Chapter 1

Impact Assessment Objectives and Background

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1 Impact Assessment Objectives and Background

SNC-Lavalin has been contracted by the North American Iron Corporation (hereinafter referred to as NAIC) to conduct an Environmental Impact Assessment, in accordance with the requirements of the *Environment Quality Act* (RSQ, c. Q.-2) and the *Regulation respecting environmental impact assessment and review* (RRQ, c Q-2, r.9, Article 2j) (Phase I) for the construction and operation, in Grande-Anse, Saguenay, of a nodular pig iron manufacturing plant with an annual capacity of 425,000 tons.

This environmental impact assessment follows the filing of a project notice with the Ministry of Sustainable Development, Environment and Fight against Climate Change (MDDELCC).

As provided for in Article 31.2 of the *Environmental Quality Act* (RSQ, c. Q-2), the Environmental Assessment Department of the MDDLECC has issued, in February 2016, a document entitled *Directive pour la réalisation d'une étude d'impact sur l'environnement d'une usine de fonte en gueuse sur le territoire de la Ville de Saguenay par la Société de fer de l'Atlantique Nord* (Dossier 3211-14-037) (Guidelines for the completion of an environmental impact assessment) outlining the nature, scope and breadth of the Environmental and Social Impact Assessment (ESIA) to be conducted.

The purpose of the ESIA is to identify, assess and minimize the environmental impacts of a project on the receiving environment and its components. This requires a multidisciplinary team of professionals to identify and analyze the various human, physical and biological valued components in the area. Field surveys and a public consultation process led to the selection of various measures to be implemented in order to mitigate the project's negative impacts as well as ways to maximize impacts that could potentially enhance positive effects. Overall, this impact assessment has made it possible to optimize the project's integration into the receiving environment.

1.1 Consultant

SNC-Lavalin is one of the world's largest engineering and construction firms and a major global player in infrastructure construction, operation and maintenance services. SNC-Lavalin has worked in the environmental field since 1973 and has a multidisciplinary team of approximately 1,000 professionals. This impact study was mainly conducted from SNC-Lavalin's Montreal office with the support of professionals from its Levis and Jonquière offices.

SNC-Lavalin hired **Subarctique**, a Chicoutimi-based firm specializing in archaeological studies. This firm has confirmed the archaeological value of the study area for both for the prehistoric and historic periods. The **BC2** firm, which specializes in urban planning, urban development and landscape architecture, is also involved in the project while being also responsible for performing the plant's landscape analysis. **BC2** will draw on the expertise of its Montreal office and its regional office located in Chicoutimi.

SNC-Lavalin has worked closely with the Italian firm **Tenova**, an engineering and equipment supply firm, and a global leader in high technology products and services for the metal industry. It provides the iron and steel industry with innovative technologies allowing their clients to increase the quality and reliability of their products, while reducing production and energy costs and thereby increasing their environmental performance. Tenova, which has demonstrated substantial international presence with its involvement in projects on every continent, was contracted by NAIC to conduct the feasibility study for the nodular pig iron manufacturing plant. It is also responsible for providing the inputs required for the description of the project (Chapter 3).

1.2 Methodological Considerations

This study was prepared by a team of professionals (see Project Team section) using proven methods to identify, describe and assess the environmental and social impacts associated with the project and propose mitigation measures to minimize these impacts. Impacts are identified through the potential interaction of impact sources, i.e., the type of work to be carried out and equipment to be used, and the valued components of the project's receiving environment.

The description of the study area's components was based on existing information (documents, statistics, and maps), *ad hoc* field trips and data collected specifically for the project (field trips, and detailed inventories). This study also required consultations with a number of organizations.

The information presented herein is a summary of the existing environmental and social conditions at the time of the preparation of the EIA in the study area.

It should be noted that some maps and full-page figures prepared for the impact assessment are presented at the end of each chapter.

1.3 Report Structure

The impact study submitted to the MDDELCC was prepared in two volumes:

Volume 1: Pig Iron Plant Project in Grande-Anse
Environmental Impact Assessment
Main Report

Volume 2: Pig Iron Plant Project in Grande-Anse
Environmental Impact Assessment
Appendices

Chapter 2

Context

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2 Context

2.1 Project Promoter

The project promoter is North Atlantic Iron Corporation (NAIC), a private joint venture formed in 2010 and registered in Quebec in December 2015, hereafter referred to as NAIC. NAIC is 60% owned by Grand River Ironsands Inc. (GRI) and 40% by Petmin Limited (Petmin). A description of these companies can be found in the following subsections. The contact information of the promoter can be found below in Table 2.1.

Table 2.1 Project Promoter Contact Information

Name	North Atlantic Iron Corporation
Address	805-1809 Barrington Street, Halifax, Nova Scotia, B3J 3K8 A project office will soon be opening in Quebec.
Project Contact	Liz MacKenzie, Director of Communications
Telephone	(902) 233-7255 (Local number to come)
Facsimile	(902) 835-0585 (Local number to come)
Email	liz@ironsands.ca
Quebec Company Number (NEQ) in the Quebec Company Register	1171449821

2.1.1 Grand River Ironsands

GRI is a private Canadian company founded in 2007. Its initial mission was to become a low-cost producer of high-purity pig iron using the mineralized sands of Labrador as feedstock. Today, through NAIC, GRI continues to pursue its goal of developing low-cost production of high-purity pig iron; however, this production will no longer be reliant on iron sands as feedstock. Instead NAIC will purchase readily available iron ore pellets from current producers, ideally those from Quebec established producers.

GRI is 56% held by a group of private Canadian investors and 44% by Metalo Manufacturing Inc., an investment company in mineral resources listed in the Canadian Securities Exchange (CSE).

2.1.2 Petmin

Petmin is a South African mining company founded in 1972 and listed on the Johannesburg Stock Exchange (JSE). Petmin is the most significant producer of anthracite coal in the country with an annual production of more than 1.3 million tonnes of this specialty product. In 2015, its stocks were evaluated at more than 130 million American dollars. Petmin has invested 25 million American dollars in the NAIC joint venture.

2.2 Project Background

The pig iron production facility project was originally planned to be in the center of Labrador, near Happy Valley-Goose Bay, where Grand River Ironsands (GRI) held the rights to the mineralized sands. These sands contain significant levels of magnetite, titanomagnetite, garnets (almandine), zircon and other potentially precious minerals. GRI partnered with Petmin and formed NAIC, initially, to develop, extract and process the mineral sands into commercially saleable products.

NAIC's business model has evolved over the years. A pig iron production facility in Labrador was added to the initial mineral extraction project. Then, as a result of the large decrease in the price of iron ore, the remoteness of the deposit and the difficulties in supplying electricity and natural gas to the site, NAIC decided to separate the development of the mining project from the pig iron project.

NAIC is now focused on developing a high-quality pig iron production facility using iron ore purchased from current producers, rather than from mineral sands. This allowed NAIC to evaluate many different sites in the United States and in Quebec, to determine the most optimal location for a pig iron production facility.

NAIC continues to evaluate the mineralized sands potential in its Happy Valley-Goose Bay deposit, however primary focus is the pig iron facility in Saguenay.

2.3 Project Objectives

The goal of the NAIC project is to construct and operate at Grande-Anse, in Saguenay, a facility producing 425,000 tonnes per year of high-quality pig iron in order to serve the foundry and steel mill markets in North America and Europe.

NAIC aims to produce nodular grade pig iron, distinguished from other merchant pig iron by its high purity as well as its low concentration in manganese, phosphorous and sulfur.

2.4 Project Justification

The production of steel using electric arc furnaces (non-integrated steel mills) and the production of cast iron in foundries require iron originating from different raw materials. Electric arc furnaces use recycled steel (**scrap iron**), **direct reduced iron (DRI)**, **hot briquetted iron (HBI)** and lower-quality **merchant pig iron**. Foundries use **recycled steel** as well as different qualities of **merchant pig iron**.

Compared to merchant pig iron, DRI and HBI have lower concentrations of iron and higher concentrations of impurities (silica and aluminum), causing the formation of larger quantities of slag. DRI and HBI thus cannot be used in the foundry production processes, making pig iron the raw material of choice. When foundries are focused on making high quality ductile iron castings, a specific grade and quality of merchant pig iron is required. This product is called **nodular pig iron**. Nodular pig iron has no substitute creating a stabilized demand and a premium price.

