REV.	DESCRIPTION	DATE	PROJ.	EXEC.	CHECK.	APPR.
3	ISSUED	4/4/18	SAG	SAG	MES	MES
2	FINAL	8/14/2016	SAG	SAG	MES	MES
1	FOR REVIEW	7/30/16	-	SAG	KJS	MES
0	FOR REVIEW	6/9/16	SAG	SAG	KJS	MES

Pure Fonte Ltée

PURE FONTE LTÉE

PIG IRON PRODUCTION PLANT – FEASIBILITY STUDY

CUSTOMER Nº: 1821

tenova

TECHINT

TENOVA

TECHINT ENGINEERING & CONSTRUCTION

SECTION 1 - SUMMARY

CHAPTER 1.5

TECHNOLOGY SELECTION AND VALUE CHAIN

ESC.: N/A

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FIGURES AND REFERENCES

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1.5 Technology selection and value chain

1.5.1 Technology selection

When deciding on a technology to produce merchant pig iron, PURE FONTE LTÉE understood profitability would not be enough for a successful project, particularly for a North American manufacturing facility, and environmental impact would be of huge importance to local communities, governments, investors and any and all other stakeholders in the project. Thus PURE FONTE LTÉE determined it must be the "Global Leader on Minimizing Environmental Emissions" for the production of merchant pig iron.

To do this required an alternative to the traditional coke based blast furnace production route. In general, this would require pre-reduction of some kind followed by smelting in an electric furnace. The selection of the iron ore reduction process has been a key decision, not only because of the impact that such decision has on the environmental footprint of the plant, but also because different routes of iron reduction have had varying degrees of technical and commercial success, would imply different type of downstream equipment and have differences in capital expenditure and operational cost.

Several technologies for iron reduction have been industrialized and are today commercially available, namely:

- Midrex direct reduction technology
- HYL III process
- HYL Energiron® Zero Reformer (ZR) process
- Fastmet/Inmetco Rotary Hearth Furnace process
- Finmet technology

A technology selection was carried out as part of this Feasibility Study, summarized in the following paragraphs.

Figure 1.5-1: photos of a Rotary Hearth Furnace (RHF) made by Tenova Core Inc. [1] and the Energiron® plant of Nucor Louisiana by Tenova HYL [2]

1.5.1.1 General process comparisons (1)

	Midrex	HYL III	HYL ZR	Fastmet/ Inmetco	Finmet
Status	Industrial	Industrial	Industrial	Industrial	Industrial
Type of process	Moving bed/continuous	Moving bed/continuous	Moving bed/continuous	Rotary hearth furnace	4-steps fluidized bed
Type of reactor	Shaft	Shaft	Shaft	Rotary hearth	Fluidized bed
Iron source	Pellet/lump ore	Pellet/lump ore	Pellet/lump ore	Fines/ concentrate	Fines 0.1-12 mm
Energy source	NG, COG, Syngas	NG, COG, Syngas	NG, COG, Syngas	Coal and NG (optional fuel)	NG
Pre-treatment of NG	Reformer	Reformer	None (in-situ reforming)	N/A	Reformer
Process Characteristics	Recycling of top gas through reformer	Selective elimination of H_2O and CO_2 in reduction circuit	Selective elimination of H_2O and CO_2 in reduction circuit	Rotating hearth furnace	Selective elimination of H_2O and CO_2 in reduction circuit
	All carbon release through flue gases	About 40% CO_2 selectively removed	About 60% CO_2 selectively removed	all carbon release through flue gases	About 40% CO_2 selectively removed
	Different config. for each energy source	Same config. for each energy source	Same config. for each energy source	only applicable for coal	Only one configuration available

Table 1.5-1.: General process comparisons (1)

1.5.1.2 General process comparisons (2)

	Midrex	HYL III	ZR ENERGIRON	Fastmet/Inmetco	Finmet
Typical module capacity (kt/y)	600-2,000	200-2,000	200-2,500	450	500
Energy consumption					
NG (GJ/t)	10.5	11.0	9.9	12.6	12.5
Electr. (kWh/t)	110	30	75	< 10	175
Product	Cold/Hot DRI and HBI	Cold/Hot DRI and HBI	Cold/Hot DRI and HBI	Cold/Hot DRI and HBI	HBI
Metallization (%)	> 94	> 94	> 94	> 90	> 92
Carbon (%)	1.0-2.5	1.0-3.0	2.0-5.0	> 3.0	0.5-1.0
Environmental	Standard with no CO_2 off-taking NOx ≤ 40 ppm with LNB	Potential CO_2 off-taking: 40% CO_2 can be commercialized NOx ≤ 25 ppm with LNB	potential CO_2 off-taking: 60% CO_2 can be commercialized NOx ≤ 25 ppm with LNB	Add. systems needed related to gases (NOx, sulfur, dust, coal handling, treatment, processing), to comply with regulation	Fulfillment with environmental regulations with no major modifications

Table 1.5-2.: General process comparisons (2)

Based on the above process comparisons, two processes were selected and considered: The Inmetco (RHF) coal based process and the ZR Energiron® process (DRI)

A more accurate process comparisons had to be carried out to understand the differences between these two routes.

