TECHNO ECONOMIC EVALUATION OF IRON ORE PELLET MANUFACTURING PROCESSES IN INDIA AND JUSTIFICATION FOR NEW UNITS IN ODISHA

H.K. Naik* and I.C.Pradhan**
*Associate Professor, Mining Engineering Department
National Institute of Technology, Rourkela
**Inspector of Mines, Government of Odisha

ABSTRACT

Iron ore is primarily found as the oxides of iron, notably haematite and magnetite and as hydroxides like goethite and limonite. Small amounts are found as the carbonates in siderite, as sulphides in pyrites and as silicates in chamosite and greenalite. Broadly iron ores may be grouped as: direct shipping ore generally better than 60 per cent iron (Fe), which is mined and used in blast furnaces requiring only simple preparation and beneficiable ore which contain as little as 25 percent Fe and can be upgraded to around 60 percent Fe by magnetic or heavy media separation. Lump ores are naturally mined ores that are crushed and screened to a certain grain size before their use. However, as a result of preparation and enrichment processes in the iron ore mines to increase the Fe content, very fine-grained ores increasingly accumulate which have to undergo agglomeration. This is done by means of sintering and pelletizing. The physical and metallurgical characteristics of the ores are as important as chemical properties. The steel industry requires iron ore which is high in iron, low in impurities particularly SiO_2, Al_2O_3, sulphur and phosphorous. It is a prerequisite that the lumps should have high strength. Therefore, beneficiation of iron ore after mining is an important stage to prepare ore to meet both physical and chemical properties suitable for the various metallurgical processes. The important aspect of ore preparation is to increase iron content, lowering impurities such as Al_2O_3, SiO_2, etc. and generate lumps with closer sizes and utilization of fines and slimes, so as to improve the economics of mining operations. After assessing the potential of pelletization of iron ore in India various companies are planning to set up pelletization plants in Odisha. This paper will give an insight in that direction.

1. Introduction

The objective of this paper is to study the techno economic parameters for setting up of iron ore pellet manufacturing plants in the state of Odisha. The sub-objectives of this paper will cover the following aspects besides the others:

- Impact of establishment of pelletization plants on the economics of the mines.
- Impact of establishment of pelletization plants on quality of iron ore.
- Assessment of environmental impact due to establishment of pelletization plants in the mining area.
- Suitability study for establishment of pelletization plant in Indian geo-mining conditions.

The study is primarily based on the data available from various sources and on the various aspects of the project planning. Some secondary information were also collected from various sources to prepare this paper which include:

- Annual reports of the major pellet manufacturing companies.
- Status of the iron & steel sector in India as available with the Ministry of Steel, GOI.
- Status of the raw material, viz. iron ore as available with the Ministry of Mines, GOI.
- Import and export statistics of the Department of Commerce, GOI.
- State specific information on policy and applicable incentives of Orissa.

To fulfill the objectives of this paper, the following methodology was adopted:

- Literature collection.
- Collection of details (data) from various sources.
- Suitability study to review the establishment of pelletization plants
- To compare the change in economics and productivity of the mine after establishment of pelletization plant.
- To assess the reduction of adverse impact on environment after establishment of pelletization plant.
- To find out the scope of working, non-workable bands by establishment of pelletization plant.
- To assess the improvement in standards of safety after establishment of pelletization plant.
- To make the mine operator aware of various advantages of pelletization plants.
- To assess the improvement in quality of iron ore by establishment of pelletization plants.

1.1 Iron Ore Production in India

India has the fourth largest iron ore reserves in the world after Russia, Brazil and Australia. As on 01.04.2000, India had recoverable reserves of iron ores estimated at 13,423 million tons (MT), which form about 6% of world's total known reserves. Iron ore occurrence in India is grouped into 5 major sectors, viz.

- Barajamda (Singbhum) in Jharkhand and Keonjhar & Sundargarh in (Orissa)
- Dalli-Rajhara-Rowghat, Bailadila
- Bellary – Hospet
- Goa-Redi
- Kudremukh
- Kundremukh – Bababudhan – Kodachadri

The hematite ores range from a massive steel grey type, to a porous laminated type to a fine soft powder and are normally grouped under the various categories i.e. massive, laminated, lateritic and powdery / blue dust. The hematite ores are rich in iron content varying between 58 to 67% iron. They suffer from two basic drawbacks i.e. high alumina content up to 7%, soft and friable nature creating the problems of fines generation. The production and consumption of iron ore is given in Table 1.

Table 1: Production and consumption of iron ore in India (in million tons)

Iron Ore	Year		
	2000-01	2001-02	2002-03
Lumps	33.567	33.025	38.424
Fines	41.189	43.988	51.850
Concentrates	6.006	6.354	6.688
Total	80.762	83.367	96.962
Ores exported	20.16	23.1	48.7
Source : Paper " Benefits of Beneficiation of Iron Ore" by Srivastav et al. 1997			

As per the Survey conducted by the Indian Bureau of Mines (IBM) in April 2000, India had 9919 million tones of recoverable reserves of haematite and 3546 million tones of magnetite. Zone A comprising of Bihar, Jharkhand and Orissa is the largest haematite ore bearing zone in the country, consisting mainly of medium grade and low grade ore (iron content 65% and below). Chattisgarh has the largest quantity of high-grade ore reserve (iron content greater than 65%) in the country. Karnataka has the highest reserves of magnetite ore followed by Andhra Pradesh and Goa. The details of recoverable reserves of haematite are given in Table 2.