Scrap iron used in the foundries and electric arc furnaces contain impurities such as zinc, copper and lead that contaminate the final product. These undesirable elements are absent from pig iron, which has become irreplaceable in the foundry industry for diluting the impurities to acceptable levels in their finished products. In addition, the supply of quality scrap iron is diminishing as a result of the increased demand of the NAFTA market for high-strength low-weight steel alloys, increasing the demand for merchant pig iron.

The following sections describe the different types of merchant pig iron as well as the materials that could substitute them in the fabrication of steel and iron products. The characteristics of each of these materials are provided in such a way as to distinguish them from nodular pig iron. The information is principally taken from the website *International Iron Metallics Association* (IIMA)[1].

2.4.1 Types of Merchant Pig Iron

Pig iron is the intermediate product of smelting iron ore. The term *pig iron* originates from metal that was originally cast into a mold that was shaped into a branching structure formed in sand, with individual ingots at right angles to a central channel or runner, similar in appearance to a litter of piglets (ingots) suckling on a sow (runner). When the metal had cooled and hardened, the ingots were simply broken from the runner, thus forming *pig iron*.

Today, pig iron is principally produced and consumed by integrated steel mills. However, “hot metal” from iron ore smelting in blast furnaces is directly transferred to the steel mill in liquid form. The term *pig iron* is thus inappropriate in this type of fabrication.

Merchant pig iron is cold iron, cast into ingots and sold as ferrous feedstock for the non-integrated steel and metal casting industries. It falls into the category of ferrous metals, of which iron and steel scrap make up by far the largest volume, followed by direct reduced iron (DRI) and hot briquetted iron (HBI).

Merchant pig iron is produced by dedicated merchant plants, all of whose production is sold to external customers. Some integrated steel mills produce blast furnace iron that is surplus to their internal requirements and this is also cast into ingots and sold as merchant pig iron.

Merchant pig iron contains at least 92% iron, for a degree of purity of around 96%. It is typically separated into three main categories:

- Basic pig iron, used mainly in electric arc steelmaking;
- Haematite pig iron, also known as foundry pig iron, used mainly in the manufacturing of grey iron castings in cupola furnaces[2];
- Nodular pig iron also known as ductile or spheroidal graphite[3], used in the manufacturing of ductile iron.

Table 2.2 presents the proportion of chemical components contained in merchant pig iron.

[1] Information from website http://metallics.org.uk/
[2] Cylindrically-shaped furnace on a vertical axis used during the second furnace melt
[3] Treated by magnesium, nodular pig iron is obtained by transforming the shape from lamellar to spheroidal or nodular.

Table 2.2 Proportions of Chemical Components in Merchant Pig Iron (MPI)

MPI Types	Iron	Carbon	Silicon	Manganese	Sulfur	Phosphorous
Basic Pig Iron	92%	3.5 – 4.5%	<1.5%	0.5 – 1.0%	<0.05%	<0.12%
Haematite Pig Iron	92%	3.5 – 4.5%	1.5-3.5%	0.5 – 1.0%	<0.05%	<0.12%
Ductile/Nodular Pig Iron	92%	3.5 – 4.5%	0.05-2.0%	<0.05%	<0.02%	<0.04%

2.4.2 Advantages of Nodular Pig Iron

Nodular pig iron is differentiated from other types of pig iron by its low manganese, phosphorous and sulfur contents, typically less than 0.05% for each element, which gives it significant advantages described below.

1. Low impurity content, allowing for:
    a. Dilution of undesirable elements in the melt;
    b. Better control and increased stability of the melting process;
    c. Tighter control of final casting composition, resulting in better mechanical properties of castings;
    d. Elimination of requirement for thermal treatment of castings, thus reducing production costs;
2. Lower melting temperature than scrap steel from electric arc furnaces, resulting in a lower energy requirement;
3. Higher bulk density than scrap steel, allowing for:
    a. Reduction in storage space;
    b. Reduced charge bucket use;
    c. Better electromagnetic effect, incurring a quicker melting process and thus reduced power consumption;
4. Lower surface area/volume ratio than scrap steel, reducing the oxidation (rust formation) and slag production;
5. An increase in the percentage of pig iron in the charge, leading generally to a higher nodule count in ductile iron.

With its high iron purity, the use of ductile pig iron allows steel mills as well as foundries to continue to use scrap iron, whose advantages and disadvantages are described below, as an iron source.

2.4.3 Advantages and Disadvantages of Scrap Iron

Scrap iron results from the recovery of metal, ferrous and non-ferrous[4], sourced from diverse materials recovered from businesses or private owners. The principal advantages to using scrap iron in the fabrication of steel and pig iron are:

- Reduction of environmental footprint, less waste in landfills, use of recycled materials;
- Reduction in consumption of raw materials;
- Energy and cost savings;
- Abundance and availability near production centers.

The principal disadvantages of using scrap iron are linked to the variation (in concentration and type) of other metals present in the scrap, that can thus end up in the atmospheric emissions, make the production of high-purity iron castings and steels more difficult and increase the production of slag.

2.4.4 Direct Reduced Iron (DRI)

Direct reduced iron (DRI), or sponge iron, is produced from the direct reduction (i.e. oxygen removal) of iron ore with reducing elements such as hydrogen gas and carbon monoxide, originating from natural gas or coal. DRI provides an alternative steel-production method from the conventional route of blast furnace and basic oxygen furnaces. DRI is an intermediate product and is a raw material for the production of steel in electric arc furnaces.

Once commercialized, DRI can come in different forms (lump, briquettes, or pellets). It can be transformed mechanically by hot compression to briquettes in order to reduce its porosity and tendency to oxidize. Once hot molded, DRI is called hot briquetted iron (HBI).

Advantages and Disadvantages of Direct Reduced Iron

For certain developing countries where supplies of cokefiable coal are limited, the production of DRI could be advantageous in the following ways:

1. Low investment costs and comparable performance to integrated steel mills;
2. High concentration of iron (90 to 94% total iron) and low concentration of impurities, creating an excellent raw material for non-integrated steel mills, allowing them to blend lower grade scrap iron for the rest of the load or to produce higher steel grades;
3. Stable and known chemical composition, certified by the producer;
4. Possibility of producing HBI, a compact form of DRI, allowing notably:
    a. Facility of transport, handling and storage of the product, HBI has a low reactivity with salty and fresh water;

[4] Ferrous metals are light iron, pig iron and heavy steel. Non-ferrous metals are copper, brass, lead, non-oxidizable steel, aluminum, bronze and zinc. These metals generally come from recovered parts such as auto parts, catalytic converters, production metal waste, demolition materials, home appliances, etc.).

b. Reduced costs and energy when consumed on the production site, as long as iron is not cooled but immediately transported and loaded into the electric arc furnace.

Finally, the ore and natural gas suppliers are often present in the same country, avoiding the costs associated with natural gas transport (the facility is normally situated near the natural gas source because it is normally more profitable to transport ore rather than gas).

DRI has, however, several disadvantages, which are the following:

1. Spontaneous ignition upon contact with air (pyrophoric);

2. Tendency to oxidize and produce rust when non-protected; it must be rapidly transformed during steel production;

3. Contact with water, particularly salty water, can generate hydrogen and lead to danger of explosion, which makes transportation difficult.

4. Higher level of slag formers than pig iron

The main disadvantage of DRI and HBI is that they cannot be used in foundries as a result of elevated levels of gangue forming oxides that stay in the DRI (i.e. CaO, Al_2O_3, SiO_2, MgO). These oxides represent 3% to 6% of the elements in DRI/HBI.

