Author: CSPA and CISERA
Date: 18-November-2024

CSPA/CISERA Steel Industry GHG Reduction R&D Overview

Background

As an industry with fixed-process emissions of greenhouse gases, the steel industry will need to research, develop and implement major technology changes in the future to drastically reduce its emissions. Significant innovation and technology breakthroughs will be essential for the industry to achieve its aspirational goal of net zero carbon emissions by 2050. The Canadian Steel Producers Association (CSPA) and the Canadian Carbonization Research Association (CCRA) have developed a R&D action plan following a stepwise transition approach.

(2020-2025) Near future R&D and implementation: Implementation of technologies to reduce GHG emissions of ironmaking and steelmaking using existing production facilities.

(2020-2050) Long term R&D: Potential reduction of fixed-process emissions. Pursuit of net-zero carbon emission steelmaking technology.

This is a living document that will be updated as required.

References:
CSPA Canada's Steel Industry: A Sustainable Choice
ArceloMittal Climate Action Report 1 May 2019
IEA Iron and Steel Technology Roadmap

Goal Statement

- To provide technical pathway to decarbonize the steel sector
- To achieve significant reduction in GHG emissions in ironmaking and steelmaking processes with existing production facilities
- To research and develop non-fossil carbon based iron and steelmaking processes to replace existing fossil carbon based technology to achieve net-zero carbon emissions in steel production
- To improve the productivity and global competitiveness of the Canadian steel sector during this transition

Specific Objectives

R&D objectives to support implementation in near future (5-10 years)
- To substitute fossil carbon reductants by renewable biocarbon in blast furnace ironmaking and EAF steelmaking
- To substitute combustion of fossil fuel by alternate low carbon fuel for heating
- To explore potential of electrification in steel production
- To improve management and utilization of waste heat
- To explore potential of carbon capture, utilization and storage in steel production

R&D objectives to support implementation inlong Term (10 years+)
- To advance alternate ironmaking technologies, including H2 DRI and electrolytic ironmaking
- To advance steelmaking technologies in order to utilize the alternative iron sources
- To develop technologies for production, storage and delivery of gaseous reducing agents to support DRI processes
- To develop technologies for non-emitting and renewable electricity generation to support alternate ironmaking technologies in the steel industry
- To apply CCUS in iron and steelmaking processes for establishing circular carbon pathway and long term carbon sequestration

Net Zero Emission Technology Development

(1) Supply of Alternate Reductants and Alternate Fuels
- Sustainable biomass feedstock supply and biogenic reductants and fuels production
- Regional H2 hub establishment
- Non-emitting electricity supply and electricity grid infrastructure development

(2) Utilization of Alternate Reductant (Biocarbon, H2, Electron)
- Solid Biocarbon Utilization
  - Utilization of solid biocarbon in iron ore pellet production
  - Blast furnace solid biocarbon direct injection
  - Incorporation of solid biocarbon in cokemaking coal blend
  - Utilization of solid biocarbon in EAF steelmaking
- Renewable Gaseous Reductant (H2 and/or biogenic gases) Utilization
  - Direct reduction of iron ore by gaseous (H2 carriers and/or biogenic gases) reductants
  - Blast furnace H2 direct injection
- Electron Utilization
  - Electrolytic ironmaking

(3) Utilization of Alternate Heating (Renewable Fuels, Non-Emitting Electricity and Small Modular Reactor Heating)
- Fuel Switching-Biogenic fuels and/or H2/H2 carriers utilization for heating
  - Enabling technology development (e.g. burner design)
- Electrical Heating Utilization
  - Indirect resistance heating (radiation and convection heating by globar)
  - Direct resistance heating (current flows directly to the material)
  - Induction heating (induce electrical current inside material by magnetic field)
  - Hot-streams heating (Pre-heated hot inert gas)
- Small modular reactor (SMR) for heating
  - Assessment of the potential of SMR heat utilization in iron and steel production
- Waste Heat Recovery and Utilization
  - Development of enabling technologies for process waste heat recovery
  - Integration of recovered heat from unit operations within the process