Table 2 : Recoverable Reserves of Haematite as on 01.04.2000 (in million tons)

Zone / State	High Grade	Medium Grade	Low Grade	Unclassified	Other / Not known	Blue Dust Black Iron	Total
Zone A							
Bihar			0.03				0.03
Jharkhand	44.04	1794.06	873.09	139.25	1.74	10.57	2862.75
Orissa	547.64	1857.33	507.54	280.83	10.54	0.03	3203.91
Zone B							
Chhattisgarh	461.24	562.06	463.17	388.07		28.52	19.03.06
Madhya Pradesh		6.23	65.2	14.93	14.16	15.27	115.79
Maharashtra	7.43	123.65	43.19	33.45	12.17		219.89
Zone C							
Karnataka	214.86	583.01	78.59	87.76	1.58	0.5	966.3
Zone D							
Goa Region	0.02	132.75	392.38	33.22	12.97	9.52	580.86
Zone E							
Andhra Pradesh	23.04	3.99	28.2	2.66	0.38		58.27
Rajasthan		0.26	9.6	1.64	0.15		11.65
Grand Total	**1298.27**	**5063.34**	**2460.99**	**981.81**	**53.69**	**64.41**	**9922.51**
Source : Ministry of Steel, GOI							

These haematite deposits belong to pre-cambrian iron ore series and the ore is in banded iron ore formations occurring as massive, laminated, friable and powdery form. The grade wise reserves as mentioned above can be distributed further into lump ore (+12.5 mm to -150 mm) and fines (-12.5 mm). The production of iron ore in Zone A is given in Table 3.

Table 3 : Production of Iron Ore in Zone-A

Year	Production (in Million Tones)
1997	23.575
1998	24.451
1999	23.782
2000	23.853
2001	26.585
Source : Ministry of Mines, GOI	

This zone has a total of 190 mining leases, out of which only 100 mines are reportedly under production. The mines of SAIL & TISCO are large opencast mines with annual capacity ranging between 2 to 5 million tons. The rest are small to medium sized mines operated by private operators. Most of these non-captive mines are manual and semi-mechanized. Many centralized crushing / screening plants were planned in the past to control closely to ratio of production of lumps and fines. But only one big plant of 1 million TPA capacities has come up in Banspani. There are 18 other small crushers of varying capacities (3000-25,000 tones per minute) having aggregate capacity of less than 3, 00,000 tons per minute. The production of iron ore by the non-captive mines in this zone in 2001 was 9.0 million tons as given in Table 4.

Table 4 : Production of iron Ore by the Non-Captive Mines

Iron ore	**Million Tones**	**Percentage recovery**
Lumps	6.0	66.5
Fines	3.0	33.5

The shortage in supply of iron ore to integrated steel plants from their captive sources is met from these non-captive mines. Besides, these mines supply iron ore to sponge iron and mini pig iron plants in the region. Of course, a few mines have the capability to supply sponge grade iron ore.

Production of iron ore (including concentrates) during the year 2002-2003 is estimated at 96.962 million tones as against 83.367 million tons in the previous year. State-wise production figures indicate that Karnataka is the leading iron ore producing state accounting for 21.95 million tons (25.4%) of the total production during 2002-2003 followed by Orissa with 19.79 million tons (22.9%), Chattisgarh with 17.28 million tons (20%), Jharkhand with 13.90 million tons (16.1%) and Goa with 12.87 million tons (14.9%). The remaining production of about 0.61 million tones is from Andhra Pradesh, Madhya Pradesh, Maharashtra and Rajasthan. Dispatches of iron ore (including concentrates) for 2002-03 are estimated at 84.7 million tones, of which 53.3 million tons were for internal consumption and 31.4 million tons for exports. The details of production and dispatches of iron ore from 1996-97 to 2002-03 are given in Table 5. As can be seen from the Table 5, almost 55-60% of the ore produced is consumed locally by the steel units in India.

Table 5: Details of production and dispatch of iron ore (quantity in MT, value rupees in crores)

Year	Production		Dispatches		
	Quantity	Value	For Internal Consumption	For Export	Total
1996-97	68.2	1479.56	38.2	29.5	67.7
1997-98	75.7	1819.70	40.5	33.7	74.2
1998-99	72.2	1855.95	38.9	30.5	69.4
1999-2000	77.6	1973.75	41.0	30.5	71.5
2000-01	80.7	2126.74	46.4	33.5	79.9
2001-02 (P)	83.4	2168.20	48.9	31.5	80.4
2002-03 (E)	86.4	2284.02	53.3	31.4	84.7
Source : Ministry of Steel					

1.2 Iron Ore Production in Odisha

In Odisha, Orissa Mining Corporation (OMC) possesses a reserve of 400 million tons of iron ore, 19 million tones of manganese ore, 28 million tons of chromite, 230 million tones of bauxite, 19 million tones of limestone and other minerals. OMC operates 11 iron ore mines, 5 chromite mines, 3 manganese mines and one limestone mine. Some more iron, manganese, granite, china clay leases are being opened up for mining. OMC has 17 iron and Manganese ore mines spread over more than 10,800 hectares with nearly 134 million tones of reserves. Prominent among these mines in Odisha are the Daitari Mines. The source of iron ore, chemical specification and current rate of production (in MT) per annum of OMC is given in Table 6 and the sales of iron ore by OMC during 2002-03; 2003-04 is given in Table 7.

Table 6: Source of iron ore, chemical specification and rate of production of OMC (in MTPA)

SOU RCE	CHEMICAL SPECIFICATION	CURRENT OF PRODUCTION PER ANNUM (IN MT)
BARBIL, BANSPANI SECTOR	<u>B. F. GRADE</u> Fe=64-63%, $SiO_2+Al_2O_3$ = 6%, Phos = 0.05%, Size = 10-50 MM <u>SPONGE GARDE</u> Fe=65% Min, $SiO_2+Al_2O_3$ = 5%, Phos = 0.05%, Size = 5-20 MM & 10-150 MM	0.750 million (All grades)
GANDHA MARDAN SECTOR	<u>SPONGE GR. IRON ORE</u> Fe=65%, $SiO_2+Al_2O_3$ = 6.5%, Phos = 0.05%, Size = 10-125 MM <u>B.F. GARDE</u> Fe=64-63%, $SiO_2+Al_2O_3$ = 6.5%, Phos = 0.05%, Size = 10-50 MM & 10-30 MM Tol = (+/-) 5%	0.50 million (All grades)
DAITARI SECTOR	<u>CALIBRATED IRON ORE (WASHED)</u> Fe : 63%, Rejection below <62% SiO_2 (Max) = 1.50%, Al_2O_3 (Max) = 3.00% $SiO_2 + Al_2O_3$ (Max) = 3.50% Phos = 0.10 % Max, Sul. (Max) = 0.02% LOI (Max) = 6%, Moisture = 8%, Size Max = 6-30 MM,	0.200 million (All grades)

