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DEVELOPMENTS IN NORTH AMERICAN IRON ORE & IRONMAKING[1]

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Abstract

North American blast furnace ironmakers continue to extend campaign life with shotcreting techniques, hearth protection measures and stable operating practices. The Marcellus shale natural gas price reductions enhance the co-injection of natural gas with other injectants such as coal. Energy recovery cokemaking continues to advance while new formed coke production techniques are being explored. Iron ore developments include commercialization of plants to recover concentrate from iron ore tailings, building of new pellet plants and pellet plant expansions while existing pellet producers continue to improve quality. Iron unit production for the EAF sector progresses with pig iron nugget production as well as projects to restore gas based shaft furnace DRI production in the USA with these techniques continuing in Mexico and Canada.

Key words: North American ironmaking; Iron ore; Iron units for EAF.

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1. INTRODUCTION

In earlier (1, 2) presentations and in addition at the 5th ICSTI 2009(3), the authors reported that the blast furnace based steel sector in North America had changed in a dramatically positive way. The EAF based steel sector plays a growing role in North American ironmaking. The role of integrated DRI/EAF steel producers in Mexico, USA and Canada will also be discussed here following our outline of blast furnace ironmaking. The North American iron ore sector is in an expansion mode, not only to supply both the BF and DRI/metallic sectors but also to serve the growing iron ore export market.

2 Blast Furnace Ironmaking

2.1 Economic Setting and Impact of Financial Crisis on BF Production

The authors reviewed the major economic factors affecting blast furnace based ironmaking earlier [1, 2, 3]. Financial restructuring, steel company consolidation, captive and local raw material positions and favorable currency shifts all helped blast furnace based producers overcome earlier problems associated with competition from both imports and EAF based producers, legacy employment costs, capital starvation, etc. The consolidation of North American ironmaking in the past two decades can be summarized by noting that in 1993 there were 19 companies with blast furnace operations with more than half of these operated only one or two furnaces. In 2011, by contrast, as seen in Figure 1, we count only 7 companies with blast furnace operations, with the two largest companies, ArcelorMittal and USSteel, dominating hot metal production on a tonnage basis with 70 % of the production from 23 furnaces. This consolidation placed the industry in a much more competitive position to survive the financial crisis. In former times, the many small companies each reduced operating levels, but, in order to satisfy their individual customers, kept essentially all the various works operating. This tactic resulted in both very high operating costs and ruinous price cutting, thus exacerbating financial losses. During the recent financial crisis the consolidated companies were very quick to re-organize their operations, reducing the number of blast furnaces in operation, as shown in Figure 2. They even closed 7 of 21 entire steel plants as demand waned. Total hot metal production in 2009 was the lowest, excluding the Great Depression era in the 1930's, in nearly 100 years.

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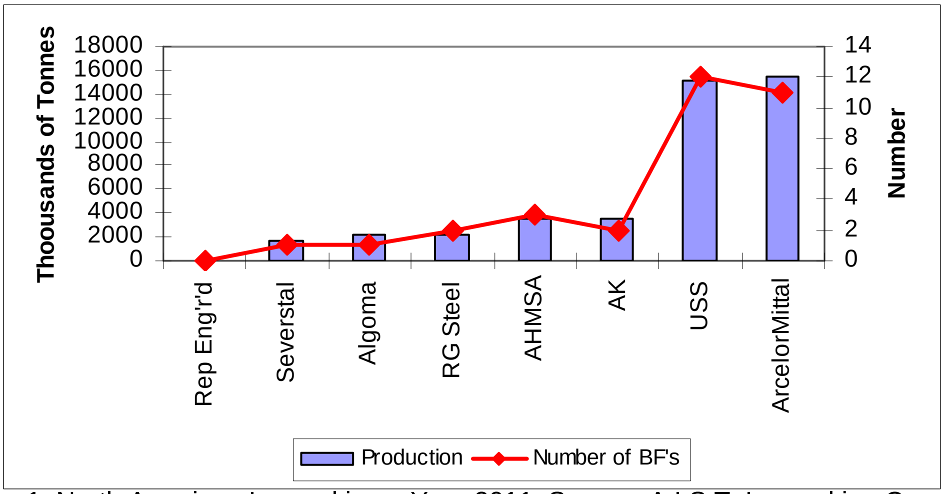

