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Emerging Energy Efficient Technologies in Steelmaking Information Session

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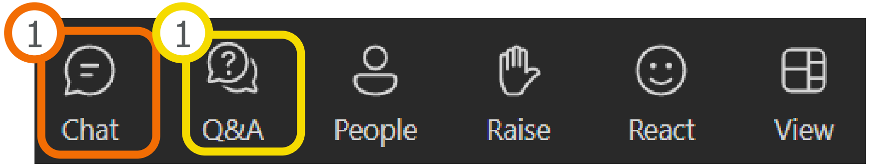

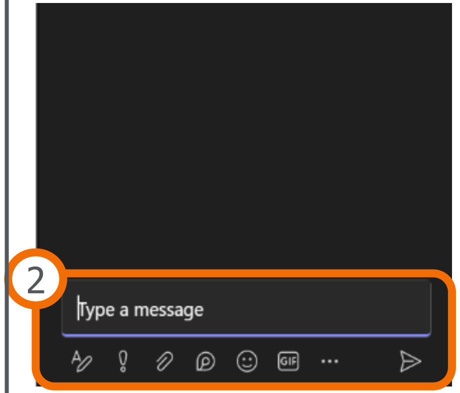

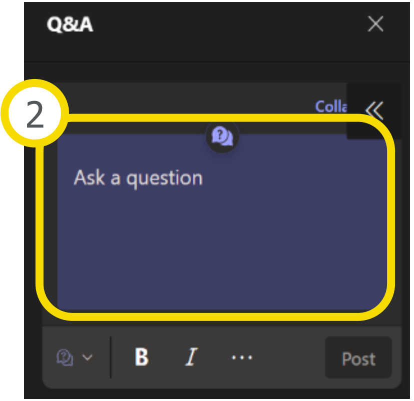

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SAVE ON ENERGY POWER WHAT'S NEXT

Introduction

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

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

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

30 years of project and operations experience, specializing 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 emerging technologies in the steelmaking sector that support energy efficiency and de-carbonization, with a focus on:

- Transition from blast furnace-basic oxygen furnace to electric arc furnace
- Transition from blast furnace to direct reduced iron
- Carbon capture utilization and storage
- Continuous scrap charging and pre-heating conveyor for electric arc furnaces

Ontario steelmaking industry – Current State

- Ontario's three integrated steelmaking operations produce all or most of their steel with the blast furnace (BF) – basic oxygen furnace (BOF) process
- Electric arc furnaces (EAF) are used in "mini-mill" sites that do not have blast furnaces, and to supplement some integrated operations
- The industry produces approximately 40% of Ontario's industrial greenhouse gas (GHG) emissions
- Direct GHG emissions (Scope 1) come from CO_2e release during the coke, iron and steelmaking processes, and from natural gas combustion for re-heating
- 15% of the industry's overall energy input is electricity (electric furnaces and ovens, gas production), motor loads (fans, pumps, rolling mills, cranes)

Transition from BF-BOF to EAF

- Requires capital-intensive investment and very complex project management
- Requires higher-capacity and higher-quality power supply and several fold increase in scrap metal preparation, storage and handling processes
- EAFs have been used for decades, but advances in technology allow power management during each of the melting phases to optimize energy efficiency and electrode consumption
- EAFs are now also able to use metal inputs other than scrap steel

By Uddeholms AB - Communications Department, Uddeholms AB, Public Domain, Link

Transition from BF-BOF to EAF

Advantages

- Removes or reduces coal, coke and natural gas inputs
- Removes some upstream supply chain processes
- Batch process, easy to start and stop
- Enables large-scale emission reductions
- Flexibility to be standalone or work with conventional BF-BOF operations
- Cost savings from reduction in carbon price paid

Considerations

- Requires up to 500 percent higher electricity input, utility may not be able to provide
- Requires significantly more investment in power supply and management
- Requires much larger amounts of scrap metal, may require significant supply chain changes
- Production of steel grades that require high iron content may not be feasible

Transition from BF-BOF to EAF – adoption

- Worldwide, 30% of steel made with EAFs, mostly in mini-mills

Algoma Steel (Sault Ste. Marie)