	+30-50 MM – 5% (Max), -6 MM – 8% (Max) FINES (WASHED) Grade –A Fe : 64%, Rejection below <63% SiO_2 (Max) = 1.50%, Al_2O_3 (Max) = 2.00% SiO_2 + Al_2O_3 (Max) = 3.50%, Phos = 0.09 % Max Sul. (Max) = 0.01%, LOI (Max) = 5% Moisture = 8%, Size Max = 5.00 MM Grade – B Fe : 63%, Rejection below <62% SiO_2 (Max) = 1.50%, Al_2O_3 (Max) = 2.50% SiO_2 + Al_2O_3 (Max) = 4.00% Phos = 0.09 % Max, Sul. (Max) = 0.01% LOI (Max) = 6%, Moisture = 8%, Size Max = 5.00 MM Grade – C Fe : 62%, Rejection below <60% SiO_2 (Max) = 1.50%, Al_2O_3 (Max) = 3.00% SiO_2 + Al_2O_3 (Max) = 4.50% Phos = 0.10 % Max, Sul. (Max) = 0.01% LOI (Max) = 7%, Moisture = 8%, Size Max = 5.00 MM	
Source : OMC		

Table 7: Sales of iron ore by OMC

Mineral	Sales during 2002-2003		Sales during 2003-2004	
	Qty (MT) In millions	Value (Rs.) In Crores	Qty (MT) In millions	Value (Rs.) In Crores
IRON ORE				
Daitari				
Export	464258	26.51	449035	70.54
Domestic	513413	16.75	534733	21.74
Gandha mardan	331390	8.35	405434	33.32
Barbil	779446	22.14	1103672	87.75
Source : OMC				

2. Existing pelletization plants in India

At present there are four manufacturing units of iron ore pellets, viz. Hy-Grade Pellets Ltd. (Essar Group), Mandovi Pellets Limited, Jindal Vijaynagar Steel Ltd. and Kudremukh Iron Ore Company Limited producing pellets in India. The installed capacity of these units is given in Table 8.

Table 8: Installed Capacity of Pelletization Units

Name of the Unit	Installed Capacity (Million Tones)
Hy-Grade Pellets Ltd. (Essar Group)	3.3
Mandovi Pellets Limited (MPL)	1.8
Jindal Vijaynagar Steel Ltd.	3
Kudremukh Iron Ore Company Limited	4
Total	12.1

Kudremukh Iron Ore Company Limited is 100% export oriented unit whereas Jindal Vijaynagar Steel Ltd. and Hy-Grade Pellets Ltd. are captive plants.

2.1. Hy-Grade Pellets Limited (Essar Group)

The Essar Group is one of India’s largest corporate houses, with an asset base of Rs. 170 billion (US $ 3.5 billion). The activities of the group include both the manufacturing and service sectors in steel, telecom, shipping, oil, power, and constructions. The Essar Group has the main companies as given in Table 9.

Table 9 : Main Companies of Essar Group

Industry	Company	Essar Group associates and co promoters' holdings (%)	Asset Base Rs. cr.	Location	Number of employees	Business
STEEL	Essar Steel Ltd.	33.07	8000	Plant : Hazira	1572	Manufacturing flat products 2.4 MTPA, Manufacturing sponge Iron 2.0 MTPA
	Hy-Grade Pellets Ltd.	49	1154	H.O. and Plant : Visakapatnam	75	Manufacturing iron ore pellets 3.3 MTPA
	PT Essar Dhananjaya	91.50	467	H.O. and Plant : Bekasi, Indonesia	310	Manufacturing cold rolled coils and sheets 200.000 TPA, Marketing hot dipped galvanized coils internationally

Pelletization Plant: Essar has set up a 3.3 million TPA pelletization plant at Vishakapatnam (Vizag) to supply high quality iron ore pellets at competitive prices to its Hot Briquetted Iron (HBI) plant. Essar Steel Consumes about half the production of this plant. The World-renowned steel trading company Stemcor of the UK has a 51% stake in this pelletization company.

Hot Briquetted Iron Plant: A 2 million TPA hot briquetted iron plant at Hazira is the world's largest gas-based sponge iron unit. This plant supplies sponge iron as the raw material to the adjacent hot rolled coils plant of Essar Group.

Hot Rolled Coils Plant: A 2.4 million TPA hot rolled coil (HRC) plant at Hazira is the first and the biggest of India's new-generation steel mills.

Downstream Complex: The complex has downstream facilities for highly customized products which has the capacity to process 1 million TPA of hot rolled coils. This centre, unique in India, includes two flying shear lines and two slitting lines of 0.2 million TPA capacity each, catering to the plates and sheets market. Essar is the only Indian plant with a 1.2 million TPA hot skin pass mill, where the steel's surface quality is enhanced to international standards.

Cold Rolled Coils Plant: Cold rolled coil (CRC) manufacturers are major customers for its hot rolled coil production. As part of its strategy of integrating operations vertically and becoming a global player in the steel industry, Essar Steel Co-promoted PT Essar Dhananjaya, a 2,00,000 tones cold rolling complex in Indonesia along with the Garama Group, one of the most respected business houses in Indonesia.

In the year 2000, the company's subsidiary, Essar Minerals Ltd. changed its name to Hy-Grade Pellets and started operating as a joint venture with Stemcor UK. The company has the capacity to produce 3.3 million TPA iron ore pellets and there are plans to expand it to 7 million TPA. Hy-Grade Pellets Ltd. a joint venture company of Essar Steel and Stemcor UK, has got TUV certification by TWTUV Systems GmbH. TWTUV systems is an international accredited certification body for fulfilling the requirements of ISO 9001: 2000 for establishing quality management system in the production of Iron Ore pellets. Hy-Grade Pellets operates the pelletisation plant at Visakhapatnam. The capacity break-up, production and capacity utilization of pellets is given in Table 10 and the specification of Essar Blast Furnace (BF) pellets is given in Table 11. The specification of Essar Direct Reduction (DR) pellets is given in Table12.

