Technical Study for the Value Adding of Philippine Iron Ore Resources

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Abstract

This paper examines the value adding of local iron ores in order to obtain maximum benefit from Philippine mineral resources. Ironmaking operations in the Philippines during the Spanish and American colonization era were reported and attempts of putting up modern operations particularly from1960s to the present were appraised. The Philippines has considerable deposits of iron ores, coal and natural gas and are of adequate supply to support an ironmaking facility in the country. Local lump magnetite is the most applicable iron source for an ironmaking facility. Natural-gas based DRI production will provide the most value adding since it can process local iron resources as well as natural gas deposits which has been recently extracted commercially in the country. Rotary kiln technology can also make use of local iron and coal resources but offers limited capacity and high environmental impact.

1. Introduction

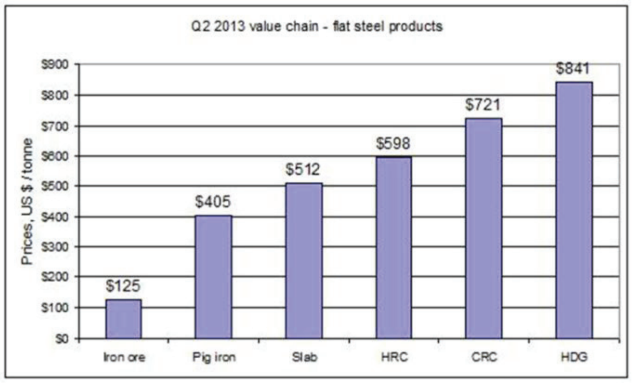
The Philippines is rich in mineral resources. It ranks among the top world producers of important precious and base metals and is considered as the fifth mineralized country in the world, third in gold reserves and fourth in copper.[1] The Philippines also ranks third in deposits of nickeliferrous laterite resources after New Caledonia and Indonesia. The more common minerals mined in the country include ores that contained copper, gold, chromium, nickel and iron.

The state of mineral resources extractions in the Philippines involves either shipping them directly as mined with little or no value adding, or they may undergo processing into intermediate products. According to a paper from Deloitte & Touche,[2] quite a large portion of the value adding process takes place outside of the resource-rich country. In most cases the resource-rich country operates the actual extraction of the ore and its subsequent concentration and further beneficiation into a saleable product defined by industry standards.

Figure 1 shows the prices of iron ore, pig iron and semi-finished flat steel products during the second quarter of 2013.[3] The transformation of iron ore to pig iron involves a value adding of around US$280/ton. A higher value adding can be realized in the Philippines considering the facilities available at Global Steel (formerly National Steel Corporation) in Iligan City which has the capacity to convert Slabs into CRCs.

In the Philippines, adding value to mineral resources may involve increasing the grade of the required metal compound or transforming the mineral into the desired metal or adopting the metal into usable items. Value adding of mineral resources thus involves mineral processing, extractive and/or adaptive metallurgical processes including manufacturing operations. The benefits of imposing value addition

Fig. 1. Value Chain of Flat Steel Products.



of mineral resources are not limited to getting more dollars from the increased value of the mined ore but it also creates additional jobs, which is essential for a developing economy.

In the case of iron resources, the Mines and Geosciences Bureau (MGB) reported that 1,255,356 DMT of iron ore concentrates was shipped abroad in 2012 by Leyte Ironsand Corp., Ore Asia Mining and Development Corp. and small scale iron sand mining companies from Region 2.[4]

There were previous and present bills in the Philippine Congress to impose prohibition on direct shipping ore and promoting value adding. The Philippine Development Plan 2011-2016 as issued by National Economic Development Authority (NEDA)[5] also recognizes the mining industry's potential as a driver of economic growth promoting the development of downstream industries to maximize the benefits or value-added from mining.

More recently, President Benigno S. Aquino III signed Executive Order No. 79, "Institutionalizing and Implementing Reforms in the Philippine Mining Sector, Providing Pol-

(This paper was presented at the 2013 Metallurgical Conference of SMEP at Davao City on October 2013)

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icies and Guidelines to Ensure Environmental Protection and Responsible Mining in the Utilization of Mineral Resources," which provides for the development of a national program and roadmap for the development of value-adding activities and downstream industries for strategic metallic ores.[6]

This study looks into the possibility of value adding Philippine iron ores. Generally, this will provide technological solutions to obtain maximum benefit from value adding of iron resources in the Philippines particularly its function in the integration of the iron and steel industry, including the iron castings industry.