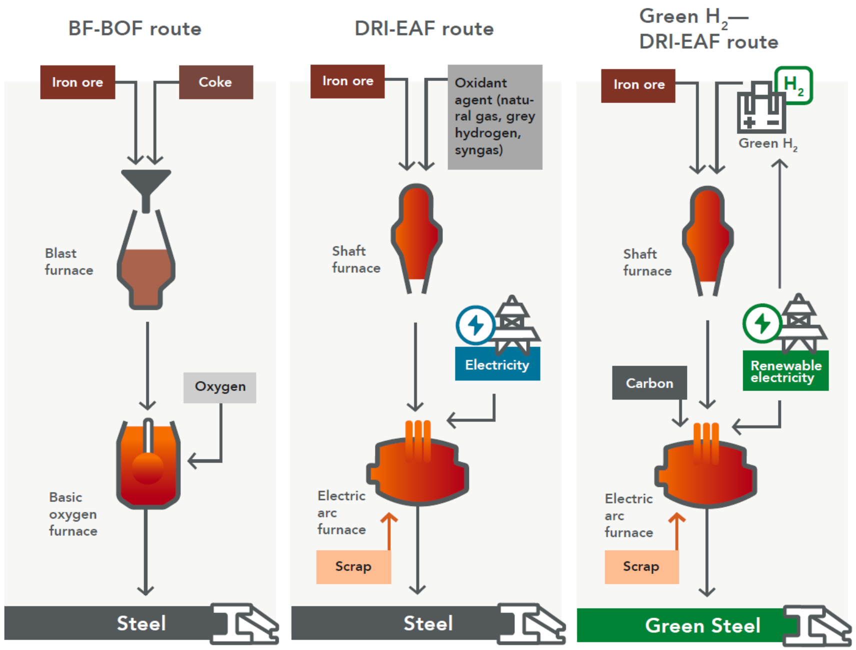
- Transitioning from BF + two BOFs to a BF + two EAFs (liquid iron and scrap)
- Closing BF once power is available (2030) to run EAFs without liquid iron
- EAFs will be compatible with hydrogen inputs (when available), also converting re-heat furnaces from gas to electric and biogas (biomass from local sawmills)

ArcelorMittal Dofasco (Hamilton)

- Currently uses a BF with one BOF and one EAF for steelmaking
- BF ironmaking will be replaced by direct reduced iron (DRI) process and will transition from BOF to all-EAF steelmaking.

Transition from BF to DRI

- DRI process uses "reduction" chemistry to remove oxygen from iron ore below the melting point of iron
- The "reducing gas" is usually carbon monoxide produced from natural gas or coal; less energy and lower CO_2 emissions than BF
- Hydrogen is also a reducing gas producing H_2O (water) instead of CO_2, but hydrogen produced from fossil fuels is not carbon-free
- DRI can be used in BOF or EAF, reduces reliance on scrap and produces some higher-value steels not possible with all-scrap input
- DRI can be used hot or stored and/or shipped



Transition from BF to DRI

Advantages

- Significant operating cost savings and environmental benefits
- DRI (especially if hot) requires significantly less electricity input than scrap steel in an EAF process
- The nature of the DRI-EAF process makes carbon capture more technically feasible than in the BF-BOF process

Considerations

- DRI-EAF requires a much higher electricity supply per tonne of steel compared to BF-BOF, utility may not be able to supply
- Generally requires significant changes in supply and cost management of electricity
- DRI is highly susceptible to oxidation and rusting if stored improperly

Transition from BF to DRI

Artist rendering of typical DRI plant

https://tenova.com/technologies/energiron

Transition from BF to DRI – adoption

- Integrated DRI steelmaking has greatest adoption in Russia, India, Trinidad and Malaysia, and gaining interest for environmental benefits since 2016
- Canada's only DRI is at ArcelorMittal (Contrecoeur QC), producing iron pellets for shipment since 1972

ArcelorMittal Dofasco (Hamilton)

- Currently operating with both BF-BOF and EAF, is replacing BF ironmaking with a DRI process, while new EAF equipment will replace the BOF
- The DRI plant will initially operate with natural gas and will reduce annual CO_2e emissions by approximately three million tonnes, (60% reduction)
- The DRI plant will be 150m tall and designed to be hydrogen-ready, when suitable supply is available

Carbon capture utilization and storage (CCUS)

- Carbon capture utilization and storage (CCUS) involves the capture of CO_2 with other process emissions at the source with gas handling systems (hoods, ductwork, fans, etc.)
- CO_2 is separated with scrubbing technologies, then compressed and transported to storage sites
- Storage can be in transportation containers (tanker trucks or railcars), pipelines or injected into underground storage cavities or porous rock formations
- There are also many uses of CO2, including in fertilizers and biofuels
- Worldwide, around 45 commercial facilities have applied CCUS to industrial processes and there are more than 700 CCUS projects in various stages of development

