Good Practices Manual

Green House Gases Emission Reduction

IRON & STEEL (SPONGE IRON) SECTOR OF INDIA

Prepared by

National Productivity Council

Supported by

Department of Industry and Policy Promotion

Prepared by

National Productivity Council, India

Supported by

Department of Industrial Policy and Promotion

Ministry of Commerce and Industry

Government of India

CONTENTS

Chapter No.	Particulars	Page No.
	Acknowledgement	1
	Preface	2
	Study Team	3
1.0	Introduction	4
1.1	Background	4
1.2	About the Project	6
1.3	About NPC	6
1.4	Outline of Energy Scenario of India	7
1.5	Green House Gases Emission in India	11
1.6	Energy Conservation and Green House Reduction Initiatives of by Government of India	15
1.7	Measure Specific to Iron & Steel sector	22
2.0	Indian Energy Scenario	23
2.1	Major energy sources for India	23
2.2	Energy demand and supply scenario	23
2.3	Availability of Various fossil Fuels of India	24
2.4	Import of Fuels	26
2.5	Renewable Energy Sources	27
3.0	Brief about Iron & Steel sector	29
3.1	Overview of Iron & Steel sector	29
3.2	Overview of Sponge Iron sector	33
3.3	Inventorization of Sponge Iron plants	34
4.0	Process Description of Sponge Iron Plant	40
4.1	Brief description of sponge iron plant process	40
4.2	Technological options for coal based plants	42
5.0	Status of Sponge Iron Plants in India	67
5.1	Questionnaire Survey	67
5.2	Identified stakeholders for consultations	67
5.3	Questionnaire Survey Analysis	68
5.4	General outlook of green house emission measures and practice adopted in India	72
5.5	Issues & Challenges faced by the Sponge Iron Industry	73
6.0	Best practices to reduce Green House Emissions	74
6.1	Improving Energy Efficiency	74
6.2	Waste Minimization/Pollution Control Measures	81
6.3	Occupational Health and Safety	85
6.4	Implementing the concept of Lean Management	86
7.0	Conclusions and Way Forward	90
7.1	Conclusion	90
7.1	Way Forward	90
	Bibliography	92

ACKNOWLEDGEMENT

Orissa Sponge Iron & Steel Ltd	Management & Executives of Orissa Sponge Iron & Steel Ltd.
Yazdani Steel & Power Ltd	Management & Executives of Yazdani Steel & Power Ltd
Aarti Sponge and Power Ltd, Raipur	Management & Executives of Aarti Sponge and Power Ltd, Raipur
Anjani Steels Ltd, Ujalpur, Raigarh	Management & Executives of Anjani Steels Ltd, Ujalpur, Raigarh
API Ispat and PowerTech Pvt Ltd	Management & Executives of API Ispat and PowerTech Pvt Ltd
Jai Durga Iron Private Ltd. (JDI)	Management & Executives of Jai Durga Iron Private Ltd. (JDI)
Aryavartya Steels Pvt. Ltd (ASPL)	Management & Executives of Aryavartya Steels Pvt. Ltd (ASPL)
Rashmi Sponge Iron and Power Industries Ltd	Management & Executives of Rashmi Sponge Iron and Power Industries Ltd
Joint Plant Committee , Ministry of Steel, Govt. of India	Mr. R.S.Das, Executive Secretary
Sponge Iron Manufacturers Association (SIMA)	Mr.Deependra Kashiva, Executive Director

PREFACE

It is now widely accepted that we have to limit the temperature rise to 2^{o}C to mitigate effects of climate change. This requires changing the portfolio of energy basket from fossils to non-renewables, reduce energy use through energy efficiency and conservation and reduce GHG emissions.

The broad intent and its goals can only be achieved by coordinated actions at various level by society, business, industry and government. As part of its endeavour the Government of India is formulating policies, action plans to support and guide industry and entrusted National Productivity Council to prepare of Best Practices Manual for Reducing GHG Emissions in various sectors namely, **Thermal Power Plant, Chlor Alkali, Cement, Pulp and Paper and Iron and Steel**.

This manual is expected to serve as reference manual for

- Identifying sources of GHG emissions
- Assess and quantify emissions.
- Evaluate and assess potential to improve energy efficiency and reduce GHG emissions.
- Propose a menu of options which industry can consider for assessment and implementation.

The scope of this manual covers GHG emissions in the plant boundary and does not include transportation of raw materials, products and wastes to secured landfills, emissions from domestic waste treatment and emissions from sales and other offices.

It is hoped the manual will be handy reference and guide for all levels of engineers and managers working in the sector.

STUDY TEAM

Project Co-ordinator	**Mr. R Virendra** **Dy. Director General, National Productivity Council**
Team Co-ordinator	**Mr. A. K. Sinha** **Director, National Productivity Council**
Team Members	**Mr. Suman Maity** **Deputy Director, National Productivity Council**
	Mr. Avijit Nayak **Deputy Director, National Productivity Council**
	Mr. Krishanu Mallick **Deputy Director, National Productivity Council**
Advisor	**Shri Saroj Kumar Patnaik** **General Manager, Orissa Sponge Iron & Steel Limited (Project & Engineering Limited)**

CHAPTER 1 : INTRODUCTION

1.1 Background

Indian industrial sectors such as Iron & Steel and Cement manufacture products for equitable growth but at the same time consume huge amounts of energy. India's total final energy consumption was estimated at 449.27 Mtoe of which the industrial sectors consumed about 30%. The Iron & Steel sector is one of the most energy intensive manufacturing industries, consuming about 25% of the total industrial energy consumption. The total GHG emissions in India were assessed at 1904.73 $MtCO_2$, and 38% (719.31 $MtCO_2$) and 22% (412.55 $MtCO_2$) were from electricity generation and industry sectors respectively. The Indian Iron and Steel sector contributed to about 117.32 $MtCO_2$ or 6.2%. Among the major industries the Iron and Steel sector is among the most energy intensive. Globally, the sector consumes almost 21% of total industrial energy consumption.

The Indian Iron and Steel industry is vital to the nation's development efforts and to support the required rapid economic growth. Steel finds its application in a wide range of sectors such as automobile, power, machine goods, and infrastructure. Energy efficiency and low carbon growth have emerged as key pathways to reduce the nation's energy intensity and emissions intensity. The industry has taken several initiatives to conserve energy at each sub process by adopting best technologies and innovative process operations or the usage of alternate materials.

The Indian Iron & Steel sector contributed to about 117.32 $MtCO_2$ (28.4% of the industrial sector). In this context, India announced a voluntary 20-25 per cent carbon emission intensity reduction by 2020 on the 2005 levels, ahead of the UNFCCC's COP15 summit held in Copenhagen. The Government of India, in 2010, announced its intent to reduce the carbon intensity in 2020 by 25% as compared to 2005 levels. This could possibly be accomplished by improved processes, adoption of energy efficient technologies and measures, and renewable energy options.

The Bureau of Energy Efficiency (BEE) under the Ministry of Power (MoP) has been entrusted with the responsibility of implementing various strategic policy mechanisms specifically to enhance the energy efficiency. The National Steel Policy has been framed by the Ministry of Steel, Government of India for long-term objectives of improving production, consumption, quality and techno-economic efficiency, environmental and social sustainability. The Central Pollution Control Board (CPCB) has set norms for permissible emissions and other hazardous pollutants from several industrial sectors.

The National Action Plan on Climate Change (NAPCC) released by the Honourable Prime Minister seeks to promote sustainable development through increased use of clean technologies. NAPCC has a mission specifically dedicated to energy efficiency – National Mission on Enhanced Energy Efficiency (NMEEE). Perform, Achieve and Trade (PAT), one of the flagship programs under NMEEE was launched and implemented by the Bureau of Energy Efficiency (BEE) to issue energy efficiency norms to energy intensive manufacturing units. Out of 15 energy intensive sectors, 8 sectors were selected for the first cycle of PAT. Baselining exercise was conducted across these sectors and 478 Designated Consumers (DCs) were given

targets to lower their Specific Energy Consumption (SEC) over baseline levels by the end of the implementation periods (2012-15). After the end of PAT cycle 1, the Scheme has saved 8.67

million TOE (tons of oil equivalent) of energy from the assessed 427 DCs which has surpassed the envisaged 6.686 million TOE (tons of oil equivalent) at the advent of the PAT I cycle aproportionate from 478 DCs. The CO2 mitigation envisaged is around 31 million tones. In the Iron & Steel Sector, 2.10 million TOE (tons of oil equivalent) of energy has been saved from 60 assessed DCs.

Presently, PAT cycle - I has completed and the BEE has already commenced the second phase of PAT w.r.t April, 2016. The baseline year for PAT cycle II is taken as 2014-15. The period of the II cycle is 2016-2019 keeping the assessment year as 2018-19. PAT cycle II (2016-17 to 2018-19), comprising of 621 Designated Consumers (DCs) which apart from 478 DCs of existing sectors, will include more number of industrial units from existing sectors (about 89 new DCs i.e. Iron & Steel, Paper & Pulp, Cement, Textiles, TPP, Aluminium, Chloro-alkali and Fertilizer) through deepening and inclusion of more units (about 84 DCs) from 3 more sectors (Railways, Electricity DISCOMs and Refinery) through widening. The total Energy consumption envisaged from 11 sectors in the new cycle is 227 MTOE and the National Target set to be achieved by the end of the cycle is 8.869 MTOE.

In the Paris Summit, India has strongly advocated climatic justice and added to the principle of equity and common but differentiated responsibilities on the issue of climate change action. Intended nationally determined contribution for the period 2021 – 30 were presented which aimed at propagation of healthy, green and sustainable path to economic development reduction of emission intensity of its GDP for 33% to 35% for 2030 from 2005 level increasing the share of non fossil fuel based energy resourced to 40 % and creation of 2.5 – 3 billion tons of CO2 equivalent.

Among the solutions carbon capture and storage (CCS) which is an emerging technology which is under development stage. This is a three step process including capturing CO_2 from its primary source, its transportation and them storage away from atmosphere. Panel on climate change (IPCC) reports indicate that geological formation have capacity of 200 GT of likely CO_2 storage this includes 675 – 900 Gt CO_2 in oil and gas feed, 1000 – 10000 GT of CO_2 in saline formation and 3200 GT in coal beds worldwide. Canada serving as a storage site for world’s first commercial post combustion CO_2 capture, transportation and storage project from a coal based power plant. It demonstrates storing liquid CO_2 at a depth of 3.4 KM underground in their deep brine and sandstone. A few large scale CO_2 capture projects in power sector are getting to be operational in 2016 – 17. As per the global carbon capture and storage institute, India is among 24 developing countries that are currently engaged in CCS activities such as capacity development planning and pre investment and project development. Policy development studies have started and CO_2 capturing research has been carried out in CSIR laboratories.

Iron & Steel sector is mostly dependent on coal and has to adopt ways to develop CO_2 materialization and recycling. Indian industry has already proposed and started a few projects namely in ONGC, BHEL, NTPC etc. to meet the target of creating additional carbon sink of 2.5 – 3 billion tons, it is opt that CCS is replaced with CCU, that is Carbon capture and utilisation using chemical, biological and mineralogical process to avoid all underlying risk involved in CO_2 storage.

1.2 About the Project

The Department of Industrial Policy & Promotion (DIPP), under Ministry of Commerce & Industry, Govt. of India has entrusted National Productivity Council of India (NPC) with the prestigious Project entitled "Preparation of good practices manuals for green house gas emission reduction in five energy intensive industry sectors in India" under the 12th Plan period (2012-2017).

The scope of the Plan Project is to conduct field and questionnaire survey in five selected energy intensive sectors of Indian economy, towards bringing out manuals on Good Practices for GHG Emission reduction in these selected energy intensive sectors. Out of these five Energy Intensive sectors, this manual highlights the best practices involved for reducing Green House Gases Emission reduction in Iron & Steel (sponge Iron) sector.