2.5 Pig Iron Market

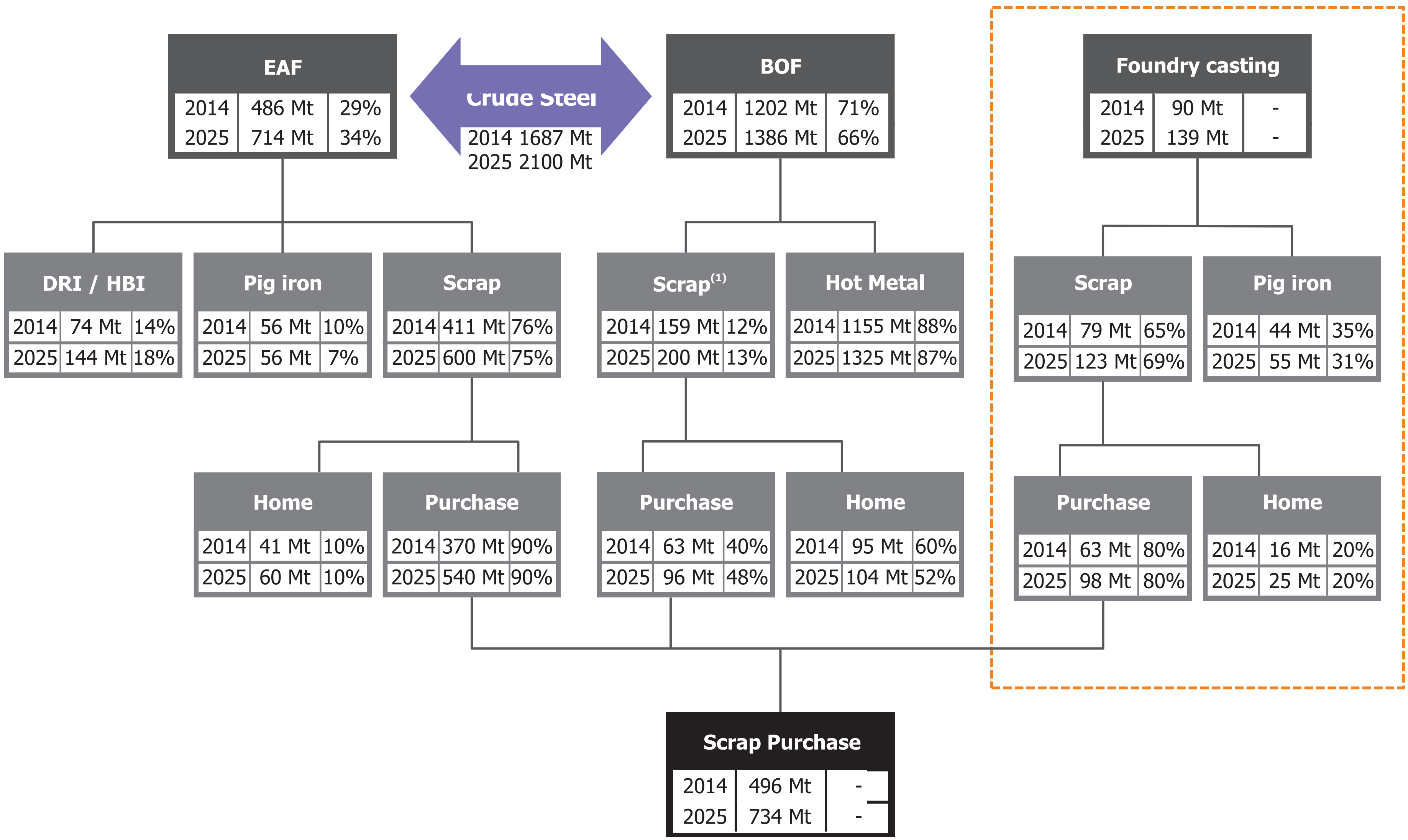
The merchant pig iron market can be divided into two categories within the primary metal transformation sector: the iron foundry and steel mill markets. The principal market targeted by NAIC for nodular pig iron are North American and European foundries, followed by non-integrated steel mills that would receive all production surplus. Figure 2.1 illustrates market opportunities for pig iron according to 2014 data as well as a projection for 2025.

2.5.1 Global Context

In 2014, the global merchant pig iron market was 100 million tonnes per year, of which 44 million tonnes were dedicated to foundries.

Table 2.3 presents the ten main countries that produced grey and ductile iron castings in 2013.

Figure 2.1 Pig Iron Market Opportunity 2014 - 2025



Mt = Million tons

(1) BOF scrap includes 1.2 Mt HBI

Sources:
Iron & Metallics Association (IIMA) - Global Metallics Balance 2014
Iron & Metallics Association (IIMA) - Global Metallics Balance 2025

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Table 2.3 Main Grey and Ductile Iron Casting Producer Countries in 2013

Country	Grey Iron (M t/y)	Ductile Iron (M t/y)	Total (M t/y)
China	20.6	11.6	32.2
United States	4.08	4.25	8.33
India	6.7	1.0	7.7
Germany	2.38	1.54	3.92
Japan	2.14	1.68	3.82
Russia	1.81	0.99	2.8
Brazil	1.83	0.75	2.57
South Korea	1.09	0.71	1.8
France	0.64	0.70	1.34
Italy	0.69	0.39	1.08
Total	**41.9**	**23.6**	**65.5**
Total without China	**21.3**	**12.0**	**33.4**

* Data has been rounded to facilitate reading;
Source: *Modern Casting – 48th Census of World Casting Production* (2014).

The total iron foundry market increased by almost eight million tons between 2007 and 2014 to 57.7 million tons. The United States also increased their production from 7.8 million tons in 2007 to 8.3 million tons in 2013. China is the top nodular castings producer with almost half the market (11.6 M t/y), followed by the United States (4.3 M t/y) and Germany (1.5 M t/y). The ductile pig iron market increased by 1.3 percent in 2013 compared to 2012 data.

The global demand for nodular pig iron is currently estimated at 1.2 to 1.5 million tons per year. According to the International Iron and Metallics Association, the demand for pig iron will have increased by 11 million tons in 2025.

2.5.2 Increase in Electric-Arc-Furnace-Produced Steel

The average annual rate of increase of the global electric-arc-furnace steel production market was 4.8% between 2010 and 2015. Much of this gain was in flat-rolled steel and specially graded steel. These types of steel products and grades require a mixture of steel scrap and alternative iron units such as merchant pig iron.

The global supply of steel scrap without impurities is deteriorating as multiple recycling stages can increase concentrations, and there is an increasing use of high strength low weight alloyed steels. The alloying agents end up being impurities in scrap steel that must then be managed by steel mills and foundries that recycle such scrap. These impurities can only be adjusted by dilution, through mixing the scrap with alternative iron units (such as pig iron) that do not contain impurities.

As a result of new electric arc furnace steel production process start-ups based in Asia, the Middle East and in Eastern Europe, it is highly likely that Russian and Chinese merchant pig iron producers will be less interested serving the North American market and would concentrate more on nearby customers.

2.5.3 Reduction in Merchant Pig Iron Production Capacity

Over the course of 2012 and 2013, difficulties in the steel market led to the closure or bankruptcy of facilities located in Russia, Brazil and the Ukraine reducing merchant pig iron production capacity. The integrated steel mills in Ukraine are susceptible to being repositioned on the local steel market, which is showing signs of equilibrium between supply and demand, decreasing merchant pig iron exports from Ukraine. Additionally, the largest global exporter of merchant pig iron is slowly withdrawing from the market as it strengthens its steel production (Koks Group, Russia). Potentially 2 million tons per year of merchant pig iron could be removed from the market when Koks begins to use it to make steel in Russia.

2.5.4 Targeted Market

The principal market targeted by NAIC is the American and European foundry market, followed by electric arc furnace steel mills. The value-added business model used by NAIC is based on an annual production of 425,000 tons of nodular merchant pig iron, for which the use of 700,000 tons of iron pellets is required. This raw material could easily come from local industries, such as the pellet export facilities of Arcelor Mittal and Rio Tinto located respectively in Port-Cartier and Sept-Iles.

The market targeted by NAIC is easily accessible by maritime transport for four to ten principal ductile pig iron producing nations (United States, Germany, France and Italy).

2.6 Choosing Quebec

2.6.1 Geographical Position of the Market

The principal consumers of nodular pig iron are mostly in the United States and Europe, around 400,000 and 500,000 tons per year respectively. Presently, the nodular pig iron consumed in the United States comes essentially from Brazil (220,000 t/y) followed by South Africa (150,000 t/y), Canada (35,000 t/y) and Russia (5,000 t/y). Russia mainly supplies Europe and Eastern Europe as a result of its geographic location.

It should be noted that nodular pig iron produced in Canada and South Africa come essentially from an intermediate product originating from the melting of ilmenite during the production of titanium dioxide. The production from these two countries is accessory and does not follow the market trends.

Producers in Russia are struggling to obtain the desired nodular pig iron quality criteria, notably for sulfur. This struggle is mainly due to the use of blast furnaces that are not adequately configured for the hot metal refining process.

The majority of iron ore from Brazil contains an elevated quantity of phosphorous and manganese, which causes a major inconvenience in the production of nodular pig iron. Additionally, Brazilian producers require 120 days to deliver the product after the order is placed. The delay includes the production of the pig iron, transport by truck to the port, delivery by boat to New Orleans and transport by barge to the Midwest.

