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Emerging energy-efficient technologies in Ontario's manufacturing sector information session

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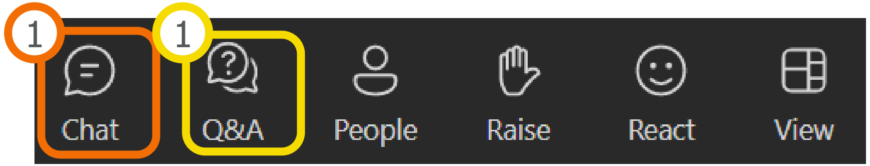
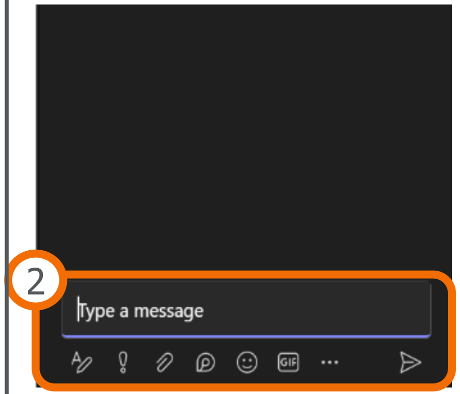
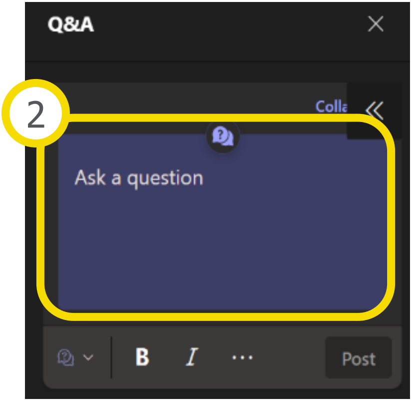






Introduction

Emily Thorn Corthay, MASc., P.Eng, CEM, CMVP, Founder and CEO of Thorn Associates

With a 20-year career in industrial decarbonization and energy management, she has assisted her clients in achieving over $100 million in implemented energy savings and reductions of over 500,000 tonnes of CO_2e, acting as project manager, technical reviewer, and energy/sustainability engineer for over 80 energy and decarbonization projects in 15+ countries. Emily is a 2025 Clean50 award winner.

Robert Storey, P.Eng., CEM Energy Engineer, Associate at Thorn Associates

He has 30 years of project and operations experience and specialized in energy since 2001, ISO 50001, codes and standards, over 300 Save on Energy projects with Toronto Hydro, client projects under the former Industrial Accelerator and Northern Industrial Electricity Rate programs.

Objectives and agenda

Introduction to manufacturing sector emerging technologies that support energy efficiency and decarbonization, with a focus on:

- Electrification of industrial process heating
- Industrial heat pumps
- The industrial internet of things

Ontario manufacturing sector – current state

- In Ontario, 36,000 manufacturing companies employing over 775,000 people and representing 11% of Ontario's GDP
- The seven most energy-intensive industries—pulp and paper, metals, refineries, chemicals, lumber, food and non-metallic minerals—represent about 90% of total energy use in the sector
- Many companies have made significant investments in conventional energy-efficiency technologies such as variable frequency drives on fans and pumps, light-emitting diode (LED) lighting and high-efficiency heating, ventilation and air-conditioning (HVAC) systems and controls
- Adoption of decarbonization and electrification technologies is just beginning

Electrification of industrial process heating

- Transforms materials by drying, activating chemicals, creating steam, heat-treating, melting, cooking etc.
- Industrial heating accounts for about 10% of entire North American greenhouse gas (GHG) emissions
- Electric heating can be applied to almost any process
- Some technologies have been available for decades, uptake increasing with low-carbon goals
- Other existing technologies are becoming commercialized at a larger scale
- New electric heating technologies, nanotechnology

Electrification of industrial process heating (1/2)

Technology	How it works	Capacity	Applications
Resistance heating	Electric current is passed through a conductor with high resistance (e.g. metal wire), generated heat is transferred to the target material by conduction, convection and infrared radiation	Up to 1,200 °C	• Water heaters, boilers • Electric ovens • Immersion heaters • 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 • Melting of metals • Industrial stoves • Heating metal hardware on other materials without heating them (e.g. closures)
Infrared heating	Resistance heating that uses reflectors to concentrate and direct infrared radiation to heat up a material from a distance without direct contact	Up to 1,000 °C	• Drying and curing paint, ink and adhesives, textiles • Forming of plastics • Glass manufacturing • Targeted personal heating

Electrification of industrial process heating (2/2)