This manual aims to bring out sources and trends driving India's greenhouse gas emissions in the sponge Iron sector, outlining present situation and technologies that offer the potential for significant emission reductions through enhanced Energy Efficiency, thus needed to put India on a sustained low-carbon path and promoting economic growth. It also showcases the likely Government of India policies and interventions that could spur energy efficiency and GHG reduction activities in the sector eventually leading to improving energy security.

1.3 About NPC

National Productivity Council (NPC), an autonomous body under the Ministry of Commerce &Industry, Government of India, was established in the year 1958, to promote productivity culture in the country. It is a tripartite, nonprofit making organization, with equal representation from the government, employers and workers organizations, apart from technical and professional institutions and other interests on its governing council. NPC also implements the plans and programmes of the Tokyo based Asian Productivity Organization (APO) an inter-governmental body of which the Government of India is a founder member.

Activities

NPC aims at being a promotional body with a professional approach and matching competence. It seeks to realize its primary objective of productivity promotion through various means, including:

Consultancy: Promoting and disseminating productivity skills through consultancy work to the private and public corporate sectors, Central and State Governments, their agencies and other client groups. NPC's consultancy services rely on problem solving and total solutions, with softer terms offered to the informal sector and labor welfare work.

Promotion: Propagating productivity, quality and efficiency consciousness through seminars, workshops, publications, celebrations of productivity and quality event campaigns, motivational awards and other suitable means.

Training: Training of consultants, managers, workers, supervisors and others.

Research: Conducting studies, research surveys, evaluations etc. on matters relating to productivity/quality improvement for enterprises, governments and others.

Strategic Planning: Identifying frontier areas in the field of productivity and quality, acting as a catalyst for work in these areas, promoting new institutions where needed and providing inputs to policy making.

The Union Minister for Industry, Government of India is the President of the NPC and Secretary, Ministry of Industry, Government of India is the Chairman. The plans and programmes of productivity promotion are undertaken through a three tier structure i.e. the NPC Headquarters at the national level, the Regional Directorates at state/region level and the Local Productivity Council. NPC has 13 Regional Directorates in India and a total strength of over 150 full time specialist/consultants. It has association with 40 local productivity councils. In addition, services of external professionals and subject matter specialists are sought on a project to project basis, depending upon the nature and scope of work.

1.3.1 METHODOLOGY

For preparing this manual, the following methodology was adopted:

- Sector reports were prepared with inputs from questionnaire survey, detailed field visits and audits, workshops and guidance from steering committee.
- The synopses of the reports were extracted to prepare this manual for comprehensive presentation of information and provide guidelines for implementation of GHG emission reduction options.
- Feedback on the manual contents and the material was sought and received from industries, Alkali Manufacture’s Association, and other stakeholders and the same was incorporated in the final manual

1.4 Outline of energy scenario in India

Energy has been universally recognized as one of the most important inputs for economic growth and human development. There is a strong two-way relationship between economic development and energy consumption. On one hand, growth of an economy, with its global competitiveness, hinges on the availability of cost-effective and environmentally benign energy sources, and on the other hand, the level of economic development has been observed to be reliant on the energy demand.

Energy is one of the major drivers of a growing economy like India and is an essential building block of economic development. In an effort to meet the demands of a developing nation, the Indian energy sector has witnessed a rapid growth. Areas like the resource exploration and exploitation, capacity additions, and energy sector reforms have been revolutionized.

1.4.1 Segregation and Share of Energy

Energy use in the demand side is segregated into transport, industry, buildings and agriculture. Each demand sector has different end-use requirements and uses different technologies to meet the end uses.

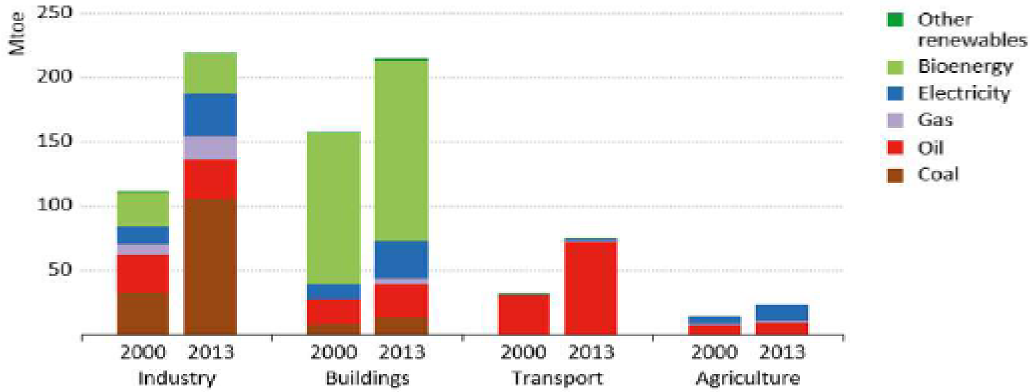
Energy demand had traditionally been dominated by the buildings sector (which includes residential and services), although demand in industry has grown more rapidly since 2000, overtaking buildings as the main energy user in 2013. In the buildings sector, a key driver of consumption in both rural and urban areas has been raising levels of appliance ownership, especially of fans and televisions, and an increase in refrigerators and air conditioners in urban areas over the latter part of the 2000s. As a result, electricity demand in the buildings sector grew at an average rate of 8% per year over 2000-2013.

Industrial energy demand has almost doubled over the 2000-2013 period, with strong growth from coal and electricity. Large expansion in the energy-intensive sectors, including a tripling in steel production, is one component. Nonetheless, consumption levels of cement and steel are still relatively low for a country of India's size and income levels: consumption of cement is around 220 kilograms (kg) per capita, well behind the levels seen in other fast-growing economies and a long way behind the elevated levels seen in China in recent years (up to 1770 kg per capita).

The agricultural sector, though a small part of energy demand, is a key source of employment and since 2000 has accounted for roughly 15% of the increase in total final electricity demand as more farmers obtained electric pumps for irrigation purposes.

Over 90% of energy demand in the transport sector in India is from road transport. The country's passenger light-duty vehicle (PLDVs) stock has increased by an average of 19% per year since 2000, rising to an estimated 22.5 million in 2013, with an additional 95 million motorbikes and scooters (two/three-wheelers). Yet ownership levels per capita are still very low compared with other emerging economies and well below ownership levels of developed countries.

Figure 1 : Energy Demand by fuel in end-use sectors



Notes: Other renewables includes solar photovoltaics (PV) and wind. Industry includes energy demand from blast furnaces, coke ovens and petrochemical feedstocks.

1.4.2 Share of Energy for Various Major Industry Sectors

Consumption of Coal and Lignite

The estimated total consumption of raw coal by industry has increased from 433.27 MT during 2005-06 to 827.57 MT during 2014-15 with a CAGR of 6.69%. The annual growth rate from 2013-14 to 2014-15 is 14.28%.

Consumption of Lignite increased from 30.24 MT in 2005-06 to 49.57 MT in 2014-15 registering a compound growth of 5.07%. Consumption of Lignite is highest in Electricity Generation sector, accounting for about 84.09% of the total lignite consumption.

Electricity generation is the biggest consumer of coal, followed by steel industries. Industry wise estimates of consumption of coal indicates that during 2014-15 electricity generating units consumed 527.10 MT of coal, followed by steel & washery industries (66.37 MT), cement industries (37.95 MT) and paper industries (1.54 MT).

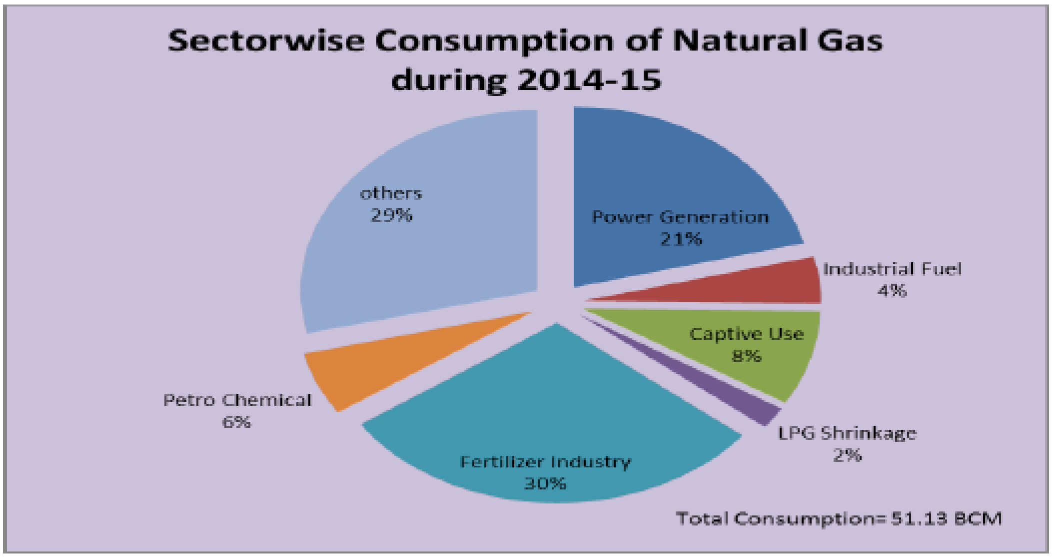
Consumption of Crude Oil and Natural Gas

The estimated consumption of crude oil has a steady increase, from 130.11 MMT during 2005-06 to 223.24 MMT during 2014-15 with CAGR of 5.55%. It increased from 222.50 MMT in 2013-14 to 223.24 MMT in 2014-15.

The maximum use of Natural Gas is in fertilizers industry (29.71%) followed by power generation (20.97%) and 0.07% natural gas was used for domestic fuel.

Industry wise off-take of natural gas shows that natural gas has been used both for Energy (55.69%) and Non-energy (44.31%) purposes.

Figure 2 : Sector wise consumption of Natural Gas during 2014-15

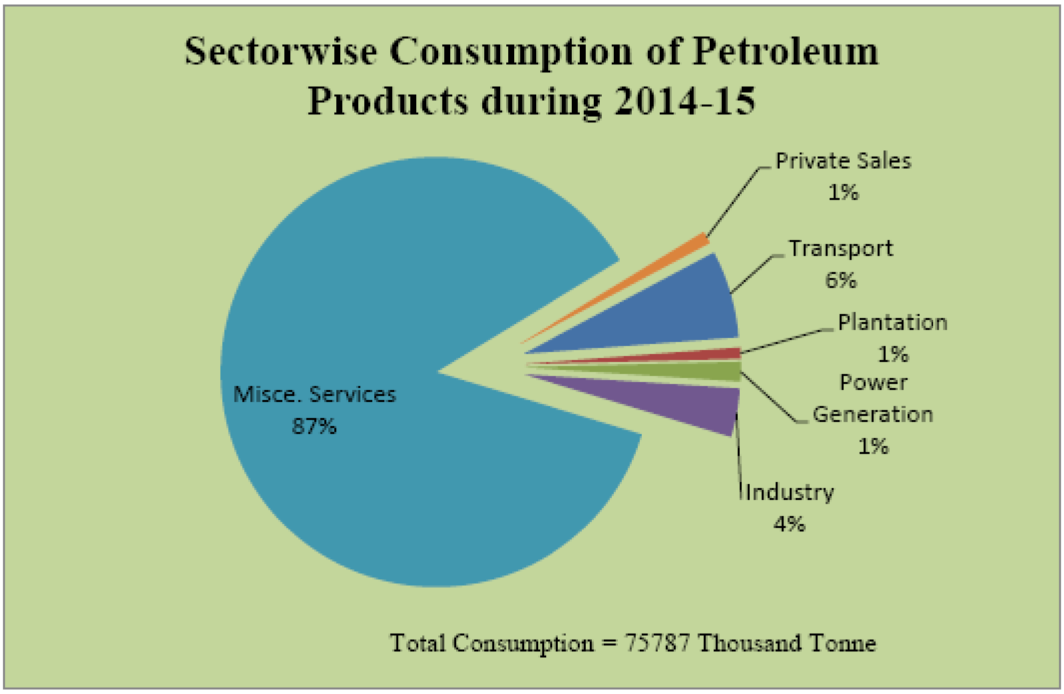


Consumption of Petroleum Products

High speed diesel oil accounted for 37.99% of total consumption of all types of petroleum products in 2014-15. This was followed by Petrol (10.44%), LPG (9.86%), Refinery (9.67), Petroleum Coke (7.88%) and Naphtha (5.98%). Consumption of Light Diesel oil continuously declined from 2005-06 (0.88 MT) to 2014-15 (0.37 MT).

