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The Strength of Green Steel

Boosting competitiveness, decarbonizing supply chains, seizing geopolitical advantage

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In 2022, PPF launched a working group to study how Canada can build the electricity supply needed for a net zero economy. Along the way, we learned about green steel and its unique input, DR-grade iron ore. The sector provides a compelling case study of the opportunity inherent in clean electrification. What follows is what we learned.

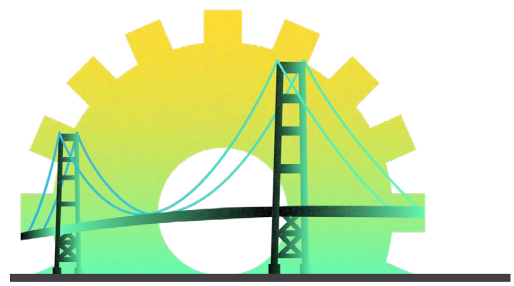
PPF thanks the members of our electrification working group:
ARC Resources Ltd., BC Ministry of Energy, Mines and Low Carbon Innovation, BC Ministry of Environment and Climate Change Strategy, Canada Infrastructure Bank, Capital Power, Deloitte, Emera Inc., Environment and Climate Change Canada, Environmental Resources Management (ERM), General Electric, Hydro Ottawa, Ivey Foundation, RBC, Rio Tinto.

Introduction

To reach net zero, the world — Canada included — will need a lot more product from one of its most emissions-intensive industries: steel-making. Wind turbines, solar panels and electricity transmission towers worldwide will require 2.8 billion tonnes of steel, or the equivalent of 40,221 Golden Gate bridges, by 2050, Bloomberg projects.[1] That's even before accounting for the steel in electric vehicles and other companion infrastructure to the energy transition. This will lead to a 10-40 percent increase in steel demand by 2050, according to the International Energy Agency (IEA).[2]

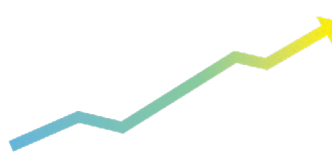
At present, producing one tonne of new steel emits nearly 1.4 tonnes of CO2 on average,[3] while the sector as a whole accounts for two percent of Canada's annual emissions and seven percent globally. Steel is responsible for almost one-fifth of global coal use.[4]

Fortunately, there is a way to square the circle. It goes by the name of green steel,



40,221

Golden Gate Bridges are needed by 2050 for wind turbines, transmission towers, solar panels



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and it has the potential to decarbonize steelmaking. Globally, 60 percent of steel production facilities are reaching the end of their prescribed lives and will be scheduled for either retirement or refurbishment by 2030.[5] This provides the industry with a once-in-a-generation opportunity to adopt the best available production methods.

Countries that lead the way in developing a green steel supply chain will forge ahead in the 21st-century battle for competitive advantage while making an outsized contribution to a net-zero emissions future. The movement to green steel can enable domestic decarbonization while generating a green industrial advantage in export markets and tamping down the geo-economic challenges of rival nations. It is a win-win-win.

Green steel output is wholly dependent on its inputs. With current technologies, one process of producing green steel requires a higher purity of iron ore — what is known as direct reduced-grade (DR-grade) iron ore. Fortuitously, Canada is blessed with iron ore deposits that can be converted to DR-grade iron ore products. As well, companies currently mining these deposits operate integrated port and rail supply chains that facilitate market access.

While significant attention and government support have been allocated to decarbonizing downstream steel manufacturing, the pivotal role that upstream mining and processing activities must play in the transition is vastly under-appreciated. Realizing the potential of green steel requires change at all stages of the supply chain, from the quality of iron ore, to the electrification of mining and processing operations, to zero-emissions transportation, to the availability of clean power in the manufacturing process.

It is well known that Canada's high quotient of clean electricity can provide a competitive advantage to heavy industries such as mining and steelmaking. Less understood is that we enjoy a privileged global position in possessing the grades of iron ore that are needed to produce high-end and low-carbon steel. Expanding access to this key resource at the front end of the supply chain will help enable net zero here at home as well as provide a product that can be sold around the world.