Figure 1: North American Ironmaking – Year 2011; Source- A.I.S.T. Ironmaking Committee

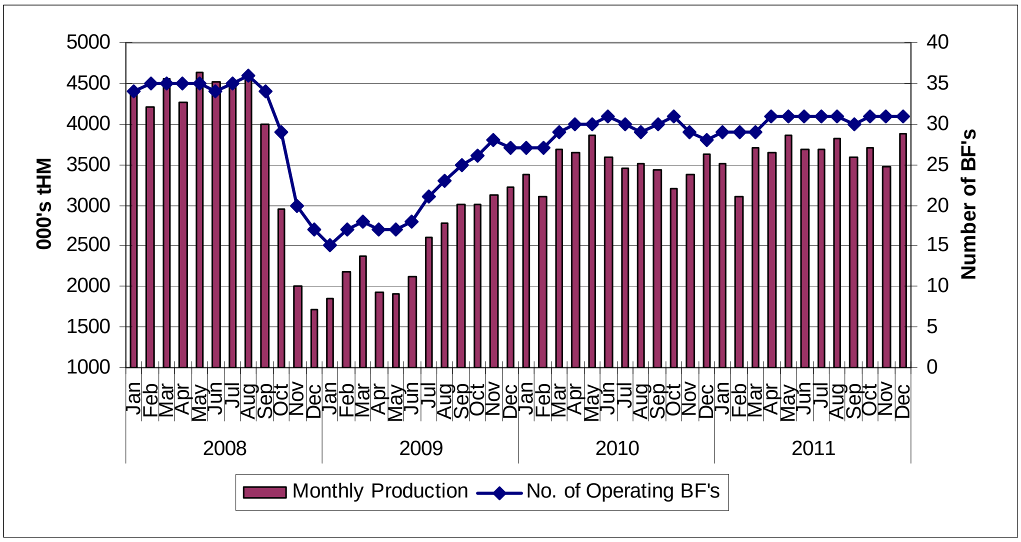

Figure 2: North American Ironmaking – Years 2007 – 2011 Source- A.I.S.T. Ironmaking Committee

Most importantly, no company was forced into bankruptcy during this crisis; quite a departure from the financial distress that accompanies earlier major downturns in the economy. As demand improved, the plants were restarted one-by-one, but production still lags behind pre-crisis levels by about 20%.

In Table 1, we list the North American blast furnaces operated in 2011 with information on size, charging system, production, ferrous burden and type of injectant. About 20% are free-standing design with 80% being of lintel design. 55% utilizing plate cooling for the bosh, 35% using staves and the remaining 10% utilizing external cooling, either spray or jacket types. Stack cooling is nearly 80% by copper plates, with only 20% by staves. All blast furnaces in Mexico and Canada and many in the USA now have bell less tops with many other furnaces are equipped with movable armor although some furnaces are not actively utilizing their movable armor. Some prominent furnaces such as those at Burns Harbor still have 2 bell tops without movable armor but overall process performance continues to be quite good at this plant. Blast temperature capability is being incrementally increased with stove oxygen enrichment systems at some sites.

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Most cast houses now have evacuation systems for pollution control. The larger blast furnaces have slag granulation systems typically owned/operated by cement producers. Other companies utilize blast furnace slag for aggregate applications. PCI (or GCI) has been installed at most furnaces but (as will be explained later) low gas prices will preclude further installations.