2.0 Iron and Ironmaking Reductant and fuel reserves of the Philippines

In order to evaluate the value adding of Philippine iron resources, the extent of iron deposits in the country must be known. Likewise, it is also necessary to examine the local coal and natural gas resources since these serve as potential reductant and fuel in many ironmaking processes. Charcoal making is also included herein since these were used as reductant and fuel in most of the indigenous small scale smelting activities.

2.1 Iron Ore

Previous studies made on Philippine mineral resources provide important information on iron ore reserves. Diaz-Trechuello's[7] study on the Philippine economy during the 18th century stated that among the first iron mines to be developed in the country were those of Mambulao (now Municipality of Jose Panganiban) in Camarines Norte where operations can date as far back as 1653. The Sta. Ines iron mines in the Province of Tondo (now part of Rizal) was also discovered around 1758. Kreiger,[8] in his study of Philippine primitive weapons, mentioned that the mining of iron ore in the country has been carried for centuries in the Angat Mountain region in Bulacan Province.

McCaskey[9] also confirms the iron ore sources in Angat, Bulacan, as reported to the US Secretary of Interior a few years after the US occupied the Philippine Islands. The report also included other important deposits of magnetite and hematite which were found in Abra Province, in San Miguel, Bulacan, in Bosoboso, Rizal, and in Camarines Norte. Foreman[10] made mention of the Sta. Ines mine which is near Bosoboso, previously of Morong district, now Rizal province.

According to the MGB, the important iron districts of the Philippines are those in Ilocos Norte, Ilocos Sur, Camarines Norte, Cotabato, Nueva Viscaya, Surigao, Cagayan Valley, Marinduque, Zamboanga del Sur, Samar, Rizal and Davao (see Table 1).[11] The important iron deposit classification are skarn (contact metasomatic) followed by magnetite sand.

The most applicable Philippine iron ore deposits for ironmaking would be the magnetite deposits, which require concentration by magnetic separation before becoming suitable for smelting reduction or direct reduction process.

Table1. Some Iron ore reserves in the Philippines[11]

Location	Ore reserves
Calamaniuga, Appari, Cagayan	1 million MT >50% Fe hematite and magnetite ores
Jose Panganiban, Camarines Norte	21 million MT of 26.1% Fe magnetite ore
Sta. Ines, Rizal	33.5 million MT 32-33% Fe magnetite ore
Carasi, Ilocos Norte	796,000 MT of 58% Fe magnetite ore
Sta. Cruz, Ilocos, Agoo, La Union	4.2 million MT magnetite sand
Surigao Peninsula	1.0 billion MT 47%Fe laterite
Nonoc Island, Dinagat	150 million MT of 47% Fe laterite

2.2 Coal

The recoverable coal reserves in the Philippines can amount to 316 million ton composed of around 41 million tons of anthracite and bituminous and 275 tons of sub-bituminous and lignite.[12]

Coal deposits, both lignite and anthracite, have been mined in Cebu during mid-1800s, although they are reportedly not quite profitable. Coal were also mined in Albay and Sorsogon province, particularly in the island of Batan. By 1925, the three (3) districts were considered principal coal fields; Cebu; Batan Island in Albay; and Malangas in Mindanao (Zamboanga Sibugay).

Coal deposits in the towns of Malangas and Kabasalan in Zamboanga Sibugay were considered the most exploited source of high grade coal ranging from semi-anthracite to subbituminous.[13] It was considered as a good source of coking coal back in 1966 owing to its grade and large quantity, estimated at round 10 million tons.

The Semirara Mining Corporation is the largest coal producer in the Philippines engaged in surface open cut mining of on Semirara Island, Antique. Coal Asia Holdings, which plans to operate the second largest coal facility in the country, has a potential coal resource of 120 million metric tons.[14]

2.3 Natural Gas

The estimated natural gas reserves of the Philippines ranges from 5.8 to 20.7 TCF (trillion cubic feet) as shown in Table 2[15]

Table 2. Estimated Philippine natural gas reserves[15]

Gas Fields	Minimum (BCF)	Prospective (BCF)	Maximum (BCF)
Proven			
Camaga/Malampaya	2,528	3,340	4,277
San Martin	243	359	454
San Antonio		4	
Total	**2,771**	**3,703**	**4,731**
Potential			
Mindoro-Cuyo	2,720	7,060	11,120
Cotabato	60	1,158	1,760
Cagayan	176	322	518
Central Luzon	78	637	2,594
Total	**3,034**	**9,177**	**15,992**
Grand Total	**5,805**	**12,880**	**20,723**

The Malampaya natural gas field comprises 90% of the proven gas reserves. It is located in the West Philippine Sea which is one of the major production offshore facilities in the Philippines that opened in 2001. The natural gas is pumped to Batangas where it is used by a natural gas processing plant and three power generation plants.