Steel is responsible for almost **20%** **of global coal use**

60% of steel production **facilities are due for refurbishment** by 2030

Steelmaking: A Process That Requires Critical Inputs

Steelmaking is an exacting science; the physical and chemical properties of manufactured products are influenced by the attributes of their inputs. Just as there are various qualities of steel outputs that are more or less suitable for different products, there are also varying qualities of key inputs, ranging from scrap steel to iron ore. Each has its own path to a green steel future.

Scrap

In scrap-based steel production, electric arc furnaces (EAFs) may be used to melt and recycle scrap steel inputs, making it possible to electrify the full process. The energy intensity of the process is about one-eighth the intensity used to produce steel from iron ore. From an energy demand and emissions perspective, an increase in the share of scrap-based steel production is desirable, but it is constrained by limited scrap availability, as well as the variability in the quality of the steel produced. Today, about 22 percent of global steel is made from scrap in EAFs.[6]

Blast Furnace

The majority of steel production relies on iron ore as its primary input. The most common production process puts iron ore into a high-temperature integrated blast furnace and basic oxygen furnace (BOF), where coke from metallurgical coal is used to reduce the ore to molten pig iron (crude iron with higher impurities and carbon content). This hot metal is then transferred to the BOF, where a controlled reaction reduces the carbon content of the metal, resulting in liquid steel.

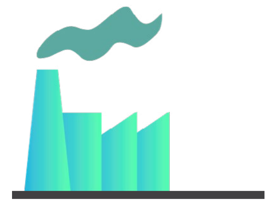
At present, about 70 percent of steel globally is manufactured using this process.[7] Despite continuous process improvements over the years and the prospect of installing carbon capture technology in the future, reliance on coal means this process remains highly emissions-intensive.

Direct Reduced Iron-Electric Arc Furnace (DRI-EAF) and Beyond

There is a second method for turning iron into steel that is dependent on a very high grade of iron ore and includes the integration of an electrified furnace to reduce or eliminate emissions from the process. In this method, DR-grade iron ore (ore with high iron content and low impurities) is reduced using natural gas (which displaces the coal), producing direct reduced iron (DRI). The natural gas is initially converted to syngas in a reformer before entering a furnace, where the carbon monoxide and hydrogen constituents of the gas act as reducing agents to purify the iron ore.

The steelmaking step is electric: DRI is put into an EAF, generating liquid steel. In the traditional blast furnace production route, iron ore is melted and impurities forming a separate liquid "slag" layer are removed. In the direct reduction route, the iron ore pellets are not melted and impurities are not removed in a slag layer. For this reason, high-grade iron ore is required to limit impurities; the quality of the final product remains closely dependent on the grade of the iron ore input.[8]