Technology	How it works	Capacity	Applications
Microwave heating	Microwave radiation penetrates materials and excites molecules, producing heat. Well-suited for continuous flow process industries	Up to 3,000 °C	• Heating liquids and fuels • Textiles, paper, insulation processing • Food and beverage processing
Graphene heating	A pure carbon nanomaterial extracted from graphite applied as an ultrathin film or even a paint to generate heat when an electric current passes through it	Up to 2,000 °C	• Medical devices • Specialized apparel • Photovoltaics • Aerospace, automotive • Construction materials • Delicate manufacturing processes
Carbon nanotube heating	Similarly to graphene but with additional structural and mechanical properties, active subject of research and development	Up to 3,000 °C	• Industrial textile products (e.g. heating pads) • Heating moulds for plastic manufacturing

Some examples

Heating gear teeth with induction heater

Infrared heater

Advantages of electric heating

- Zero local emissions
- Heating can be more precisely targeted and controlled
- Much wider wide range of operation and very low turndown possibilities
- 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)
- Greatly reduced fire risks
- No gas or liquid fuel storage, delivery or leaks; can be instantly shut off
- Most are 99% thermally efficient during operation vs 80% (non-condensing) although condensing systems can be over 95% efficient
- Less complex, with high reliability and lower maintenance costs

Consideration of electric heating

- Introducing large electric heating systems may significantly increase facility level electricity demand and may require enhanced demand response and global adjustment management practices
- A large electric heating load may be affected by or cause changes to facility power factor
- May require a service upgrade, larger transformer, upgraded distribution system devices and/or new wiring
- For large-scale deployment, need to ensure there is sufficient capacity in the local electrical grid
- The North American market for high temperature electric heating equipment is still developing
- To optimize project economics, consider life cycle costs and organizational benefits as well as pursue available incentives

Electrification of industrial process heating – adoption

Chemical manufacturing: Polymerization, distillation and reaction processes requiring precise temperature control and rapid heating rates

Plastics manufacturing: Drying and heating of plastic resins

Glass production: For melting, forming and annealing at high uniform temperatures (infrared heating, possibly graphene/nanotube)

Food processing: Melting, drying, baking, cooking and sterilizing

Pharmaceutical: Sterilization, tight temperature control

Automotive: Curing coatings, induction heating and mould heating

Metal casting: Melting metals with induction furnaces

Mining and steelmaking: Electric arc furnaces, induction furnaces

Industrial heat pumps

- Provide both heating and cooling, moving heat from one location to another by circulating and controlling the temperature and pressure of a refrigerant fluid between a heat exchanger that receives external heat (evaporator) and a heat exchanger that releases heat (condenser) externally
- Simple (one-way) heat pumps are kitchen refrigerators and residential air conditioners

Industrial heat pumps (continued)

- The most common performance rating of a heat pump is the coefficient of performance (COP):

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

- Customized for a particular process application, can be as small as a residential air-conditioning unit (10 kW) or larger than a bus (50 MW or more)
- 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

Industrial heat pump capabilities

- Can deliver heat between 100-200 °C
- Commercially available for temperature needs under 150 °C
- Specialized and developmental units can deliver much higher temperatures