Another natural gas field located in the same area is the Sampaguita gas field in the Recto Bank (also known as Reed Bank) which is 80 nautical miles northwest of Palawan, well within the Philippine's maritime Exclusive Economic Zone (EEZ). This gas field has been an area of exploration since 1970. It has an estimated high of 16.6 TCF and 416 million barrels of oil.

2.4 Charcoal

In the Philippines, charcoal production is basically done through the indiscriminate cutting of trees from the forest thus mitigating the recent issuances of charcoal making bans in several provinces. Tree plantations in the country are growing trees for purposes of lumber and little or none is aimed at charcoal production.

Charcoal and its other forms play a major role in meeting the energy requirements of the population more so in the rural areas.[16] Charcoal making in the Philippines as an industrial material has been limited to the carbonization of coconut shell into activated carbon for the gold processing industry and as an absorption agent. In Brazil, charcoal has been used in the production of metallic iron from ore,[17] wherein the resulting pig iron has low sulfur content than those iron produced using coal or coke.

3.0 State of Ironmaking in the Philippines

The smelting of iron ore into pig iron in the Philippines always went hand in hand with its mining during Spanish rule, These smelters also served as foundries where the melt is cast directly into usable items; ship-nails, plowshares, plow points, anchor, etc.[7] instead of producing pig iron. Iron ore was not treated then as a commodity that can be traded, and thus necessitating its value adding for local consumption.

During the American occupation, the value adding of iron ore continued the practice and use of the smelting furnaces during the Spanish time. These furnaces were said to be similar to iron smelters used in China.[18]

3.1 Angat, Bulacan smelting furnaces

Blast furnaces operated in the country during the entry of American occupation as reported by McCaskey,[9,19] are around 1.8 m high with internal diameter of 0.7 m at the bottom and widening to 0.82 m at the top and having an output of around 2-3 t/month. In a report by Dalburg and Pratt in 1925,[20] bigger furnaces were also operated at heights of 2.25 m and diameters of 1.0 m at the top and with an output of around 7 t/month. The operating at fuel rates of 1,700 kg of charcoal per ton of ore which are inefficient based on today's standards. These smelting furnaces were operational even up to the 1970s.

3.2 NASSCO Project

In view of Republic Act No. 1396, the National Shipyards and Steel Corporation (NASSCO) was tasked to put up a Pig Iron smelting facility. Based on initial designs of the metallurgical plant, it has a projected rated capacity of 40 tons pig iron per day or 12,000 MT per annum at an estimated 300 operational days in a year.[21] The NASSCO pig iron smelting plant was designed to make use of local iron ores, coal and limestone. It reportedly had a working height of 6 m and a working volume of 30 m^3. It completed a total of eight (8) campaigns from January 1966 to March 1969 where it produced a total of 4,745 tons of pig iron.[22] Its longest campaign lasted for 88 days producing 1,761 tons equivalent to around 20 tons/day or half its rated capacity. The highest average daily output was during its 7th campaign which yielded 27 tons/day. The coke rate was at 1,140kg for every ton of pig iron.

During its trial operations, it used imported coke instead of local coal leading to its closure since it was deemed uneconomical at that time due to the high cost of coke which comprised 62% of the operating cost.

3.3 Sta. Ines Steel Corporation

In March 1961, the ironmaking plants of Sta. Ines Steel Corporation were almost nearing completion at Laguna de Bay. This project involved Germany's Krupp Industries and the Inter-Consulting Ltd., of Zurich, Switzerland. This project was started during the term of President Carlos P. Garcia but appeared to have been discontinued during the term of President Diosdado P. Macapagal which started in December 30, 1961, since the latter supported the creation of the Iligan Integrated Steel Mill Inc. (IISMI).

3.4 Nippon Steel Corporation Study

In this study, Nippon Steel recommended the erection of two (2) blast furnaces with a combined capacity of 2 million tons per year of crude steel after 8 years (1981).[23] However, start-up will consider a single blast furnace at a capacity of 970,000 tons per year which can be established in a 5-year period (1979). Construction of the second blast furnace at 1,030,000 tons per year capacity will however commence even if the first furnace is not yet completed.