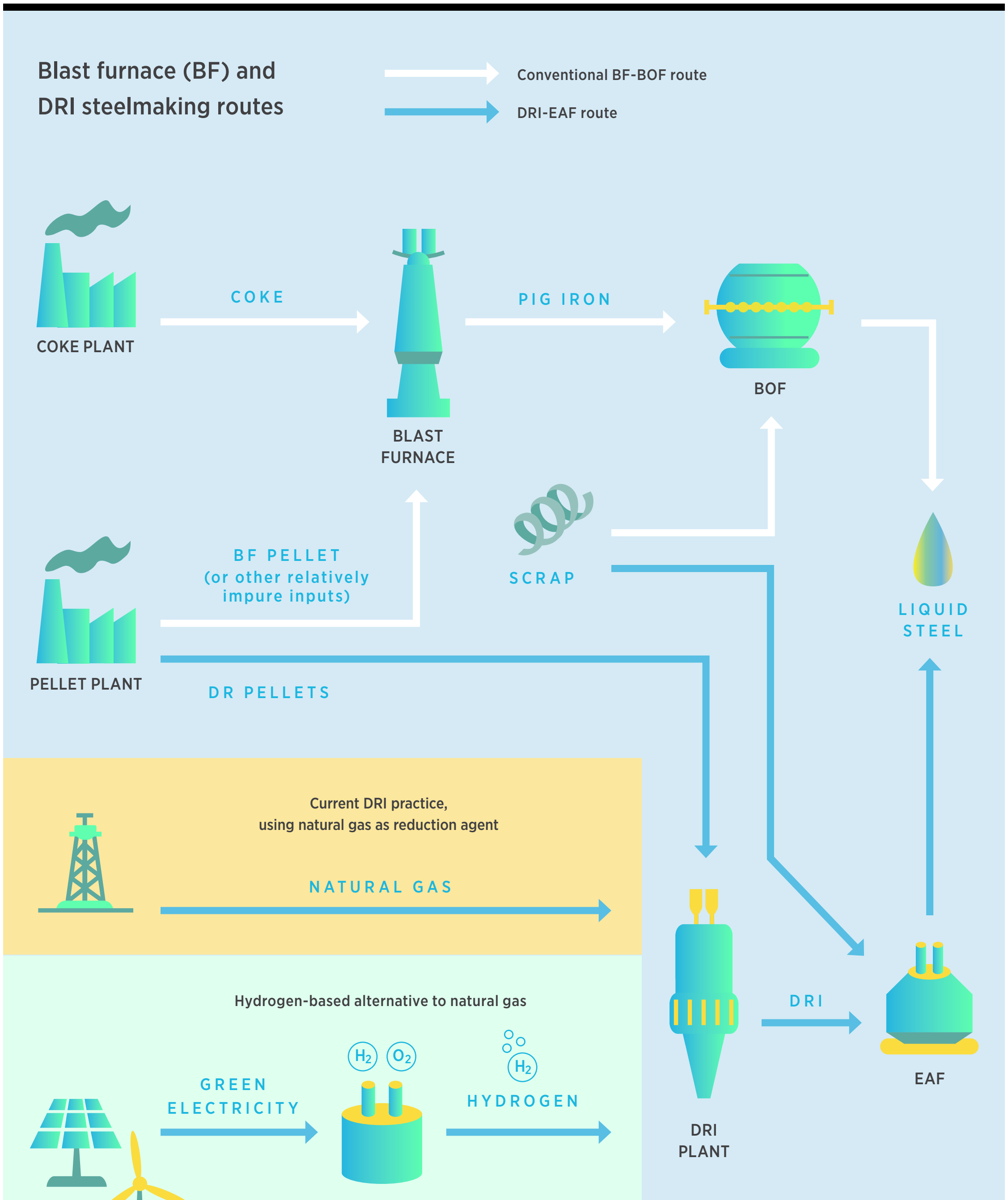
This process, known by the shorthand DRI-EAF, emits on average about 50 percent less CO_2 per tonne of steel compared to the integrated blast furnace method, with even greater emissions reductions possible if the electricity used comes from clean sources.[9] Beyond this substantial emissions reduction from displacing coal as a reductant, the natural gas input has the potential to be replaced by clean hydrogen. With hydrogen-based DRI (H-DRI), near-zero emissions steel can be obtained if low-carbon electricity is used.[10]



About
70%
of steel today is made using **emissions-intensive coal**

With hydrogen-based DRI (H-DRI), **near zero emissions steel can be obtained** if low-carbon electricity is used

DRI is typically used in electric arc furnaces (EAFs), while blast furnace pig iron is consumed in basic oxygen furnaces (BOFs).

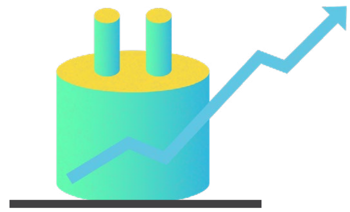


SOURCE: Doyle, A. Voet, T. (2021). The DRI dilemma: Could raw material shortages hinder the steel industry's green transition?