(4) CO2 Capture, Utilization, Transportation and Storage
- CCS hubs development roadmap
- Further development of post combustion CO2 capture technology
  - Absorption and adsorption
  - Calcium looping
  - Algae
  - Microbial fermentation
  - Other technology
- Application of CO2 capture in iron and steel production
  - Assessment of CO2 capture options in BF-BOF process
  - Assessment of CO2 capture options in DRI process
  - Assessment of CO2 capture options in EAF process
  - Development of technology for enabling CO2 capture in primary processes
- Utilization of captured CO2
  - Development of technology to convert CO2 into marketable products (e.g. methanol, jet fuel, ethylene)
  - Assessment of technology options in iron and steel industry
  - Assessment of other raw materials input to enable conversion
- Transportation of captured CO2
  - Development of CO2 pipeline routing
  - Assessment of CO2 transportation cost

Net Zero Emission Technology Development

- Long term storage of captured CO2
  - Assessment of CO2 storage locations
  - Assessment of CO2 storage cost

(5) System Integration and Optimization
- Assessment of decarbonization scenarios on downstream process and product properties
- Process Integration
  - Integration of CO2 capture into BF-BOF process
  - Integration of CO2 capture into DRI process
  - Integration of CO2 capture into EAF process
  - Integration of biogenic reductants and fuels production into steel production
  - Integration of waste heat recovery within steel production
- Business case assessment
  - Modeling tool development including scope 1, 2 and 3 emissions
  - Techno-economic and techno-dynamic analysis of various scenarios and combination of scenarios for development of net-zero emission roadmap
  - Life cycle analysis on overall energy and GHG benefits of biocarbon utilization in steel production

Technology Implementation

(1) To be implemented in near future (5-10 years)
- Support industrial transition to lower GHG steelmaking routes.
  - Pareto of CO2 generation in steel plants and heavy industries – would need companies to provide so we can see the size of the problem.
  - Recognition of potential further reduction in GHG within heavy industries.
- Biofuels will continue to play a key role in industrial decarbonization. Current applications in coke and iron will continue, but further work is needed in other areas
  - Biocarbon application in the EAF, this work has started but is becoming more important in Canada. This will have broader applications to other CSPA member companies.
  - Biomass supply chain development – need a better understanding of quality, quantity, and location/supply routes for Canadian biomass – forestry has strong potential.
  - Biogas/RNG applications – potential to replace process NG.
- Develop key partnerships and funding opportunities for industrial partners/members
  - Working with Indigenous groups which is most important for stakeholders.

(2) To be implemented in long terms (10 years+)
- This work would encompass the non-fossil fuel conversion of heavy industry using electrons and hydrogen.
- Alternative green fuels and processes.
- Hydrogen will need support from other industries and regional hubs to support demand and lower prices
  - Understand key users and identify potential hydrogen hubs
  - Development of supply technologies (e.g., electrolysers)
  - Steelmaking research to focus on H2 substitution
- Development of CCS and CCU for various heavy industries.
  - Develop key partnerships and funding opportunities for industrial partners/members. Business plan development.
- By-products of CO2 capture.
- Business case development.

Author: Peter Gogolek
Date: 18 November 2024

Net Zero Emissions Steel R&D: Supply of Alternate Reductants/Fuels

CISERA

Background

In responds to the CSPA call for climate action (Canada's Steel Industry: A Sustainable Choice), CCRA has developed a research program to address the technical challenges in achieving net-zero emission steel production by 2050 (New Ear for CCRA). In the CCRA research program, activities are categorized into 5 pillars for promoting collaboration between research groups and with industrial partners. The supply of alternate reductants and alternate fuels is one of the R&D pillars.

The drive to replace fossil-based fuels and reductants targets three complementary routes: biomass and its derivatives, hydrogen (low-carbon), and renewable electricity. Each has the same general issue of developing the supply at a reasonable price. Biomass, bioproducts and bioenergy is perhaps the most challenging as the supply chains, conversion technologies, and properties needed in the bioproducts are still being developed.

Goal Statement

To establish the economically sustainable supply of alternate reductants and alternate fuels by:

- Identification of sustainable biomass feedstock supplies and biogenic reductants and fuels production, with the necessary processing to provide bioproducts suitable to the iron and steel industry;
- Establishment of regional renewable hydrogen hubs; and
- Non-emitting electricity supply and electricity grid delivery infrastructure development.