As a result of high wait times for delivery and the quality of the nodular pig iron, few producers can supply the market of North America. The construction of a nodular pig iron fabrication facility in Quebec is thus strategic. Table 2.4 summarizes the advantages that strengthen this choice.

Table 2.4 Advantages of Constructing a Nodular Pig Iron Facility in Quebec

Variable	Advantage
1. Production and delivery (USA and Europe)	› Direct access to the Great Lakes and to the Atlantic Ocean (<5 days for delivery) › Reduced transportation costs to the USA and Europe (compared with Brazil and Russia) › Availability of inputs at reduced costs (e.g. iron ore, electricity, natural gas) › Low production costs and delivery costs allow for profitability through fluctuating economic cycles
2. Well-established American and European iron foundry market	› Potential in North America of 1 Mt/y, in addition to an analogous market in Europe › Sufficient market size to absorb the production of NAIC
3. Distant competition (Brazil, Russia, Ukraine, South Africa)	› Zero competition in North America and weak competition in Europe › Reduced logistics costs › Reduced geopolitical risks
4. Excess production can be purchased by non-integrated steel mills (vast market)	› > 4 Mt/y of merchant pig iron is imported by North-American steel mills
5. Quality of the product prevails over the quantity	› High quality pig iron produced in Quebec could be sold at a premium of up to $100 US/t compared to the price of basic pig iron sold to steel mills
6. Complements the market needs	› No rivalry with Canadian or American mines, foundries and steel mills

2.7 Site Selection

In total, 14 sites were evaluated of which five were in Canada and nine in the United States. Among the selection criteria used to compare the sites were:

- Accessibility of the maritime waterways (deep water port) as well as railway and roads;
- Availability and reliability of energy resources (natural gas and electricity);
- Proximity to raw material;
- Proximity to the markets of the United States and Europe;
- Site characteristics (zoning, land purchase, industrial infrastructure, etc.);
- Taxes;
- Accessibility to qualified labor.

In Quebec, three locations were considered: Sept-Iles, Port-Cartier and Saguenay. Sept-Iles and Port-Cartier were eliminated for lack of site availability and accessibility to natural gas as well as zoning in the case of Sept-Iles. The possibility of liquefied natural gas (LNG) supply was evaluated but judged to be too costly and unpredictable. There is no LNG receiving facility on the North Shore and the announced projects have no firm start-up date.

2.7.1 The Saguenay Site

NAIC chose to construct its pig iron production facility on industrial land belonging to the Saguenay Port Authority (APS), near the maritime terminal of Grande-Anse in the City of Saguenay, La Baie Borough.

In order to fulfill its mission, which consists of favoring the expansion of outside business as well as the industrialization and development of the inland region of Saguenay-Lac-Saint-Jean-Chibougamau-Chapais, the APS has recently developed the land in order to allow businesses to grow and use the proposed utilities. These properties are located on either side of the Chemin du quai Marcel-Dionne giving access to the jetty by the same name.

In 2015, APS saw the designation of the industrial-portuary zone by the Quebec government in the context of its maritime strategy. Globally, industrial-port zones will allow Quebec exports to increase through an improved integration of manufacturing to global supply chains (Quebec government, Stratégie maritime, 2015). This designation aligns with the general orientations of the APS that are strengthened by them. NAIC could thus benefit from the functional developments by sharing infrastructure and port services with the goal of increasing the efficiency of these activities in terms of logistics.

This federal industrial-port zone offers several advantages to the construction of a pig iron production facility:

- Deep water port accessible year-round situated at a reasonable distance from raw material suppliers of the market;
- Space available near to the port (2.4 km) and at the jetty (for temporary storage as needed);

- Commitment by the APS to construct a multi-user conveyor between the jetty and the industrial zone that could be used for the transport of pellets and pig iron;
- Site provided by the APS already cleared and leveled;
- Land at the heart of an industrial-use zone;
- Remoteness of urban perimeters allowing for the existence of major industrial operations;
- Availability and reliability of natural gas supply (commitment from Gaz Metro to extend its network to serve the facility);
- Availability and reliability of the electric network (commitment from Hydro Quebec to extend its network to serve the facility);
- Willingness of different levels of government to develop this sector for industry;
- Qualified labor in the steel industry sector.

The exact location of the site on the APS land was defined following a geotechnical study as well as discussions with APS that wishes to both set aside land for the construction of a future railway that would serve this sector, and to maintain its commitments to other private project promoters. The land would remain the property of APS and would be leased to NAIC via a long-term lease. The site location is presented in figure 2.2.

2.7.2 Regulatory Context

The regulations governing the land of the facility's location (project site) is intimately related to the site selection.

The site considered for the construction of the facility is found within Zone 71770, as outlined by the City of Saguenay. According to the zoning regulation for this zone, the allowed uses are predominantly industrial and port-related, to be carried out in the Grande-Anse sector.

The site zone is in line with the development of the land, planning unit 119, identified as a predominantly industrial zone whose vocations are linked to port activities in Grande-Anse. The site is located in the industrial expansion zone of which the Intermodal Maritime Industrial Park is part.

2.8 Project Overview

The project consists of the construction and operation of a nodular pig iron production facility from iron pellets. Annual forecasted production is 425,000 metric tons. Production of nodular pig iron will be carried out using known and proven technologies, which is direct reduction followed by smelting in an electric arc furnace. Natural gas is used as a reducer element as well as a combustible for the preheating furnace. The iron pellets originating from the pellet plants of the North Shore will be transported by boat and then conveyed or trucked to the facility. Bentonite will be used as a binder for the pellet fines that will be combined into briquettes to be reused as raw material. Lime will be used in the electric arc furnace to create the slag. Metal, liquid iron, will be casted into pig iron form. The different sources of atmospheric emission will be treated to reduce dust emissions. The wastewater generated by the processes will be treated and reused within the facility. With the exception of slag of the pig iron that will be stored outside, all other material will be contained.

Figure 2.2 Site Location

2.9 Technology Selection

2.9.1 Pig Iron Production Technologies

Three main technological pathways to produce pig iron out of iron ore are available:

- Traditional BF;
- Coal-based DR technologies followed by electric smelting;
- Gas-based DR technologies followed by electric smelting

The coal-based smelting reduction process (i.e. Corex/Finex process) and all the other emerging technologies with little commercialization are excluded from this review.

2.9.1.1 Traditional vs. Direct-Reduction Ironmaking

For over a century, pig iron and liquid steel have been produced at integrated mills that process virgin raw materials such as iron ore, coking coal, and a burden material like limestone and dolomite. As the name implies, integrated mills are characterized by networks of independent material and energy streams between processes including cokemaking, ironmaking, steelmaking, and steel finishing. An integrated mill producing nodular pig iron from virgin iron ore and coal would require a cokemaking plant and a BF.

Introduced in the late 1960s, direct reduction ironmaking is the most common alternative to BF ironmaking with iron ore pellets. In this process, synthesis gas (or syngas) which is a mixture of hydrogen (H_2) and carbon monoxide (CO), is generated, providing an effective reducing agent converting the iron ore into direct-reduced iron (DRI or sponge iron) in a furnace.

Several natural gas-based DRI processes are available on the market with the MIDREX and HYL technologies being the most common worldwide. They both have different features but all in all they provide a DRI product that can be loaded into EAFs as a clean substitute to ferrous scrap. Non-coking coal-based DRI processes are also available although more limited commercially. It uses, for example, a rotary hearth furnace in which a mixture of iron ore and pulverized coal is continuously fed and heated at varying temperatures to produce sponge iron (Fastmet process).

The primary benefit of DRI processes is that they can operate without coke or sinter. This aspect avoids the necessity for cokemaking plants and sinter machines that have significant environmental impacts and energy requirements. The use of natural gas instead of coal as the reducing agent also limits greatly the emissions associated with sulfur but also with carbon dioxide (CO_2). Other benefits but also inconveniences are associated with DR ironmaking. <u>NAIC has selected the natural gas based direct reduction route</u>. Table 2.5 generalizes these differences between the traditional and DR ironmaking technological pathways.