Table 10 : Supply Details of Hy-Grade Pellets Limited

Year	1997-98	1998-99	1999-00	2000-01
Capacity Volume (unit)				
Pellets (Tones)	3,300,000.0	3,300,000.0	3,300,000.0	3,300,000.0
Production Break-up				
Pellets (Tones)	1,542,010.0	325,545.0	NA	NA
Capacity Utilization	46.7%	9.9%	NA	NA
Source : Company Annual Reports				

Table 11 Specification of Essar BF Pellets

Physical Analysis			
Fe	65.50%	+16mm	3%
$SiO_2+Al_20_3$	4.20%	+8 to 18 mm	92%
P	0.04	-5 mm	4%
S	0.01	Tumbler index +6.3mm	94%
MgO+CaO	1.25	Abrasive Index	5%
H_2O	2%	Cold Crushing Strength (kg. per pellet)	250
Basicity	0.30	Bulk Density	2.1 t/m^3
Source : Essar Website			

Table 12 : Specification of Essar DR Pellets

Fe Total	67.8%
Silica+Alumina	2.25%
Phosphorus	0.04%
Sulphur	0.005%
FeO	0.10%
TiO_2	0.10%
MnO	0.15%
Na_2O	0.12%
K_2O	0.11%
Basicity	0.25%
Bulk Density	2.1 t/m^3
Moisture	1.5%
Crushing Strength	250 kg/Pellet (min)
Size distribution	9 to 16 mm – 90 % (min) Under 5mm – 1% (max)
Tumber Strength (ISO)	+6.3mm – 94% (Min) -0.6mm 5% (max)
Swelling Index	15% (max)
Midrex Jumbo Test (800^{o}C)	93%
Metallization Crushing Strength after reduction	50 Kg.
Source : Essar Website	

2.2. Jindal Vijaynagar Steel Ltd.

Jindal Vijaynagar Steel Ltd. (JVSL) was incorporated on 15th March 1994. The company is promoted by the Jindal group with participation from Karnataka State Industrial Investment and Development Corporation Ltd. The Company entered into a technical collaboration with Voest Alpine for technical details with respect to productivity etc. The company also entered into joint venture agreements for power supply, oxygen plant and mining. JVSL is one of the few steel manufacturers in the world to follow the Corex process for production of hot metal. JVSL produced 6, 60,000 tones of hot metal in the first year of production compared to Posco's production of 5, 00,000 tones and Saldanha's production of 4, 50,000 tones. Posco and Saldanha are two other companies using the Corex process.

JVSL has the capacity to produce 1.6 million TPA hot rolled coils. Around 50-55 % of the company's production is sold to Group Company Jindal Iron and Steel Company for further processing into cold rolled coils and galvanized products. The Corex process, as adopted by the company for steel making is expected to keep the company's cost of production low in comparison to other producers. The 3 million TPA pelletisation plant was installed and started production in 2000. The commissioning of the pellet plant has reduced JVSL's cost of production by Rs. 1000/ton.

2.3. Mandovi Pellets Ltd.

Mandovi Pellets Limited (MPL), Goa is a joint venture company floated by Government of India through National Mineral Development Corporation Ltd. and Chowgule & Co. Pvt. Ltd. (CCPL) a Private Sector Company. The company has its pellet plant in Goa with an annual capacity of 1.8 million MT, which was commissioned in 1979 for supply of blast furnace grade pellets to Japanese Steel Mills (JSM) under a 10 years contract. It is located in Shiroda in Goa, 25 Kms Inland from Mormugoa harbor and enjoys the benefit of inland waterways to receive iron ore fines and for dispatch of pellets. The Pellets Plant has consistently supplied Blast Furnace (BF) grade pellets fully complying with the strict quality specifications of the Japanese Steel Mills. The contract between JSVL and MPL having expired, the Company (MPL) has diversified its production to other markets. The production and sales of MPL is given in Table 13.

Table 13: Production and Sales of Pellets by Mandovi Pellets Limited

Production					
		2000	**2001**	**2002**	**2003**
Iron Ore Pellets	MT	328029	594161	538945	147884
Sales Volumes					
Iron Ore Pellets	MT	240102	332309	256991	127723
Sales Value					
Iron Ore Pellets	Rs. (Million)	337.6339	570.5344	450.3992	187.085

2.4. Kudremukh Iron Ore Company Limited

Kudremukh Iron Ore Company Limited, a wholly owned Government of India Enterprise, was established in 1976 to develop the mine and plant facilities to produce 7.5 million tones of concentrate per year. The mines and plant facilities were commissioned in 1980 and the first shipment of concentrate was made in October 1981. A pelletization plant with a capacity of 3 million tons per year was commissioned in 1987 for production of high quality blast furnace and direct reduction grade pellets for exports. The land of legend and wild beauty, Kudremukh, in the state of Karnataka, is known to have one of the largest deposits of Iron ore in the world. The idea of beneficiating the ore deposits was first proposed when several Japanese companies came together with the National Mineral Development Corporation (NMDC), a Government of India undertaking, evincing an interest in such a project. Pilot studies suggested that the surface ore with 38% iron could be enriched to a concentrate of 67% iron with available new technologies. The concentrate could be transported to Mangalore, on the coast of the Arabian Sea, 110 kms to the west of Kudremukh. But global steel industry went into decline in the late sixties. The Japanese withdrew from the project. The interest in the project was revived in nearly 1970s when

Iran drew up its plans for an ambitious domestic steel industry and was looking for a reliable supplier of iron ore, Kudremukh seemed ideal, abundant and just across the sea and an agreement was signed. The quality specification of Kudremukh Pellets – Blast Furnace Grade is given in Table 14.