Specific Objectives

- To establish reliable quantification of the supply of biomass in Canada, with database of properties, and models for different collection/transformation/distribution scenarios
- To establish the gasification technologies suitable to feed DRI and the range of syngas composition produced from likely feedstocks
- To establish rigorous descriptions of the effect of process parameters and feedstock properties on the properties of biocarbon produced by slow pyrolysis, and relate these properties to behaviour in industrial equipment
- To establish the properties of bio-oils from fast pyrolysis and the means to use these products in the iron and steel industry
- To establish international standards for pyrogenic biocarbon, mitigating risk for adoption by industry and assisting the development of the supply-side
- To establish the characteristics of economically attractive and environmentally sustainable hydrogen production and supply hubs

Projects Overview

Biomass Supply

- **High-Impact Feedstocks**
  - Identify feedstocks with high volumes and concentrations
    - Survey and reconcile public domain estimates of residues
    - Rank according to three categories – woody, agricultural and municipal
  - Database of properties
  - Evaluation of hub-and-spoke compared to linear conversion supply models

Gasification

- **Survey of technologies and syngas compositions suitable for DRI**
  - Biosyngas combined with renewable hydrogen to optimize thermal performance
- **Identification of mid-scale gasification technologies to displace natural gas as a fuel**
  - Updraft and downdraft gasifiers produce fuel gas at 1 – 20 MWth scale
  - Applications in smaller facilities like reheat furnaces
- **Production of renewable hydrogen**
  - Biosyngas processing to maximize hydrogen production
  - Possibility of CO2 capture for negative carbon emissions
- **Electricity generation from product gas**
  - Scenario development for electricity generation in engines and turbines using product gas (air-blown) or syngas, or residual gas from hydrogen production

Slow Pyrolysis

- **Rotary drum/screw reactor**
  - Effect of temperature, residence time of biocarbon properties
  - Effect of feedstock properties on biocarbon properties
  - Possibility of interactions for combinations of feedstocks
- **Upgrading vapour by-products**
  - Characterize yield and composition of vapour products
    - Variability with feedstock and processing conditions
  - Condense and separate liquids
    - Chemical and physical properties (fuel suitability)
    - Chemical upgrading to liquid transportation fuel
    - Uses as bioproduct – binder, additive
  - Autothermal reforming to high-quality fuel gas
    - Processing conditions
    - Reactor design
    - Use reforming to minimize variability of fuel gas

Fast Pyrolysis

- **Processing High-Impact Feedstocks**
  - Effect of temperature, residence time of bio-oil properties
  - Effect of feedstock properties on bio-oil properties
- **Uses of bio-oil**
  - Nozzle design for bio-oil burners for standard combustion applications
  - Combustion behaviour in non-standard conditions (i.e., PCI injection) and design solutions
  - Applications as binder for biocarbon applications
  - Slurry production and properties as gasification feedstock to maximize energy content

Projects Overview

Biocarbon Standards

- **Participate in ISO TC238 to adopt and develop standards for pyrogenic biocarbon**
  - Identify the existing international standards that suit pyrogenic biocarbon
  - Identify gaps in the suite of existing standards and work to develop suitable standards
  - Identify standards most applicable to iron and steel production uses
  - Direct a Canadian mirror committee to ensure the national perspectives for both producers and users are represented internationally
  - Lead, where necessary, the international efforts at development of particular standards

Hydrogen Network

- **Modeling, TEA, and LCA of Blue-H2 Production, Purification, and Transportation**
  - Determine the lowest cost and lowest environmental impact pathways for blue-H2 production, purification, and transportation
  - Scenario-based supply and demand models developed for several key H2-hubs across Canada

Project Team

Research Area	Canmet Lead	Industry Lead
Biomass Gasification	Travis Robinson CanmetENERGY-Ottawa Travis.robinson@NRCan-RNCan.gc.ca	
Slow Pyrolysis	Guillaume Gagnon-Caya CanmetENERGY-Ottawa Guillaume.gagnon-caya@nrcan-rncan.gc.ca	
Fast Pyrolysis	Jawad Jeaidi CanmetENERGY-Ottawa Jawad.jeaidi@NRCan-RNCan.gc.ca	
Supply Quantification	Leslie Nguyen CanmetMATERIALS Leslie.nguyen@nrcan-rncan.gc.ca	
Hydrogen	Robert Symonds CanmetENERGY-Ottawa Robert.symonds@NRCan-RNCan.gc.ca	

Author: Ka Wing Ng
Date: 18 November 2024

Net Zero Emissions Steel R&D: Alternate Reductants Utilization

CISERA

Background

In responds to the CSPA call for climate action (Canada's Steel Industry: A Sustainable Choice), CCRA has developed a research program to address the technical challenges in achieving net-zero emission steel production by 2050 (New Ear for CCRA). In the CCRA research program, activities are categorized into 5 pillars for promoting collaboration between research groups and with industrial partners. Alternate reductants utilization is one of the R&D pillars.