Table 1 North American Blast Furnaces 2011 Operating Data

	Company	Works	Furnace	Hearth	Working	Chging	2011		2011 Burden				Injectant
			I. D.	Diam	Volume	Control			Pellets		Sinter	Ore &	Used
				meters	cu m	Device	thm / 24 Hrs	t / m3wv	Fluxed	Acid		Other	2011
	CANADA												
1	Algoma	S St Marie, Ontario	7	10.66	2367	PW	6529	2.1	100	0	0	0	G
2	Arcelor Mittal	Hamilton, Ontario	2	7.30	1062	PW	2054	1.9	73	27	0	0	C,G,O
3			3	6.50	963		1910	2.1	73	26	0	1	C,G
4			4	8.53	1595	PW	3511	2.2	74	25	0	1	C,G,O
5	US Steel	Nanticoke, Ontario	L.E.W. 1	10.28	2418	PW	5863	2.3	24	70	0	6	G
	MEXICO												
6	AHMSA	Monclova	4	6.40	1034	PW	3174	3.1	8	29	54	9	C,G
7			5	11.19	1914	PW	6497	2.9	90	10	0	0	C,G
8			6			PW	3960	2.8	2	40	49	9	C,G
9	Arcelor Mittal	Lazaro Cardenas	1	9.00	1649	PW	3659	2.2	78	8	0	14	C
	U. S. A.												
10	AK Steel	Ashland, KY	Amanda	10.18	2039	MA	4629	2.3	93	0	0	7	C,G
11		Middletown, OH	3	8.93	1462	MA	5496	3.7	87	0	0	13	G
12	Arcelor Mittal	Burns Harbor, IN	C	11.65	2461		6171	2.3	0	72	27	1	C,G
13			D	10.89	2437		6306	2.4	0	73	26	1	G
14		Cleveland, OH	C5	8.99	1546	MA	3509	2.3	0	94	0	6	G
15			C6	8.99	1598	PW	2849	1.8	0	85	0	15	G
16		Indiana Harbor, IN	IH 3	9.00	1586	MA	3067	1.9	0	90	3	7	G
17			IH 4	9.98	1918	MA	4368	2.1	0	90	2	8	G
18			IH 7	13.72	4163	PW	10114	2.4	82	0	15	3	C,G
19	RG Steel	Sparrows Point, MD	L	13.49	3762	PW	6352	1.7	58	10	26	6	C,G
20		Warren, OH	1	8.53	1530	PW	3306	2.2	6	87	0	7	G,O
21	Severstal	Dearborn, MI	C	9.23	1798	PW	4948	2.8	87	8	0	5	C,G
22	U. S. Steel	Fairfield, AL	8	9.98	2326	PW	5096	2.0	89	0	0	11	C,G
23		Gary, IN	4	8.80	1496	MA	3124	2.2	61	12	19	8	C,G
24			6	8.53	1507	MA	3472	2.3	58	19	12	11	C,G
25			8	8.53	1299		2895	2.2	75	8	5	12	C,G,T
26			14	11.96	3241	MA	6636	2.0	75	0	25	0	C,G
27		Granite City, IL	A	8.30	1435		2622	1.8	0	92	0	8	G
28			B	8.30	1402	MA	3461	2.5	0	93	0	7	G
29		Great Lakes, MI	B	8.61	1645		3684	2.2	94	0	0	6	C,G
30			D	8.53	1508		3494	2.3	82	11	0	7	C,G
31		Mon Valley, PA	1	8.78	1598	MA	3494	2.3	74	16	0	10	G,COG
32			3	7.69	1381		3061	2.2	73	17	0	10	G,COG

With respect to instrumentation and process control, the NAFTA furnaces perhaps lag somewhat behind leading global competitors with the larger furnaces generally better equipped with expert systems, probes, burden profile meters and arrays of thermocouples covering the furnace proper and the cooling systems.
Campaign life extension efforts include both process (improved process stability and higher quality raw materials) and equipment related activities such as remote repair techniques or interim repair methods include gunniting and shotcreting. The process and lining life benefits of shotcreting have been well described already[4,5]).
In the hearth life area North American blast furnace operations establishing global leadership through:

- widespread use of the North American (UCAR) small brick sidewall design [(1-4),]

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- use of high quality coke, made possible by excellent North American coals, to maintain hearth drainage and,
- very selective use of ilmenite lump ore and now rutilite fines injection.