Sector-wise consumption of different petroleum products reveals that miscellaneous service sector accounts for the lion's share (87%) of the total consumption of petroleum products.

Figure 3 : Sector wise consumption of Petroleum products during 2014-15

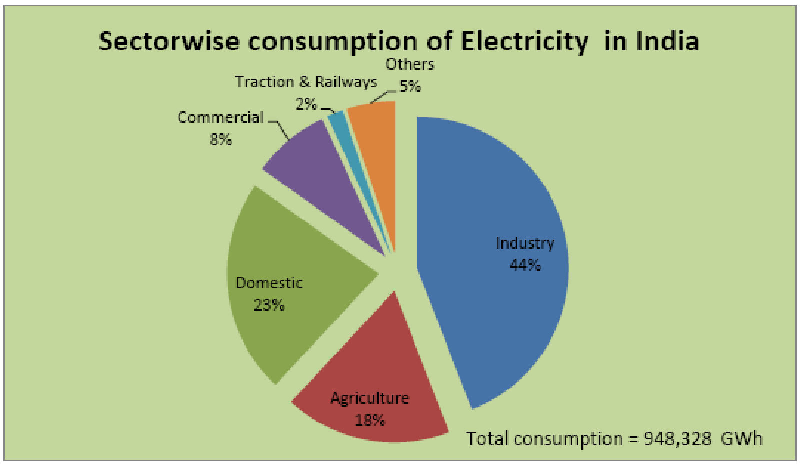


Consumption of Electricity

The estimated electricity consumption increased from 411887 GWh during 2005-06 to 948328 GWh during 2014-15, showing a CAGR of 8.72%. The increase in electricity consumption is 8.48% from 2013-14 (874209 GWh) to 2014-15 (948328 GWh).

Of the total consumption of electricity in 2014-15, industry sector accounted for the largest share (44.11%), followed by domestic (22.93%), agriculture (17.81%) and commercial sectors (8.27%).

Figure 4 : Sector wise consumption of Electricity during 2014-15



The electricity consumption in Industry sector and commercial sector has increased at a much faster pace as compared to other sectors during 2005-06 to 2014-15 with CAGRs of 10.69% and 8.10% respectively. Loss of electricity due to transmission has decreased from 30.42% during 2005-06 to 22.79% during 2014-15.

1.5 Green House Gas Emissions in India

1.5.1 Segregation of GHG from Industries and others

Energy:

The energy sector emitted 1100.06 million tons of CO_2 eq due to fossil fuel combustion in electricity generation, transport, commercial/Institutional establishments, agriculture/fisheries, and energy intensive industries such as petroleum refining and manufacturing of solid fuels, including biomass use in residential sector. Fugitive emissions from mining and extraction of coal, oil and natural gas are also accounted for in the energy sector. The distribution of the emissions across the source categories in energy sector.

Electricity Generation:

The total greenhouse gas emissions from electricity generation in 2007 was 719.31 million tons CO_2 eq. This includes both grid and captive power. The CO_2 eq emissions from electricity generation were 65.4% of the total CO_2 eq emitted from the energy sector. Coal constituted about 90% of the total fuel mix used.

Petroleum Refining and Solid Fuel Manufacturing:

These energy intensive industries emitted 33.85 million tons of CO_2 eq in 2007. The solid fuels include manufacturing of coke & briquettes.

Transport:

The transport sector emissions are reported from road transport, aviation, railways and navigation. In 2007, the transport sector emitted 142.04 million tons of CO_2 eq. Road transport, being the dominant mode of transport in the country, emitted 87% of the total CO_2 equivalent emissions from the transport sector. The aviation sector in comparison only emitted 7% of the total CO_2 eq emissions. The rest were emitted by railways (5%) and navigation (1%) sectors. The bunker emissions from aviation and navigation have also been estimated but are not counted in the national totals.

Residential & Commercial:

The residential sector in India is one of the largest consumers of fuel outside the energy industries. Biomass constitutes the largest portion of the total fuel mix use in this sector. Commercial and institutional sector uses oil & natural gas over and above the conventional electricity for its power needs. The total CO_2 eq emission from residential & commercial/institution sector was 139.51 million tons of CO_2 eq in 2007.

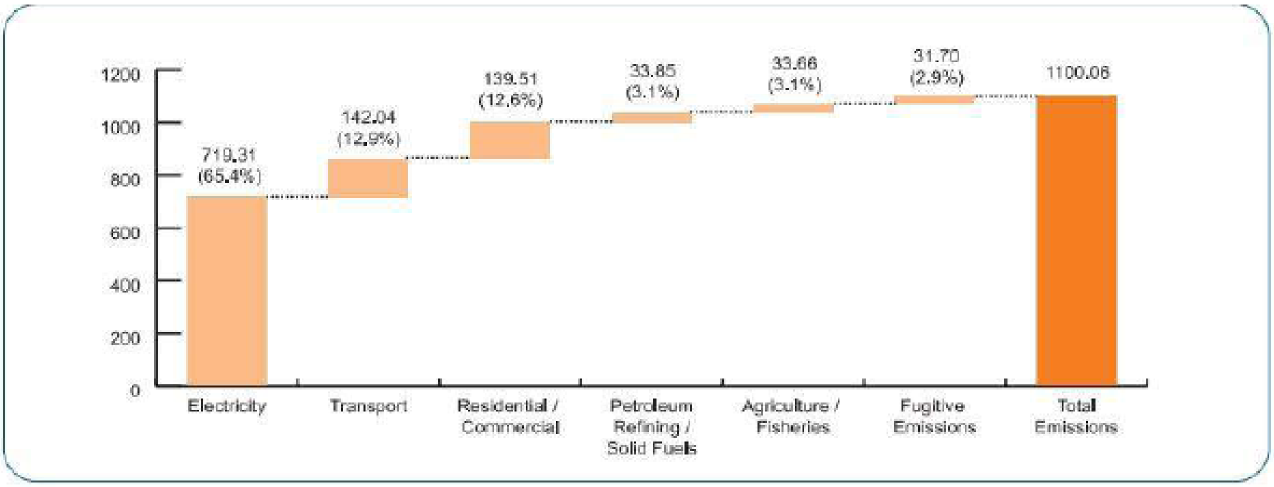
Agriculture & Fisheries:

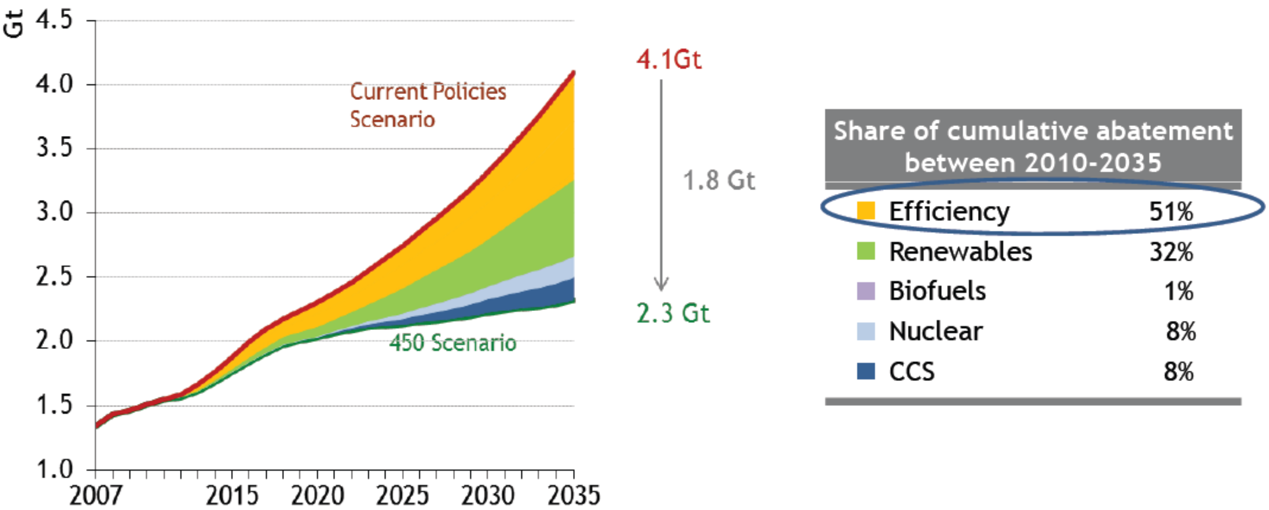
The agriculture/ fisheries activities together emitted 33.66 million tons of CO_2 eq due to energy use in the sector other than grid electricity.

Fugitive Emissions:

CH4 escapes into the atmosphere due to mining of coal, and due to venting, flaring, transport and storage of oil and natural gas. The total CO_2 eq emissions from this source category in 2007 was 31.70 million tons CO_2 eq.

Figure 5: GHG Emissions from Energy Sector (millions tons of CO_2 eq)





WEO, 2010

1.5.2 SHARE OF GHG FOR VARIOUS MAJOR SECTORS

The industry sector includes emissions from fossil fuel combustion and the emissions related to various processes to manufacture industrial goods. The categories covered under this sector are:

- Minerals - Cement, glass production, ceramics;
- Chemicals - Ammonia, nitric acid, Carbides, Titanium Oxide, Methanol, Ethylene, EDC and VCM production, Carbon black, and Caprolactam etc.; „
- Metal - Iron and steel, Ferro alloys, Aluminum, lead, zinc & copper; „
- Other industries - textiles, leather, food & beverages, food processing paper & pulp, non – specified industries and mining and quarrying;
- Non energy product uses of Lubricant and paraffin wax.

While the GDP has increased in India, the share of industry in the increased GDP has remained constant at 27% between 1990 and 2007. The annual growth of the overall Index of Industrial Production (IIP), a measure of the absolute level and percentage growth of industrial production, has shown a steady increasing trend between 2000 and 2007. The growth rate has doubled with growth rate increasing from 5% to 10.6% (Ministry of Statistics & Programme Implementation, 2009), a sign of a fast emerging economy.
In 2007, the total CO2 equivalent emission from this sector was 412.55 million tons. It emitted 405.86 million tons of CO2, 0.15 million tons of CH4 and 0.21 million tons of N2O. 31.7% of the total CO2 equivalent emissions from Industry sector were from mineral industries where as 28.4% of the total GHG emissions were from metal industries. About 8.1% of the total GHG emissions were from chemical industries. The other industries consisting of pulp and paper, food & beverage, non-specific industries, textile & leather, and mining/ quarrying together constituted 30.4% of the total GHG emission from the energy sector.

MINERALS
Minerals like, cement, glass, ceramics and soda ash use emitted 130.78 million tons of CO2 eq of which the cement production lead to an emission of 129.9 million tons of CO2 eq., glass & ceramics production emitted 0.43 million tons and soda ash use emitted 0.59 million tons.