Alternate reductants refer to biogenic carbon, hydrogen and electricity from renewable sources for converting iron ore into metallic iron. It focuses on enabling the utilization of reductants from renewable source to replace the currently used fossil carbon reductants in steel production processes. Current efforts emphasize on the utilization of alternate reductants in existing steel production processes to facilitate implementation in near future. It includes utilization of alternate reductants in iron ore pellet induration, cokemaking, blast furnace ironmaking, EAF steelmaking and DRI production. In long term, electrolytic ironmaking will also be addressed when the technology is more mature.

Goal Statement

- To enable replace of fossil carbon reductants by renewable alternate reductants in existing steel production processes
- To inform renewable alternate reductants producers on properties requirement for further enhancement in products suitability for steel production utilization
- To inform steel producers on process modifications in accommodation of alternate reductant utilization while maintaining productivity and products quality

Specific Objectives

- To address the technical challenges in utilization of highly reactive solid alternate reductants for replacement of coke breeze in iron ore pellet production
- To incorporate solid alternate reductants in cokemaking coal blends while maintain resultant coke quality suitable for blast furnace ironmaking
- To replace pulverized coal for blast furnace direct injection by pulverized solid alternate reductants
- To replace nut coke by densified alternate reductant pellet in blast furnace ironmaking
- To replace solid fossil carbon injection for slag foaming in electric arc furnace operation by solid alternate reductants
- To enable utilization of gaseous alternate reductants in direct reduced iron production without affecting energy efficiency of the subsequent melting step

Projects Overview

Iron Ore Pellet Production

- **Substitution of Coke Breeze in Iron Ore Pellet Production**
  - Combustion characteristics evaluation
    - Development of TG-DSC-FTIR analysis technique
    - Application of analysis technique for potential candidates' suitability evaluation
  - Combustion characteristics enhancement
    - Effect of raw biomass feedstock and pyrolysis conditions
    - Post treatment of biocarbon
  - Utilization of alternate carbon in iron ore pellet production
    - Agglomeration of alternate carbon with iron ore
    - Effect on resultant iron ore pellet quality
  - Industrial scale plant trial

Cokemaking

- **Incorporation of Biocarbon in Cokemaking Coal Blend via Partial Briquetting**
  - Coal/Solid Biocarbon/Biobinder briquette production
    - Briquette composition optimization
  - Proof of principle
    - Small scale carbonization of coal/briquette mixture
  - Pilot scale demonstration
    - Pilot scale carbonization of coal/briquette mixture for resultant biocoke quality quantification
  - Resultant biocoke quality enhancement
    - Microscopic analysis of resultant biocoke to reveal effect of biocarbon incorporation on surrounding coal transformation into coke
    - Selection of coal with optimal property for briquetting with biocarbon to enhance resultant biocoke quality

Blast Furnace Ironmaking

- **Substitution of Pulverized Coal Injection by Biocarbon Injection**
  - Grindability of coal/biocarbon mixture
    - Effect of biocarbon substitution on injectant pulverization
  - Biocarbon combustion behavior
    - Injection rig assessment
  - Industrial scale plant trials
- **Substitution of Nut Coke by Densified Biocarbon Pellet**
  - Candidate suitability assessment technique development
    - Physical properties (density, impact strength, abrasive strength)
    - Devolatilization and CO_2 gasification behavior
    - Effect on iron ore pellet reduction performance
  - Potential candidates' suitability assessment
    - Application of the developed technique for suitability assessment
  - Handling and storage
    - Laboratory weathering of potential candidates
    - Properties assessment of weathered sample
    - Leachate analysis for environmental impact assessment
  - Industrial scale plant trial

Projects Overview

Electric Arc Furnace (EAF) Steelmaking

- **Substitution of Injection Carbon for Slag Foaming**
  - Interaction between molten slag and biocarbon
    - Tensiometer observation of interfacial phenomena for assessment of potential candidates' foaming capability
    - Technology development on potential candidates' foaming capability enhancement
  - Delivery of material to slag surface
    - Assessment of biocarbon flowability for pneumatic transportation
    - CFD modeling on particle trajectory in furnace and interaction with molten slag surface
  - Slag Foaming Capability of Assessment
    - Setup of injection facilities for physical simulation of carbon injection for slag foaming
    - Physical assessment of potential candidates' foaming capability
    - Generate data for CFD model develop to assist scale up
  - Industrial scale plant trial