1.5.1.3 Detailed process comparisons

	Coal-based process (RHF)	ZR ENERGIRON (DRI)
Raw Material	Canadian Iron ore and coal	Canadian Iron Ore Pellets
Drying	by gas burners, CO_2 emissions	not required
Mixing & Briquetting	added maintenance & energy	not required
Ore Reduction	higher CO_2 emissions higher SO_2 emissions need of SO_2 scrubber higher NO_x emissions	lower CO_2 emissions possible CO_2 capture low SO_2 emissions lower NO_x emissions
Melting	higher amount of slag produced	lower amount of slag produced
De-Sulfurization	required to achieve MPI spec production of hi-S slag	not required
Pig Casting	same equipment	same equipment

Table 1.5-3.: Detailed process comparisons

The above table compares the two different routes from ore to pig iron if adopting the RHF technology or the DRI technology for the reduction phase. It is clear from this table that the DRI route has a very important advantage because it does not require a drier, a mixer and a briquetting machine, it has lower emission footprint and it will not require desulfurization equipment. Avoiding such a large amount of equipment is due to the fact that DRI uses iron ore pellets. These pellets come at a higher cost compared to iron concentrate, but provide an advantage of lowered operating costs (less maintenance, less internal material handling, etc) and a much simpler plant process.

1.5.1.4 Plant comparisons

	Coal-based process (RHF)	ZR ENERGIRON (DRI)
Water consumption	below 200 m3/h	below 200 m3/h
Water Treatment Plant	Simple	more complex
Bag House size	approx. 1,200,000 Nm3/h	approx. 800,000 Nm3/h
Additional stacks	#3: coal drier, ore dryer, scrubber	#2: Flare, Process Gas Heater
Real Estate required	Approx 35 acres	Approx 26.5 acres
Highest point	56 m (Melting Building)	110 m (DRI tower)
Reference plants	ITmk3 (2009) – 500,000 tpy (idled) IDI (1995) – 250,000 tpy Inmetco (1978) – 100,000 (idled) Kobe Nippon (2 plants)	Jindal (2016) – 2,500,000 tpy (u/engine.) Taichin (2016) – 500,000 tpy (u/erection) Nucor (2013) – 2,500,000 tpy Suez (2013) – 1,950,000 tpy Gulf (2012) – 200,000 tpy Welspun (2009) – 600,000 tpy Hylsa (1998) – 930,000 tpy (+ 16 more references of ZR predecessor)

Table 1.5-4 Plant comparisons

The above table of detailed comparisons show that the DRI route has clear advantages in the required real estate, in the fume treatment plant (smaller baghouse and lower number of stacks), and it has more plants of the same type and utilizing the very same process that are currently in operation and can certify the ability of such process to deliver the expected results. Moreover, these existing and operating plants, which have any range of sizes from smaller to bigger than PURE FONTE LTÉE, are also available as possible training sites for the PURE FONTE LTÉE personnel.

The more complicated water treatment plant and the height of the DRI tower will be discussed in the environmental section of this Feasibility study, but both are very manageable using state of the art technology and engineering design.

1.5.1.5 Emissions Comparisons: CO_2, NOx and Sulfur

	Coal-based process (RHF)	Natural Gas-based process (DRI)
CO_2 (t/ t mpi)	**~1.5**	**below 1.0**
NO_x (tpa)	**~125**	**below 75**
Sulfur at stack (tpa of S)	~300	below 40
Sulfur in scrubber dust (tpa of S)	2,600	None
Sulfur in EAF slag (tpa of S)	2,500	Below 10
Sulfur in de-sulf slag (tpa of S)	2,612	None
Sulfur in pig iron (tpa)	~42.5	~42.5

Table 1.5-5.: Emissions Comparisons CO_2, NOx and Sulfur

Most of the emissions from the RHF case are due to the coal. CO2/t pig iron for the DRI case will be under 1.0, but it would be 1.5 for the RHF case, a clear advantage to the DRI.

NOX emissions in the gas-based process are less than 60% than the coal based process.

There is 150x more S to deal with in the RHF case than the HYL case, because of the absence of coal from the gas based process. The S from the coal requires off-gas scrubbers which will remove +90% of the S from the off-gas, however this creates fines with S that must be disposed of.

The S grade PURE FONTE LTÉE must achieve in its Nodular Pig Iron has to be below 200 ppm. In the HYL case such spec is reached without the need of any additional purification after hot metal is tapped from the furnace; however, in the RHF case, a de-sulfurization station is required, with the consequent generation of high S slag that has to be disposed.

1.5.1.6 Process selection

Based on the comparisons tables of the previous paragraphs relevant to:

- Energy requirements
- Environmental impact
- Plant size and infrastructure
- Reference plants in operation

The process route that has been eventually selected for this Feasibility Study is the **Direct Reduction Gas-based route through the Energiron® technology**, coupled with conventional **electric arc furnace melting and pig casting technology**.

Figure 1.5-2.: Energiron® DRI plant at Ezz Steel, Egypt [3]

1.5.2 Value Chain

PURE FONTE LTÉE aims to produce 425,000 tons per year of high purity MPI, which would require more than 600,000 tons of iron ore pellets. This raw material, although being available from multiple suppliers worldwide, will be preferably provided by producers located in the Quebec, North East Canada and possibly the Great Lakes area. The pellets will be transported by ship straight to the site at a reduced cost compared to peers, thanks to the proximity of PURE FONTE LTÉE to its suppliers.