The proposed facility is complete with coking ovens, sintering plant, steelmaking, hot strip mill, blooming/slabbing and billeting mill. The source of iron ore however was partly imported, considering the depletion of reserves since the Philippine Iron Mines at Larap, Jose Panganiban, Camarines Norte was already near its mine life at that time.

3.5 ECAFE Study

Complementary to the study being made by Nippon Steel Corporation, the Economic Commission for Asia and the Far East (ECAFE) under the United Nations Industrial Development Organization (UNIDO) made a five-week study to address the "widening gap between rising steel demand in the Philippines and stagnant indigenous capacity."[24]

The study made mentioned of value adding plans of three (3) Philippine companies which were contemplating sponge iron production. The Engineering Equipment Inc. (EEI) embarked on a pilot scale operation involving reduction of an ore-coke briquette in an inclined shaft. FILMAG planned to add value to the iron sand concentrates mined at the coasts of La Union and Ilocos Sur involving solid-solid reduction by charging the iron sand together with coal in a rotating kiln. Marcelo Steel was in negotiations with HyL and Midrex where bench scale tests were already conducted by these companies.

The UNIDO/ECAFE considers both the blast furnace and direct reduction processes. However, the study recommends putting up one large blast furnace (about 1 – 1.2 million tons per year) instead of two small ones which would require less capital. For the direct reduction route, it recommends either HyL or Midrex since they are already commercially applied elsewhere.

3.6 JICA Study

Between 1977 and 1979, President Marcos approved a recommendation by Japan's Ministry of Trade and Industry (MTI) of an Integrated Steel project under Japan's offer for concessionary financing for one major. A pre-feasibility study was undertaken by the Japan International Cooperation Agency (JICA) wherein the project was seen to be viable at a capacity of 1.5 million tons per year of crude steel.

The project however, was deprioritized by the Philippine Government in 1979 in favor of allocating the Japan Government financing for Project of Considerable Economic Importance.

3.7 NSC's Five-Year Expansion Program (FYEP) I and II

The National Steel Corporation (NSC) initiated a ten-year expansion program (Five-Year Expansion Program I and II or FYEP I and FYEP II) back in 1981 which included plans to establish a 1.5 million tpy Ironmaking-Steelmaking facility based on a Direct Reduction-Electric Arc Furnace (DR-EAF) route.[25]

The NSC considered several commercially available DR technologies which included the SL/RN, Krupp-Codir, DRC, Midrex and HyL Process. However, due to the absence of natural gas resources during that time, Midrex and HyL were dropped in the evaluation.

NSC was already in the final phase of negotiations with Thyssen-Krupp for the installation of a Krupp-Codir direct reduction process in Iligan City when Sen. Benigno Aquino was assassinated in August 1983 which brought an end to these plans.

3.8 US Steel Study

In 1990, the US Steel Corp. (USC) performed a study on the integration of the National Steel Corporation (NSC), particularly on its Flat Product steel plant in Iligan City. The USC recommended that a 2 million tons per year integrated Blast Furnace and a Basic Oxygen steel plant with continuous casting to produce slabs is a viable integrated iron and steel mill. However, the Philippine Government found the US$ 1,000/ton/year capacity a bit too high back in 1992 and decided to put the project on hold until it could find a financing source.

3.9 Proposed Ironmaking plants under the PISC

The Presidential Iron and Steel Committee (PISC) was created under Executive Order No. 7316) in order "to advise and recommend policies to the President of the Philippines on the over-all directions of the iron and steel industry in the country." Several proposals for the putting up of primary ironmaking facilities were received by the committee for endorsement to the President.

F. Jacinto Group, Inc. (FJGI)

In 1993 to 1994, the FJGI has submitted three (3) proposals for the local ironmaking projects and their integration to steelmaking:[26,27]

1. Transplanting of the mothballed Krupp Hoesch Rheinhausen Works of Germany to the Philippines which involved two (2) blast furnaces at a capacity of 2 million tons each.

2. Relocation of the 2.8 million ton capacity Ravenscraig integrated iron and steel facility of British Steel of Scotland.

3. Establishing the Philippine Integrated Steel complex by using the Corex process. Three (3) alternatives were proposed: a 1-furnace at 1.4 million tpy hot metal; 2-furnaces at 700,000 tpy hot metal and the last option is for a furnace operating at 300,000 tpy hot metal.

All of these proposals allowed FJGI to claim pioneer status for incentives from the government, but none was realized.