Direct Reduced Iron

- **Biogenic gas utilization in DRI shaft furnace**
  - Reduction and Carburization by H_2/Biogenic gas
    - Setup of laboratory facilities for examining reduction and carburization of iron ore pellet
    - Technical feasibility of biogenic gas utilization
    - Chemical and mineralogy characterisation of resultant DRI
    - Melting characteristics of resultant DRI
    - Define biogenic gas composition requirement

Project Team

Research Area	Canmet Lead	Industry Lead
Iron Ore Pellet	Xianai Huang CanmetENERGY-Ottawa xianai.huang@NRCan-RNCan.gc.ca	
Cokemaking	Kun Liu CanmetENERGY-Ottawa kun.liu@nrcan-rncan.gc.ca	
Blast Furnace	Ka Wing Ng CanmetENERGY-Ottawa kawing.ng@NRCan-RNCan.gc.ca	
Electric Arc Furnace	Christopher DiGiovanni CanmetMATERIALS christopher.digiovanni@nrcan-rncan.gc.ca	
Direct Reduced Iron	Xianai Huang CanmetENERGY-Ottawa xianai.huang@NRCan-RNCan.gc.ca	

Author: Kelly Atkinson
Date: 18 November 2024

Net Zero Emissions Steel R&D: Carbon Capture, Utilization, and Storage

CISERA

Background

In response to the CSPA call for climate action (Canada's Steel Industry: A Sustainable Choice), CCRA has developed a research program to address the technical challenges in achieving net-zero emission steel production by 2050 (New Era for CCRA). In the CCRA research program, activities are categorized into 5 pillars for promoting collaboration between research groups and with industrial partners. Carbon capture, utilization, and storage (CCUS) is one of the R&D pillars.

Most steelmaking facilities in Canada are transitioning from the conventional blast furnace-basic oxygen furnace (BF-BOF) production route to electric arc furnaces (EAF), sometimes coupled with direct reduced iron (DRI) production upstream. Transitioning to DRI-EAF has the potential to reduce steelmakers' CO_2 emissions by up to 68%; CCUS is one tool available to eliminate the remainder and attain net-zero. While post-combustion CCUS technologies have been developed commercially for application in industries such as power generation, they are not currently compatible with the dynamic nature of some of the process gas streams from steelmaking, particularly from the EAF. Research and development of new candidate carbon capture technologies is required to be able to apply CCUS to the EAF and achieve net-zero by 2050. Development of CO_2 utilization technologies, as well as de-risking of CO_2 transportation and storage, will be required to enable Canadian steelmakers to pursue these decarbonization strategies with confidence.

Goal Statement

- Create a technology roadmap and decarbonization strategy for hard-to-abate CO_2 emissions from Canadian iron and steel production
- Advance the technology readiness level of priority emerging carbon capture technology(ies) to TRL6 for dynamic applications
- Demonstrate how application of CCUS for iron and steel production fits into the bigger picture of decarbonization of Canada's industry via CCUS and hydrogen production/utilization
- Advance the development of CO_2 utilization technologies
- Address key knowledge gaps in CO_2 transportation safety, geological storage in Central and Eastern Canada, and quantification of CO_2 emissions from storage wells

Specific Objectives

- Develop a model of the EAF in order to generate off-gas profiles for different operating scenarios, including different iron supplies (scrap, conventional DRI, H_2-CRI, etc) and different carbon charge sources (fossil fuels, bio-based fuels)
- Evaluate 2-3 candidate carbon capture technologies via bench-scale testing, including fixed bed chemical looping and inertial CO_2 separation
- Develop tools to predict the cost and environmental impact of CO_2 capture/removal, transportation, utilization, and storage Canada-wide for various scenarios
- Develop CO_2 utilization processes in the areas of conversion and mineralization with higher efficiencies and lower energy consumption than existing conversion and mineralization technologies

Projects Overview

Dynamic Carbon Capture for Iron and Steel Production

Electric Arc Furnace Model Development

Knowledge of the off-gas properties from the EAF is required to be able to design, model and test suitable carbon capture technologies. The project will acquire representative operating data from Canadian EAF facilities (off-gas composition, flow, temperature, and pressure vs. time); build a stochastic model to predict EAF off-gas based on operating data for various operational archetypes; and evaluate how EAF off-gas properties will be affected through the use of biogenic reductants in the EAF.