Table 14 : Specifications of Kudremukh Pellets – Blast Furnace Grade

Chemical Quality		
Parameter	Specification	Typical
Fe	65%	65.5%
$SiO_2 + Al_2O_3$	5% Max	4.5%
Al_2O_3	0.60% Max	0.55%
Na_2O	0.05% Max	0.025%
K_2O	0.05% Max	0.025 %
TiO_2	0.10 % Max	0.10%
Mn	0.10% Max	0.08 %

3. Production Capacity Justification

The production of Iron Ore Pellets is a part of the overall production of Iron Ore. For estimating the demand for pellets, the future production for Iron Ore Pellets has been calculated. The past production data of Iron Ore indicates a Compounded Annual Growth Rate of 9.6%. It is estimated that the future demand/ production for iron ore is expected to grow at the same rate in India. The Iron Ore pellets comprise 9.4% of total production of Iron Ore. For conservation demand estimates, the production for pellets can be assumed to remain at the same level of the total iron ore production. Based on this assumption, the future production of Iron Ore Pellets is calculated as given in Table 15.

Table 15 : Estimated Future Demand for Iron Pellets in India (In Million Tones)

Year	Estimated Demand for Iron Ore	Future Production for Iron Ore Pellets
2003-04	106.24	10
2004-05	116.41	11.64
2005-06	127.55	12.76
2006-07	139.76	13.98
2007-08	153.14	15.31
2008-09	167.80	16.78
2009-10	183.86	18.39
2010-11	201.46	20.15
2011-12	220.74	22.07
2012-13	241.87	24.19
2013-14	265.02	26.50
2014-15	290.38	29.04
Source : DMM Estimates		

At present, the total installed capacity of iron ore pellets in India is 12.1 million tones. In such a scenario, there will be requirement of additional pellet manufacturing units to meet the estimated pellet demand.

4. Availability of iron ore fines as raw material

India has the advantage of having the raw material for the iron & steel sector which can be used for making the value added raw material for domestic market and exports. The Iron ore produced, meets the requirements of domestic steel industry and exports. The demand of iron ore has been increasing to meet domestic consumption and exports. After liberalization in 1990, a large number of pig iron plants, sponge iron plants and integrated steel plants have been set up by many private companies. The proportion of different products during mining of Iron ore is generally 50% lumps, 30-35 % as fines and nearly 15-20% slimes. This proportion varies depending on the nature of mined ore fed to the plants. As on today, there is nearly 125 million tones of accumulated unutilized fines at various mines and generation of about 8 million tones of slimes (below 0.2 mm) annually containing 14-60 % Fe ore lost as tailings in beneficiation / washing plants. In Orissa, approximately, 5.5 million tons of iron ore fines are produced per year. Availability of such a huge quantity of iron ore fines in India and Orissa justify the establishment of pelletisation units based on regular supply of raw material to sustain the unit's functionality. Table 16 presents the estimated availability of fines in Zone A (in Million Tonnes).

Table 16: Estimated availability of fines in Zone A (in Million Tonnes)

Years	Total Production of Iron Ore	Production		
		Lumps	Fines	Concentrate
2002	27.40	13.70	9.59	4.11
2003	28.23	14.12	9.88	4.23
2004	29.09	14.55	10.18	4.36
2005	29.98	14.99	10.49	4.50
2006	30.89	15.45	10.81	4.63
2007	31.84	15.92	11.14	4.78
2008	32.81	16.40	11.48	4.92
2009	33.81	16.90	11.83	5.07
2010	34.84	17.42	12.19	5.23
2011	35.90	17.95	12.57	5.39
2012	37.00	18.50	12.95	5.55
2013	38.12	19.06	13.34	5.72
2014	39.29	19.64	13.75	5.89
2015	40.48	20.24	14.17	6.07
Source DMM Estimates				

5. Description of the manufacturing process

The finished steel production in India has grown from a mere 1.1 million tones in 1951 to 31.63 million tons in 2001-2002. During the first two decades of planned economic development i.e. 1950-60 and 1960-70, the average annual growth rate of steel production exceeded 8%. However, this growth rate could not be maintained in the following decades. During 1970-80, the growth rate in steel production came down to 5.7% per annum and picked up marginally to 6.4% per annum during 1980-90, which further increased to 6.65% per annum during 1990-2000. The growth in the steel sector in the early decades after Independence was mainly in the public sector units set up during this period. The situation has changed dramatically in the decade 1990-2000 with most of the growth originating in the private sector. The share of public sector and private sector in the production of steel during 1990-91 was 46% and 54% respectively, while during 2001-02 the same was 32% and 68% respectively. This change was brought about by deregulation and decontrol of the Indian Iron & Steel Sector in 1991. India's per capita crude steel consumption, as per the latest available data is 27 Kg. which is far below the level of other developed and developing countries – 472.4 Kg, 428.6 Kg, and 128 Kg in USA, EU and China respectively. With the ongoing economic liberalization resulting in faster economic growth, steel consumption is expected to increase rapidly.

Proposed Pelletization Plant Location in Odisha-The proposed plant may be located in industrial area of Keonjhar district in Odisha which is rich in iron ore deposits.