CHEMICALS
Emission estimates have been made on account of combustion of fossil fuel and processes involved in the production of chemicals such as ammonia, nitric acid, carbide, methanol, titanium dioxide, adipic acid, ethylene, carbon black and caprolactam. The total amount of GHG emitted from this sector in 2007 was 33.50 million tons of CO_2 equivalent. Total amount of CO_2 produced from this sector was 27.89 million tons. CH_4 and N_2O emissions were 0.11 & 0.17 million tons respectively.

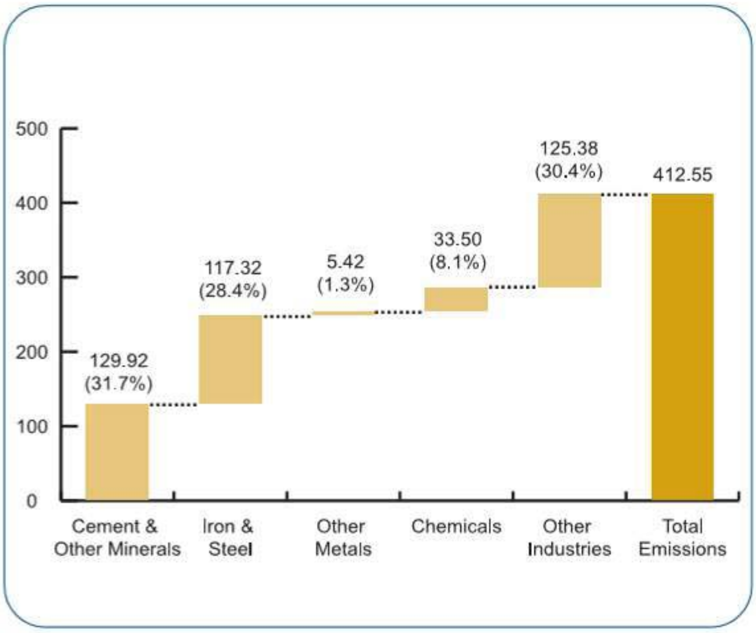
METALS
The metal production emissions are estimated from production of iron and steel, aluminum and from other metals such as zinc, lead, magnesium, ferro alloys and copper. The total GHG emission from this sector was 122.74 million tons which constituted 29.7% of the total GHG

emitted from this category in the industry sector. The total amount of CO_2 emitted from this category is 122.37 million tons; miniscule emissions are emitted in the form of CH_4 and N_2O.

OTHER INDUSTRIES

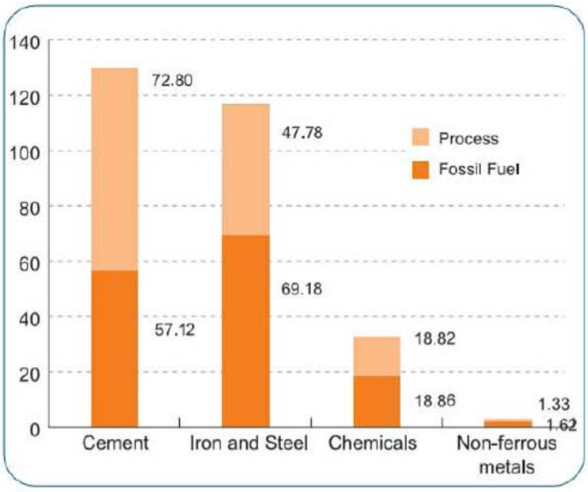
These include emissions from pulp and paper production, food and beverage, textile & leather, non-specified industries, and mining/quarrying activities. The non-specified industries include Manufacture of rubber and plastics products, medical, precision and optical instruments, watches and clocks, other transport equipment, furniture, recycling etc. for which data is not available separately. Other industries emitted together 124.5 million tons of CO_2 equivalents in 2007, of which 123.9 million tons were emitted as CO_2. Miniscule amounts of CH_4 and N_2O were also emitted from this sector, which constituted less than 1% of the total GHG emission from this sector.

Figure 6 : CO2 emission in Million Tons from Industry



Iron & Steel industry - emitted 117.32 million tons of CO_2. 48% of these emissions were from process and 69% from fossil fuel combustion. These emissions are from diverse types of technologies for manufacturing Steel in India.

Figure 7 : Relative CO2 emissions in Million tons due to fossil fuel and process emissions in different industries



1.6 ENERGY CONSERVATION AND GHG EMISSION REDUCTION INITIATIVES BY GOVERNMENT

Kyoto Protocol

The **Kyoto Protocol** is an international treaty, which extends the 1992 United Nations Framework Convention on Climate Change (UNFCCC) that commits State Parties to reduce greenhouse gases emissions, based on the premise that

(a) global warming exists and
(b) man-made CO_2 emissions have caused it.

The Kyoto Protocol was adopted in Kyoto, Japan, on 11 December 1997 and entered into force on 16 February 2005. There are currently 192 Parties (Canada withdrew effective December 2012) to the Protocol.

The Kyoto Protocol implemented the objective of the UNFCCC to fight global warming by reducing greenhouse gas concentrations in the atmosphere to "a level that would prevent dangerous anthropogenic interference with the climate system" (Art. 2). The Protocol is based on the principle of common but differentiated responsibilities: it puts the obligation to reduce current emissions on developed countries on the basis that they are historically responsible for the current levels of greenhouse gases in the atmosphere.

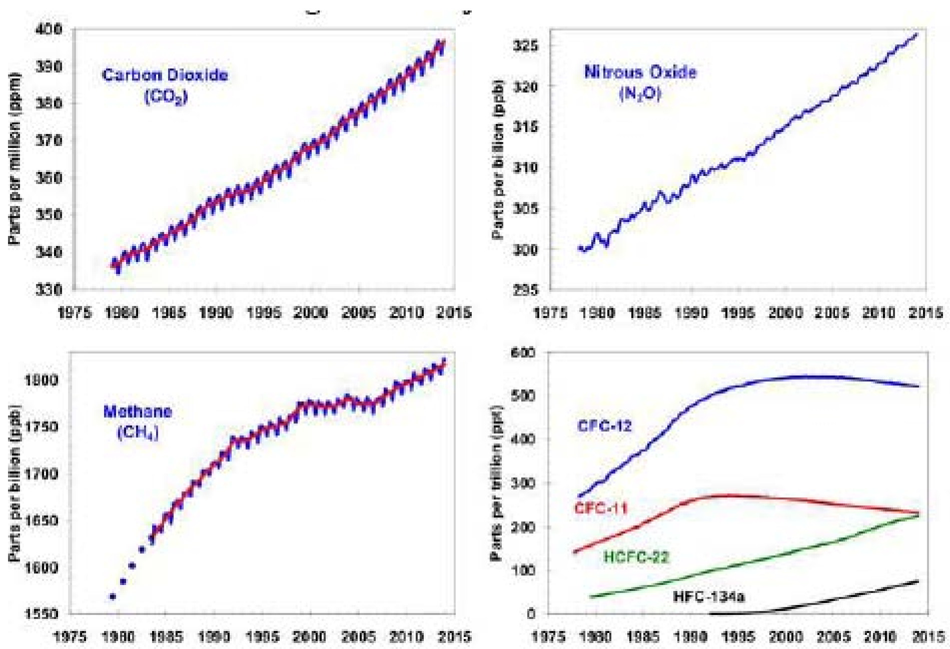
The main goal of the Kyoto Protocol is to control emissions of the main anthropogenic (i.e., human-emitted) greenhouse gases (GHGs) in ways that reflect underlying national differences in GHG emissions, wealth, and capacity to make the reductions. The treaty follows the main principles agreed in the original 1992 UN Framework Convention. According to the treaty, in 2012, Annex I Parties who have ratified the treaty must have fulfilled their obligations of greenhouse gas emissions limitations established for the Kyoto Protocol's first commitment period (2008–2012). These emissions limitation commitments are listed in Annex B of the Protocol.

The Kyoto Protocol's first round commitments are the first detailed step taken within the UN Framework Convention on Climate Change. The Protocol establishes a structure of rolling emission reduction commitment periods. It set a timetable starting in 2006 for negotiations to establish emission reduction commitments for a second commitment period. The first period emission reduction commitments expired on 31 December 2012.

The ultimate objective of the UNFCCC is the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would stop dangerous anthropogenic interference with the climate system." Even if Annex I Parties succeed in meeting their first-round commitments, much greater emission reductions will be required in future to stabilize atmospheric GHG concentrations.

For each of the different anthropogenic GHGs, different levels of emissions reductions would be required to meet the objective of stabilizing atmospheric concentrations of Carbon dioxide (CO_2) is the most important anthropogenic GHG. Stabilizing the concentration of CO_2 in the atmosphere would ultimately require the effective elimination of anthropogenic CO_2 emissions.

Figure 8 : Major GHG trends



Some of the principal concepts of the Kyoto Protocol are:

- **Binding commitments for the Annex I Parties**. The main feature of the Protocol[25] is that it established legally binding commitments to reduce emissions of greenhouse gases for Annex I Parties. The commitments were based on the Berlin Mandate, which was a part of UNFCCC negotiations leading up to the Protocol.

- **Implementation**. In order to meet the objectives of the Protocol, Annex I Parties are required to prepare policies and measures for the reduction of greenhouse gases in their respective countries. In addition, they are required to increase the absorption of these gases and utilize all mechanisms available, such as joint implementation, the clean development mechanism and emissions trading, in order to be rewarded with credits that would allow more greenhouse gas emissions at home.

- **Minimizing Impacts** on Developing Countries by establishing an adaptation fund for climate change.

- **Accounting**, Reporting and Review in order to ensure the integrity of the Protocol.

- **Compliance**. Establishing a Compliance Committee to enforce compliance with the commitments under the Protocol.

The 2015 United Nations Climate Change Conference, COP 21 or CMP 11 was held in Paris, France.

According to the organizing committee at the outset of the talks, the expected key result was an agreement to set a goal of limiting global warming to less than 2 degrees Celsius (°C) compared to pre-industrial levels. The agreement calls for zero net anthropogenic greenhouse gas emissions to be reached during the second half of the 21st century. In the adopted version of the Paris Agreement, the parties will also "pursue efforts to" limit the temperature increase to 1.5

°C. The 1.5 °C goal will require zero emissions sometime between 2030 and 2050, according to some scientists.

India has strongly advocated climatic justice and added to the principle of equity and common but differentiated responsibilities on the issue of climate change action. Intended nationally determined contribution for the period 2021 – 30 were presented which aimed at propagation of healthy, green and sustainable path to economic development reduction of emission intensity of its GDP for 33% to 35% for 2030 from 2005 level increasing the share of non fossil fuel based energy resourced to 40 % and creation of 2.5-3 billion tons of CO_2 equivalent.

Among the solutions carbon capture and storage (CCS) which is an emerging technology which is under development stage. This is a three step process including capturing CO_2 from its primary source, its transportation and them storage away from atmosphere.

Panel on climate change (IPCC) reports indicate that geological formation have capacity of 200 GT of likely CO_2 storage this includes 675-900 Gt CO_2 in oil and gas feed, 1000-10000 GT of CO_2 in saline formation and 3200 GT in coal beds worldwide.

Canada serving as a storage site for world's first commercial post combustion CO_2 capture, transportation and storage project from a coal based power plant. It demonstrates storing liquid CO_2 at a depth of 3.4 KM underground in their deep brine and sandstone.

A few large scale CO_2 capture projects in power sector are getting to be operational in 2016-17. As per the global carbon capture and storage institute, India is among 24 developing countries that are currently engaged in CCS activities such as capacity development planning and pre-investment and project development. Policy development studies have started and CO_2 capturing research has been carried out in CSIR laboratories.

Our industrial sector is mostly dependent on coal and has to adopt ways to develop CO_2 materialisation and recycling. Indian industry has already proposed and started a few projects namely in ONGC, BHEL, NTPC etc to meet the target of creating additional carbon sink of 2.5-3
billion tons, it is opt that CCS is replaced with CCU, that is Carbon capture and utilisation using chemical, biological and mineralogical process to avoid all underlying risk involved in CO_2 storage.