Screening of Candidate Carbon Capture Technologies

A literature review will identify technologies that have the potential to meet the needs of the EAF. Membrane separation, fixed bed chemical looping, and inertial separation of CO_2 have all been shortlisted for evaluation at this stage, with more to be added as they are discovered or conceived. The strongest candidates will be evaluated by building detailed optimized process simulations and conducting techno-economic and life cycle assessment (TEA-LCA) in order to down-select 2-3 technologies for evaluation with bench-scale testing.

Fixed Bed Chemical Looping Technology Development

Fixed bed chemical looping (CL) is an oxy-fuel process with the potential for turn-down that can meet the needs of the EAF. It can be applied to buffer the oxygen from the EAF off-gas stream during oxidizing periods and recover energy during reducing periods. The resulting CO_2 stream will be concentrated (compared energy recovery *via* air-fired combustion), allowing this technology to be effectively paired with further CO_2 capture/purification technologies to meet the product specifications required for transportation and storage. The projet will include building a detailed model of a CL reactor with EAF off-gas as the feed, followed by bench-scale testing and model validation with simulated EAF off-gas.

Inertial CO_2 Separation Technology Development

This technology uses supersonic nozzles to de-sublimate CO_2 from a gas stream, followed by a section that removes the solid CO_2 particles via centrifugal force. Within this project, a technology developed by a collaborator will be scaled up to 5 tonnes per day of CO_2 capture at CE-O and evaluated against the dynamic needs for carbon capture from the EAF.

Technology Roadmap for CCUS at Canadian Iron and Steel Facilities

This task is the synthesis of all modelling and experimental results from previous tasks to create clear and concise guidelines for policy development and dissemination of carbon capture knowledge to industry.

National CCUS Assessment Framework (NCAF)

This project supports the development of a strategy to implement CCUS in Canada in a cost-effective manner. It aims to develop rigorous datasets, network models, and tools that translate process, techno-economic, and life cycle/environmental data for carbon management into a clear, consistent, and accessible format. It will enable predicting the cost and environmental impact of CO_2 capture/removal, transportation, utilization, and storage in order to support development of technical guidelines, policy/market decision-making, infrastructure investment, and industry technology adoption.

Advanced CO_2 Utilization through Conversion and Mineralization

This project will develop CO_2 utilization processes in the areas of conversion and mineralization, with at least 5-10% higher efficiency and 10-15% lower energy use compared to the incumbent processes. One activity specifically targets optimization of aqueous-based CO_2 mineralization of metal slags.

Projects Overview

Investigation of Safety for Accidental CO_2 Release During Transport

Examine key leak scenarios; based on release-, terrain-, and wind-types; and model the resulting CO_2 dispersion to address the key questions:

1. Over what distance from the release is the threat to human health a concern,
2. Where should leak detection and monitoring devices be placed, and
3. What release mitigation measures should be employed?

Develop a tool for broad use by planners, regulators, and the public safety community that estimates the distance over which the threat to human health exists. Support planning and regulation of leak detection and release mitigation.

CO_2 Storage in SW Ontario and Eastern Canada

Address knowledge gaps in three key areas in support of geological CO_2 sequestration by

1. investigating the potential for CO_2 storage in oil and gas reservoirs and saline aquifers in Central and Eastern Canada, including offshore Atlantic reservoirs;
2. Carrying-out field work R&D in shallow reservoirs to better understand CO_2 migration in the shallow subsurface and to better understand the storage potential in basaltic rocks; and
3. Investigating wellbore leakage in abandoned oil and gas wells and developing options to mitigate leakage.

Advancement of Canadian Energy Sector Emissions Measurement, Reporting, Verification, and Mitigation

Investigate volatile organic compound losses due to weathering in storage tanks, methane emissions from de-pressurized energy products (including storage tanks, phase separators, recycled water streams) and develop a new method for real-time methane, carbon dioxide and volatile organic compound quantification from wells, reservoirs and other point-sources. Models will be developed for black carbon and benzene emissions from flares in the gas sector.