2.4 Natural Gas Consumption and Co-Injection

An interesting development has been the resurgence of natural gas injection. Natural gas has been widely used as a tuyere injectant for decades given its' cost, availability, and ease of injection as well as the operating benefits of improved furnace permeability and high replacement ratio at about 1.3 coke :1 NG. Natural gas had been used as an additive to oil injection but now mainly as an additive to PCI, as well as the sole injectant for furnaces without PCI. BF operators using PCI noted the loss in furnace permeability as the PCI was raised. The beneficial effects of the hydrogen in the natural gas on furnace permeability led BF operators to "co-inject" gas with PCI. At the end of 2011, of the 33 blast furnaces which operated, 20 utilized PCI, and, of those, 17 co-injected natural gas. In 2011, 99 % of the furnaces injected gas while 66 % co injected with gas.
In Table 3 we will observe the sharp increase in gas consumption starting in 2009. In general, the consumption rate generally followed the price curve shown in Figure 3. The big increase in price during 2004 – 2008 moderated the use of natural gas, but gas use continued as some BF's had no PCI and/or coke was not in excess. The most significant event changing this was that an enormous gas field (The Marcellus Field) was discovered in the eastern US, which dramatically increased supply, thereby reducing the price.

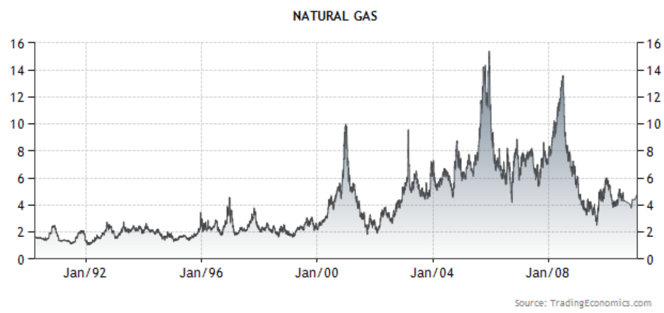

Figure 3: North American Natural Gas Prices: Tuyere Injectants; Source- TradingEconomics.com

2.5 "New" Blast Furnace Construction

As first introduced at ICSTI06 and updated later (1-4), the improved economic outlook for North American blast furnace based led to projects to completely rebuild a number of key blast furnaces in North America. These include those furnaces listed in Table 1: AHMSA BF 6, ArcelorMittal (Dofasco BF 2, Indiana Harbor BF 7), SeverstalNA BF C, USS Gary BF 14. The restart of ArcelorMittal Dofasco BF 3 (hearth diameter, 7.3 m); following an in-kind reline occurred in 2010. The Nucor Steel greenfield blast furnace project in Louisiana, on the Mississippi River, has now been switched to construction of a DRI plant, to be discussed later. The Severstal Dearborn Blast Furnace B re-construction project, delayed by the economic crisis, is now being resumed but at a slower pace.

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2.6 Blast Furnace Raw Materials

The North American blast furnace based companies have greater than 90 % of the iron units coming mainly from North American ore mines and pellet plants while more than 95 % of the coking and injected coal coming from North American mines. North American coke capacity is still sufficient to supply over 95 % (at current hot metal production) of the coke requirement, and with increased gas injection rates, this will only improve. This has provided a competitive advantage over global competitors reliant upon seaborne iron ore and coal supply while paying ocean freight rates for both incoming raw materials and outgoing steel products. The blast furnace hot metal/liquid steel cost position has also been favorable relative to the EAF mills given the very high prices for scrap and scrap supplements: pig iron, HBI, DRI.

New cokemaking capacity – We had outlined (1,2) how concerns about coke supply security and the high price of imported (mainly Chinese) coke led to expansion of the Sun Coke heat recovery technology in the USA with total capacity reaching 4.25 MTPY as shown in Table 2:

	Capacity Mtpy
Jewell Coke	0.70
Indiana Harbor	1.25
Haverhill I and II	1.10
Granite City	0.65
Middletown	0.55

Table 2: Heat Recovery Coke Facilities in NAFTA

In addition to heat recovery cokemaking, the rebuilds of several conventional slot oven coke batteries: Mountain States Carbon (SeverstalNA) and at USS Clairton have helped the coke balance.
New cokemaking technology continues to be pursued. USSteel is starting up this year two 0.2 MTPY coke plant modules using the Carbonyx (a type of formed coke) technology at USS Gary, following encouraging trials at their USS Fairfield plant.