India is currently the third largest polluting country in the world, emitting 2407 million t CO_2 as of 2015. It is expected to contribute 6% of global GHG emissions by 2020. India ratified the Kyoto protocol in 2002; however, as a developing country, it was not required to submit any obligatory reduction commitments. India did submit, in 2009, a voluntary target for reducing the emissions intensity of its GDP by 20-25% relative to 2005 levels by 2020. The basis of India's climate policy framework is its 2008 National Action Plan on Climate Change (NAPCC), which specifies eight national objectives for 2017 that center on improving, respectively, energy efficiency, solar technology, sustainable habitats, water, Himalayan ecosystems, "green India", agriculture, and strategic knowledge.

India's Missions at a Glance

Launched in 2008, India's National Action Plan on Climate Change (NAPCC) identifies a number of measures that simultaneously advance the country's development and climate change related objectives of adaptation and mitigation. The implementation of the NAPCC is designed to take place through eight National Missions, which form the core of the National Action Plan and incorporate multi-pronged, long-term and integrated strategies for achieving India's key goals in the context of climate change.

Jawaharlal Nehru National Solar Mission

Mission Objective is to establish India as a global leader in solar energy, by creating the policy conditions for its diffusion across the country as quickly as possible.

The Mission has adopted a three phase approach. The first phase (2010-2013) was designed to focus on capturing the low-hanging options in solar thermal; promoting off-grid systems to serve populations without access to commercial energy and modest capacity addition in grid-based systems. In the second (2013-2017) and third (2017-2022) phases, capacity will be aggressively ramped up to create conditions for scaled-up and competitive solar energy penetration in the country. To achieve this, the mission targets that by year 2022 it will:

- Create an enabling policy framework for the deployment of 20,000 MW of solar power
- Create favourable conditions for solar manufacturing capability, particularly solar thermal
- for indigenous production and market leadership
- Promote programmes for off grid applications reaching 2,000 MW
- Achieve 20 million sq. meters solar thermal collector area
- Deploy 20 million solar lighting systems for rural areas

National Mission for Enhanced Energy Efficiency

Mission Objective is to achieve growth with ecological sustainability by devising cost effective and energy efficient strategies for end-use demand side management.

To achieve its objective, the mission focuses on the following initiatives:
Perform Achieve and Trade (PAT):

A market based mechanism to facilitate energy efficiency improvements in large energy intensive industries and facilities, by issuing energy saving certificates that can be traded

Market Transformation for Energy Efficiency (MTEE):

Accelerating the shift to energy efficient appliances and equipments in designated sectors through innovative measures that make such products more affordable

Energy Efficiency Financing Platform (EEFP):

Creating mechanisms to finance demand side management programmes in all sectors of the economy by capturing future energy savings

Framework for Energy Efficient Economic Development (FEEED):

Developing fiscal instruments to promote energy efficiency. By 2015, implementation of the mission is expected to deliver estimated fuel savings of about 23 million tonnes of oil-equivalent every year, along with avoided capacity addition of over 19,000 MW. The resultant annual reduction in carbon dioxide emissions is estimated to be around 98.55 million tonnes.

National Mission on Sustainable Habitat

Mission Objective is to promote sustainability of habitats though improvements in energy efficiency in buildings, urban planning, improved management of solid and liquid waste including recycling and power generation, modal shift towards public transport and conservation.

To achieve its objective, the mission targets are:

Extension of the Energy Conservation Building Code, which addresses the design of new and large commercial buildings to optimise their energy demand. Incentives will be provided for re-tooling existing building stock.

Better urban planning and modal shift to public transport by making long term transport plans to facilitate the growth of medium and small cities in such a way that ensures efficient and convenient public transport.

Recycling of material and urban waste management under which a special area of focus will be development of technology for producing power from waste. The mission will include a major R&D programme, focussing on bio-chemical conversion, waste water use,sewage utilisation and recycling options wherever possible. The mission includes timelines for all the strategies and sub-components of each strategy. These range between 2009 to 2017.

National Water Mission

Mission Objective is to conserve water, minimise wastage and ensure equitable distribution both across and within states through integrated water resources development and management. To achieve its objective, the mission targets are:

- Development of comprehensive water database in public domain and assessment of impact of climate change on water resources;
- Promotion of citizen and state actions for water conservation, augmentation and preservation;
- Focused attention to vulnerable areas including over-exploited areas;
- Increase water use efficiency by 20%;
- Promotion of basin level integrated water resources management.

National Mission for Sustainable Agriculture

Mission Objective To transform agriculture into an ecologically sustainable climate resilient production system while at the same time, exploiting its fullest potential and thereby ensuring food security, equitable access to food resources, enhancing livelihood opportunities and contributing to economic stability at the national level. To achieve its objective, the mission will work on the following major programme components or activities:

- **Rainfed Area Development**: Adopt an area based approach for development and conservation of natural resources along with farming systems
- **On-Farm Water Management**: Enhance water use efficiency by promoting efficient on farm water management technologies and equipment

- **Soil Health Management**: Promote location as well as crop specific sustainable soil health management
- **Climate Change and Sustainable Agriculture** - Monitoring, Modelling and Networking:
- **Creation and bi-directional** (farmers to research institutions and vice versa) dissemination of climate change related information and knowledge

National Mission for Sustaining the Himalayan Ecosystem

Mission objective is to evolve management measures for sustaining and safeguarding the Himalayan glaciers and mountain ecosystem and attempt to address key issues namely impacts of climate change on the Himalayan glaciers, biodiversity, wildlife conservation and livelihood of traditional knowledge societies.

To achieve its objective, the mission targets (selected) are:

- Creation of a fund (approx. INR 1,650 crore or USD 266 million) for developing capacities for Sustaining Himalayan Ecosystem.
- Establishment of a State of the Art National Centre for Himalayan Glaciology.
- Identification and networking of all knowledge institutions in the region which possess the institutional capacity for studies on Himalayan ecosystems.
- Establishment of about 10 new centres in existing institutions in areas of knowledge gaps complete with special mechanisms and tools to create knowledge capacity for sustaining Himalayan ecosystems.
- Annual status reports on the health of various sub-components of the Himalayan ecosystems and bi-annual advisories to the Himalayan Sustainable Development Forum through state councils for climate change in the Indian Himalayan states for actions for implementation.
- Standardisation of data collection systems for interoperability and mapping of natural resource wealth systems.
- Identification and training of about 100 experts and specialists in areas relevant to sustaining the Himalayan ecosystem including about 25 glaciologists.
- Conduct 25 programmes on capacity building for linking innovations from traditional and modern knowledge systems.
- Establishment of an observational network for monitoring and forewarning of changes in the ecosystems of the Himalayan region.

National Mission for a Green India

Mission Objective is to use a combination of adaptation and mitigation measures in enhancing carbon sinks in sustainably managed forests and other ecosystems, adaptation of vulnerable species/ecosystems, and adaptation of forest-dependent communities.

To achieve its objective, the mission targets are:

- Increase forest/tree cover on 5 million hectares of forest/non-forest lands and improve quality of forest cover on another 5 million hectares.

- Improve ecosystem services including biodiversity, hydrological services and carbon sequestration through treatment of an area of 10 million hectares.

- Increase forest-based livelihood income of about 3 million households living in and around the forests.

- Enhance annual CO_2 sequestration by 50 to 60 million tonnes in the year 2020
- The implementation of the mission will spread over 10 years, coinciding with the 12th (2012- 2017) and 13th (2017-2022) five year plan periods.

National Mission on Strategic Knowledge for Climate Change

Mission Objective is to identify the challenges and the responses to climate change through research and technology development and ensure funding of high quality and focused research into various aspects of climate change.

To achieve its objective, the mission targets are:

- Form well designed knowledge networks with a well-structured framework for harmonisation, interoperability, sharing and exchange of data of relevance to climate change and responses

- Enhance the research capability in climate science

- Position a technology watch system for key sectors related to economic development, likely to be affected by climate change.

- Leverage development of suitable technologies for adaptation and mitigation of climate change under various missions

- Assist other agencies engaged in the implementation of the National Action Plan on Climate Change and supporting the actions under the other Missions, as and if necessary.

Renewable Purchase Obligation (RPO)

The Electricity Act & National Action Plan on Climate Change (NAPCC) provide roadmap for increasing renewable energy in total generation. Renewable Purchase Obligation (RPO) – is mandated by SERC for promotion of renewable energy.

Renewable Purchase Obligation (RPO) – is mandated by SERC for promotion of renewable energy. RPO stipulates minimum percentage of renewable energy in energy mix of

- Distribution licensee
- Open Access Consumer
- Captive consumer

1.7 MEASURE SPECIFIC TO IRON & STEEL SECTOR

Targets Assigned to the Iron & Steel Sector

The threshold limit of 30,000 tonnes of oil equivalent (toe) has been marked as the cut-off limit criterion for any unit in the iron & steel sector to be identified as designated consumer (DC) under PAT. Cycle 1 of the scheme has identified 67 iron & steel plants as designated consumers with coal/lignite/gas/diesel as primary energy sources. The iron & steel sector has been categorised on the basis of their products/processes into eight sub-sectors, i.e. integrated steel plant, sponge iron, sponge iron + steel melting shop, sponge iron + steel melting shop + others, ferro alloys, ferro chrome, mini blast furnace and steel processing units. The total reported energy consumption of these designated consumers is about 25.32 million tonne of oil equivalent (mtoe). By the end of the first PAT cycle, energy savings of 2.10 million tonnes of oil equivalent/year (MTOE) from 60 Nos. of assessed DCs which surpassed the 1.486 MTOE expected to be achieved, at the beginning of the Cycle 1.***The total reduction in GHG emission achieved in PAT Cycle-I is 6.72 MnTCO$_2$.***[1]

Presently, PAT cycle - I has completed and the BEE has already commenced the second phase of PAT w.r.t April, 2016. The baseline year for PAT cycle II is taken as 2014-15. The period of the II cycle is 2016-2019 keeping the assessment year as 2018-19. PAT cycle II (2016-17 to 2018-19), comprising of 9 Nos. of additional DCs which apart from 67 DCs of PAT Cycle I. The threshold limit is kept unchanged for this sector.

[1] MnT is Million Tonns @ 3.223TCO$_2$ for 1 MTOE

CHAPTER 2 : INDIAN ENERGY SCENARIO

2.1 MAJOR ENERGY SOURCES FOR INDIA

The energy consumption in India is the fourth biggest after China, USA and Russia. The total primary energy consumption from crude oil (29.45%), natural gas (7.7%), coal (54.5%), nuclear energy (1.26%), hydroelectricity (5.0%), wind power, biomass electricity and solar power is 595 Mtoe in the year 2013.In the year 2013, India's net imports are nearly 144.3 million tons of crude oil, 16 Mtoe of LNG and 95 Mtoe coal totaling to 255.3 Mtoe of primary energy which is equal to 42.9% of total primary energy consumption. About 70% of India's electricity generation capacity is from fossil fuels. India is largely dependent on fossil fuel imports to meet its energy demands — by 2030, India's dependence on energy imports is expected to exceed 53% of the country's total energy consumption. In 2009-10, the country imported 159.26 million tonnes of crude oil which amounts to 80% of its domestic crude oil consumption and 31% of the country's total imports are oil imports. The growth of electricity generation in India has been hindered by domestic coal shortages and as a consequence, India's coal imports for electricity generation increased by 18% in 2010.