Project Team

Research Area	Canmet Lead
Dynamic Carbon Capture for Iron and Steel Production	Nicole Bond, CanmetENERGY-Ottawa nicole.bond@NRCan-RNCan.gc.ca
National CCUS Assessment Framework	Robert Symonds, CanmetENERGY-Ottawa Philippe Navarri, CanmetENERGY-Varennes robert.symonds@nrcan-rncan.gc.ca / philippe.navarri@nrcan-rncan.gc.ca
Advanced CO_2 Utilization through Conversion and Mineralization	Kourosh Zanganeh, CanmetENERGY-Ottawa kourosh.zanganeh@NRCan-RNCan.gc.ca
Investigation of Safety for Accidental CO_2 Release During Transport	Allan Runstedtler, CanmetEnergy-Ottawa allan.runstedtler@nrcan-rncan.gc.ca
CO_2 Storage in SW Ontario and Eastern Canada	David Ryan, CanmetENERGY-Ottawa david.ryan@nrcan-rncan.gc.ca
Advancement of Canadian Energy Sector Emissions Measurement, Reporting, Verification, and Mitigation	Brian Crosland, CanmetENERGY-Ottawa brian.crosland@nrcan-rncan.gc.ca

Author: Milad Aghabararnejad
Date: 18 November 2024

Net Zero Emissions Steel R&D: System Integration and optimization

CISERA

Background

As a major emitter of greenhouse gases, the steel industry needs to undergo major technology changes to drastically reduce its emissions. Innovation and technology breakthrough will be crucial for the transitioning from current status to carbon neutral ironmaking.

In responds to the CSPA call for climate action (Canada's Steel Industry: A Sustainable Choice), CCRA has developed a research program to address the technical challenges in achieving net-zero emission steel production by 2050 (New Era for CCRA). In the CCRA research program, activities are categorized into 5 pillars for promoting collaboration between research groups and with industrial partners. System Integration and optimization is one of the R&D pillars. Sustainable system integration and optimization involves incorporating decarbonization technologies into steel production processes and developing a validated modeling tool to assist in business case assessment. However, the availability of low-carbon energy sources, at the scale required for industrial decarbonization, is limited, Therefore, a system-level/holistic approach to pathway arbitrage (i.e., order-of-merit) is needed to prioritize and optimally allocate scarce resources in the industrial sector. Our plan is to delve deeper into the drivers and barriers of implementing selected decarbonization strategies, with a meticulous examination of the risks and opportunities in the supply chain of specific regions. This approach aims to maximize the economic and environmental benefits of these pathways by exploring regional energy arbitrage and the risks and opportunities within the entire iron and steel value chain. By assessing factors such as the availability of green electricity in Ontario and Quebec, competition with other industries for limited resources like biomass and hydrogen, and the implementation of CCUS strategies, we aim to gain a better understanding of the risk factors and opportunities associated with net-zero CO_2 technologies in both regional and global market to avoid stranded assets in high regret. pathways.

Goal Statement

To reduce the greenhouse gas emissions within the iron and steel sector by leveraging waste heat recovery techniques and integrating energy systems.

Specific Objectives

- To reduce energy consumption in the iron and steel sector and consequently reduce GHG emissions not only within each I&S plant, but also in a regional concept.
- To optimize the CO_2 capturing unit from energy point of view by integrating it with the existing I&S plants.
- To optimize the H_2/biocarbon production unit from energy point of view by integrating it with the existing I&S plants.
- To develop the road map to achieve net-zero targets in 2050 for the I&S sector.