5.1. Project Profile:

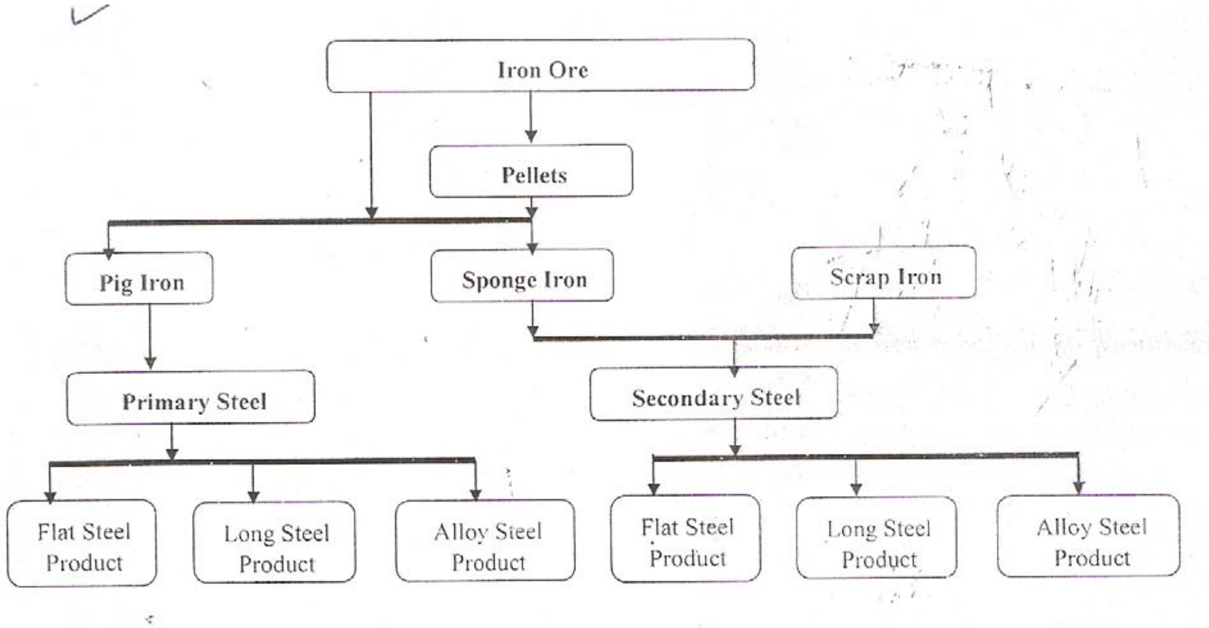

Figure 1 : Value chain of iron ore

5.2. Pellet production technology

There are two main technologies/processes for producing iron ore pellets: The Grate-Kiln System and the Straight Grate System. The First Grate Kiln System pellet plant was installed in 1960. The plant used iron ore concentrate as input and produced superior iron ore pellets for blast furnace and direct reduced iron feed. Since then, Grate-Kiln Systems have been used for over 50 plants worldwide on both Magnetic and Hematite ores, with a total installed capacity of over 115 million TPA. The advantages of Grate-Kiln System via-a-vis the straight grate system is detailed below.

(i) Process Flexibility

In the straight grate system, a continuous parade of grate cars moves at the speed through the drying, induration and cooling zones. Any change in one section affects the residence time in another. In the Grate –Kiln System, independent speed control of the grate, Kiln and cooler are available to the operator. This provides process flexibility to adjust the changes in concentrate feed. Another part of the Grate Kiln System process Flexibility is because there is only one burner. The Kiln burner can use liquid gas or solid (Coal or wood) fuels separately or in combination. One burner reduces the maintenance costs and improves fuel efficiency. In the Grate Kiln System, 95% of the air used for combustion is at + 1000^0 C. A straight grate, with up to 50 burners, cannot match this level of energy recovery.

(ii) Energy Efficiency

In a Grate-Kiln System, the travelling grate is used to dry and preheat the pellets. A refractory lined rotary kiln is used for induration. In a straight grate, the grates cars have to go through the drying and induration zones. So, a deep bed of pellets with a hearth layer is required. The modern Grate-Kiln System will have a power requirement of less than 20 KWH/ton, while a straight grate system will use over 35 KWH/ton.

(iii) Pellet Quality

Because the induration of the pellets occurs in the rotary kiln, the pellets produced in a Grate-Kiln System are consistently of higher quality than those produced in a straight grate. The rotary Kiln provides constant mixing of the pellets, bringing all the pellets to the same temperature. In a straight grate, the pellets at the top of the bed are “over cooked” and those at the bottom are “under cooked”. Higher quality means fewer fines, better reducibility and less variation in compression strength.

(iv) Continuous Improvements

There are on-going developments in the Grate-Kiln System that has significantly improved the reliability and ease maintenance of the equipment. The use of higher grade alloys in the traveling grate has proven effective for longer life. Floating seals in the travelling grate reduces air leakage. Annular coolers are now made with water seals and fabricated steel pallets. The rotary Kiln uses the patented Svedala Superdeal$_{TM}$ Kiln seals to reduce air leakage.

Finite element analysis is used on the grate components to improve life. CFD analysis is used to continuously reduce the fuel and power requirement. Heat and Mass Balance model studies are done to optimize a system for a particular iron ore concentrate or fuel. Predictive Control System using expert system design continuously monitors the operation to get maximum product quality and stable performance. These changes have also made it possible to increase the capacity of the Grate-Kiln System. The original plant based on Grate-Kiln System technology had a capacity of 3, 00,000 TPA. The plant today is operating at close to 6.0 million TPA.

5.2.1 Features of Grate Kiln System

The Grate Kiln System technology has excellent features

- Superior quality pellets with high flexibility: This pelletizing Process produces superior quality pellets because of application of rotary kiln where pellets are heated and fired uniformly, better know-how of plant operation & quality control, and advanced process control system.
- Low running cost: In Pelletizing Process. Heat treatment stages (Induration section) are generally carefully separated as Travelling grate/ Rotary kiln/Annular cooler and each unit is expected to optimally carry out a specific process function. This increases the plant availability and reduces the requirement for spare parts, resulting in low maintenance cost.
- Best Pellets for DR process: In the near future, it is expected that pellet demand will increase according to new construction of DR plants. This Pelletizing Process develops best pellets for DR plants.

5.2.2 Process Description of Grate Kiln System

Pelletization essentially consists of formation of green balls by rolling fine iron bearing material (Hematite) with critical amount of water and Bentonite as a binder. These green balls of nearly 8-16 mm size are then dried, preheated and fired, all under oxidizing conditions, to a temperature of around 1200-1250^0 C. The sensible exhaust heat is recovered and is fed back in the induration operation. Figure 2 shows Process flow diagram of pelletization unit.