CCUS – advantages

- Can be applied to many existing or new heavy industrial processes, including BF-BOF and DRI-EAF steelmaking, without significantly affecting production
- For newer BF-BOF steelmaking, smelters, refineries, etc. with a long service life, CCUS presents a valuable opportunity
- Significant government funding opportunities and tax credits are available

https://fossil.energy.gov/archives/cslf/Projects/AlReyadah.html

CCUS – considerations

- Requires capital-intensive investments
- Introduces unique technical challenges and environmental risks at each site
- Highly dependent on geological conditions, availability of geological data, seismic activity, legacy water and gas wells, etc. for successful underground CO_2 storage
- Creating a CO_2 transportation network (trucks, trains, pipelines) presents a distinct set of challenges not unlike transportation of natural gas
- In the province of Ontario, the regulatory and legal frameworks for off-site carbon storage are yet to be developed

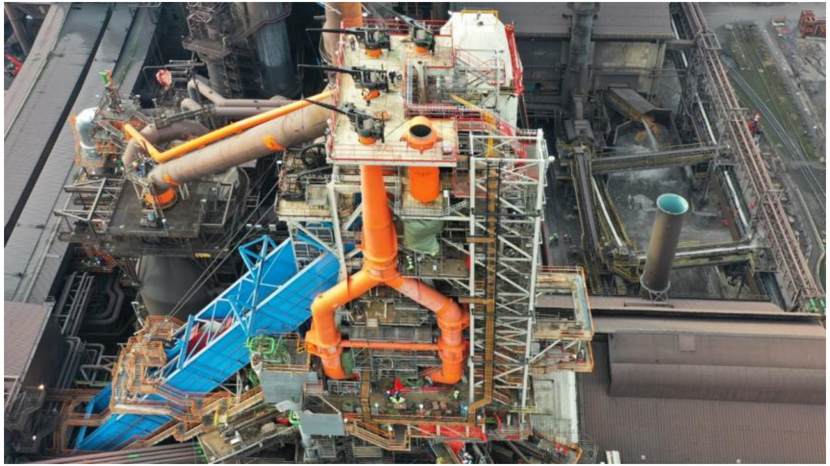
CCUS – adoption

- CCUS has not yet been used in the Canadian steel industry
- Alberta Carbon Trunk Line (ACTL) is a 240-kilometre pipeline that collects CO_2 from several Edmonton-area refineries for use in enhanced oil-recovery projects or stored underground in depleted oil reservoirs
- Alberta's Quest Carbon Capture and Storage project at the Scotford Upgrader (oil refinery) captures CO_2 using amine absorption technology and transfers it by pipeline for injection into suitable rock formations
- Al Reyadah (UAE) CCUS facility, started in 2016, world's first and only operating commercial-scale plant in the steel sector, captured 27% of the DRI plant emissions in 2023