Philippine National Oil Company (PNOC)

In 1999, The PNOC proposed a project on "Combined Gas-Fired Power Plant and Iron and Steelmaking Facility," to the PISC. The iron making facility makes use of the Corex technology with a projected 1.66 million tons of steel production per year. The proposed facility also produces electric power, slag for cement production, and possibly methanol and urea for fertilizers.

Though this project was already endorsed by the PISC to the Office of the President for approval, it was caught in the transition of leadership from Estrada to Arroyo and never took off.

3.10 Treasure Steelworks Corporation (TSC)

The TSC is a subsidiary company of TKC Steel which manufactures and distributes steel products. In 2009, TSC put up 2 mini-Blast Furnaces (BFs) at 128 cubic meters each designed to produce about 700 MT of liquid iron per day. When operational, the 2 mini BFs will consume about 1200 MT of iron ore, 420 MT of coke and 180 MT of limestone per day. TSC holds the pioneer status from the BOI for this undertaking. However, recently, TSC announced that it is going to produce nickel pig iron using local laterite sources for burden.

3.11 Ferromet Resources, Inc.

Ferromet Resources, Inc., a Filipino-owned single proprietorship company, started trial runs in value adding of local iron ores in San Ildefonso, Bulacan in 2009. Ferromet initially employed the direct reduction process for sponge iron production, where metallization was only at 75%,[28] though target is at 90%.

In 2012, Ferromet shifted their trial iron smelting procedure from direct reduction process to low-shaft blast furnace using local ore and locally sourced charcoal producing pig iron. The charcoal blast furnace of Ferromet is 5 m high and internal diameter of 0.8 m producing low sulfur pig iron.

4.0 Considerations in the Choice of Ironmaking Process for Philippine Resources

The compatibility of commercially available ironmaking processes with the Philippine mineral resources can be evaluated base on the scale of production. The ironmaking process that would prove most viable in the value adding of Philippine mineral resources considers not only the type of ores to be treated, but also the kind of reductants and fuel that will be utilized.

4.1 Scale of Production

The Philippine Iron and Steel Institute (PISI) and the Philippine Steelmakers Association (PSA) reported that the Apparent Steel Consumption (ASC) of the country stands at 6 million tons in 2012 which is quite a big jump from consumption of 4.1 million tons in 2010.[29,30] It was further estimated that for such ASC, 50% can be attributed to local production and the rest due to imports of semis and customer products.

By focusing only on the local steel demand, there is a big potential for the localization of crude steel amounting to around 3.0 million tpy thereby creating a potential for the value adding of domestic iron ores. Furthermore, putting up an ironmaking facility with higher capacities, e.g. over a million tons per year, will have an impact on the localization of the domestic steel demand.

4.2 Type of Ironmaking Product

The type of ironmaking product is of utmost consideration when factoring in the value chain of downstream industries. The production of DRI will be of importance to the domestic steel industry since it can be further processed for the production of steel with an electric arc furnace. However, it has little significance to the local foundry industry since they require their ferrous raw material to already contain carbon particularly for producing cast iron products. Foundries prefer pig iron as raw material in gray and ductile iron production since they already contain the required carbon content of the aforementioned castings. These foundries also prefer to use steel scrap instead of DRI in producing cast steel for reasons of cost and ease in melting.

Thus, considering only the demand of the steel industry, DRI and hot metal (pig iron) production are the types of iron products which are both applicable for steelmaking purposes.