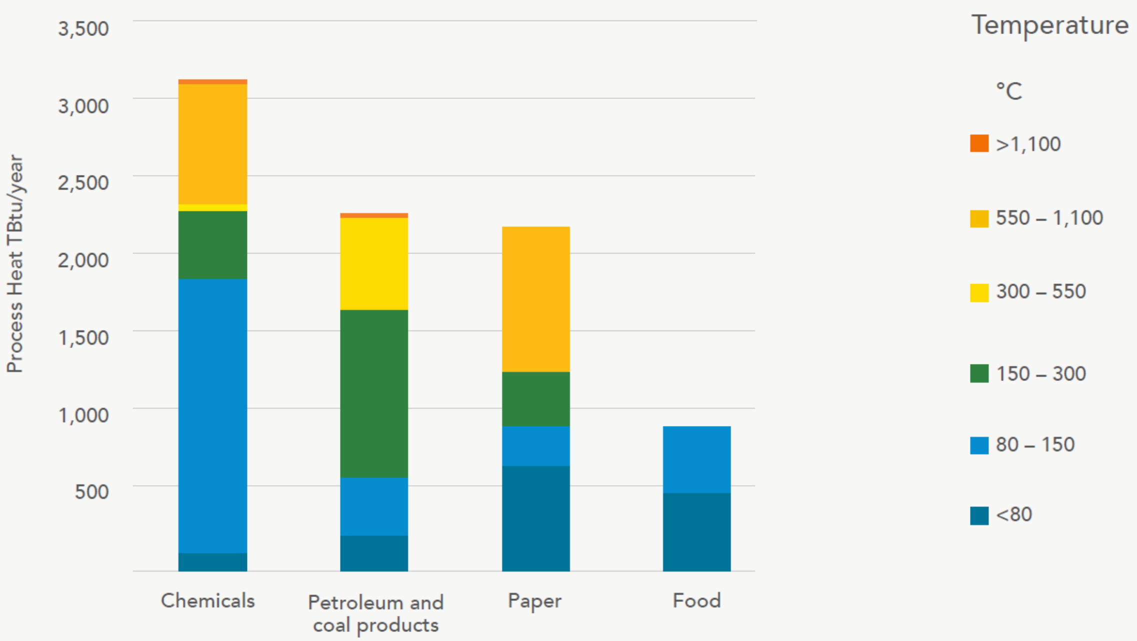


Figure 1: From ACEEE – Building the Industrial Heat Pumps Domestic Market, Andrew Hoffmeister, Neal Elliott, Paul Scheihing, Hellen Chen, 10/16/23.

Industrial heat pump types

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

Industrial heat pump advantages and considerations

Advantages

- Enables thermal system design, recovering and boosting low-quality thermal loads of higher qualities
- Can reduce or replace need for combustion or electric heat generating systems
- Electric heat pumps produce no local emissions
- Gas heat pumps can reduce natural gas consumption (vs furnace/boiler) by 50%

Considerations

- Higher capital cost and larger physical size/footprint than conventional systems
- Engineering, sizing and selection of components and refrigerants are critical; not as easy to boost or tune down
- Requires possibly more difficult to find local maintenance and troubleshooting skills
- Ensure that design and procurement staff are familiar with significant incentive programs that may apply

Industrial heat pumps – adoption

- Numerous suppliers of industrial heat pump technologies in Canada and USA
- Various programs working hard to increase awareness and adoption
- Installations to date in Ontario, across Canada and USA are few but include:

Conestoga Meats (pork processing, Breslau ON):

- Installed an ammonia heat pump in 2013 to upgrade waste heat from its refrigeration system to heat water up to 38 ºC with a COP of 3.15
- The project resulted in energy savings of 3,374 MWh per year and emission reductions of 3,000 tonnes of CO2 per year

Industrial heat pumps – adoption examples

Maple Leaf Foods (pork processing, MB):

- 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
- This resulted in natural gas savings totalling $200,000 per year

Markham District Energy (ON):

- Planning the installation of a single-screw ammonia heat pump in 2025 to upgrade waste heat from sewage, entering the heat pump at 5 ºC and heating up water to 95 ºC
- At full capacity, the project is expected to result in emission reductions of 30,000 tonnes of CO2 per year

Industrial internet of things (IIoT)

- Includes the interconnection of equipment, devices, sensors, software, communication and networking technology can collects, monitors and analyzes data
- Improves understanding of processes and enables process optimization, troubleshooting, maintenance, health and safety, productivity and GHG emission reductions
- IIoT systems are more complex and critical than generic IoT used for offices, etc.
- Failure of manufacturing, refinery, power generation or mine systems can result in catastrophic consequences well beyond the immediate facility

IIoT – Applications in energy management (1/2)

Smart energy monitoring: Collect and monitor energy consumption in real time and report unusual conditions

Predictive maintenance monitoring: Monitor equipment performance and condition to indicate required corrective action to prevent failures or energy waste

Automated lighting systems: Interactive control of light quality and energy consumption of large and high bay areas, outdoor lighting and process lighting

HVAC optimization: Interactive control of processes and sensors to optimize indoor air quality, filtration, fresh air intake and conditioning as well as detect unsafe conditions

IIoT – Applications in energy management (2/2)