Projects Overview

Integration of waste heat recovery within steel production

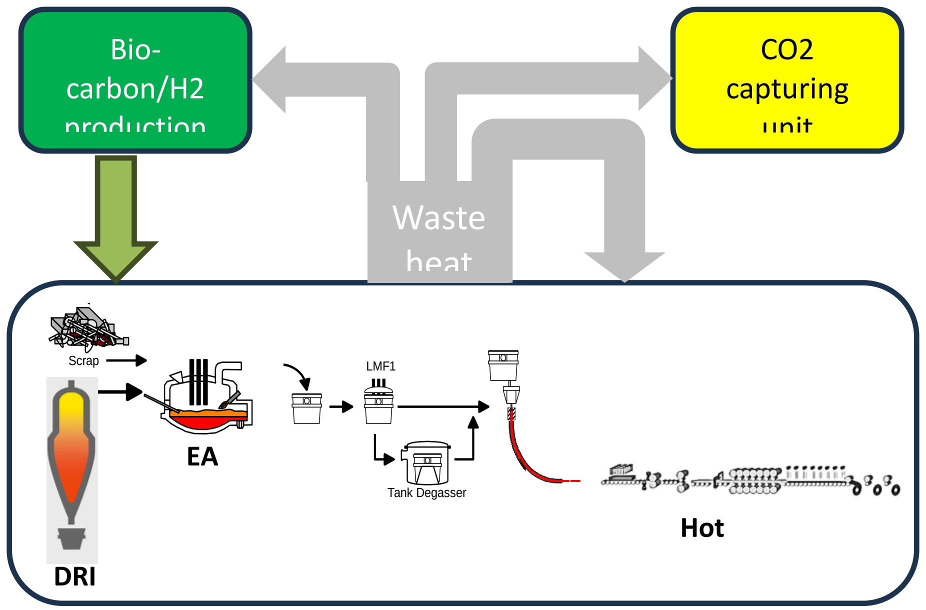
- Assess the current energy consumption levels across various stages of iron and steel production.
- Conduct a comprehensive analysis to identify the primary areas within the iron and steel sector where energy consumption is high or there is a high potential of energy recovery.
- Develop models to maximize energy efficiency, carbon recirculation, and heat recovery for the existing steel refining and casting processes.
- Identify most efficient design of DRI/EAF process considering criteria such as low energy demand, compatibility with renewable resources such as H_2 and biomass and compatibility with BECCS.

Integration of biogenic reductants and fuels production into steel production

- Model the H_2 and bioenergy production pathways integrated with an I&S mill required resource quantities and their respective compatibility with CCS.
- Model the effect of low carbon reductants such as H_2 and biocarbon on the overall integrity of the process.

Integration of CO_2 capture into various sub-processes

- Integration of CO_2 capture into BF-BOF process
- Integration of CO_2 capture into DRI/EAF process

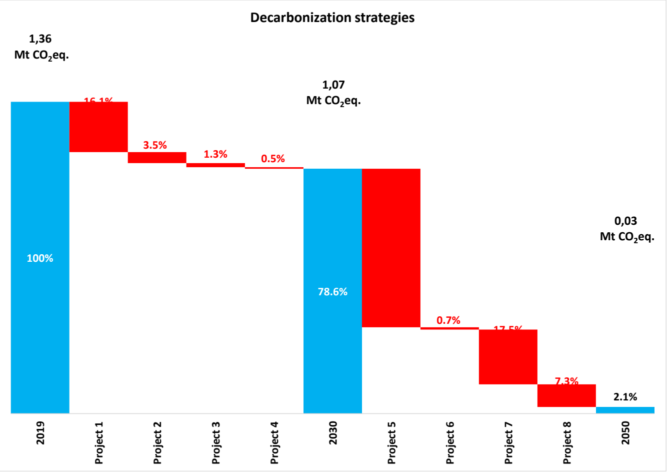


An integrated steel production through the DRI/EAF route

Projects Overview

Carbon neutral/negative I&S plants

- Identify the most viable decarbonization strategies and roadmaps toward a net-zero I&S mill.
  These roadmaps will illustrate the competing decarbonization pathways that are achievable for each sub-sector and regions in Canada, with a view to rapid and cost-effective decarbonization on a national scale, while avoiding stranded assets due to competition for scarce renewable resources.
- Analyse the drivers and barriers for implementing the selected decarbonization strategies.
- Perform regional energy arbitrage, risks analysis, and opportunities for the Canadian steel value chain to better understand competition versus other industries to access limited resources like biomass, renewable electricity and hydrogen and the implementation of CCUS strategies.



Project Team

Research Area	Canmet Lead	Industry Lead
Waste heat recovery	Serge Bédard CanmetENERGY-Varennes Serge.bedard@ NRCan-RNCan.gc.ca Hamed Bashiri The Office of Energy Research and Development (OERD) Hamed.bashiri@NRCan-RNCan.gc.ca	
Integration of H2/biogenic reductants	Milad Aghabararnejad CanmetENERGY-Varennes Milad.aghabararnejad@NRCan-RNCan.gc.ca	
Integration of CO_2 capture	Philippe Navarri CanmetENERGY-Varennes Philippe.navarri@ NRCan-RNCan.gc.ca	
Carbon neutral/negative I&S mills	Etienne Bernier CanmetENERGY-Varennes Etienne.bernier@NRCan-RNCan.gc.ca	