Table 2.5 Traditional vs. DR Ironmaking[5]

Features	Traditional BF (Blast Furnace)	DR (with gas) + EAF
Scale of Production	Long established and energy and resource efficient with unit plant throughputs of hot metal of 2 to 4.77 Mt/yr and greater.	Gas-based processes account for the vast majority of installed DR capacity worldwide, dominated by HYL and Midrex technologies. DRI is normally used as a virgin metallic feed, supplementing scrap in the EAF steelmaking route. DRI is also used as metalized burden in BF for coke reduction/hot metal productivity increase. DR plants range from 0.2–2.5 Mt/yr; Midrex being the largest module in operation based on the HYL ZR (ENERGIRON), already in the lower limit of the BF size.
Feedstocks	**Coal**: Coking coals required for cokemaking; coke breeze and anthracite required (where used) for sinter plants; coal for BF injection (can be non-coking coal specification). **BF Injectants**: Besides coal, oil (incl. waste oil), natural gas, plastics, and a flux material (i.e. limestone) are injected into the BF. **Metallics**: A wide range of feedstock of variable quality and specification can be used.	**Coal** (where used-minority of processes): A wide range of solid fuels from anthracite to lignite including charcoal can be used. **Gas** (where used): Sulphur content of gas must be low to avoid poisoning of the reformer catalyst and effecting product quality for the Midrex process. **Metallics**: As no physical change of state takes place in the process, high-quality pellets and lump ore are required.

[5] Adapted from European Commission, Integrated pollution prevention and control – Reference documents on best available techniques for the production of iron and steel, February 2008.

Features	Traditional BF (Blast Furnace)	DR (with gas) + EAF
Energy Requirements	Typically around 17–18 GJ/t of liquid iron (less gas, steam and heating credits from carbon in iron). The majority of energy comes from the coking coal (13–15 GJ/t LS) and fossil fuel (natural gas & oil) (2-3 GJ/t LS). Electricity requirements range between 150–250 kWh/t LS. Several measures can improve the energy efficiency of integrated mills,[6,7] including reduction of coal moisture, coke dry quenching, top pressure turbines at BF, etc. Most of these practices would result in lower fossil fuel use. However, the overall energy intensity of an integrated mill making the most of best practices is not expected to be much lower than 15 GJ/t LS.[8]	Typically 9.9–12.6 GJ/t solid DRI (gas-based) assuming 100% commercial DR grade pellets. Most energy comes from natural gas either as reducing agent or for direct-firing at the DR unit (9.9–11.5 GJ/t DRI) to which about 1 GJ/t DRI should be added for energy use at the EAF melt shop. Electricity requirements range between 30–130 kWh/t DRI for the DRI unit and 450-650 kWh/t LS for the EAF melt shop. Hot DRI can be directly charged to the EAF bringing most of its heat in the process and providing savings in electricity and fuel. In contrast, hot DRI is also known to contain a lot of gangue which leads to an increase in power consumption at the EAF.
Product Quality	Stable and of dependable quality.	Product subject to re-oxidation except if it is passivated or briquetted. The quality depends heavily on the quality of the feedstock. The DRI with a high level of carbon (> 3.5% C) of the HYL ZR process is more stable according to the tests carried out and the experiences of facilities. It provides supplementary energy to the EAF. In the case of NAIC, the hot DRI will be fed directly to the EAF and quality of the product is thus stable and reliable.

[6] European Commission, Integrated pollution prevention and control – Reference documents on best available techniques for the production of iron and steel, February 2008.
[7] United States Environmental Protection Agency, Available and emerging technologies for reducing greenhouse gas emissions from the iron and steel industry, October 2010.
[8] Canadian Industry Program for Energy Conservation, Benchmarking energy intensity in the Canadian steel industry, prepared for Canadian Steel Producers Associations and Natural Resources Canada, 2007.

Features	Traditional BF (Blast Furnace)	DR (with gas) + EAF
Environmental Performance	Main energy and carbon feedstock is coking coal, which inherently contains toxic chemicals including VOCs, PAHs and a variety of other chemicals like H_2S. Other releases at the cokemaking plant are dust along with some CO, SO_2 and NOx. Sinter plants release SO_2, NO_X, dust, VOCs, PCBs, PCDD/F and PAHs. BFs discharge dust and SO_2 from cast houses and NOx from the hot blast stoves. Dust fumes and CO are the main contaminants from BOFs. H_2S can also be a nuisance. This process route uses large quantities of water. In general, the wastes and by-products per tonne of liquid steel from the BF route are almost 3-times the ones from the EAF route. It exceeds 400 kg/t crude steel on average. However, it provides for the recycling of various solid wastes/by-products that would not be possible in various direct reduced iron treatment processes. For example, BF slag can be used for road construction or pelletized to make slag cement which reduces the demand for primary aggregates.	As most DR processes make use of iron pellets, the environmental impact of releases from the pelletization process should be taken into account. The DRI product typically contains 2–4% gangue requiring further energy for processing and additional environmental releases to be considered. Wastes and by-products for the DR/EAF route is less than 200 kg/t crude steel. Fines are processed in cold briquettes and recycled in the process. NOx is released at the gas reforming stage in the Midrex and HYL III processes. For Midrex, SCR technology is normally used to comply with NOx limits whilst for the HYLIII and HYL ZR, no need of additional systems are required. SO_2 emissions are limited by the sulphur content in the pellets and natural gas. In any case, for the HYL process, sulphur can potentially be removed from the CO_2 stream. Slag from smelting of the DRI in an EAF contains fewer impurities than those produced by the BF route and can be recycled as aggregate.

Features	Traditional BF (Blast Furnace)	DR (with gas) + EAF
	The desulphurising capability of the BF also allows for higher sulphur-containing fuels and reductants to be used in an environmentally friendly manner. It is important to remember that the traditional ironmaking route provides for many recycling and disposal opportunities for ferruginous arisings, filter cakes and oils from downstream steel production that may not be available in many reduction processes. The traditional route also has the ability to use a wide range of feedstocks and reductants of varying quality. The majority of GHGs (as CO_2) are emitted from the hot blast stove. A smaller amount of CO_2 emissions may also occur from flares, leaks in the ductwork for conveying the gas, and from emergency venting. The CO_2 emissions intensity per activity is 0.2–0.45 t CO_2/t coke for coke plants, 1.35–1.7 t CO_2/t HM for BF and <0.2 t CO_2/t LS for BOFs. Hence, typical CO_2 emissions intensities falls between 1.7–1.8 t CO_2/t LS for integrated mills. Although sharing 71% steel production, BF route represents a share of 82% of energy consumption and 88% of CO_2 emissions.	From the carbon footprint point of view, the DR/EAF route emits about 1 t CO_2/t LS. For the HYL ZR technology, total CO_2 emissions are about 0.92 tCO_2/t LS, which is reduced to about 0.68 tCO_2/t LS if selective CO_2 removal and commercialisation is integrated to the plant. Gas-based DR/EAF has an energy share of 4% and 3% of CO_2 emissions.
General and Cross-media Effects	Steel production through BF-BOF route has drastically declined during the last decade in North America and Europe while increasing in China, which accounts for about 46% of the total. The main reasons for this drop in reputation: large investments, large capacity to be feasible, significant environmental impact and the highest carbon footprint.	DR-EAF route can produce all steel qualities, presents much lower environmental effects and the lowest carbon footprint. This route is also flexible in terms of required mill capacity.

2.9.1.2 Gas-based vs. Coal-based DR Processes

As mentioned earlier, there are two general categories of DR processes on the market. There are those based on natural gas and those based on non-coking coal as the main energy and iron ore reductant source.

Two gas-based DR processes are more prominent: MIDREX and HYL technologies where the natural gas is steam-reformed in tubes filled with nickel-based catalysts into a mixture of H_2 and CO. The preheated syngas is eventually blown in from about the middle of a shaft furnace while the iron ore pellets are charged at the top. While descending, the ore is gradually reduced into DRI which can be discharged at the bottom of the furnace as hot DRI or cold DRI. The furnace exhaust gas containing up to 70% of residual syngas as well as dust, CO_2 and H_2O is cleaned, cooled, recompressed, and recycled back into the syngas circuit.

The HYL Energiron ZR process is another gas-based DR process that operates without a steam reformer.