CCUS – adoption

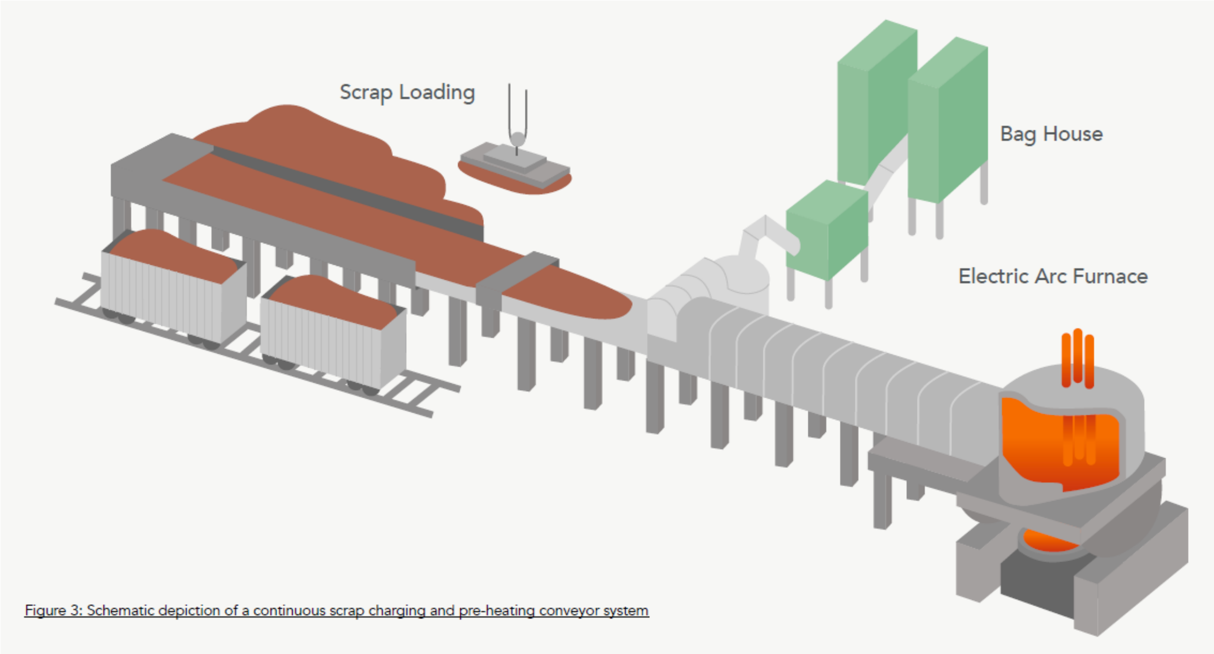
ArcelorMittal and partners operate a pilot carbon capture unit on the blast furnace off-gas system at Gent, Belgium, with plans to supply CO_2 transport and storage projects under development in the North Sea region.

One technology under investigation involves using plasma to convert captured CO_2 into carbon monoxide, which can be used as an energy source in steelmaking and for chemical production.



Arcelor Mittal CCUS Pilot Plant in Belgium

Continuous scrap charging and pre-heating conveyor for EAF



Schematic Depiction of Consteel® System

Continuous scrap charging and pre-heating conveyor for EAF

- Charges scrap through the side of EAF, no withdrawal of electrodes or opening of EAF roof to charge from above, reduces handling time and heat loss
- Serves as main heat and fume collection system, drawing EAF off-gas
- Scrap is pre-heated to 300-400ºC, reducing electricity requirements
- When EAF emissions are drawn through the conveyor, metallic dust that would end up in the baghouse sticks to the hot scrap metal, reducing the need to handle / dispose of dust and increasing steel yield
- Pre-heating scrap eliminates moisture, preventing steam reactions in the EAF
- As hot scrap is continuously introduced into a molten bath, electrodes make arc contact with liquid instead of solid scrap, reducing wear and tear and harmonic and flicker problems

Continuous scrap charging and pre-heating conveyor for EAF

Advantages

- Scrap charging crane not required, EAF roof removal not required
- Reduces tap-to-tap cycle time up to 30 percent, and up to 30 percent electricity savings
- Increases steel yield, eliminates moisture from scrap, reduces emissions and baghouse dust
- Improves electrode life, reduces electrical harmonic and flicker issues
- Can be applied to existing EAF

Considerations

- Complex installation if existing EAF system in constrained location
- Requires a relatively large footprint
- Requires airtightness and maintenance for pre-heating section
- Requires process continuity to achieve a high level of savings

Continuous scrap charging and pre-heating conveyor for EAF

Adoption

- Worldwide, about 500 steelmaking plants operate full-size EAFs
- Most common continuous charging and pre-heating system is Consteel® by Tenova, first installed in USA (1989) still operating, now 80 other installations operating from Brazil to Vietnam, most installed after 2010
- There are other pre-heating technologies that use side conveyors and some that use top-loading (EAF shaft)

Continuous scrap charging and pre-heating conveyor for EAF

Adoption

- Ivaco Rolling Mills in L'Orignal, Ontario installed a Consteel® system in 2012, realizing 21,700 MWh in annual electricity savings, and 8 year project payback
- https://saveonenergy.ca/-/media/Files/SaveOnEnergy/Industry/IVACO-CaseStudy.pdf

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Appendix – acronyms

- Greenhouse Gas (GHG)
- Carbon Dioxide Equivalent (CO_2e)
- Blast Furnace (BF)
- Basic Oxygen Furnace (BOF)
- Electric Arc Furnace (EAF)
- Direct Reduced Iron (DRI)
- Carbon Capture Utilization and Storage (CCUS)