The Pelletization process consists of the following major stages:

(a) Feed preparation
(b) Green ball production
(c) Green ball Induration
- Drying
- Preheating
- Firing

(d) Cooling of hardened pellets

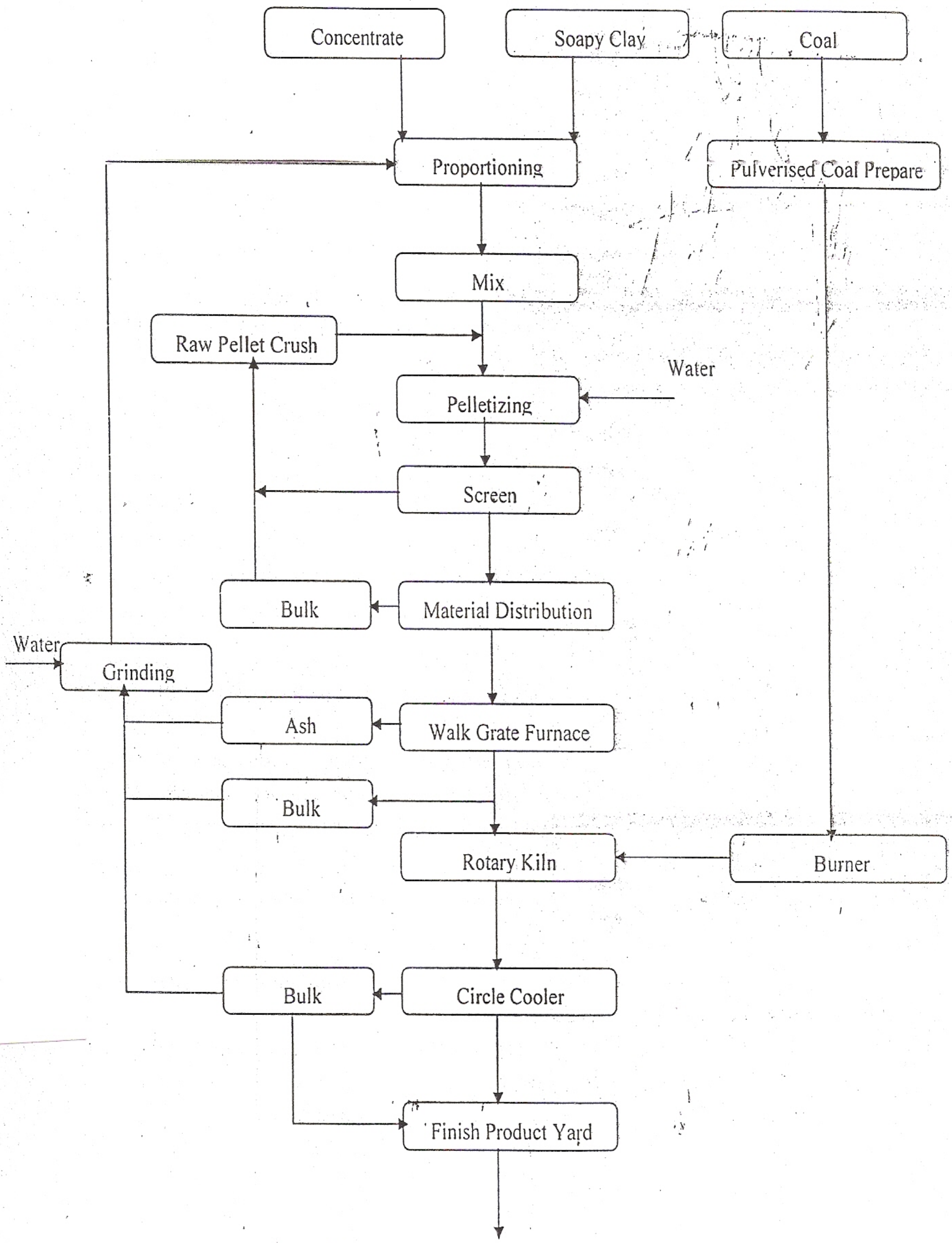

Figure 2: Process flow diagram of pelletization unit

5.2.3 Feed Preparation

For the feed preparation, a proper proportion of Iron ore powder and Bentonite is put in the horizontal mixer.

5.2.4 Green Ball Production
Green ball production takes place by adding proper amount of water to the feed during balling in Disc Pelletizer. The size of pellets after balling should be in the range of 8-20 mm. The undersize and oversize pellets are sent back to the mixer.

5.2.5 Green Ball Induration
Drying and preheating of pellets take place in Grate Kiln with the help of fuel coming from Rotary Kiln. Heating of already preheated pellets takes place in Rotary Kiln through burner where combustion of pulverized coal takes place to generate working temperature of 1200-1250^0 C. The pellets become hard and strong after heating.

5.2.6 Cooling of Hardened Pellets
Cooling of hardened pellets takes place with the help of Annular Cooler where cooling is carried out with the blast of cold air. Cooled product is stocked in open yard for dispatch. The system has adequate de-dusting and heat recovery provisions.

6. Government Policy and Directives
The Government is likely to clamp down restrictions on exports of iron ore in a bid to augment the supply of raw materials to domestic steel producers at cheaper costs and promote export of value-added products instead of primary commodities.

6.1. Energy Saving
It has reported in various studies on the existing pellet based units that pellets reduce coke consumption by more than 50 kg per ton in blast furnace operating with 100% pellets. The pellets are energy saving and environmentally friendly raw materials vis-à-vis iron ore.

6.2. Requirement of High Iron Content Raw Material
It has been reported that the low iron content ores / fines remain unutilized at various mines which ultimately lead to deposition of iron ore waste at mining site. With Conversion of iron ore fines / lumps (low grade Fe Content) into pellets, the mining waste can be better utilized. It also fetches a good price in the market.

6.3. Requirement for Low Level of impurities in Raw Material
Occasionally, the Iron & Steel units using iron ore as raw material face problems due to high level of impurities in iron ore. Pelletization is one of the best options to reduce the impurity levels in iron ore. There is a great demand among steel / iron manufacturing units for high quality raw material like pellets to compete in steel export market.

6.4. Limited Number of Pellets Manufacturing Units in India
As detailed earlier, there are only 4 pellet manufacturing plants in India. Either they are engaged in export of pellets or use it as raw material for their own steel manufacturing units. In such a condition, other manufacturing units have to use iron ore as a raw material or import pellets from other countries.

6.5. Increase in Productivity of Sponge / Pig Iron Units
It has been reported in various documents that there is increase in production (20-30%) of sponge iron/ pig iron with the usage of pellets as raw material. Use of pellets as raw material in sponge and pig iron units reduce the production of iron ore fines as by product, its inventory and further sale efforts.