Due to rapid economic expansion, India has one of the world's fastest growing energy markets and is expected to be the second-largest contributor to the increase in global energy demand by 2035, accounting for 18% of the rise in global energy consumption. Given India's growing energy demands and limited domestic fossil fuel reserves, the country has ambitious plans to expand its renewable and most worked out nuclear power programme. India has the world's fifth largest wind power market and also plans to add about 100,000 MW of solar power capacity by 2020. India also envisages to increase the contribution of nuclear power to overall electricity generation capacity from 4.2% to 9% within 25 years. The country has five nuclear reactors under construction (third highest in the world) and plans to construct 18 additional nuclear reactors (second highest in the world) by 2025.

2.2 ENERGY DEMAND AND SUPPLY SCENARIO

The installed capacity of utility power plants is 267,637 MW as on 31 March 2015 and the gross electricity generated by utilities is 1106 GWh (1106 billion kWh) which includes auxiliary power consumption of power generating stations. The installed capacity of captive power plants in industries (1 MW and above) is 47,082 MW as on 31 March 2015 and generated 166.426 billion kWh in the financial year 2014-15. In addition, there are nearly 75,000 MW aggregate capacity diesel generator sets with unit's sizes between 100 KVA and 1000 KVA. All India per capita consumption of Electricity is nearly 1010 kWh during the financial year 2014-15. The total installed Power generation Capacity (end of March 2015) is given below:

Source	Utilities Capacity (MW)	%	Captive Power Capacity (MW)	%
Coal	164,635.88	61.5	27,588.00	58.6
Hydroelectricity	41,267.43	15.4	83	0.17
Renewable energy source	31,692.14	11.8	Included in Oil	-
Natural Gas	23,062.15	8.61	5,215.00	11.1
Nuclear	5,780.00	2.16	-	-
Oil	1,199.75	0.44	14,196.00	30.2
Total	267,637.35		47,082.00	

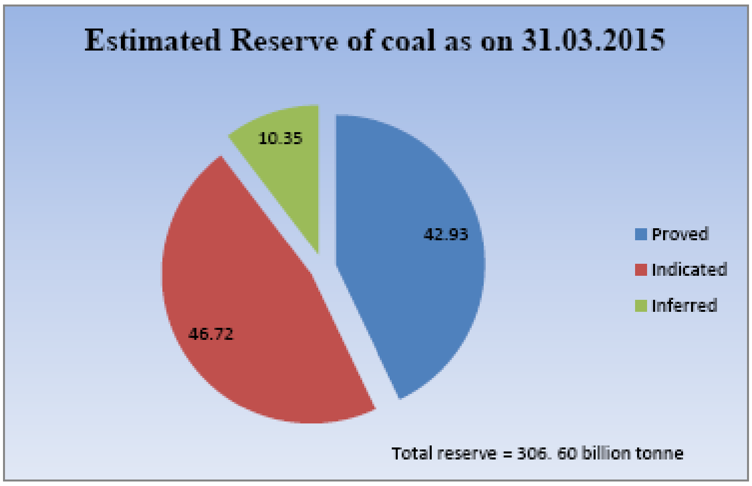
2.3 AVAILABILITY OF VARIOUS FOSSIL FUELS IN INDIA

a. Coal and Lignite

Coal deposits are mainly confined to eastern and south central parts of the country. The states of Jharkhand, Odisha, Chhattisgarh, West Bengal, Madhya Pradesh, Telangana and Maharashtra account for 99.08% of the total coal reserves in the country. The State of Jharkhand had the maximum share (26.44%) in the overall reserves of coal in the country as on 31st March 2015 followed by the State of Odisha (24.72%).

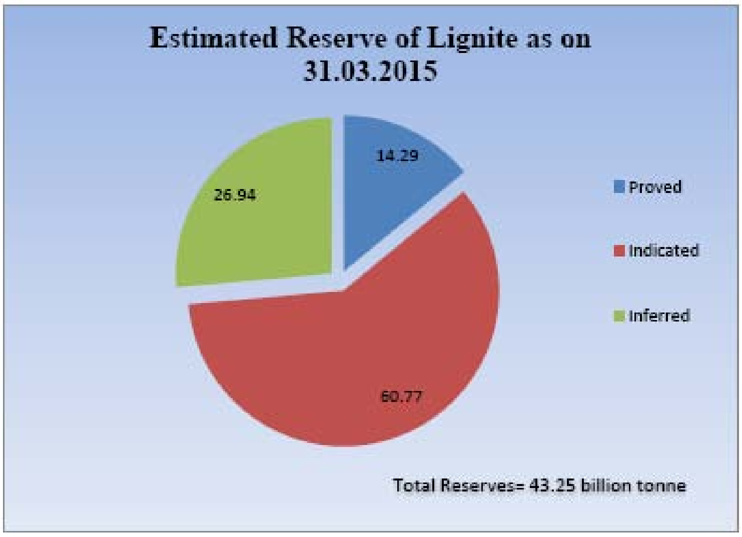
As on 31.03.15, the estimated reserve of coal was 306.60 billion tonnes, an addition of 5.04 billion over the last year. There has been an increase of 1.67% in the estimated coal reserves during the year 2014-15 with Chhattisgarh accounting for maximum increase of 4.53%.

Figure 9: Estimated Reserve of coal



The estimated total reserve of lignite as on 31.03.15 was 43.25 billion Tonne which is equivalent to the total reserve as on 31.03.14.

Figure 10: Estimated Reserve of lignite

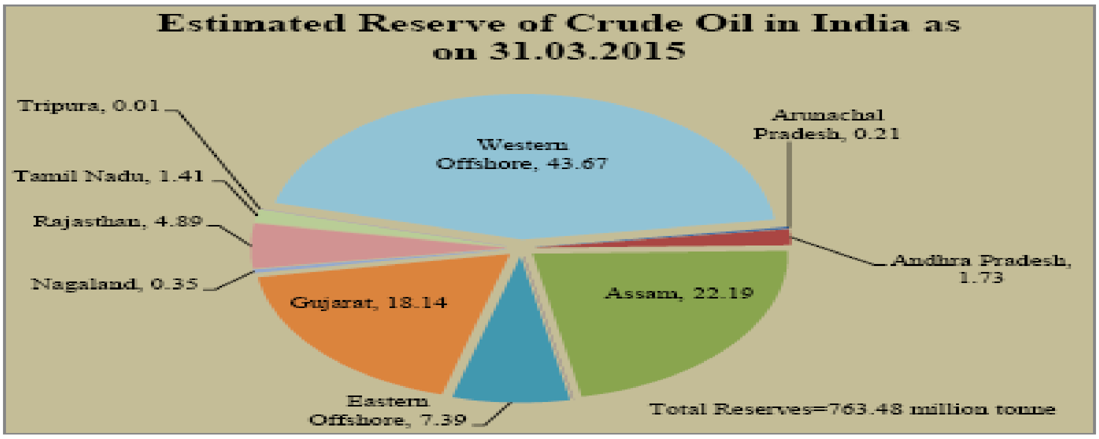


Petroleum and Natural gas

The estimated reserve of crude oil in India as on 31.03.2015 stood at 763.48 million tonne (MT).

Geographical distribution of Crude oil indicates that the maximum reserves are in the Western Offshore (43.67%) followed by Assam (22.19%), whereas the maximum reserves of Natural Gas are in the Eastern Offshore (37.10%) followed by Western offshore (29.34%).

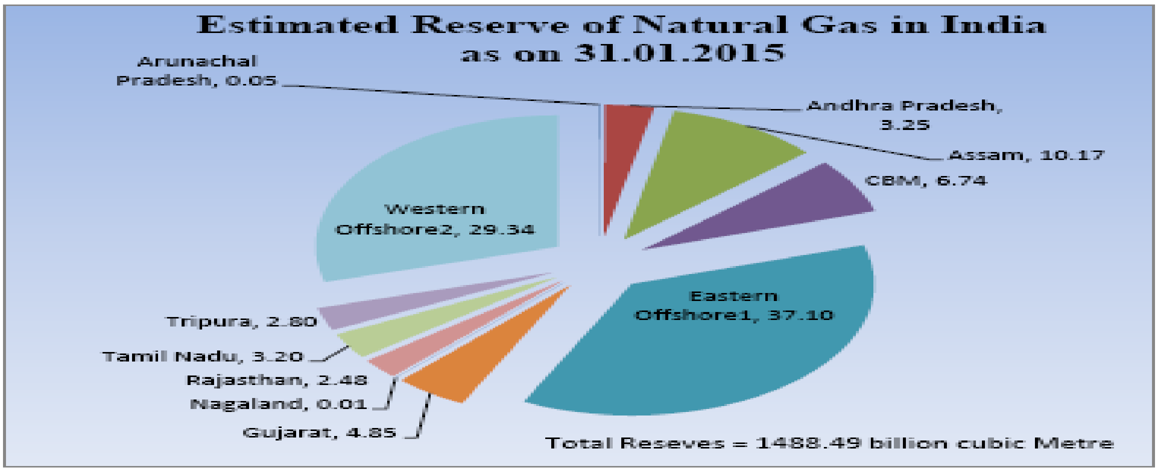
Figure 10: Estimated Reserve of Crude Oil



There was increase of 0.10% in the estimated reserve of crude oil for the country as a whole during 2014-15 as compared to the position an year ago. During the same period, estimated reserves of crude oil in Arunachal Pradesh, Rajasthan and Assam decreased by 44.75%, 17.04% and 2.11% respectively, while the same in Tamil Nadu, Andhra Pradesh, Gujarat, Western Offshore and Eastern Offshore increased by 18.42 %, 15.30 %, 2.58%, 1.88% and 0.59% respectively.

The estimated reserves of natural gas in India as on 31.03.2015 stood at 1488.49 billion cubic meters (BCM).

Figure 11: Estimated Reserve of Natural Gas



In case of Natural Gas, the increase in the estimated reserve over the last year was 1.40%. The maximum contribution to this increase has been from Eastern Offshore (37.10%), followed by Western Offshore (29.34%).

2.4 IMPORT OF FUELS

Import and export of coal

The average quality of the Indian coal is not very high and this necessitates the import of high quality coal to meet the requirement of steel plants. There has been an increasing trend in the import of coal.

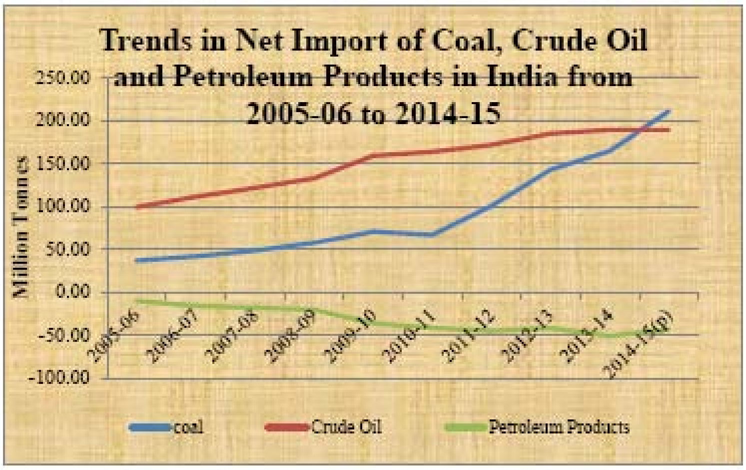
Import of coal has steadily increased from 38.59 MTs during 2005-06 to 212.10 MTs during 2014-15 (Table 4.1). During this period, the quantum of coal exported increased from 1.99 MTs during 2005-06 to 2.44 MT during 2012-13 and then decreased to 1.24 MTs during 2014-15.

There is growth rate of 27.12% of gross import and 28.05% in net imports of coal in 2014-15 over the previous year. However, there was decrease of 43.42% in export of coal during the same period.

Crude oil and petroleum products

India is highly dependent on import of crude oil. Net imports of crude oil have increased from 99.41 MTs during 2005-06 to 189.43 MTs during 2014-15.