The Fastmet coal-based DR process uses a similar concept as the syngas is generated from coal inside a rotary hearth furnace. In this process, a fine iron ore and pulverized non-coking coal are mixed together with a binder material before being pelletized and dried on site. These dried pellets are then layered on a rotary hearth furnace where they are gradually heated with fuel-fired burners that heat the atmosphere over the iron ore layer. Heat is transferred efficiently by radiation from the atmosphere to the surface of the pellets and by conduction from the pellet to its interior. As the temperature increases, CO is generated from coal which subsequently converts iron ore into DRI following a series of reaction mechanisms. The residence time of the iron material on the rotating determines the degree of metalized iron in the DRI. After that residence time, the material is discharged from the furnace and can be used as hot DRI, cold DRI or briquetted into HBI. The heat of the fully-combusted flue gas off to the gas cleaning unit can be recovered to dry the feedstock. The treated flue gas is then discharged to the atmosphere.

Table 2.6 generalizes the differences between gas-based and coal-based DR ironmaking. Advantages of gas-based DR processes include:

- Lower energy requirements;
- Better quality of DRI product with higher metallization and less sulfur;
- Lower CO_2, NOx and SO_2 emissions.

NAIC initial project development was a coal-based DR plant, somewhat similar to the FASMET process, which evolved into a natural gas-based DR process. More information on the selection factors that have driven the project towards a gas-based DR plant is presented in section 2.9.2.

Table 2.6 Gas-based vs. Coal-based DR Ironmaking

Features	Gas-based DR + EAF	Coal-based DR + EAF
Status	Industrial	Industrial
Type of Reactor	Shaft	Rotary hearth or rotary kiln
Iron Source	Pellet/Lump Ore	Fines/Concentrate
Energy Source	Natural gas	Lignite to higher rank coal
Process Main Characteristics	› Recycling of residual top gas. › Selective elimination of H_2O and CO_2 in reduction circuit is possible. › Low amount of slag produced.	› Mixing and drying of feedstock are required. › All carbon is released through flue gases. No residual gas recycling possible. › Higher amount of slag produced.
Typical Module Capacity (kt/y)	600 – 2,500	100 – 450
Land/visual	› More compact unit, less footprint › Some equipment are outdoors and are taller (on the order of 100 m)	› Larger footprint › Furnace is inside a building, height is approximately 50 m
Energy Requirements (GJ/t)	~9.9 – 11	~12.6
Electricity Requirements (kWh/t)	~30 – 110	< 10
Product	Cold/Hot DRI and HBI	Cold/Hot DRI and HBI
Metallization (%)	> 94	> 85
Carbon in DRI (%)	1 – 5 (depending on process)	3 – 5
Environmental	› CO2 removal: 0–60% is CO2 is potentially commercialized. › Reduction of 0.9–1.0 t of CO2/t DRI down to 0.6–0.7 t CO2/t DRI with selective CO2 removal and recovery. › NOx ≤ 40 ppm with the use of low-NOx burners. › SO2 emissions are limited with the use of natural gas as feedstock.	› Additional systems needed related to gases (NOx, sulfur, dust, coal handling, treatment, processing) to comply with regulation. › 1.5–1.6 t CO2/t DRI. › NOx is in the range of 0.3–1.5 kg/t DRI. › Sulfur is absorbed in the DRI which reduces its quality. High sulfur slag needs to be disposed. High SO2 emissions are also obtained (2–2.5 kg/t DRI)
Water Treatment Plant	More complex	Simple

2.9.1.3 Reformer vs. Reformerless Gas-based DR Processes

The Midrex and HYL gas-based DR technologies both use a natural gas steam reformer in their process layout to produce syngas but they still have different features. These differences include the DR shaft furnace configuration (i.e. number of reaction zones like preheating, reduction, cooling, and carburization) and operating parameters (i.e. different pressure and temperature). However, the main difference is the DR gas circuit configuration. For the HYL process, natural gas is first reformed into syngas which can be further refined into a gas with a higher percentage of H_2 using a water-gas shift reaction and CO_2 removal unit. The syngas feed is then mixed with the recycled DR exhaust gas and preheated before entering the shaft furnace.

The HYL Energiron ZR process on the other hand employs a DR route where natural gas is converted into H_2 and CO directly at the inlet of the DR shaft furnace, excluding the need for a stand-alone steam reformer. It also provides means to recycle the furnace off-gas by removing the bulk of CO_2 and H_2S. The amine-based CO_2 removal unit prevents its build up into the DR recycled gas circuit.

The current HYL Energiron ZR technology employs a continuous shaft furnace in which the operating conditions are characterized by high temperatures (>1,080 °C) and high pressures (6-8 bar at the top gas exit). Higher pressures allow lower gas velocities through the shaft, which minimize dust losses through top gas carry-over.

Table 2.7 generalizes the differences between the Midrex, HYL and HYL Energiron ZR technologies.

Table 2.7 Comparison of Gas-based DR/EAF Plants[9]

Features	Midrex	HYL	HYL ZR ENERIRON
Status	Industrial	Industrial	Industrial
Type of Process	Moving bed/continuous	Moving bed/continuous	Moving bed/continuous
Type of Reactor	Shaft	Shaft	Shaft
Iron Source	Pellet/lump ore	Pellet/lump ore	Pellet/lump ore
Pre-treatment of Natural Gas	Reformer	Reformer	None (in situ reforming)
EAF Melt Shop	Same equipment	Same equipment	Same equipment

9 Based on information provided by Tenova

Features	Midrex	HYL	HYL ZR ENERIRON
Process Characteristics	› Recycling of top gas with fresh natural gas through a reformer. › All carbon (CO_2) released through flue gas. › Different configuration for each energy source.	› Recycling of top gas with freshly reformed natural gas. › Selective elimination of H2O and CO2 in the gas circuit. Up to 40% of CO2 can be removed. › Same configuration for each energy source.	› Recycling of top gas with fresh natural gas. › Selective elimination of H2O and CO2 in the gas circuit. Up to 60% of CO2 can be removed. › Same configuration for each energy source.
Current Module Capacity (t/y)	600 – 2,000	200 – 2,000	200 – 2,500
Typical Energy (GJ/t) Requirements at DR Unit	10.5	11.0	9.9
Typical Electricity (kWh/t) Requirements at DR Unit	110	30	75
Typical Electricity (kWh/t) Requirements at EAF Unit	380–430 (hot charging) 520–570 (cold charging)	380–430 (hot charging) 520–570 (cold charging)	380 (hot charging) 520 (cold charging)
Product	Cold/Hot DRI and HBI	Cold/Hot DRI and HBI	Cold/Hot DRI and HBI
Metallization (%)	> 94	> 94	> 94
Carbon (%)	1.0 – 2.5	1.0 – 3.0	2.0 – 5.0
Environmental	› 0.85 t CO_2/t LS › NOx ≤ 40 ppm with low NOx burners. › SO_2 emissions are limited with the use of natural gas as feedstock. › More graphite in DRI resulting in more dust emissions at the EAF.	› 0.9 t CO_2/t LS › 0.5–0.6 t CO_2/t LS with selective CO_2 removal and recovery › NOx ≤ 25 ppm with low NOx burners. › SO_2 emissions are limited with the use of natural gas as feedstock. › More graphite in DRI resulting in more dust emissions at the EAF.	› 0.8 t CO_2/t LS › 0.3–0.4 t CO_2/t LS with selective CO_2 removal and recovery › NOx ≤ 25 ppm with low NOx burners. › SO_2 emissions are limited with the use of natural gas as feedstock. › More iron in the form of Fe_3C which is less prone to be lost as dust at the EAF.

NAIC has selected the HYL Energiron ZR technology which includes the following advantages:

- Slightly lower energy requirements since the elimination of process water and CO_2 from the DR gas circuit improves syngas utilization;
- The higher carbon DRI is more stable and provides more chemical energy to the EAF, thus resulting in lower electricity requirements at the EAF;
- The improved presence of carbon into the EAF slag allows further precipitation of iron units contained in the furnace slag back into the liquid iron bath. Without carbon in slag, iron units would be lost into the EAF slag;
- The HYL Energiron ZR process provides DRI with more chemically combined carbon (i.e. Fe_3C) compared to other gas-based DR processes. Fe_3C is less prone to be lost as dust since it is chemically bonded with iron. In that state, the carbon is first melted before reacting with other agents. Meanwhile, graphite is not chemically bonded with iron and can quickly become dust and be lost in fumes upon contact with hot liquids in the EAF;
- High CO_2 abatement potential, if the CO_2 stream can be commercialized and used for other purposes.

2.9.2 Reducing Agent

The production of pig iron consists of concentrating iron in oxide form found naturally in ore. Oxygen bonded to iron is removed by a reducing element. This reducer element normally comes from a carbon source under the effect of heat and air, which will form carbon monoxide and hydrogen.