Coal injection facilities – Sharp increases in imported coke prices should have spurred coal injection projects but the rebuild of SeverstalNA BF C with PCI and the ArcelorMittal Dofasco PCI projects are the only new PCI projects in this decade. The recent sharp drop in natural gas prices virtually guarantees that no new PCI or GCI projects will proceed.
There has been a steady decrease in the average coke rate for North American blast furnaces with a summary of North American progress updated from earlier papers [2] presented in Table 3 below :

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Table 3 Weighted (by Production Rate) Averages of Reductants by AISI BF's

	Hot Metal Production, M tonnes	# of Operating BF's	Reductant Usage, kg/tHM Coke Lump	Nut	Total	Coal	Oil	Gas	Tar	COG
1990	55.55	60	454	1	455	1	12	23	3	0
1995	61.00	51	402	8	410	34	13	38	1	1
2001	51.92	45	395	24	419	59	9	17	3	2
2004	52.75	38	366	26	392	58	10	35	4	2
2007	47.85	35	377	28	405	65	9	27	2	2
2008	44.80	35	379	29	408	62	9	32	0	2
2010	41.80	33	376	32	409	73	2	39	0	1
2011	43.70	32	364	36	400	69	1	50	0	1

Ferrous raw materials – Pellets comprise about 90 % of the blast furnace feed in North America. Pellet plant details are in the next section under iron ore mining. The all-pellet operations focus on fluxed pellet usage but acid pellets are prominent as a complement to sinter and also at several operations where hot metal demand can be met with acid pellet usage. As noted in Table I, the all-pellet operations charge between 5 – 10 % BOF slag, reclaimed scrap, pellet chips, and waste oxide briquettes. The latter are produced on-site by third party companies at 6 plant sites. For sinter feed, AHMSA relies on local ores while the USA plants use some off shore sintering ores but mainly revert materials (pellet screenings, mill scale, breeze, BOF slag, dusts and sludges).

3. UPDATE ON ALTERNATIVE IRONMAKING

3.1 Role of Alternative Ironmaking in North America

Alternative ironmaking is aimed mainly at the supply of virgin iron units as feed materials for the electric arc furnace (EAF) particularly for flat-rolled steel production. Another application of alternative ironmaking is waste oxide processing but so far several rotary hearth furnace (RHF) DRI plants have been built in North America; all are idle at present except for the IDI process (to be discussed below). The only other operational waste oxide processes, besides sinter plants, are the briquetting plants mentioned earlier, but these are not reduction processes but only providers of blast furnace or BOF feed material. One process hoping to reach the demonstration plant phase is the McMaster University straight hearth reduction furnace concept of Prof. WK Lu; a consortium led by two steel companies is studying this project.

3.2 Long term reduction of CO2 emissions

Another role for alternative ironmaking is aimed at long term reduction of CO2 in the BF/BOF steel production sector. The two major low carbon steelmaking technologies being studied the US are Molten Oxide Electrolysis [MOE] at Massachusetts Institute of Technology and Hydrogen Flash Smelting [HFS] at University of Utah. Both projects are in the pilot stage. MOE is a high temperature electro-chemical process with the potential to produce hot metal at one-fifth the CO2 emissions of the BF/coke route. It requires green electricity to achieve that level of performance. HFS, as the name implies, uses hydrogen as the main fuel, although it can work with natural gas

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and even coal. It is a shaft-based process and when operating on hydrogen, its potential CO2 emissions are only 5% of BF/coke emissions. Both have produced molten iron in the lab but both also have technical and economic hurdles to overcome.
Next we will discuss metallic sources for the EAF

3.3 Direct Reduction Processes

The shaft furnace gas based direct reduction processes (Midrex, HyL) are prominent but natural gas pricing had been a major problem for the MIDREX and HyL processes in North America. With the major gas field discovery mentioned earlier and other advances in natural gas production, its pricing has moderated somewhat, so gas based processes can now be considered. North American DRI production is about 5 MTPY, with over 4.0 MTPY of this in Mexico; all of these provide DRI to EAF's in captive steel plant settings. The leading shaft furnace processes, Midrex and HyL (now called EnergIron), were developed in North America and the engineering companies offering these processes and their customers have contributed to ongoing technical developments that have increased productivity, decreased energy consumption and improved product quality in an evolutionary manner similar to that already noted for the blast furnace process
Nucor continues to operate Nu-Iron in Trinidad (the relocated AIR Midrex MegaMod plant); production is about 2 MTPY of DRI; an expansion is ongoing, with all DRI shipped to Nucor's EAF's in the USA. Nucor had planned to build a greenfield blast furnace plant in Louisiana to produce pig iron for their EAF operations but concerns about environmental, CO2 and capital cost issues, combined with their success in Trinidad, caused Nucor to switch this project to production of DRI in a gas based MegaMod shaft furnace. Planned production will exceed 2 MTPY of DRI. Other EAF based steel producers are studying DRI projects, given the projections for low gas prices well into the future.