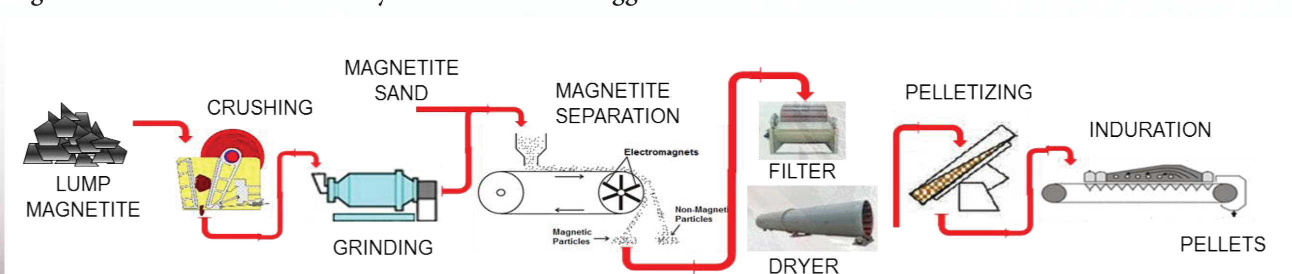
4.3 Type of Iron Ore

The Philippines lack hematite ore as discussed earlier, but lump magnetite ore abounds where around 55 million tons of deposit is known. However, the iron content of these lump magnetite deposits contains an average of 30%Fe, necessitating their beneficiation to increase iron grade to above 65%Fe making them suitable for ironmaking processes. Beneficiation to increase this grade will yield around 25 million tons of fine magnetite concentrate. Iron sand sources can also be used but Philippine mining and environmental laws restrict their extraction.

Since the raw material of iron ore to be used for ironmaking will be in the form of fine magnetite concentrate, agglomeration is required to produce pellets which will make it viable for the different ironmaking processes involved, including those making use of fluidized bed techniques. Figure 1 illustrates the operations involved in beneficiation and agglomeration of lump magnetite ore.

The run-of-mine lump magnetite ore will undergo crushing and wet grinding to liberate magnetite minerals which is then separated from the nonmagnetic materials (gangue) using a magnetic separation machine. This will raise the %Fe in the magnetic concentrate. The recovered magnetic minerals are filtered and dried prior to pelletizing in a pelletizing drum yielding 10-20 mm diameter pellets of iron ore. These pellets are indurated to harden the pellet and also transform Fe_3O_4 to Fe_2O_3. The transformation of

Fig. 1. Pre-treatment of iron ore by Beneficiation and Agglomeration



magnetite to hematite is needed since it dramatically boosts the reducibility of iron oxides.

4.4 Type of Reductant and Fuel

The reductants and fuels locally available for ironmaking purposes are coal and natural gas. Coal deposits, however, are mostly not of the coking coal variety which makes them unfit for blast furnace operations. Ash and volatile matters content of these coals are also quite high.

On the other hand, the Philippines have just recently make discoveries of natural gas deposits which were not being considered in previous studies for ironmaking. In view of the potentially high amount of natural gas deposits in the country, their use as reductant for high capacity DRI production is highly recommended.

With respect to charcoal as reductant and fuel, there are several concerns particularly that the forest cover of the Philippines is now quite small compared to decades ago.

In the 1970s, the Philippines embarked on wood-fired power plant projects to reduce its dependence on costly imported oil, which was referred to as the Dendrothermal program. This program was a failure and discontinued for reasons which include among others, the inability to properly grow the feedstock trees of Ipil-ipil (Leucaena leucocephala). Managed tree plantations for Ipil-ipil can yield 22-30 ton/hectare/year.[7] Typical commercial charcoal operations yield 1 ton charcoal for every 5 tons of wood. Thus, an hectare of land can yield around 4.4 to 6 tons of charcoal a year.

5.0 Value adding of Philippine mineral resources using a blast furnace

Most of the hot metal production in the world can be attributed to blast furnaces. The blast furnace has been one of the major ironmaking process contemplated for the integration of the iron and steel industry in the Philippines.

Among the commercial ironmaking processes the blast furnace is the only existing technology available in the Philippines at present being represented by the two (2) mini blast furnaces already installed by Treasure Steelworks Corp. in Iligan City. Thus, it is very important to determine compatibility of this facility to the value adding of Philippine iron ores as well as potential reductants and fuels that are also locally available. Fluxes of limestone and dolomite for use in the blast furnace can already be sourced locally.

The iron ore currently used in blast furnaces are usually hematite ore, which may be in the form of lump ores, as sinters (iron ore together with limestone and coke), or as pellets (iron ore mixed with binder and indurated). However, Philippine iron ores are mostly lump magnetite which needs to be pelletized or sintered first.

Our iron reserves will be more than sufficient to support iron ore burden requirements for the mini blast furnaces at TSC which will consume about 430,000 tons of iron ore per year. It must be noted that the annual production of hot metal from these two mini blast furnaces is only around 250,000 tons per year and comprises a meager 4% of the apparent steel consumption.

With respect to the fuel and reductant requirements for operating a blast furnace, there are very few coking coal deposits in the Philippines, and thus, the coke required will involve either the direct importation of coke or importing coking coal and processing them into coke by operating a coking oven locally. Both options will not contribute to value adding of Philippine coal resources.