Figure 11: Trends in Net Import



There has been an increase of 0.10% in the net imports of crude oil during 2014-15 over 2013-14, as the net import increased from 189.24 MTs to 189.43 MTs.

Although more than 70% of its crude oil requirements and part of the petroleum products is met from imports, India has developed sufficient processing capacity over the years to produce different petroleum products so as to become a net exporter of petroleum products.

The export of petroleum products has increased from a 23.46 MT during 2005-06 to 63.93 MTs during 2014-15. During 2014-15, exports recorded a decrease of 5.80% from previous year.

The import of petroleum products has increased from 13.44 MT in 2005-06 to 20.42 MT during 2014-15, although there are some fluctuations in the trend. There is growth rate of 22.16% in the import of petroleum products over the previous year.

2.5 RENEWABLE ENERGY SOURCES

India was the first country in the world to set up a ministry of non-conventional energy resources, in early 1980s. India's cumulative grid interactive or grid tied renewable energy capacity (excluding large hydro) has reached 33.8 GW, of which 66% comes from wind, while solar PV contributed nearly 4.59% along with biomass and small hydro power of the renewable energy installed capacity in India.

There is high potential for generation of renewable energy from various sources- wind, solar, biomass, small hydro and cogeneration bagasse.

Figure 13: Source wise Estimated potential

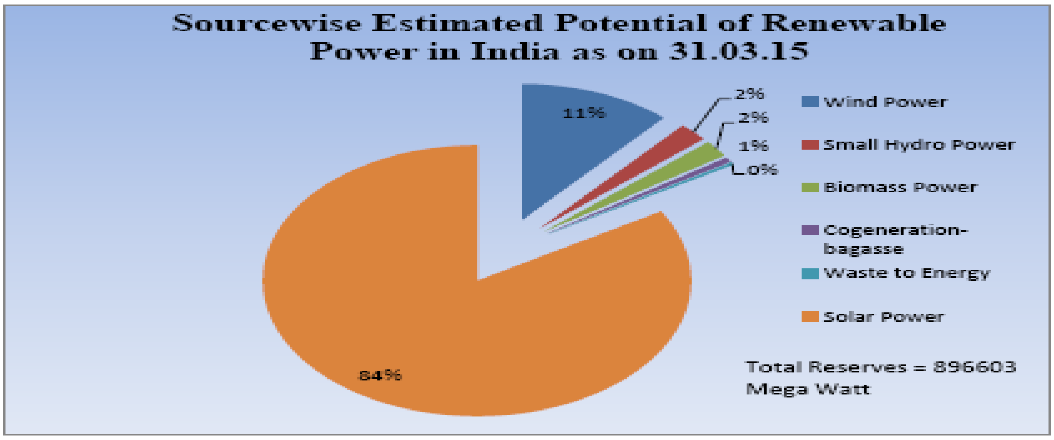
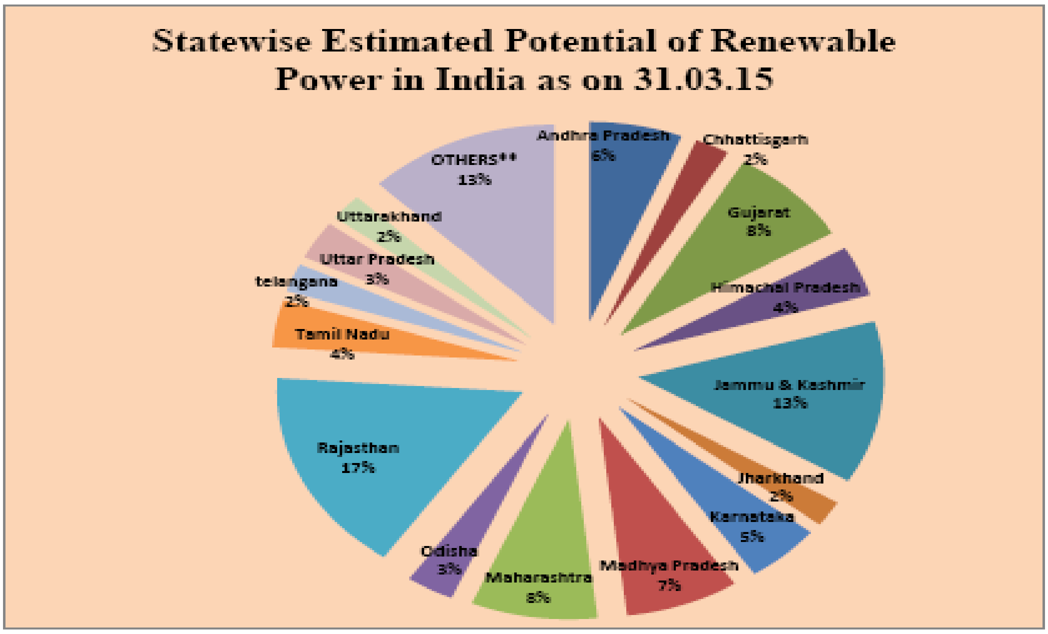


Figure 14: State wise Estimated potential



The total potential for renewable power generation in the country as on 31.03.15 is estimated at 896603 MW. This includes wind power potential of 102772 MW (11.46%), SHP (small-hydro power) potential of 19749 MW (2.20%), Biomass power potential of 17,538 MW (1.96%), 5000 MW (0.56%) from bagasse-based cogeneration in sugar mills and solar power potential of 748990 MW (83.54%).

The geographic distribution of the estimated potential of renewable power as on 31.03.2015 reveals that Rajasthan has the highest share of about 17% (148518 MW), followed by Jammu and Kashmir with 13% share (118208) and Gujarat with 8% share (72726 MW), mainly on account of solar power potential.

CHAPTER 3 : BRIEF ABOUT IRON & STEEL SECTOR

3.1.1 Global Scenario

In 2014, the world crude steel production reached 1665 million tonnes (mt) and showed a growth of 1% over 2013. China remained the world's largest crude steel producer in 2014 (823 mt) followed by Japan (110.7 mt), the USA (88.2 mt) and India (86.5 mt) at the 4th position. WSA has projected Indian steel demand to grow by 6.2% in 2015 and by 7.3% in 2016 as compared to global steel use growth of 0.5% and 1.4% respectively. Chinese steel use is projected to decline in both these years by 0.5%. Per capita finished steel consumption in 2014 is estimated at 217 kg for world and 510 kg for China by WSA.

3.1.2 Indian Scenario

The Indian steel industry has entered into a new development stage from 2007-08, riding high on the resurgent economy and rising demand for steel. Rapid rise in production has resulted in India becoming the 3rd largest producer of crude steel in 2015 and the country continues to be the largest producer of sponge iron or DRI in the world. As per the report of the Working Group on Steel for the 12th Five Year Plan, there exist many factors which carry the potential of raising the per capita steel consumption in the country. These include among others, an estimated infrastructure investment of nearly a trillion dollars, a projected growth of manufacturing from current 8% to 11-12%, increase in urban population to 600 million by 2030 from the current level of 400 million, emergence of the rural market for steel currently consuming around 10 kg per annum buoyed by projects like Bharat Nirman, Pradhan Mantri Gram Sadak Yojana, Rajiv Gandhi Awaas Yojana among others.

At the time of its release, the National Steel Policy 2005 had envisaged steel production to reach 110 million tonnes (mt) by 2019-20. However, based on the assessment of the current ongoing projects, both in greenfield and brownfield, the Working Group on Steel for the 12 th Five Year Plan has projected that domestic crude steel capacity in the county is likely to be 140 mt by 2016-17 and has the potential to reach 149 mt if all requirements are adequately met.

The National Steel Policy 2005 is currently being reviewed keeping in mind the rapid developments in the domestic steel industry (both on the supply and demand sides) as well as the stable growth of the Indian economy since the release of the Policy in 2005.

3.1.3 Production

Steel industry was de-licensed and de-controlled in 1991 & 1992 respectively. Today, India is the 3rd largest producer of crude steel in the world. In 2014-15, production for sale of total finished steel (alloy + non alloy) was 91.46 mt, a growth of 4.3% over 2013-14. Production for sale of Pig Iron in 2014-15 was 9.7 mt, a growth of 22% over 2013-14.

India is the largest producer of sponge iron in the world with the coal based route accounting for 90% of total sponge iron production in the country.Data on production for sale of pig iron, sponge iron and total finished steel (alloy + non-alloy) for last five years is as follows:

Indian steel industry : Production for Sale (in million tonnes)					
Category	**2010-11**	**2011-12**	**2012-13**	**2013-14**	**2014-15**
Pig Iron	5.68	5.371	6.870	7.950	9.694
Sponge Iron	25.08	19.63	14.33	18.20	20.38
Total Finished Steel (alloy + non alloy)	68.62	75.70	81.68	87.67	91.46
Source: Joint Plant Committee					

3.1.4 Challenges of the Sector

SrNo.	**Issues**	**Description**
1.	Un-remunerative Prices	• Stagnating demand, domestic over supply and falling prices in the last four years[1]. • Barring sporadic rise in demand in the recent months.
2.	Endemic Deficiencies	• These are inherent in the quality and availability of some of the essential raw materials available in India. • Advantage of high fee content of indigenous ore is often neutralized by high basic index.
3.	Systemic Deficiencies	• Most of the weaknesses of the Indian Steel Industry can be classified as systemic deficiencies refer point 7 given below
4.	High Cost of Capital	• Steel is a capital intensive industry • Steel companies in India are charged an interest rate of around 14% on capital as compared to 2.4% in Japan and 6.4% in USA.
5.	**Low Labor Productivity**	• **In India, the advantage of cheap labor gets offset by low labor productivity.** • **e.g. At comparable capacities, labor productivity of SAIL and TISCO is 75 t/man year and 100 t/man year, for POSCO, Korea and NIPPON, Japan the values are 1345 t/man year and 980 t/man year.**
6.	High Cost of Basic Inputs and Services	• High administrative price of essential inputs like electricity puts Indian State industry at a disadvantage. • About 45% of the input cost can be attributed to the administered costs of coal, fuel and electricity. • Freight cost from Jamshedpur to Mumbai is higher ($50/Ton)than from Rotterdam to Mumbai ($34/Ton)
7.	Others systemic deficiencies include	• Poor quality of basic infrastructure like road, port, etc. • Lack of expenditure in research and development. • Delay in absorption in technology by existing units. • Low quality of steel and steel products. • Lack of facilities to produce various shapes and qualities of finished steel on-demand such as steel for automobile sector, parallel flange light weight beams, coated sheets etc. • Limited access of domestic producers to good quality iron ores which are normally earmarked for exports. • High level taxation.

2

[2] **The Ref. year is 2015**

3.1.5 National Steel Policy

The steel sector is one of the important sectors which drive the country's economic growth. Countries have strongly relied on domestic steel production during their journey towards economic development. The National Steel Policy 2012 aims to attract investment in Indian steel sector from both domestic and foreign sources to reach the ambitious goal of crude steel production capacity of 300 Mt with a production level of 275 Mt by 2025-26. One more objective is to ensure easy availability of inputs and necessary infrastructure to achieve a projected ambitious production level. The key goals of NSP 2012 are depicted below.