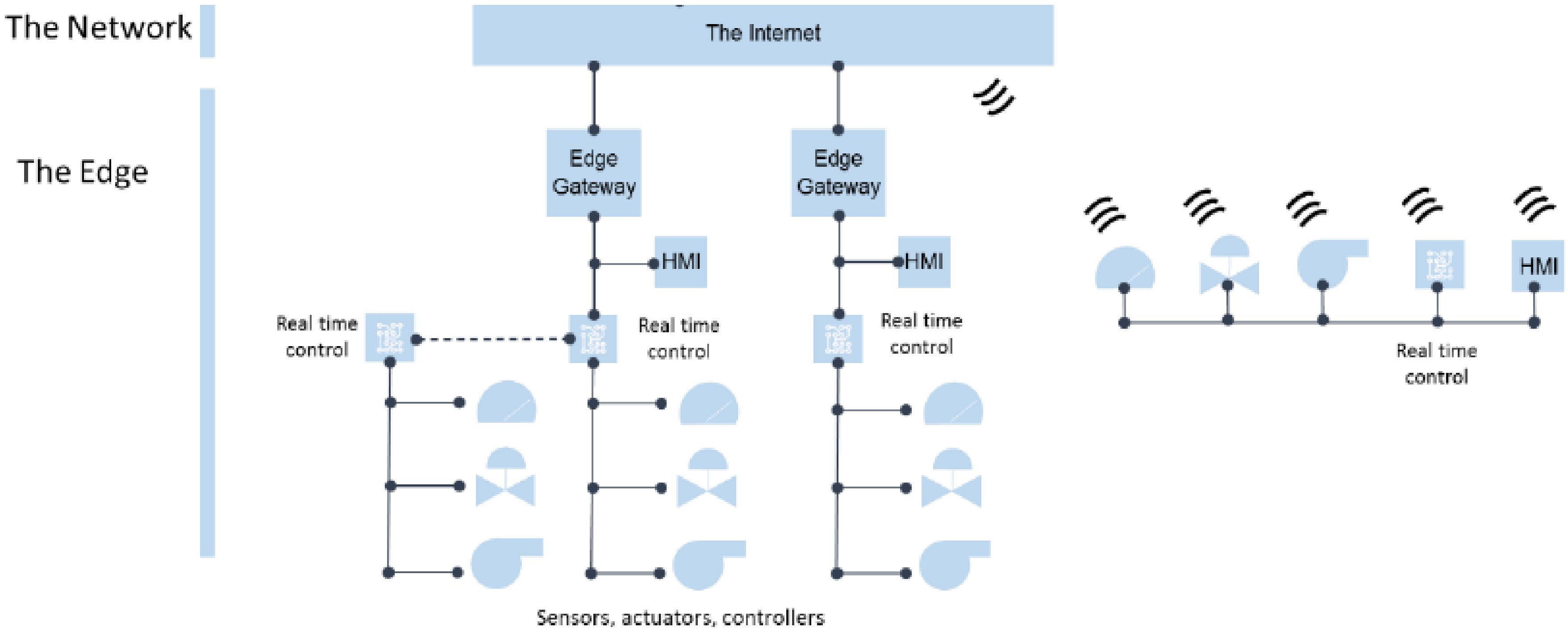
Process optimization: Monitor production processes and provide data to be used for energy-efficiency optimization and to detect equipment or process issues

Electricity demand management: Devices and systems to support 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

IIoT visual representation



IIoT - Advantages

- Enables increased efficiency, reduced downtime and increased productivity
- Enables optimization and adaptation over fixed settings, enhances process and quality control
- Takes human guesswork out of process control, reduces human error, reduces skill and experience levels required for some processes, reduces unnecessary adjustments, manual data collection, testing and maintenance
- Enables early detection of potential hazards, enhances safety management
- Enables remote and centralized monitoring
- Accelerates response times with real-time collection and processing of operational data
- Enables automated regulatory compliance and utility program performance

IIoT - Considerations

- Requires replacing analog devices with digital devices
- More connections mean more potential points for cyberattacks; IIoT systems require encryption, authentication and regular security audits
- Integration of IIoT with existing IT and communication systems can be a complex task
- IIoT systems generate massive amounts of data that 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, humidity, etc.)
- Many of these devices and systems require calibration and maintenance by skilled workers in high demand

IIoT – Adoption

- Most industrial facilities in Ontario have internet-connected electrical, gas and water meters
- Other common applications include access control and building automation systems for HVAC, lighting etc with remote access and monitoring
- IIoT devices and systems for process control, logistics and product traceability are being adopted in industries with very demanding supply chains, such as automotive, pharmaceuticals, aerospace, logistics as well as some food and beverage plants
- Early adopters report overall energy savings of up to 25%, maintenance cost reductions of up to 30% and improvements in defect reduction and productivity increases of up to 15%

IIoT – Adoption (Cont'd)

- Ontario examples include torque measurements on fastening robotics, welding quality monitoring, Thermolator® control (plastic moulding), vibration analysis, oil quality monitoring, vehicle tracking, blockchain traceability of products, complex temperature monitoring with hundreds of sensors, etc.
- Heavy industry IIoT systems are focused on major safety, environmental and energy system management such as leak monitoring, power management, personnel and vehicle locators and emission control equipment performance
- Growing rapidly as technologies, qualified suppliers and trained users increase
- 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

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 new support tools and resources
- Live training calendar: Visit this page to easily register for upcoming events and workshops
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