In the case of operating a low shaft blast furnace, it has a disadvantage of high fuel rate, consuming more coke than a regular blast furnace. The NASSCO low shaft furnace had a coke rate of 1,140kg for every ton hot metal as compared to 450 kg/ton hot metal for large blast furnaces. Also, the shorter shaft height reduces the throughput time for an ore feed at the top by around 1/5 that of a regular blast furnace thus, shortening the reduction zone for the transformation of iron oxide to iron. The use of magnetite which has relatively poor reducibility may not be applicable for this kind of smelting reduction furnace. Thus, value adding of our magnetite resources using the low shaft furnace may not be efficient, but possible.

Operating a charcoal blast furnace is not feasible due to unreliable sources of charcoal. In order to operate a charcoal blast furnace producing 10,000 tons of pig iron per year, it will require around 7,000 tons/year charcoal. For a plantation harvest cycle of three years, this is equivalent to around 3,500 to 4,770 hectares planted with Ipil-ipil dedicated entirely to charcoal blast furnace operation. Low yields of the Ipil-ipil plantation can mean shortages in charcoal, and thus stoppage of the charcoal blast furnace operations. The failed project on the dendrothermal power operation in the Philippines may be repeated and would also spell disaster for the sustainability of a charcoal blast furnace.

6.0 Value adding using the Corex Process

In the COREX process, the metallurgical processes are done in two separate reactors: the Reduction Shaft and the Melter-Gasifier. Iron ore is fed into the Reduction Shaft where it is reduced to Direct Reduced Iron (DRI) by the reducing gas produced at the Melter-Gasifier in a counter current fashion.

The application of the COREX process to local iron ores and reductants cannot be fully realized. Experience indicate that non-coking coal of very high VM or very low FC cannot be used in this process,[31] which would make most of our coal unusable. In fact, coke is also used in COREX operations to blend with non-coking coals to lower VM and increase FC.

It is important to note that the recent ironmaking plans of the Philippines during the time of the Presidential Iron and Steel Committee in the 90s considers the COREX method as the most promising technology for the integration of our iron and steel industry. But that was during the time when natural gas in the Philippines was only starting commercial use.

7.0 Value adding thru Direct Reduced Iron (DRI) Production

During the plans for the integration of the iron and steel industry in the 1950s, the blast furnace was always the major consideration against other ironmaking processes. Caution in the adaption of DRI production technology has always been raised. However, quite a number of DRI processes has been proven commercially.

The recent commercial application of natural gas in the Philippines presents a large potential for a locally sourced raw material in ironmaking.

7.1 Midrex and HyL Processes

The Midrex process is the most adapted DRI process with 74 operating plants worldwide with scales of production varying from 350,000 to 1.76 million tons per year (tpy) of DRI.[32] This process involves the reduction of iron ore by natural gas which passes through a gas reformer. The Midrex process can make use of our magnetite concentrates and natural gas deposits. The process needs 16.2 BCF natural gas to produce 1.76 million t DRI/year equivalent to 2.3 Gcal/t DRI, which the Philippine natural gas reserves can fully provide. Most of the existing Midrex plants are near the natural gas source which could be a challenge when this ironmaking plant is going to be established here.

The Midrex process was among the technology thought of during the 70s by Marcelo Steel and NSC in the 80s but the reductant being considered then was reformed gas from coal sources. The recent commercialization of natural gas in the country would boost the potential of this process.

Similar to Midrex, the HyL (Hoganas y Lamina) process also makes use of natural gas as reductant. This is the second most adapted natural gas-based technology in DRI production. Around 29 HyL facilities are operating worldwide with capacities ranging from 200,000 to 1.60 million tpy of DRI.

The process comprises a moving bed in a shaft furnace reactor wherein reducing gases are introduced to remove the oxygen from iron ore pellets. It operates at slightly higher reduction temperatures and intermediate reduction pressures than the Midrex process.

The iron ore material input for HyL Process is flexible even with those containing high Sulfur since the process includes a sulfur removal step prior to the conventional steam reformer. It must be noted that Sta. Ines iron ores, and those mined in Larap contained considerable Sulfur as pyrite, FeS. This particular process stands a high applicability for the processing of our indigenous iron ores.

7.2 Rotary Kiln Technology

The most widely used coal-based ironmaking process using non-coking coal as reductant and fuel is the rotary kiln method. The process can make use of lump ore, pellets or beach sand and solid carbon to produce DRI.