3.4 Alternative Hot Metal, Pig Iron Processes

In the USA and Canada, the focus of new process development had been on coal based processes such as Iron Dynamics, Inc (IDI) and ITmk3 (Mesabi Nugget). The Steel Dynamics IDI (Butler, Indiana) hot metal process had been modified to produce briquettes of iron bearing materials, coal, binders and fluxes; these briquettes are then be reduced in a rotary hearth furnace (RHF). The DRI produced is then melted in a submerged arc furnace to produce liquid hot metal for EAF charging. IDI is now rated at a capacity of 240,000 tons/year of liquid hot metal. The feed is mainly waste oxides (pellet screenings, mill scale, dusts, etc); little or no iron ore is used. This now becomes the first successful waste oxide reduction ironmaking process in North America. IDI hot metal quality is: C, 3.6 % : Si, 2.3 % ; S, 0.02.
Another development is the Mesabi Nugget (ITMk3 process) RHF process that uses iron ore fines, mainly pellet plant feed, coal, binders, etc. The first commercial plant, rated at 0.5 MTPY, the Mesabi Nugget plant, an SDI/Kobe Steel JV in Minnesota started up in 2010. The plant is operating at 75-80 % of feed rate capacity in their extended ramp up phase. Typical pig iron quality is: Fe, 96 %; C, 2.5 – 3.0 %; Si, 0.10%; S, < 0.1 %; P, 0.016 %; 4.4 t/m3; 80 % 6 x 16 mm. This project also includes the reopening of the Erie mine to provide concentrate for Mesabi Nugget but the project has been badly delayed by environmental permitting issues. In the interim,

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they are being supplied with Magnetation (reclaimed hematite) concentrate. Mesabi Nugget has formed a JV with Magnetation for a 1000 KT/year concentrate processing plant. A similar Cliffs pig iron nugget project in Michigan was cancelled several months ago.

Nucor had been conducting research on its own variant of a pig iron nugget process. This activity apparently has been discontinued. The prospect of ongoing low natural gas prices suggest that EAF producers will shift their focus away from coal based processes to shaft furnace DRI production. The existing SDI coal based process initiatives outlined above will continue but other companies are not likely to follow.

4. IRON ORE MINING IN NORTH AMERICA

Iron ore mining in North America is now serving three market sectors:

- Blast furnace/BOF producers in North America,
- Alternate process/EAF producers in North America,
- The seaborne export market, mainly China

4.1 Blast Furnace/BOF sector

Until the past decade, iron ore mining in the USA and Canada had been strongly focused on the first market, the blast furnace/BOF sector. Historically and through WWII, the rich natural ores of the Mesabi Range were the primary source along with local iron ore deposits at or near blast furnace plants in states such as Michigan, New York, Pennsylvania, Alabama, Tennessee, Colorado, Utah, California, Wyoming, etc, along with some deposits in Ontario, Canada. The depletion of the Mesabi natural ores spurred the development of the Mesabi taconite (magnetite) ore processing whereby lower grade (25 – 35 % Fe) taconite ore was ground fine and magnetically upgraded to about 65 % Fe. The ground ore was too fine for sintering so the pelletizing process was developed in the 1950's and gradually became the primary iron ore source in North America. The building of additional, modern pellet plant capacity in the late 1970's left the industry with excess pellet plant capacity in Minnesota, Michigan and Canada as the BF/BOF sector of the industry was contracting. This and the absence of coarse sintering ores, along with the age and environmental liability of steel plant sintering facilities, led to the closure of most of the latter, leaving NAFTA blast furnaces about 90 % dependent upon pellets.

In Canada, the major development was the Labrador Trough projects that led to the development of what is now IOC (Iron Ore Company of Canada), ArcelorMittal Mines Canada (ex-QCM) and Wabush Mines. Thee projects were initiated in the late 1950's by consortia of NAFTA and some European steel producers who were concerned about security of supply (political instability issues) from seaborne iron ore from South America. These operations supply to North America, Europe and selectively to the Asian market.