Only five percent of steel globally is made through natural gas-based DRI-EAF today, but more is on its way. Algoma Steel in Sault Ste. Marie, Ontario, and ArcelorMittal Dofasco in Hamilton are both transitioning to EAF with the assistance of more than $800 million in support from the governments of Canada and Ontario.[11] The former will produce scrap-based steel with its EAF,[12] and the latter will rely on its vertically integrated DR-grade iron ore from its pellet plant in Port-Cartier, Quebec, for transition to the DRI-EAF steel production method.[13]

While there are no commercial plans for hydrogen-driven H-DRI in Canada today, ArcelorMittal has signalled its intent to harness green hydrogen in the second phase of its steel decarbonization plans.[14] According to Bloomberg, the H-DRI share of global steel production could rise to 31 percent by 2050, with another 45 percent sourced from recycled scrap metal and the remaining steel coming from integrated plants retrofitted with carbon capture.[15]

DRI-EAF emits approximately 50 percent less than the conventional method, and H-DRI has the potential to produce net-zero steel. But simply installing new furnaces is not enough. Both technologies require a reliable supply of the irreplicable DR-grade iron ore and clean energy to extract and process this ore. That's where Canada comes in.



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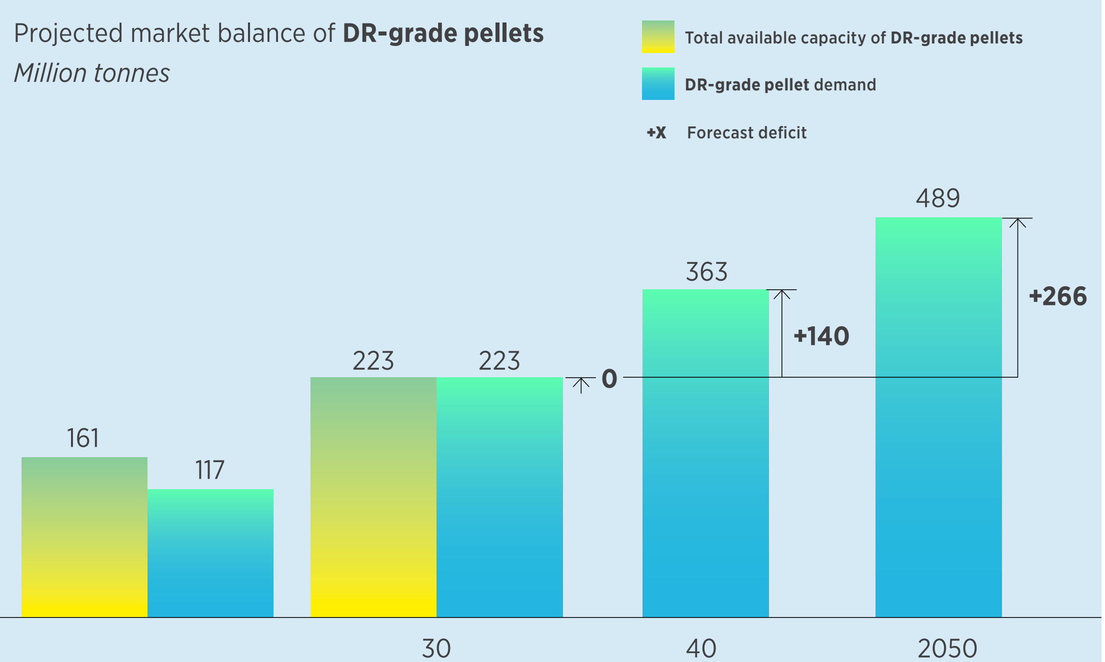
Unlocking an Existing Asset: Canadian Industrial Competitive Advantage

Today, DR-grade iron ore makes up only about 4 percent of global iron ore production.[16] But demand for this product is set to grow rapidly as the steel industry transitions, more than doubling by 2050. The production capacity needed to meet growing demand is projected to be exhausted as soon as 2030.[17] A massive untapped market is emerging.



Projected market balance of **DR-grade pellets**
Million tonnes

SOURCE: McKinsey analysis conducted for IOC using MineSpans model

Two of the largest global suppliers of DR-grade iron are located in Canada.