The PURE FONTE LTÉE site is located about one and half miles from the unloading wharf and the pellets will initially be trucked to site. Long term contracts for natural gas and electricity will be secured, to operate the transformation plant at the lowest possible operation cost.

PURE FONTE LTÉE will transform the iron ore pellets in high purity merchant pig iron, a product with extremely low values of Silicon, Phosphorous, Sulfur and Manganese, used by specialized foundries to produce the so called “nodular castings”. PURE FONTE LTÉE will secure offtake agreements with traders and clients specialized in nodular castings located in the North East and the Great Lakes area of the United States as well as Western Europe. PURE FONTE LTÉE’s plant location will allow timely, inexpensive access to all of its target markets providing an significant competitive advantage.

PURE FONTE LTÉE clients will transform PURE FONTE LTÉE's high purity MPI, a semi-finished product, into high value "ductile iron" nodular castings. Ductile iron is specifically useful in many automotive components, is used in agriculture vehicles, oil well pumps and in the wind power industry, all healthy sectors of the industry in western countries.

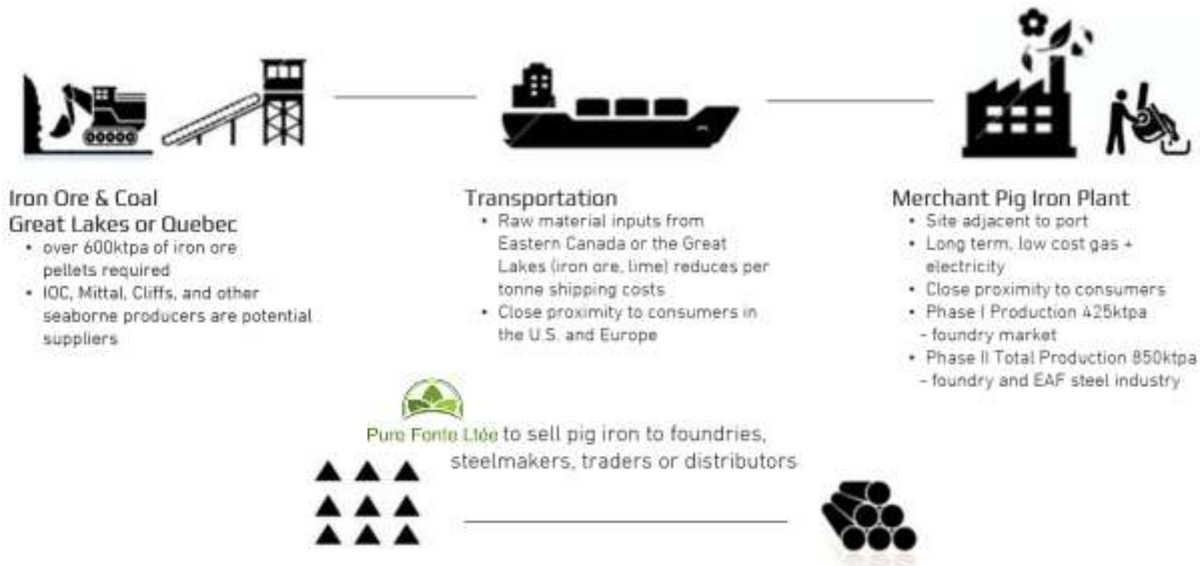

Figure 1.5-3.: PURE FONTE LTÉE Value chain [4]

The following chapters provide some additional details of this value chain.

1.5.3 Iron Ore and other raw materials

The Direct Reduction Gas-based Energiron® technology requires the utilization of iron ore pellets. There is a large number of suppliers in the World, most of which operating more than one pellet plant. Some of the most significant suppliers for PURE FONTE LTÉE are:

- Arcelor Mittal (Canada)
- IOC (Canada)
- Cliff (USA)
- United States Steel Corp (USA)
- Vale (Brazil)
- Samarco (Brazil)
- LKAB (Sweden)
- GIIC (Bahrain)
- Shougang Hierro Peru (Peru)

Iron Ore pellets are classified as DR pellets (for DRI production) and BF pellets (for Blast furnace utilization). The table below provides an analysis of some of the pellets available to PURE FONTE LTÉE:

	AM.BMC Pellet	AM.BBS Pellet	IOC BF Pellet	IOC DR Pellet	Cliff BF Hibbing	USS BF Minntac	LKAB KPRS DR	Hierro Peru DR
Fe tot	65.50	67.70	67.30	67.25	66.08	63.27	67.9	66.00
Fe+2	1.17	0.23	2.76	0.12				
Ored	26.48	28.76	24.98	28.72				
Fe2O3	91.98	96.46	92.28	95.97				
FeO	1.50	0.30	3.55	0.16				
SiO2	3.57	1.600	2.600	1.200	4.51	4.60	0.75	3.95
CaO	1.43	0.650	0.750	0.700	0.37	3.52	0.90	0.40
MgO	0.63	0.300	0.350	0.450	0.30	1.10	0.65	0.84
Al2O3	0.46	0.400	0.250	0.250	0.19	0.21	0.16	0.40
TiO2	0.15	0.153	0.040	0.040	0.031	0.021	0.16	0.09
P	0.01	0.010	0.008	0.008	0.012	0.10	0.025	0.010
Mn	0.03	0.031	0.140	0.150	0.07	0.08	0.06	0.020
K2O	0.03	0.015	0.010	0.015	0.019	0.025	0.030	0.07
Na2O	0.04	0.035	0.020	0.020	0.032	0.022	0.40	0.17
S	0.01	0.002	0.003	0.003	0.002	0.003	0.002	0.008
Gangue Tot	6.35	3.20	4.17	2.84				