In Mexico, the two blast furnace based operations, AHMSA Monclova (4.0 MTPY) and ArcelorMittal Lazaro Cardenas (2.1 MTPY) Long Products (ex Sicarsta) built pellet plants fed by slurry pipeline from mine/concentrator complexes owned by these companies.

The current BF pellet supply/demand balance can be shown as follows:

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Table 4 North America Blast Furnace Pellet Supply/Demand Balance, Estimated for 2011 (6)

MTPY Supply and Demand in Balance = 68.9 MT

Steel Company	Demand	Equity Supply	Cliffs	IOC	AMMC	Sinter
AHMSA	6.7	5.1	0.5	0	0	1.0
AK Steel	5.2	0	1.4	2.4	1.4	0
Essar Algoma	4.1	0	4.1	0	0	0
ArcelorMittal	22.8	11.3	8.7	0	(3.0)[1]	2.8
SeverstalNA	2.8	0	2.8	0	0	0
RG Steel	4.0	0	1.6	1.4	0	1.0
USSteel	23.3	20.8	0.6	0	0	1.9
Available for export		1.3[1]	1.4	8.7	5.1	-

1 included in ArcelorMittal equity supply

USSteel has a strong equity position with sole ownership of Minntac (14.5 MTPY) and KeeTac (6.0 MTPY) and partial ownership of two other properties. ArcelorMittal has sole ownership of Minorca (2.8 MTPY) and AMMC, majority ownership of Hibbing (total capacity 8.0 MTPY) and partial ownership of another property. Cliffs, the dominant merchant supplier, has sole ownership of UTAC (5.0 MTPY), Northshore (5.2 MTPY), Wabush (6.0 MTPY) and majority ownership of Tilden (8.0 MTPY) and Empire (6.0 MTPY) and minority interest in Hibbing.
We can foresee the following pellet supply increases (MTPY): Essar Minnesota (7.0), USSteel KeeTac Expansion (3.0) and Magnetation/AK Steel (4.0). In the concentrate area, AMMC and IOC are expanding production by 8.0 and 5.0 MTPY, respectively.

4.2 Alternate processes/EAF sector

Several of the Canadian mines/pellet plant operations mentioned above, AMMC (total pellet capacity=9.2 MTPY) and IOC (total pellet capacity = 12.5 MTPY), have also been producing DR grade pellets for both North American and global DRI customers. The AMMC operation was originally built as a JV between an EAF steel producer, Sidbec Normines and British Steel where the latter company was intending to build DR modules in the UK. The plant was built with the intention to produce about 50 % DR grade pellets. Today about 2.5 to 3.5 MTPY of DR pellets are produced for both ArcelorMittal and external DR plant customers. IOC for many years only produced BF pellets, given their initial ownership by BF/BOF steel producers. The sale of IOC majority ownership to Rio Tinto paved the way for a flotation plant project to facilitate DR pellet production, now approaching 2 MTPY, for export to the Caribbean and MENA regions.
The Essar Minnesota pellet plant (start-up in 2013 at 7 MTPY) is being configured for both BF and DR pellet production while Cliffs is exploring some conversion to DR pellet production, given possible additional DRI projects based on low gas prices.
In Mexico, major steel producers such as Ternium and ArcelorMittal (ex-Imexsa) had long been involved in DR pellet production via mines and pellet plants in the western part of Mexico (Ternium Las Encinas (3.5 MTPY) and Pena Colorado (4.0 MTPY)). The latter is a 50:50 JV between Ternium and ArcelorMittal. ArcelorMittal also has a

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3.5 MTPY DR pellet plant at Lazaro Cardenas, formerly fed with imported pellet feed, but now mainly supplied by a new ArcelorMittal mine, Volcan, in northern Mexico.
Fines based DRI/alternative iron production has been a focal point for the past decade, especially based on coal as a reductant, given high gas prices until recently. As noted earlier, the first commercial plant, Iron Dynamics, started out with use of AMMC concentrate but now mainly uses waste oxides. The second commercial plant, Mesabi Nugget, is now using Magnetation concentrate, reclaimed from hematite tailings (6).