As seen in the preceding section, the reducing element selection is intimately related to the selection of technologies. The traditional route of the blast furnace and oxygen converter uses coke while direct reduction processes may use coal, natural gas or raw gas from coke furnaces. The reducing element choice is influenced by the possibility of integration with other processes, the energy balance, reducing agents also acting as a combustible, as well as the available raw material.

In the case of the NAIC project, it's more of a choice of reducing element that influenced the technology choice.

The project initially developed by NAIC aimed at the reduction of a cold briquette in a rotary hearth furnace. The reducing element, coal, was mixed with iron ore concentrate as well as with a binder, bentonite, to form briquettes. These materials were fed into a rotary hearth furnace heated by natural gas. The coal and concentrate being intimately bound in the form of briquettes, it resulted in a very good metallization. The coal allowed for the reduction of iron oxides as well as the contribution of reaction heat.

The partial replacement of coal and coke by forest biomass, a renewable carbon source, as a reducing element in the traditional production route of blast furnaces is conceivable from a technological standpoint, if it is injected in the lower part of the blast furnace. Even the type of wood used may influence the subsequent coal properties obtained by pyrolysis. It is however an emerging technology that requires research and development (Research Institute of Sweden, 2015). For use in a rotary hearth furnace, technology originally foreseen by NAIC, the consumption in weight would be 5 to 6 times higher with biomass than with coal. New equipment would be required to crush the wood needing to be added to the briquette. As wood contains more humidity than coal, it would have had to have been dried, requiring more energy. Its volume per mass being more than two times higher than that of coal, several pieces of equipment would have had to have been oversized.

In other respects, wood used in the silicon metal production route is principally for increasing the porosity of the bed of the load placed in the furnace. As it contains carbon, wood is also used in part for the reduction that is satisfied mainly by a fixed source of carbon such as coal. Wood as a reducing element is incompatible with direct reduction technologies.

During the public consultations held in Saguenay at the beginning of winter of 2016, certain concerns were raised about the dust emissions linked to handling, storage and use of iron concentrate and coal. In addition, the government of Quebec announced in the wake of the Paris COP21 conference on climate change very ambitions objectives to reduce greenhouse gases: a 37.5% reduction in 2030 of 1990 levels (Cible de réduction d'émission de gaz à effet de serre du Québec pour 2030 – Document de consultation- 2015). In addition to the regulation on greenhouse gas cap and trade system, the government encourages promoters of new projects to maximize their efforts in reducing at the source GHG emissions. Finally, in April 2016, the government of Quebec announced its plan to adopt a "zero coal" law aiming to completely eliminate coal as a source of energy by 2030. Thus, a caution was put on using coal in the fabrication process proposed by NAIC. Note that coal was essentially used as a reducer element in the process, however its volatile content was put to use toward the energy required. In response to concerns from project sector residents and the provincial government, NAIC asked its technology providers to revise its approach and deliver a facility that did not use coal in order to reduce its dust and greenhouse gas emissions.

2.9.3 Cooling Methods

Production of pig iron from the smelting of DRI in an EAF requires a significant quantity of heat. Transformers, compressors, the hydraulic circuit, the electrode arms, the electrode clamps, the door and the roof of the electric arc furnace are all equipment that requires cooling.

Cooling is mainly carried out by indirect contact. The cooling fluid could be water (cooling tower) or air (air cooler).

A cooling tower is a heat exchanger that removes heat from water by putting it in contact with air. Heat transfer occurs through an exchange of heat between air (natural or forced circulation) and water by evaporation of a small part of water to cool. In this way, it is possible to cool to a temperature lower than the dry ambient temperature, which constitutes an important advantage of towers over air coolers. Make-up water must continuously be added in order to compensate for the losses by evaporation. A continuous blow-down must also be necessary to maintain the mineral concentrations of the water. Chemical additions are necessary to prevent corrosion, scaling and the proliferation of bacteria. Among the other disadvantages are the vapor cloud that in winter will become a visual pollutant as well as possibly lead to fog and icing of streets of neighboring roads.

Air coolers are made up of large-diameter fans that dissipate the heat in the atmosphere using fins configured like a conventional radiator. This choice of cooling route is justified when water is available in a limited quantity or when the receiving element is environmentally sensitive, since it uses no water conditioning chemicals. On the other hand, its efficiency varies as a function of meteorological conditions, with a low efficiency in summer and a high efficiency in winter. Its electricity consumption is also more significant and could be another source of noise.

Considering the small capacity of the receiving body of water and in order to minimize water emissions, NAIC has chosen to use a combination of the two cooling methods. The decision will be made as a function of the thermal loads to cool off different equipment.

Certain pieces of equipment must be cooled by direct contact with cooling water. Electrodes and pig iron casting molds are both cooled with water spraying. Treated process water is used for the electrodes and will reduce its oxidation. As for the pig iron mold, direct contact with potable water allows for rapid cooling of the thermal load.

2.9.4 Sanitary Wastewater Treatment Methods

The proposed project site is not serviced by the City of Saguenay's sewer, so the site must treat all wastewater produced at the facility.

A conventional sanitary wastewater treatment system is generally more reliable in the long run and is also preferable because they require less maintenance than non-conventional systems and infiltrate treated effluent directly into the ground.

Conventional systems consist of a septic tank followed by a spray field, which infiltrates water into the soil, where treatment is completed with bacteria. There is, thus, very little maintenance apart from emptying and cleaning the septic tank periodically. The spray fields, however, lose their effectiveness over time as they become saturated and must be reconstructed, approximately every thirty years. Spray fields also require pervious soil, and cannot be used with clay, silty clay or clayey silt.

The non-conventional alternative must be selected because local soils consist, for the most part, of rock, boulder-engineered backfill or clayey deposits, all of which are unsuitable for a conventional system. Some sand is present, but only in the middle of the facility, which is impractical for the location of the sanitary treatment system. In this non-conventional option, the system consists of a septic tank, an equalization tank for phosphorous precipitation, and Ecoflow(R) shell purifier unit, and a final UV disinfection unit. The purifier unit consists of a plastic or organic media on which thousands of bacteria colonies sit, treating the wastewater biologically as it passes through.

2.9.5 Process Wastewater Treatment Methods

The philosophy of management of wastewater generated by the facility aims to recover, treat and reuse process-generated water. According to the EPA (2002), the best practicable control technology currently available (BPT) includes a high recycling rate and solids removal using a classifier and clarifier, cooling, sludge dewatering, and treatment of blowdown with multimedia filtration.

The system proposed by NAIC not only uses the BPT, but includes additional steps of treatment before discharge to surface water. Additionally, the pre-treated wastewater is treated by additional treatment units including an ammonia stripping tower, secondary clarification, and final sand filtration.

Considerable efforts are made to treat and recycle the effluents within the plant in order to minimize the discharge flowrate and reduce the water consumption. The ultimate objective would be to move towards a zero process effluent discharge plant.

During the detailed engineering of the project, NAIC will evaluate the different options available to reduce the flow of the final effluent, notably through increasing the number of cycles of concentration of the water in the two cooling circuits. The increase in the concentration cycle is influenced by:

- the capacity of the receiving environment;
- the quality of the water at the influent;
- the choice of water treatment technology;
- the desired water quality by the process.

The project site is not served by the sewer system of the City of Saguenay. The process water exceeding criteria must be treated before being discharged to the environment. Once treated, the water will be discharged to water course no. 5, a low-flow stream. Rather than discharging directly to a low-flow water course, a pipe discharging directly into the Saguenay River could have been constructed.

This alternative was quickly ruled out considering the costs of constructing a conduit of more than 2.4 km as well as the constraints and impacts related to work in a water course. The principal advantage of a discharge via an outlet pipe in the Saguenay is to be able to consider a certain dilution factor when establishing environmental discharge objectives, which are fixed depending on the capacity of the receiving environment.

As the discharge flow is relatively small, NAIC decided to rely on water treatment optimization techniques and the reuse of process water to aim for a facility without liquid discharge.

The water treatment techniques for the cooling towers are numerous: softening, descaling, reverse osmosis, demineralization, ion exchange resins, etc.; moreover, some of them can be combined. Generally speaking, softening is the most efficient technique in terms of quality of water produced and volumes of produced regeneration solution as well as being the least costly. It is however disadvantageous since it produces a fairly concentrated brine that cannot be discharged to the environment.