Table 1.5-6.: Iron ore pellets analyses [5]

Thanks to the process route selected (Energiron® DRI-conventional EAF), for the production of high purity merchant pig iron (HP-MPI) PURE FONTE LTÉE will not have to use a DR pellet grade, but will be able to use also BF pellet grade. This is because unlike in a traditional DRI product, PURE FONTE LTÉE will be removing slag formers as part of the production process allowing the flexibility to use pellets with higher gangue content than DR pellets.

Elements like Si and P will be naturally removed from the metal in the EAF phase, others like S and Mn will have to be controlled at the source. Depending on the MPI grade to be produced, PURE FONTE LTÉE will be able to source from different suppliers helping to control raw material csots. Based on the above table, the most favorable pellets are the ones from Arcelor Mittal Canada.

Another significant raw material needed for PURE FONTE LTÉE process is lime, which is commercially available in the area of Quebec, thanks to the presence of the smelting industry (aluminum and other metals). Lime, dololime and bauxite will be purchased locally.

Figure 1.5-4.: Shovel and Haul truck at IOCC [6]

1.5.4 Transport to site

Raw materials to be transported at plant site:

- Iron ore pellets (Blast Furnace grade or DRI grade)
- Lime, dolomitic lime and bauxite
- Mold spray coating

Other main consumables used in the plant

- Electrodes
- Refractory

The main raw material by volume and cost is the iron ore pellets and the following paragraphs outline the main method of transportation to plant site, divided in two steps:

a. Transportation of the iron ore pellets from supplier's site to Port Saguenay's wharf
b. Transfer of the iron ore pellets to Port Saguenay's wharf to plant site

1.5.4.1 Origin of iron ore pellets

As said above, PURE FONTE LTÉE can use a variety of iron ore pellets produced worldwide; however, proximity to Canadian iron ore pellets from Arcelor Mittal Canada (AMC) and Iron Ore Canada (IOC) will provide a cost advantage and allow the project to be a Canadian consumer of Canadian raw materials.

Both of these suppliers have the ability to ship vessels of 35,000 tons via the St. Lawrence river to the Saguenay river and ultimately Port Saguenay. This is the size of vessel that is required to fill the storage dome at PURE FONTE LTÉE site. With only 20 shipments, one every 2 weeks, PURE FONTE LTÉE will receive all the material needed to produce the projected quantity of MPI in a year.
This Feasibility Study is so considering the river shipment as the main transportation method of the iron ore pellets to plant site.

As an alternative for the future, it has to be noted that the plant site is reached by a railway that potentially can be used to transport raw materials. Due to current railway shipment costs, this alternative is not taken into consideration as economically viable.

Figure 1.5-5.: both Arcelor Mittal Mines of Canada, located in Port Cartier, QC and Iron Ore Company of Canada, located in Sept-Iles, QC are less than 24 hours of navigation from North Atlantic Corporation, located in Port Saguenay, up the fjord of the Saguenay River [7]

1.5.4.2 Self-Unloaders for Iron Ore pellets transportation

The most economical way to ship iron ore pellets to Port Saguenay is using the so called "Self-Unloaders".

Self-unloaders are specialized ships equipped with onboard cargo-handling systems, enabling them to discharge without shore-based unloading equipment.

