but use energy that would otherwise be wasted. | Gas/waste heat and electricity | 0.4 – 0.5 |

### ADVANTAGES

Heat pump systems can enable a thermal system design approach that reduces both wasted energy and costs of the system by recovering and boosting the lowest-quality thermal loads in the facility to higher qualities.

Heat pumps can reduce or completely replace the need for combustion hot water and steam heating systems.

Electric heat pumps produce no local emissions.

Gas heat pumps can reduce direct combustion gas consumption by 50 percent.

### CONSIDERATIONS

- Higher capital cost and larger physical size/footprint than conventional systems.
- Engineering, sizing and selection of components and refrigerants is critical; it is not as easy to boost or tune down a heat pump vs. combustion or resistance heating.
- May require new and possibly hard-to-find local maintenance and troubleshooting skills.
- Ensure that design and procurement staff are familiar with significant incentive programs that may apply.

## 2. INDUSTRIAL HEAT PUMPS

### ADOPTION

There are numerous suppliers of industrial heat pump technologies located in Canada and the USA and ambitious government and industry programs that aim to increase awareness and adoption of heat pumps for industrial applications.

Installations to date in Ontario, across Canada and USA include:

- A pork processing facility run by Conestoga Meats in Breslau installed an ammonia heat pump in 2013 to upgrade waste heat from its refrigeration system to heat water up to 38 °C with a COP of 3.15. The project resulted in energy savings of 3,374 MWh per year and emissions reduction of 3,000 tonnes of $CO_2$ per year.
- Another pork processing facility run by Maple Leaf Foods in Manitoba installed a 1,000 HP ammonia heat pump in 2015 to upgrade waste heat from its large refrigeration system to heat water from 30 °C to 60 °C, resulting in natural gas savings of $200,000 per year.
- Markham District Energy is planning the installation of a single-screw ammonia heat pump in 2025 to upgrade waste heat from sewage, entering the heat pump at 5 °C and heating up water to 95 °C. At full capacity, the project is expected to result in emissions reductions of 30,000 tonnes of $CO_2$ per year.

There are also a number of interesting applications in other countries, especially in Europe:

- A large candy plant in the Netherlands installed a 1,400 kW heat pump system to boost waste heat from refrigeration units to heat water up to 63 °C for heating chocolate and syrup storage tanks and air-handling units.
- A slaughterhouse in Switzerland installed a heat pump system with a heating capacity of 800 kW that collects waste heat at 20 – 30 °C from multiple sources to heat process water to 90 °C, reducing 30 percent of the plant's annual $CO_2$ emissions.
- A malting plant (malt for beer brewing) in Vietnam installed several large heat pumps to help maintain optimum conditions for germinating barley. The process requires cool, humidified air as well as heat for the kilning process, during which the germinated malt is dried. The heat pump upgrades the waste heat from the cooling plant and channels it to the drying area, significantly reducing the natural gas that was being used and eliminating 2,000 tonnes of $CO_2$ per year.

## 3. INDUSTRIAL INTERNET OF THINGS (IIOT)

### TECHNOLOGY DESCRIPTION

IIoT includes the interconnection of equipment, devices, sensors, software, communication and networking technology that can collect, monitor and analyze data from any type of facility. This enhances the understanding of processes and enables vastly superior control of process optimization, troubleshooting, maintenance, health and safety conditions, productivity improvements and GHG emission reductions.

IIoT systems can be much more complex and critical than the generic commercial IIoT systems used for access control, office HVAC and lighting control. Failure of manufacturing, refinery, power generation or mining systems can result in catastrophic consequences well beyond the immediate facility. IIoT systems can provide a wide range of additional data and signals to aid in all aspects of operations, maintenance, safety and environmental systems.

Energy-related examples of IIoT technology applications include:

- **Smart energy monitoring:** devices that record, collect and monitor energy consumption in real time and report unusual conditions.
- **Predictive maintenance monitoring:** devices that monitor equipment performance and condition and proactively indicate that corrective maintenance action is required to prevent failures or energy waste.
- **Automated lighting systems:** interactive timers, occupancy sensors and daylighting sensors that control lighting levels and energy consumption of large and high-bay work areas and outdoor lighting, as well as specialty process lighting.
- **HVAC optimization:** interactive timers, process data, occupancy sensors and air quality detectors to process and optimize indoor air quality, filtration, fresh air intake and conditioning, as well as detect unsafe conditions.
- **Process optimization:** devices that monitor production processes and provide data to use for energy-efficiency optimization and to detect equipment or process issues.
- **Demand response (for electrical power usage):** devices and systems to assist with participation in demand response or global adjustment actions.
- **Battery management:** devices and systems to optimize charging and discharging facility batteries or mobile equipment batteries.
- **Renewable energy integration:** devices and systems to manage on-site renewable energy sources such as solar panels or wind turbines.

## 3. INDUSTRIAL INTERNET OF THINGS (IIOT)

### ADVANTAGES

Enables increased efficiency, reduced downtime and increased productivity.

Enables earlier detection of potential hazards.

Enhances quality control.

Reduces labour spent doing unnecessary adjustments, data collection, testing and maintenance.

Enables remote and centralized monitoring.

Takes human guesswork out of process control, reduces human error, reduces skill and experience levels required for some processes.

Accelerates response times with real-time collection and processing of operational data.

Enables optimization and adaptation over fixed settings.

Enables enhanced safety management.

Enables automated regulatory compliance and utility program performance.

### CONSIDERATIONS

- More connections mean more potential points for cyber-attacks. IIoT systems require encryption, authentication and regular security audits.
- Integration of IIoT with existing IT and communication systems can be a complex task.
- Adoption requires replacing analogue information sources with digital sources and securely networking these sources.
- IIoT systems generate massive amounts of data, which need to be stored, processed and analyzed effectively.
- Switches, routers and wireless equipment that connect IIoT devices must provide the needed bandwidth and be able to withstand conditions on factory floors or outdoors (e.g., dust, vibrations, temperature and humidity, etc.).
- Many of these devices and systems require calibration and maintenance by skilled workers. There is strong competition for workers with the necessary skills to implement and manage IIoT systems.

## 3. INDUSTRIAL INTERNET OF THINGS (IIOT)

### ADOPTION

Some aspects of IIoT can be found in most industrial facilities in Ontario—for example, internet-connected electrical, gas and water meters. Other common applications are access control and building automation systems for HVAC, lighting, fire and security control with remote access and monitoring.

More complex IIoT devices and systems for process control, logistics and product traceability are being adopted in industries with very demanding supply chains, such as automotive, pharmaceutical, aerospace and logistics, as well as in some food and beverage plants. The IIoT systems collect and coordinate production equipment performance information with logistics systems, HVAC and other environmental and safety systems.

Early adopters in Ontario report overall energy savings of up to 25 percent, maintenance cost reductions up to 30 percent and improvements in defect reduction and productivity increases up to 15 percent. Specific examples include torque measurements on fastening robotics, welding quality monitoring, "thermolator" monitoring and control (plastic moulding), vibration analysis, oil quality monitoring, vehicle tracking, blockchain traceability of product, complex temperature monitoring with hundreds of sensors, etc.

Heavy industry IIoT systems focus on major safety, environmental and energy systems management such as leak monitoring, power management, personnel and vehicle locators, and performance of emission control equipment.

In general, the application of IIoT systems is growing rapidly as the availability of technologies, qualified suppliers and trained users increases. There have been significant advancements in digital, fibre optics, wireless technologies and plug-and-play capability that make real-time desktop, mobile device and remote monitoring and control a reality.