4.3 The seaborne export market, mainly China

Until the “China boom” in 2003/2004 NAFTA iron ore exports had been mainly from the Canadian producers that have long relied on the seaborne markets in Europe and Asia for more than 50 % of their sales. China has been seeking iron ore from North America from both small scale producers and by investing in major projects including the following:

- Consolidated Thompson (now owned by Cliffs) started up an 8.0 MTPY hematite concentrate operation in 2010 with an expansion to 16.0 MTPY ongoing; Wuhan Steel had been a 45 % equity investor and major off taker.,
- Announced investments by Wuhan Steel, Hebei Steel and others in various other Canadian projects such as Adriana Resources, Alderon Iron, Century Mining, etc. None of these projects have broken ground yet.

Chinese steel companies and traders have also been buying ore (about 2 MTPY) from some properties that long been dormant in the USA in the states of Utah and Tennessee while iron ore production is being considered in other states, as well. Another 3 to 4 MTPY is being exported mainly from small natural ore mines in western Mexico. It is likely that these exports from such higher cost, logistically challenged operations will cease while global iron ore supply eventually catches up to demand and prices drop below the production costs of such mines.
Aside from Consolidated Thompson, the only other new Canadian entrant in active production is Labrador Iron Mines where natural hematite ore properties once mined by IOC in the Schefferville area north of Labrador City is being mined and processed. Shipments began in 2011 with production planned for a 4 – 5 MTPY level; shipments are currently going to Chinas but eventually the European and North America markets will be the focal point.
While China has been the major investor in Canadian projects, another prominent project is under intensive study by Tata Steel: the New Millennium Limited project whereby magnetite deposits in the Labrador tough would be upgraded, with the concentrate to be sent through a slurry pipeline to a pellet plant/ shipping port on the St. Lawrence River. The pellets and pellet feed products would be shipped to Tata Steel plants in Europe and to other consumers.
Another major Canadian project is Baffinland Iron Mines, now owned 70 % by ArcelorMittal. Located north of the Arctic Circle, this site could produce high quality (66-68% Fe) natural magnetite lump and fines (70:30 lump: fine split) mainly for the European market. Major logistical and climate challenges lie ahead.
While the Labrador Trough has been the major focus of project stidies, other sites in Canada in Newfoundland, Quebec, Ontario and Manitoba are being explored.
While optimism runs high among the project promoters and developers, it should be noted that nearly all of these projects (with notable exception of Baffinland and Labrador Iron) are slated to produce concentrate, pellet feed and/or pellets whereas

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sintering ore fines are the preferred product in Asia and Europe. Furthermore, the market growth is in Asia whereas these Canadian projects are logistically more suited for the Atlantic Basin.

In the USA, aside from Essar Minnesota, the major new entrant is Magnetation with 700 KT/year being exported to Mexico while also supplying Mesabi Nugget (< 500 KT/year). Three processing plants are now operational; two more will be built as production should reach nearly 5.0 MTPY by 2015 with 4.0 MTPY needed to feed the AK Steel pellet plant, Until this pellet plant starts up (hopefully by 2015), some concentrate will be exported to Europe and Asia.

5. CONCLUSION and FUTURE EXPECTATIONS

The competitive position of the blast furnace based steelmakers in North America has dramatically improved due to consolidation, cost reduction, global economic trends, a favorable raw material cost position, freight advantages, currency shifts, etc. However, technological developments have also contributed to the resurgence of the North American blast furnace based steel sector: heat recovery cokemaking technology and Leadership in the "endless campaign" technique with improved shotcreting along with continued excellence in hearth life design, refractory selection and maintenance.

While the blast furnace based sector is now well positioned for the intermediate term, the leading EAF mini-mill companies continue to aggressively pursue alternative iron projects to strengthen their metallics position.

The iron ore mining sector in the USA had been mainly configured to supply pellets to the blast furnace sector. New entrants such as Essar and Magnetation are now supplying (or aiming to supply) the EAF sector. The major Canadian producers IOC and QCM have also been supplying DR grade pellets while large scale new entrants are mainly aimed at supplying world markets including Asia and Europe. Mexican steel producers are well served by their captive iron ore mines with selective imports from Minnesota.

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