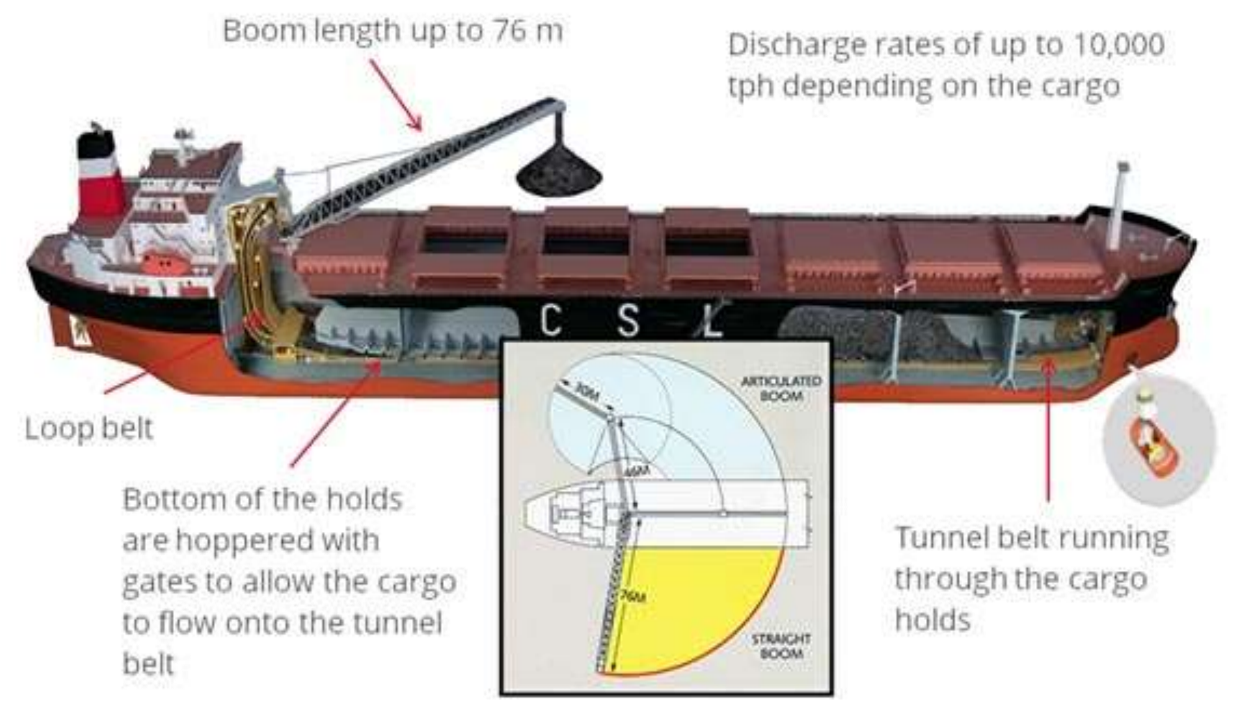

Figure 1.5-6.: Anatomy of a gravity-fed self-unloader [8]

Their rapid discharging rate, and reduced infrastructure and labor requirements, make this bulk cargo handling option an effective solution. It helps keeping costs down and minimize the environmental impact. Self-unloaders are then the ideal solutions for shipping iron ore pellets.

Operating 24 hours a day at an unloading speed up of up to 5,000 tons per hour, self-unloaders discharge faster than conventional dry-bulk carriers and do not require the expense of stevedores or cleanup crews. Self-Unloaders deliver more useable product than conventional vessels by virtually eliminating waste and contamination. Self-unloaders can discharge directly into a hopper, a barge, a quay or a warehouse or store. In the case of Port Saguenay, self-unloaders will discharge on a dedicated section of the wharf that will be made available by the Port Authority to PURE FONTE LTÉE.

Self-unloading vessels reduce a cargo's overall delivered cost per ton because they are efficient and less capital and labor intensive than on-shore based systems. The rapid turnaround time associated with self-unloaders frees up congested berths, thus reducing port costs and demurrage.

Loading and discharging cargo from a self-unloader can be carried out within a completely enclosed system. This ensures a clean ship and a clean dock, no dust pollution around the harbor and reduced noise levels.

Figure 1.5-7.: A vessel during charging operation at the wharf adjacent to the pellet plant for Arcelor Mittal Mines of Canada (AMMC) in Port Cartier [7]

1.5.4.3 Trucking from the wharf of Port Saguenay to the plant site

The iron ore pellets will be delivered by the self-unloading vessels onto the wharf of Port Saguenay, as per agreement between PURE FONTE LTÉE and the Port Authority. The transportation of the pellets from the wharf to the site will initially be realized by trucks. There are several trucking companies in the area (Groupe Goyette inc., Les Entreprises de transport PAG inc., Guylain Marquis, Logistique Saint Laurent), and the operation of transferring the IO to PURE FONTE LTÉE site will be coordinated by Quebec Stevedoring Company Ltd. (QSL), which will be discussed in this FS.

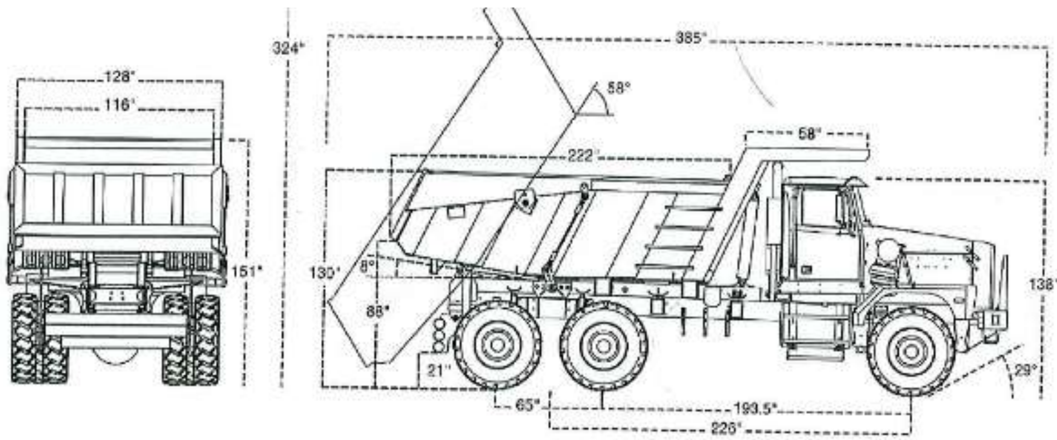

Figure 1.5-8.: Body dimensions of a truck able to transport 50 ton per load by Logistique Saint Laurent

Figure 1.5-9.: the distance between the wharf and PURE FONTE LTÉE site is 2.5 km of paved road [7]

1.5.4.4 Pipe conveyor / Belt conveyor from port to site

At the time of issuance of this Feasibility Study, it is known that the Port Saguenay Port Authority is discussing with equipment suppliers the construction of a pipe conveyor or a conventional belt conveyor that will connect the port wharf to the area adjacent to PURE FONTE LTÉE site.