The application of rotary kiln technology is also included as a potential ironmaking process since our local coal deposits are of the non-coking variety. This technology has been widely used in India and South Africa since it can make use of use low-quality coal. Thus, our local deposits of bituminous (low, medium, high VM) coal deposits can be used in this process. The use of a rotary kiln is less energy efficient than the blast furnace due to very high residual gases, wherein some plants resort to using these residual gases for power generation.

India leads in the commercial application of rotary kiln for ironmaking where 38 rotary kilns are operating at capacities of 30,000 to 150,000 tpy of DRI. The rotary kiln process will be applicable for processing local iron ores and will make use of our local coal deposits as well. However, the scale of production for each plant is limited to 150,000 tpy, and thus a battery of them is needed to address the apparent steel consumption.

7.3 Rotary Hearth Technology

In the Rotary Hearth Furnace technology, the process can make use of our magnetite concentrates, non-coking coal and natural gas deposits. Steel Dynamics Inc. in the USA is one commercial application of this technology which produces 500,000 tpy of iron nuggets containing 96 to 98% iron and the remainder being carbon. This plant makes use of the ITmk3 (Ironmaking technology mark 3), an ironmaking process owned by Kobe Steel of Japan.

The application of this technology in the Philippines will benefit both the steel industry as well as the foundry industry since the product is similar to pig iron. It can make use of the local magnetite ores, non-coking coal as well as our natural gas. The plant operation is also very flexible since retention time is very quick compared to the other ironmaking technologies.

8.0 Concluding Remarks

The Philippines has considerable deposits of iron ores, coal and natural gas. These raw materials can be utilized and are of adequate supply to support an ironmaking facility in the country. The recent commercial extraction of natural gas deposits in the country and its continued exploration would mean a cheap and readily available reductant and fuel for iron ore processing.

The following are assessments of several commercial ironmaking processes for their applicability to the value adding indigenous iron and reductant resources:

1. A conventional Blast furnace (BF) operations can make use of our local iron ores but will not add value to local coal deposits since most are non-coking varieties. The same is true for adapting a mini BF since input material are the same, and thus importation of coke is inevitable. Using charcoal as fuel and reductant may not be sustainable considering the extent of plantation required for charcoal making.

2. Adaption of a Corex process will make use of our iron resources but will only partially use our coal deposits since most local coals have more than 25% Volatile Matters (VM); a limitation for reductants used for

Corex. Coke is inevitably part of this process which will be imported.

3. Both the natural gas-based Midrex process and HyL process can make use of our magnetite concentrates and natural gas deposits. The HyL process further stands out due to its applicability for high sulfur iron content ores which characterizes some of our lump magnetite deposits.

4. The use of rotary kilns can make use of local iron ores and domestic coal deposits but plant capacities are low. To address the apparent steel consumption of the country, several units has to be constructed which will also impact on the environment.

5. Production of iron nuggets through the ITmk3 Rotary Hearth furnace technology can make use of our magnetite concentrates, non-coking coal and natural gas deposits. The product of this process which is similar to pig iron is applicable to both the steel industry and the foundry industry.

9.0 Recommendations

In view of the evaluation of the applicability of commercial ironmaking technologies to the value adding of our indigenous resources, it is recommended to further conduct a techno-economic feasibility of the following ironmaking processes for the value adding of local mineral resources, including environmental impact and the potential locations:

1. Midrex process
2. HyL process
3. Rotary kiln processes
4. Rotary Hearth Furnace (RHF) Process.

To conduct the techno-economic feasibility, a pilot plant may be needed to provide reliable data for putting up an ironmaking facility in the country. A pilot plant may need to be constructed first to reduce the risk associated with the construction of an actual facility. In identifying which ironmaking pilot plant will be proposed for construction, it is recommended to visit established ironmaking plants of the above processes, as well as visit their existing pilot plants and laboratories operating bench scale tests.

Lastly, due to the big potential in making use of our natural gas for ironmaking purposes, it is recommended that changes in the current policies regarding the use of coal and natural gas for industrial use on top of its being presently used in power generation should be advocated.

ACKNOWLEDGEMENT

This technical study results from the collaborative research supported by the Philippine Council for Industry, Energy and Emerging Technology Research and Development (PCIEERD-DOST). The authors express their deep gratitude to Dr. Nathaniel Anacleto of MSU-IIT, Engr. Bernardo Bitanga of MGB, Engr. Emil Aco of Ferromet Inc. and Mr. Danny Panganiban of Marycheck Trading Corp. We also acknowledge the Management and staff of MIRDC, MSU-IIT, MGB and PCIEERD for their support to the Project team in the pursuit of this study.

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