7. Discussions

7.1 Industrial Licensing

The establishment of pelletization plants viz. manufacture of iron pellets does not require an Industrial License from the GOI. However one has to submit the information on the project in the form IEM (Industrial Entrepreneurs Memorandum) to the Secretariat for Industrial Approvals (SLA).

7.2. Import and Export Policy

The end products i.e. iron ore pellets can be freely imported into India. The export of Iron Ore pellets is canalized through MMTC (Minerals and Metals Trading Corporation). However Iron ore pellets (up to 64% iron content) are allowed to be exported freely.

7.3. Import (Customs Duty)

The standard rate of applicable import duty on the plant and machinery and the product during the last few years is given in Table 17.

Table 17 : Rate of Import Duty

Sl.	Description	2001-02	2002-03	2003-04	2004-05
1	Iron Ore Pellets	5%	5%	5%	5%
2	Iron Ore Fines (Iron Content 62% and above)	5%	5%	5%	5%
3	Plant and Machinery	25%	25%	25%	25%
Source : Customer Tariff Ready Reckoner					

The standard rate of import (customs duty) on iron pellets is 5% *ad valorem*. In addition, additional duty (countervailing duty) equal excise duty on the product and special additional duty is applicable. In the Union Budget of 2004-05, the government has imposed education cess of 2% which is applicable on the aggregate of duties. The import of capital goods (plant & machinery) under the EPCG scheme attracts 5% duty as against the usual rate of 25%. However, the concessional rate of duty is applicable only if the company undertakes export obligation as mentioned in Table 18.

Table 18. Export Obligation under EPCG Scheme

Sl.	Description	Minimum Export Obligation
1	1st to 6th year from the date of license	50%
2	7th and 8th Year	50%

Import of capital goods requires approval from the Secretariat of Industrial Approvals. However, the approval is automatic if CIF value of imported equipment is less than 25% of the total value of plant and machinery, up to a ceiling of Rs. 2 crores.

7.4. Export Duty

The export duty on iron pellets is nil.

7.5. Excise Duty

The rate of excise duty during the last few years is given in Table 19.

Table 19 : Rates of Excise Duty

Sl. No.	Description	2001-2	2002-03	2003-04	2004-05
1	Iron Ore Pellets	16%	16%	16%	16%

2	Iron Ore Fines (Iron content 62% and above)	16%	16%	16%	16%

The standard rate of excise duty is 16% *ad valorem*. In the 2004-05 budgets the GOI has imposed an additional education cess of 2%.

7.6. Locational Incentives

For the purpose of incentives, the state of Odisha has been divided into three zones: A, B, and C. District Keonjhar lies in Zone B.

7.7. Capital Investment Subsidy

New industrial units in zone B are eligible for capital investment subsidy equal to 15% of the fixed capital investment subject to a limit of Rs. 15 lakhs if the maximum project cost is less than Rs. 5 crores. Special class entrepreneurs (Entrepreneur belonging to scheduled caste or tribe/ women technical entrepreneur / handicapped entrepreneur) would be eligible for an extra 5% capital investment subsidy subject to a limit Rs. 5 lakhs.

8. Conclusion

Lump ores are naturally mined ores that are crushed and screened to a certain grain size before their use. However, as a result of preparation and enrichment processes in the iron ore mines to increase the Fe content, very fine-grained ores increasingly accumulate which undergo agglomeration. The agglomeration is done by means of pelletizing and sintering. Pelletizing involves forming of ore fines (pellet feed) and concentrates with grain sizes of well under 1 mm into pellets measuring around 10 to 15 mm in diameter. The forms that affect blast furnace productivity-fines (fine ores), lump, and pellets-are also the primary market products. Minor quantities of iron ore concentrates are also sold. Fines are iron-ores with particles measuring less than 4.75 millimeters diameter and lumps are iron-ores with majority of individual particles measuring more than 4.75 millimeters diameter. Fines and lumps are produced from the same ore and are separated by screening and sorting. Neither product is concentrated. Pellets, the third product type (form), begin as a fined-grained concentrate. A binder, often bentonite clay, is added to the concentrate, which is then rolled into balls. The balls then pass through a furnace where they are indurated and become pellets, usually measuring from 9.55 to 16.0 millimeters (3/8- 5/8 inch). AISCO has set up a 1.2 MTPA merchant pelletisation plant in Orissa state, one of the most iron enriched regions of the world. This plant is the largest and first of its kind (Grate Kiln Technology) in Orissa. The plant uses Haematite ore from the iron ore belt of Barbil District Keonjhar. AISCO planned to cater to both the domestic as well as the international markets. The current production of Pellets in India is approximately 15 million tons is mostly being used for captive consumption. AISCO will be the 1st Merchant Plant which will be selling 100% of the product in the domestic and international markets. Iron Ore pellets are superior to other substitutes due to its High Cold Crushing Strength resulting in minimal fines generation while multiple handling and resulting in increased savings. With uniform composition of material, size and Guaranteed Porosity, Swelling Index and negligible moisture due to dry process provides an added advantage for Smooth Operation in Kiln / Furnace and improves productivity.

9. Scope for future study

The scope of future study for the techno-economic evaluation will cover the following aspects:

- Market (availability of product and competing products, present suppliers, their capacity, imports, exports and prices, justification for setting up the new units).
- Manufacturing process (description of the manufacturing process including technology suppliers), machines and equipments (list of machines and equipments required).

- Raw materials (requirement, availability of raw materials including cost); utilities (details of utilities required per ton of output and cost); manpower (skill set requirements, estimation of manpower requirement and cost of manpower).
- Site (location details, cost of land and development and site layout).
- Estimation of project cost including details such as land and civil works, plant and machinery cost, cost of miscellaneous fixed assets, preliminary and pre-operative expenses.
- Estimation of cost of production including cost of raw material and utilities, manpower cost, cost of term loan and working capital and other fixed and variable costs.
- Estimation of project profitability.
- Projected financial statements such as interest and repayment schedule, cash flow, balance sheet, profit and loss account etc.

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