This belting system will initially be only to deliver material from the wharf to the site and could be later upgraded to transport material from the site down to the wharf.

Since this project is not part of the investment of PURE FONTE LTÉE, it is not considered as part of the feasibility study. Nevertheless, there is a good chance that such equipment will be realized concurrently with the construction of the PURE FONTE LTÉE plant. In such case, the logistics from wharf to site for the iron ore pellets will become much easier and the operation cost will diminish. So the trucking option considered in this Feasibility Study shall be assumed to be a conservative one.

Figure 1.5-10.: one of the possible options of belting system from port to site, as per discussions between Tenova Takraf and the Port Authority [7]

1.5.5 Material transformation process

As discussed at the beginning of this chapter, the process route that has been selected for this Feasibility Study is the Direct Reduction Gas-based route through the Energiron® technology, coupled with conventional electric arc furnace melting and pig casting technology. The process steps will be the following:

Cold process:

- Iron Ore (IO) Pellets storage at plant site
- IO pellets screening (>3.2 mm)
- IO pellets cement coating
- IO pellets curing

Direct reduction process:

- Energiron® ZR direct reduction
- DRI hot discharge (>600°C)

Hot process

- Electric Arc Furnace (EAF) melting
- Hot metal stirring
- Pig Casting

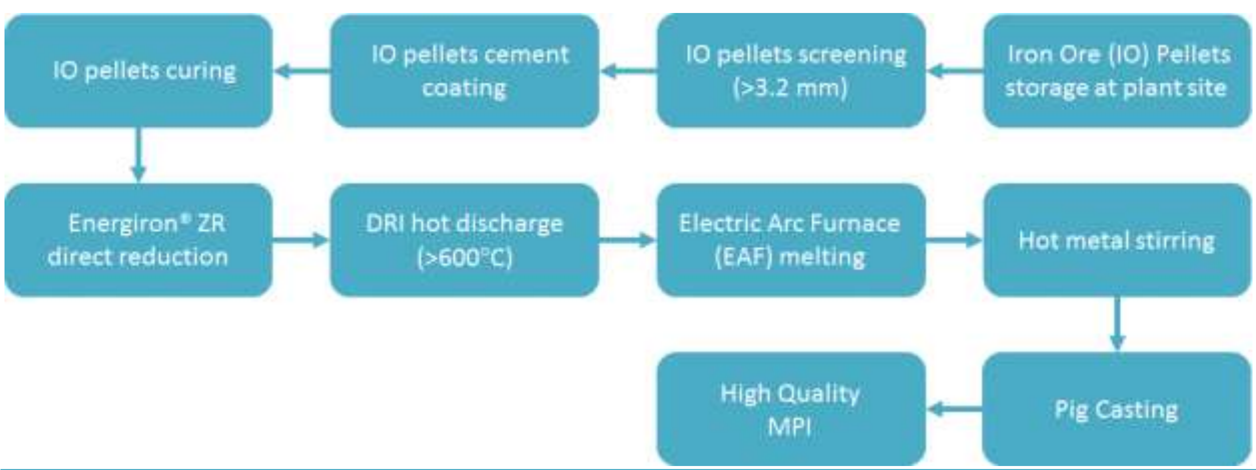

Figure 1.5-11.: Material transformation process flow diagram

1.5.5.1 Energiron® ZR direct reduction

Energiron® is the state-of-the-art technology for the production of premium quality DRI.

The process is designed to convert iron ore (pellet and also lump) into metallic iron by the use of reducing gases in a solid-gas moving bed shaft furnace. Oxygen is removed from the iron ore by chemical reactions based on hydrogen (H_2) and carbon monoxide (CO), for the production of highly metallized DRI.

In the Zero Reformer (ZR) configuration – the most advanced and eco-friendly of the process families – the reducing gas is generated by in-situ reforming of natural gas inside the shaft furnace. Natural Gas is the input that generates the reducing gasses and no coal is needed in this process.

One of the inherent characteristics of the Energiron® process scheme and of high importance environmentally is the selective elimination of both by-products generated from the reduction process; water (H_2O) and carbon dioxide (CO_2), which are eliminated through top gas scrubbing and CO_2 removal systems, respectively.