The Iron Ore Company of Canada (IOC) is a leading North American producer and exporter of premium iron ore pellets and high-grade concentrate located near Labrador City in Newfoundland and Labrador. IOC produces 19 million tonnes per annum (Mtpa) of high-grade intermediate products, of which a portion is used to produce up to 12.5 Mtpa of higher-value iron ore pellets, including direct reduction pellets suitable for DRI-EAF (and potentially H-DRI) steelmaking.

The other Canadian supplier is ArcelorMittal Mining Canada (AMMC), which produces DR-grade pellets to supply its DRI steelmaking plants in Quebec and Germany. AMMC currently produces 10 Mtpa of pellets, of which three Mtpa are DR-grade pellets. With up to $80 million in support from the government of Quebec, ArcelorMittal says its entire pellet production will be converted to DR-grade pellets by 2025.[18]

Globally, IOC in Labrador and AMMC in Quebec are two of only a handful of iron ore producers with the proven quality of ore grade and technological know-how to produce DR-grade pellets suitable for DRI-EAF. Given the market projection for DRI-grade inputs — 84 percent growth in North America and 59 percent growth globally (at 8.2 and 71.9 Mtpa by 2030) — the potential for Canada to establish a world-leading low-carbon supply of this essential green steel input is significant. Canada currently accounts for 2.5 percent of the world's total iron ore production, but its share of DR-grade ore export supply is already 10.7 percent.[19, 20]

Seizing this opportunity in the emerging green steel supply chain will require the expansion of iron ore production, as well as a decarbonization pathway. IOC, for example, estimates it can potentially reduce global iron ore and downstream steel emissions by up to 38 million tonnes of CO2 annually if DR-grade potential is maximized. The company is assessing site decarbonization options to produce one of the lowest carbon-intensity iron ore products globally, which may lead to a dramatic abatement of GHG emissions globally from the steel industry's supply chain, as well as increased domestic and North American security of supply of high-purity green iron ore.

The comparative scarcity of DR-grade iron ore globally and its essential role in green steel manufacturing underscores its critical role in the clean economy. The Government of Canada should incorporate decarbonization potential as a category by which mineral and metal criticality is assessed and recognize DR-grade iron ore on Canada's Critical Minerals List. Doing so would give this nationally strategic asset greater consideration for the key policy supports needed to unlock its potential, including greater access to clean power.

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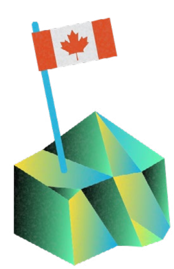

The Electrification Challenge

To pull off these ambitious plans, each link of the supply chain needs more clean electricity. Growing and decarbonizing Canada's DR-grade mining and pelletizing operations is contingent on this essential and very Canadian input — access to adequate volumes of clean power.

In the case of IOC, its existing transmission power infrastructure operates seasonally at full load, leaving no additional capacity for electricity delivery. This means GHG abatement and growth opportunities are limited, given the scale and energy-intensity of the operations. Stationary applications — such as electrifying the company's iron ore concentrator and pelletizing plant — and mobile applications, including electrifying the mine's haul trucks and railway, together require 800 MW of additional capacity (an increase from the current capacity of 262 MW). If this additional capacity becomes available, it could unleash the opportunity for growth in production, electrification of steam and hauling, and fuel switching in the metallurgical process. Without clean electricity infrastructure expansion, including both generation and transmission capacity, growth will be limited and incongruent with Canada's 2030 emissions abatement objectives.

Early action on electrification that unlocks production will help avoid the kind of supply-demand imbalances in green steel that increasingly characterizes the global transition to electric vehicles, solar panels, wind turbines and dams. Lessons from the current raw-material supply deficit and price surge in the battery minerals-to-EV transition should be applied here, with proactive and intentional planning, to avoid a volatile green steel transition and allow Canada to unleash its superpowers in the new world of green steel.

Access to clean electricity through the value chain will help avoid supply-demand imbalances in green steel

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