Saguenay potable water has a high level of hardness, at around 170 mg/l $CaCO_3$, and the frequency of the resin regeneration would also be quite high, increasing the volume of brine generated.

The quality of water desired for the two cooling circuits presents a significant problem in the selection of the cooling water treatment technique.

Theoretically, the number of concentration cycles in the two cooling circuits could be optimized up to 12 by softening around 75% of the make-up water, thus resulting in a reduction of the blowdown of around 80% and a reduction in the make-up water of around 25%.

The EAF cooling water circuit is in indirect contact and the treatment is insignificantly influenced by the reduction process. There are thus no constraints to its performance guarantee.

The cooling water from the QCT is in direct contact with the process gas. The experience of the technology provider, Tenova, is to use a concentration cycle lower than 3. Any modification of the number of concentration cycles must be evaluated specifically by Tenova who provides the performance guarantee of the reduction process.

In addition, in both cases, the treatment of the brine remains problematic. Softening allows for the blowdown to be reduced but generates a relatively high volume of brine considering the water hardness and requires a particularly high regeneration frequency. One of the envisioned options would be to recycle the brine upstream of the clarifier. Since the clarifier receives the quench water and the QCT cooling water, which are in direct contact with the process gas, it is necessary to evaluate the impact of this recirculation on the reduction process. Another option would be to concentrate the brine and produce solid salts.

The selection of the cooling water process will be thus evaluated during detailed engineering by the technology provider in collaboration with the cooling water treatment system provider. The impact study considers the use of untreated fresh water (potable water) as make-up water to the two cooling water circuits, presenting thus the worst case in terms of final effluent flow and consumed water volume.

The literature makes no mention of ammonia in the discharge of reduction facilities. However, the designer and the technology provider, Tenova, foresees concentrations of around 250 ppm in ammonia in the cooling circuit of the QCT. The wastewater produced by the DRI process will contain ammonia and nitrates that could be formed during the reduction reaction.

Biological and physical-chemical processes are available to eliminate ammonia in the water. Biological methods consist in oxidizing ammonia into nitrates (nitrification/de-nitrification) using autotrophic bacteria. This technique, usually used to decrease the organic load in parallel, is inconvenient in that it is sensitive to many chemical compounds. The physical-chemical methods are better adapted to industrial wastewater because of the variability of concentrations and flows. The physical-chemical methods the most used are extraction, adsorption onto resins and chlorination. Adsorption onto resins generated a liquid waste that has to be disposed while chlorination is mostly a polishing technique and implicates the use of hazardous materials and a control of the residual chlorine concentration at the exit.

The study in 2014 carried out by Hatch on the identification of the best available technologies economically achievable (BATEA) for the management and the control of mining effluent quality proposes to add total ammonia to the list of substances of Appendix 4 of the Metal Mining Effluent Regulations (MMER). For the mineral iron subsector, the BATEAs identified are decanting and precipitation with the addition of coagulant and flocculant. There could be natural ammonia degradation in the basins. The limit proposed is 8 mg/l of total ammonia. The BATEAs identified in this study, for the iron and other metal sectors, is not easily transposable to the pig iron sector or for the NAIC facility, the production technologies and the effluent flows to treat are different. The concentrations in ammonia vary according to the sector, from 4 mg/l to 12 mg/l.

The wastewater will be treated using an air extraction column, which will allow the ammonia concentration to be reduced to below 5 mg/l before being discharged to the final environmental receiver. This method, recommended for integrated steel mills[10] by the International Finance Corporation of the World Bank (IFC, 2007), is distinguished by the following advantages:

- Facility of operation and resistant to load variations;
- Does not require regeneration and does not generate wastewater;
- Is not affected by toxic compounds, in contrast with biological methods.

The dust contained in the process gas is transferred in part to the process water and is removed in the form of sludge after precipitation. The sludge, a source of iron, will be pressed, dried, put into briquettes and reintroduced in the reduction process. The recovered dust in the filtering bags of the baghouses will also be made up principally of iron. As with the sludge, this dust will be briquetted to be introduced to the reactor.

2.9.6 Atmospheric Emission Control

Classic particulate matter (PM) emission reduction technologies are mechanical collectors (cyclones), baghouses (fabric filters), electrostatic precipitators and wet scrubbers.

Cyclones

Cyclones use centrifugal force to remove particles, and are often used as pre-cleaners for more expensive final control technologies. Typically, the incoming gas stream enters a tangential inlet duct at the top of a conical shaped chamber inducing a circular motion downward. At the bottom of the cyclone, the gas turns and spirals up through the center of the outlet tube at the top of the cyclone. The particles reaching the cyclone's wall fall by gravity into the bottom hopper. High collection efficiencies are achieved if the gas stream contains high-density particulates subjected to greater centrifugal force.

Baghouses - NAIC Choice

Baghouses, or fabric filter collectors, are designed to capture particulate emissions from industrial stationary sources. Fabric filters are normally assembled vertically in bundles of tightly woven tubular bags and placed in isolable compartments. During operation, the dusty gas flows through the bag prior to its release into the atmosphere. A dust cake builds up on the

[10] This directive includes direct reduction processes as an alternative production route for primary steel.

tubular bags gradually improving the filtration capacity for smaller particles. The filter bags must be cleaned periodically as the differential pressure drop reaches a limit. Removed agglomerated dust is accumulated in a bin and periodically discharged. The NAIC project uses a jet-pulse baghouse to control dust emissions. With the pulse jet fabric filter, the particles are collected on the outside of the bags instead of the inside. The dust can thus be removed by a reverse pulse of high pressure air by injection at the top of the bags. When dust accumulates inside the bags, they have to eventually come off line for cleaning using either bag shaking or reverse-air techniques. The selected bag filter will be "negative pressure" type, with bag cleaning performed by means of compressed air. The filter will be constructed in such a way that the body is parted in separate cells to be cut off by dampers. The top of the filter is equipped with liftable covers to allow the periodic maintenance operation performed without the need to enter inside the filter shell.

Electrostatic Precipitators

Electrostatic precipitators use an electric field to move particulates out of the flowing gas stream onto collecting plates. They have high removal potential for all particulate sizes including the very fine. Gas-borne particles flow through a series of high-voltage discharge electrodes (ionizers) located between grounded parallel plates of sheet metal (collecting electrodes). An electric current is applied through discharge electrodes causing gas ionization. The particles charged by resulting ions migrate across the electric field onto the collecting plates. Periodically, the collecting plates are knocked mechanically to dislodge the particles into hoppers.

Wet Venturi Scrubber

The waste gas flows in a duct before entering a narrowed section ("throat") where it accelerates and atomizes the incoming scrubbing liquid (normally water) at speeds over 50 m/s. After the throat section, the mixture decelerates and is sent to the entrainment section consisting of a cyclonic separator and/or a mist eliminator. It separates the clean gas from wetted particles that are recovered in a sink. The performance of a scrubber, which relies mostly on inertial impaction, is highly dependent on the PM size distribution. Particulates with diameters under 5 µm procure the highest efficiencies normally above 98%. It decreases exponentially with particle size. It is common to install a mechanical collector prior to the scrubber in order to reduce the coarse particulate loading and improve the scrubber's collection efficiency.

The main advantage of baghouses over wet scrubbers is that they produce a dry solid, iron dust that can be fully recovered within the process. In comparison to electro-static precipitators and cyclones, they can handle gas stream fluctuations and can be adapted to SOx reduction.

2.9.7 CO_2 Management

As mentioned earlier, the reduction process will generate CO_2 which needs to be removed from the process gas circuit to avoid its build-up. Options with regard to the CO_2 stream by-product include:

- the incineration of the CO_2 stream for the oxidation of H_2S into SO_2, in which case the CO_2 will have no further use;

- the delivery of the raw CO_2 stream, as a valuable by-product to gas companies for further treatment and commercialization;
- the installation and operation of a sulfur removal system for CO_2 purification and immediate commercialization as a valuable by-product.

The option chosen by NAIC consists in oxidizing gaseous effluents in order to convert H_2S into SO_2. Steps have been taken with companies involved in the production of industrial gases, including CO_2, to assess their interest in recovering and capturing the CO_2 produced. The location of the plant away from potential consumers of CO_2 and the production rate, which is relatively low from a marketing point of view, means the CO_2 capture appears to be an unattractive alternative at this stage of the project, despite the avoided costs of recovering CO_2 as per the Regulation respecting a cap-and-trade system for greenhouse gas emission allowances.