Main features of energiron technology		Process in brief	
Product	Low environmental impact	The process converts lump iron, iron oxide or pellet lump mixtures into highly metallized iron product	The reducing gas mix extracts from iron oxide the chemically bonded oxygen. The overall reduction reactions are:
Product Flexibility: COLD DRI, Hot DRI (HYTEMP® and HBI) in every modality	Low dust carry over determined by the low gas velocity into the shaft furnace	The most common types of iron ores have the composition of hematite (Fe_2O_3) and contain about 30% oxygen. In the Energiron process this chemically bonded oxygen is removed by means of a reducing gas mix at high temperature.	(1) $Fe_2O_3 + 3H_2 \rightarrow 2Fe + 3H_2O$ (2) $Fe_2O_3 + 3CO \rightarrow 2 Fe + 3CO_2$ moreover there is an additional reduction given by the following reaction (3) $3 Fe^0 + CH4 \rightarrow Fe_3C + 2H_2$
	High efficiency of the selected dedusting system		
Product Quality: High metallization, high carbon DRI. Energiron is the only DR technology currently capable of producing high carbon DRI with more than 90% of the carbon as iron carbide. Unique passivation characteristic due to high iron carbide content.	Low suspended solid content of water	The reducing gas is a mix of carbon monoxide (CO), hydrogen (H_2) and methane (CH_4). These gases react with oxygen contained in iron ore giving carbon dioxide (CO_2) and water (H_2O(g)) as products	Reaction (3) is part of the "in site reforming" reactions. The high carbon DRI produced with the Energiron plant has a very high metallization and controlled carbon content between 0.8% and 5% according to EAF requirements in the form of Fe_3C.
	Exhaust gas re-utilization as burner gas for gas burned in fume system greatly reduced the environmental impact		
	Incorporated CO_2 recovery system		
	Low Nox emissions due to high efficiency of the thermal equipment		

Figure 1.5-12.: Main features of the Energiron® direct reduction process [9]

Since the reducing gases are generated in the reduction section, optimum reduction efficiency is attained, and thus an external reducing gas reformer is not required. Therefore, the overall energy efficiency of the ZR process is optimized by the in-situ reforming inside the shaft furnace, since the product takes most of the energy supplied to the process, with minimum energy losses to the environment. As compared to other processes for which the overall efficiency is below 80%, for this scheme the efficiency is around 86%.

This plant configuration has been operated successfully since 1998 with the HYL DR 4M plant, and also was incorporated in 2001 to the 3M5 plant at the Ternium steel mini mill in Monterrey, Mexico. The new ZR Energiron® plant in Nucor Louisiana, USA is a world reference for this technology.

An advantage of The ZR process scheme is the wider flexibility for DRI carburization, which allows attaining carbon levels up to 5%. This is due to the improved carburizing potential of the gases inside the shaft, which allow for the production primarily of iron carbide. MPI requires a carbon content of 3.5% to 4.5%, so being able to produce high carbon DRI (5% C) for smelting will allow PURE FONTE LTÉE to avoid having to carburize the hot metal in the EAF.

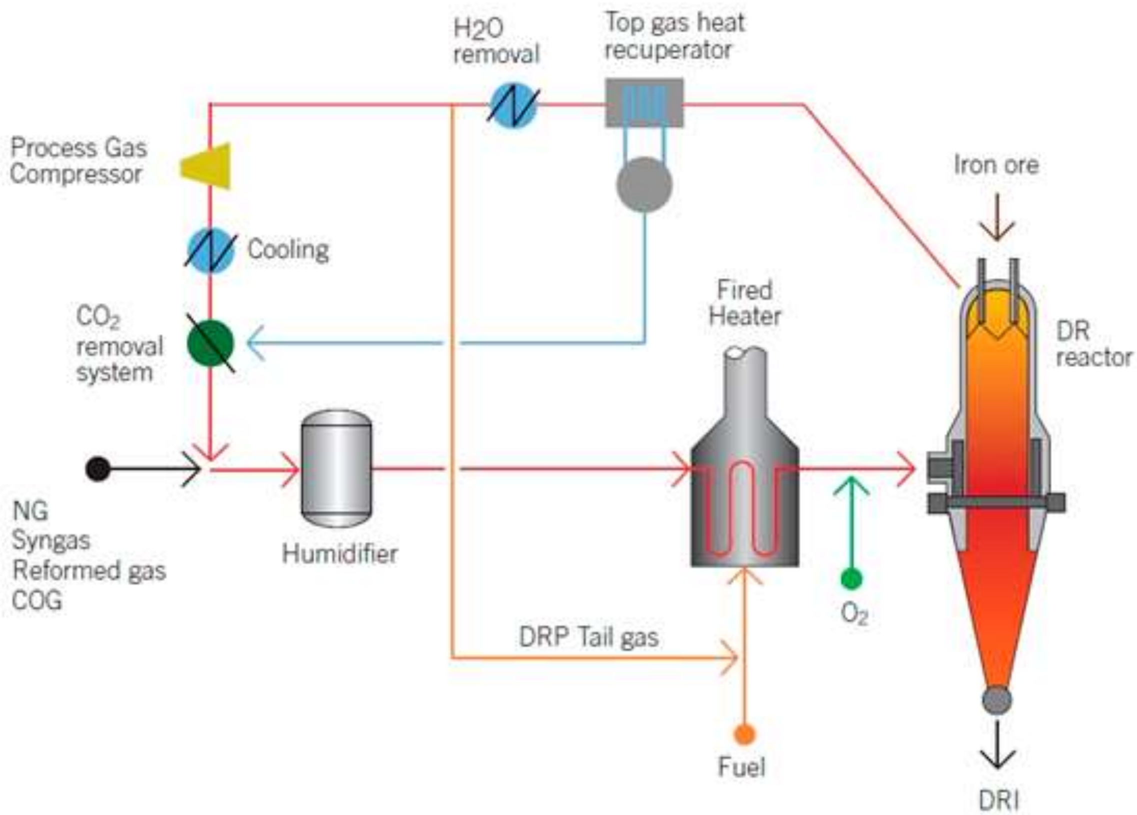

Figure 1.5-13.: Energiron® ZR process scheme [10]

1.5.5.2 EAF melting

The hot DRI from the Energiron® process will be charged by gravity into an electric arc furnace at more than 600°C. This hot DRI will be charged having more than 5% carbon content allowing for pig iron with a carbon content of 3.5% - 4.5%.

The hot DRI will be charged continuously from the reactor to the EAF for 80-90 minutes and the EAF will melt this flow of DRI at a constant electric power. The EAF will not use oxygen injection to prevent carbon loss and will only use electrical energy to melt the bath. The EAF will be sealed to prevent air infiltration and preserve the carbon of the bath.

Every 120 minutes, the EAF will tap 120 metric tons of liquid metal into a ladle through a spout system that will be opened automatically by a robotized tool. The EAF will be equipped with the proprietary Tenova technology “no-man-on-the-floor”, a set of devices, robots and software automation that allow the full control of the EAF from the control room, without the need for the furnace operator to leave the protected environment. The safety of the plant is a key feature of the PURE FONTE LTÉE project and the “no-man-on-the-floor” technology will be adopted all across the plant.

During the melting operation, chemical elements like phosphorous, silicon and other impurities will be removed from the liquid metal by migrating into the slag. The low level of input Sulfur and Manganese from the iron ore pellets will remain but at acceptable levels. The result of this simple and conventional operation will be a high purity liquid pig iron

Figure 1.5-14.: Photos of the inside and outside of a conventional spout design EAF [11]

1.5.5.3 Pig Casting

The liquid pig iron will be transformed into solid pig iron using a conventional pig casting machine. The vendor selected for this Feasibility Study is Paul Wurth, a leading supplier of such equipment whose technology aims to decrease maintenance and installation time.

These machines are built based on a modular construction type design. The machine for PURE FONTE LTÉE will have a single strand. The size the caster will be of 100 tons an hour, so that every approximately 73 minutes a full ladle of 120 ton will be casted. For the rest of the time, before the next EAF tap, the pig caster will be prepared for the next ladle of material.

Also for the pig caster, the operation will be fully automated, with a very minimum requirement for operators.

Figure 1.5-15.: Pouring iron at ISCOR in Pretoria [12] and photos of Paul Wurth pig casting machines [13]

1.5.6 Shipment of the product

Once the HP-MPI is casted by the pig casting machine, it is moved by front-end loaders into the covered space allocated in the plant for pig iron storage. The pig iron will be protected from the elements to prevent rain, snow and ice from oxidizing its surface.

Once the volume of pig iron will reach the size required for transportation, the pig iron will be charged on the same trucks that are moving the iron ore pellets from wharf to the site. The trucks will move the pig iron down to the wharf where the product will be charged on ships or barges to be shipped to the final clients or to the traders.

Ships will be directed northeast through the St. Lawrence river to the Atlantic Ocean, to reach clients of the east coast of North America or the clients in the UK and Europe. Ships or barges will be directed south west along the St. Lawrence river to reach the area the U.S. Great Lakes.

Figure 1.5-16.: Discharge of pig iron in bulk at IRPC Port Rayong, Thailand [14], and shipment of pig iron by river barge [15]

1.5.7 Energy Resources

The energy sources required for the transformation process of IO pellets into MPI are natural gas and electrical energy. Two companies have expressed interest in providing PURE FONTE LTÉE with the requires infrastructure investment.

1.5.7.1 Electrical Energy

Electrical Energy will be supplied to the site by **Hydro Quebec (HQ)**. At the time of issuance of this Feasibility Study, HQ already completed a preliminary assessment of the required investment and the extent of the project to bring the required power (about 75 MW) to the site. HQ will have to build a relatively short new HV power line, of 161 kV, for a distance of 9 km. The time estimated by HQ for this work is in line with the required construction time for the PURE FONTE LTÉE project. The capital cost of the line will be covered by a letter of credit to be provided by PURE FONTE LTÉE that will be retired as the plant reaches operation and consumes electrical power. Construction timelines and upfront costs are not included in this FS, because responsibility of HQ.

1.5.7.2 Natural Gas

The other energy resource required for the transformation process is Natural Gas. The area of Port Saguenay is served by the company **Gaz Metro (GM)**. At the time of issuance of this study, Gaz metro has already provided to PURE FONTE LTÉE a preliminary estimation of the required work needed to bring a pipeline for NG to the site. GM has estimated that a pipeline of 10" will be built alongside the road that goes to the port, which will provide enough volume for the PURE FONTE LTÉE usage. GM will construct this pipeline. The molecules of natural gas can be purchases from Gaz Metro or any other natural gas supplier PURE FONTE LTÉE should choose to work with. Construction timelines and upfront costs are not included in this FS, because responsibility of GM.