Raw Material Requirement at 7 and 8% GDP

Raw Material Requirement		
At 7% GDP	**2016-17**	**2025-26**
Iron Ore	203	392
Coking Coal	89	173
Non-coking coal	27.8	66.2
PCI	4.5	9
Met Coke(including captive)	67.4	89.2
At 8% GDP	**2016-17**	**2025-26**
Iron Ore	215.4	452
Coking Coal	94.2	200
Non-coking coal	30.4	78
PCI	4.8	10.4
Met Coke(Including Captive)	72.5	153.9

Parametric goal towards 2025-26 from the existing level [3]

Parameter/Area	Unit	Existing Level	Strategic Goal/Projection by 2025-26
Specific Energy Consumption	GCal/tcs	6.3	4.5
CO_2 emissions	T CO2/tcs	2.5	2.0
Material Efficiency	%	93.5	98.0
Specific Make up Water Consumption (Works excluding power plant)	T/tcs	3.3	2.0
Utilization of BOF slag	%	30	100
Share of continuous cast production	%	70.0	95.0
BF Productivity	T/m3/Day	1.9	2.8
BOF productivity	No. of Heats/ Converter/year	7800	12000
R&D expenditure/turnover	%	0.2	1.5

[3] BF is Blast Furnace

TCO_2/tcs is TCO_2/Tonne of Crude Steel

3.1.6 Opportunities for growth of Iron and Steel in Private Sector

The New Industrial Policy Regime:The New Industrial policy opened up the Indian iron and steel industry for private investment by (a) removing it from the list of industries reserved for public sector and (b) exempting it from compulsory licensing. Imports of foreign technology as well as foreign direct investment are now freely permitted up to certain limits under an automatic route. Ministry of Steel plays the role of a facilitator, providing broad directions and assistance to new and existing steel plants, in the liberalized scenario.

The Growth Profile

(i) Steel : The liberalization of industrial policy and other initiatives taken by the Government have given a definite impetus for entry, participation and growth of the private sector in the steel industry. While the existing units are being modernized/expanded, a large number of new steel plants have also come up in different parts of the country based on modern, cost effective, state of-the-art technologies. In the last few years, the rapid and stable growth of the demand side has also prompted domestic entrepreneurs to set up fresh greenfield projects in different states of the country.

Crude steel capacity was 109.85 mt in 2014-15 and India, which emerged as the 3 rd largest producer of crude steel in the world in 2015 as per ranking released by the WSA, has to its credit, the capability to produce a variety of grades and that too, of international quality standards. The country is expected to become the 2 nd largest producer of crude steel in the world soon, provided all requirements for creation of fresh capacity are adequately met.

(ii) Pig Iron: India is also an important producer of pig iron**.** Post-liberalization, with setting up several units in the private sector, not only imports have drastically reduced but also India has turned out to be a net exporter of pig iron. The private sector accounted for 91% of total production for sale of pig iron in the country in 2014-15. The production for sale of pig iron has increased from 1.6 mt in 1991-92 to 9.7 mt in 2014-15.

(iii) Sponge Iron: India is the world's largest producer of sponge iron with a host of coal based units, located in the mineral-rich states of the country. Over the years, the coal based route has emerged as a key contributor and accounted for 90% of total sponge iron production in the country. Capacity in sponge iron making too has increased over the years and stood at 46.23 mt in 2014-15.

After de-licensing of Indian iron and steel industry and as a result of the steps taken for creation of additional capacity in the private sector, projects involving a total investment of Rs. 30,835 crores equivalent to a capacity of approx. 13 million tonnes per annum were cleared by financial institutions.

Over time, with further opening up of the Indian economy, a focused reform process in place and a rapid but stable growth of the Indian economy, investments have flown significantly into the steel industry of the country and the country is likely to achieve a crude steel production capacity of 140-149 mt by the year 2016-17 as per estimates of the report of the working group on steel for the 12th Five Year Plan. Major investment plans are in the States of Odisha, Jharkhand, Karnataka, Chhattisgarh and West Bengal. The government has also unveiled plans of developing four mega greenfield steel plants each of 6 mtpa, through the SPV route, at an estimated combined investment of $24 billion in the states of Chhattisgarh, Odisha, Jharkhand and Karnataka.

Global steel giants have also announced plans to set up integrated steel plants in the country either through setting up of green-field integrated steel plants in the country or strategic tie-ups, which is expected to introduce state-of-the-art technology into steel making. These include either independent projects like those of Posco (Odisha, Karnataka) and Arcleor-Mittal (Jharkhand, Karnataka) or joint venture projects with local companies like those of SAIL-Kobe, SAIL-Posco, JSW Steel-JFE, among others.

3.2 OVERVIEW OF SPONGE IRON SECTOR

Sponge iron, customarily called direct reduced iron (DRI) is used as prime metallic in the secondary steel making process using the electric furnace or Induction furnace route. DRI is a substitute to scrap. Sponge iron is produced by reduction of iron ore in the solid phase using either solid (non coking coal) or gas (Reformed natural gas or coal gasification) as reductant. Besides supplying the reducing agents, namely carbon monoxide and hydrogen, the energy requirement for the reduction reaction is also supplied by a part of the reductant as fuel.

Sponge iron plants based on two major commercially established processes, namely coal based rotary kilns and gas based shaft furnace reactors. The coal based rotary kilns produce DRI lumps/ pellet being more stable can be stored for longer time. The gas fired shaft furnace produces DRI that needs to be used immediately or converted to blocks of Hot Briquetted Iron (HBI), that can be packed and stored for longer time.

India is the world’s largest producer of sponge iron with a host of coal based units, located in the mineral-rich states of the country. Over the years, the coal based route has emerged as a key contributor and accounted for 89% of total sponge iron production in the country. Capacity in sponge iron making too has increased over the years and stood at 45 mt in 2013-14.

The sponge iron capacity over the years also has increased since the capacity utilization of these plants are largely dependent on the internal market price of the scrap. The National steel policy of 2005 envisaged 110 million tones out of which 30% will be through the sponge iron route. India is also a leading producer of sponge iron with a host of coal based units, located in the mineral-rich states of the country. Over the years, the coal based route has emerged as a key contributor to overall production. Capacity in sponge iron making has also increased over the years and currently stands at 46.23 million tone in 2014-15.

The major players in DRI route are TATA Sponge, ESSAR, JSPL and ISPAT. The major production of sponge iron (about 60%) comes from the States of Chhattisgarh, Orissa and West Bengal.

These are plants operating in smaller capacities and are coal based. The larger capacity gas plants contribute to about 30% and are based in the western region (Gujarat / Maharashtra).

Energy Consumption Pattern in Sponge Iron Plants

All manufacturing Industries are required energy to produce different products. The type of energy required is depending on equipment/machinery and raw material used in the plant. The details of energy used for manufacturing of Sponge Iron from Iron Ore are discussed below.

The following energy is required for manufacturing of sponge Iron from Iron Ore.

• Thermal Energy

• Electrical Energy

Major energy consumption in Sponge Iron Plants is thermal followed by electrical energy.

Thermal Energy

All sponge Iron units are operated the rotary kiln and operated with coal based. Coal is used as a fuel for heating the Iron Ore and as well as reaction agent in process. The Temperature required for heating of Iron Ore is 700-900 C which is below the Iron melting point.

Electrical Energy

Another form of energy required for the Sponge Iron Plant is electrical energy. The electrical Energy is used to operate the different equipments involved in Sponge Iron Plants. The electrical energy is used to prepare the raw material, rotating the kilns and cooler kilns.

3.3 INVENTORIZATION OF SPONGE IRON PLANTS

3.3.1 Historical Developments of Sponge Iron Making

Sponge iron provided the main source of iron for many centuries before the blast furnace was developed. In historic times, sponge iron was produced in shallow hearths, which used charcoal as reductant fuel. The product of these early smelting process was a sponge mass of coalesced granules of nearly pure iron intermixed with considerable slag. Usable articles of wrought iron were produced by hammering the sponge mass, while still hot, to expel most of the slag and compact the mass. By repeated heating and hammering, the iron was further freed of slag and forged into the desired shape.

All of the methods through which low carbon wrought iron can be produced directly from the ore are referred to as direct reduction processes. After the development of the blast furnace, which produced high carbon pig iron, direct processes were nearly abandoned. However, direct reduction process is still used because of the ease with which iron ores are reduced making the processes appear enticingly simple, and primarily because the reduction takes place at relatively low temperature compared to Blast Furnace. Process that produce iron by reduction of iron ore, below the melting point of the iron produced, are called direct reduction processes, and the products referred to as Direct Reduced Iron (DRI), commonly called sponge iron.

In modern times, sponge iron has found increasing use in the manufacture of wrought iron and as substitute of scrap during steel making. Sponge iron is chemically more active than steel or iron millings, turnings or wire strips. Sponge iron is produced as granular material or as sintered mass, depending upon the methods of treatment applied to hot material. In the granular form, it is commonly known as powdered iron and used in the manufacture of many useful articles by the techniques of powder metallurgy.

Today the major portion of DRI is melted along with Hot Metal / Pig Iron/scrap in the Electric Arc Furnace (EAF) and Induction Furnace(IF) for steel making and producing steel castings (rounds/ slabs/ billets/ blooms). The attempts to develop large-scale DRI plants have embraced practically every known type of apparatus suitable for the purpose, including pot furnaces, shaft furnaces, reverberatory furnaces, regenerative furnace, rotary hearth furnace / rotary kilns, electric furnaces, fluidized bed furnaces and plasma reactors. Many different kinds of reducing agents, such as natural gas, coal, coke, graphite, charcoal, distillation residues, fuel oil, tar, producer gas, coal gas, and hydrogen have been tried. However, no effort has been made to evaluate or compare the different processes on either on economical or technical basis because in many cases, factors associated with location, capital cost and availability of ore and fluxes, availability of trained manpower, and proximity of markets, may be overriding.

Over the past several decades, experiments were made to develop a low cost and simple to operate substitute of blast furnace. Many of these developments were targeted to use non-coking coal or natural gas as reducing agent.

The processes that produce molten product (similar to blast-furnace hot metal) directly from ore are generally classified as direct smelting processes. In some of the more ambitious projects, the objective is to produce liquid steel directly from ore and these processes are generally classified as direct steel making process. These broad categories are clearly distinguished by the characteristics of their respective products, although all of these products may be further treated to produce special grades of steel in the same refining or steel making process. The direct smelting process and direct steel making process is outside the scope of this project.

3.3.2 Location

Sponge iron, customarily called direct reduced iron (DRI) is used as prime metallic in the secondary steel making process using the electric furnace or Induction furnace route. DRI is a substitute to scrap. Sponge iron is produced by reduction of iron ore in the solid phase using either solid (non coking coal) or gas (Reformed natural gas or coal gasification) as reductant. Besides supplying the reducing agents, namely carbon monoxide and hydrogen, the energy requirement for the reduction reaction is also supplied by a part of the reductant as fuel.

Sponge iron plants based on two major commercially established processes, namely coal based rotary kilns and gas based shaft furnace reactors. The coal based rotary kilns produce DRI lumps/ pellet being more stable can be stored for longer time. The gas fired shaft furnace produces DRI that needs to be used immediately or converted to blocks of Hot Briquetted Iron (HBI), that can be packed and stored for longer time.

Sponge iron constitutes around 3-4% of world's total iron making capacity. Today, India is the largest producer of sponge iron in the world, with an installed production capacity of 46.23 million tons per annum (mTPA). 100% sponge iron demand of India is met from internal sources. The sponge iron plants in India are located near the source of raw materials. The gas based plants are located along the west coast of Maharastra and Gujarat. The coal based plants are concentrated near iron ore and coal mines of Jharkhand, Orissa, West Bengal, Chattisgarh, Maharastra, Andhra Pardesh, Goa and Karnataka. The typical areas are Durgapur, Ranigunge, Purulia, Bankura, Midnapore, Raipur, Siltara, Raigarh, Taraimal, Bilaspur, Champa, Durg, Adityapur near Jamshedpur, Giridih, Chaibasa, Chandil, Hazaribagh, Koderma, Keonjhar, Jharsuguda, Rourkela, Brajrajnagar, Sundergarh, Sambalpur, Jajpur, Mayurbhanj, Nagpur, Bhandara, Chandrapur, Bellary, Hospet, Kurnool, Khammam and Goa.

Figure 15: Various DRI Technologies followed in the World

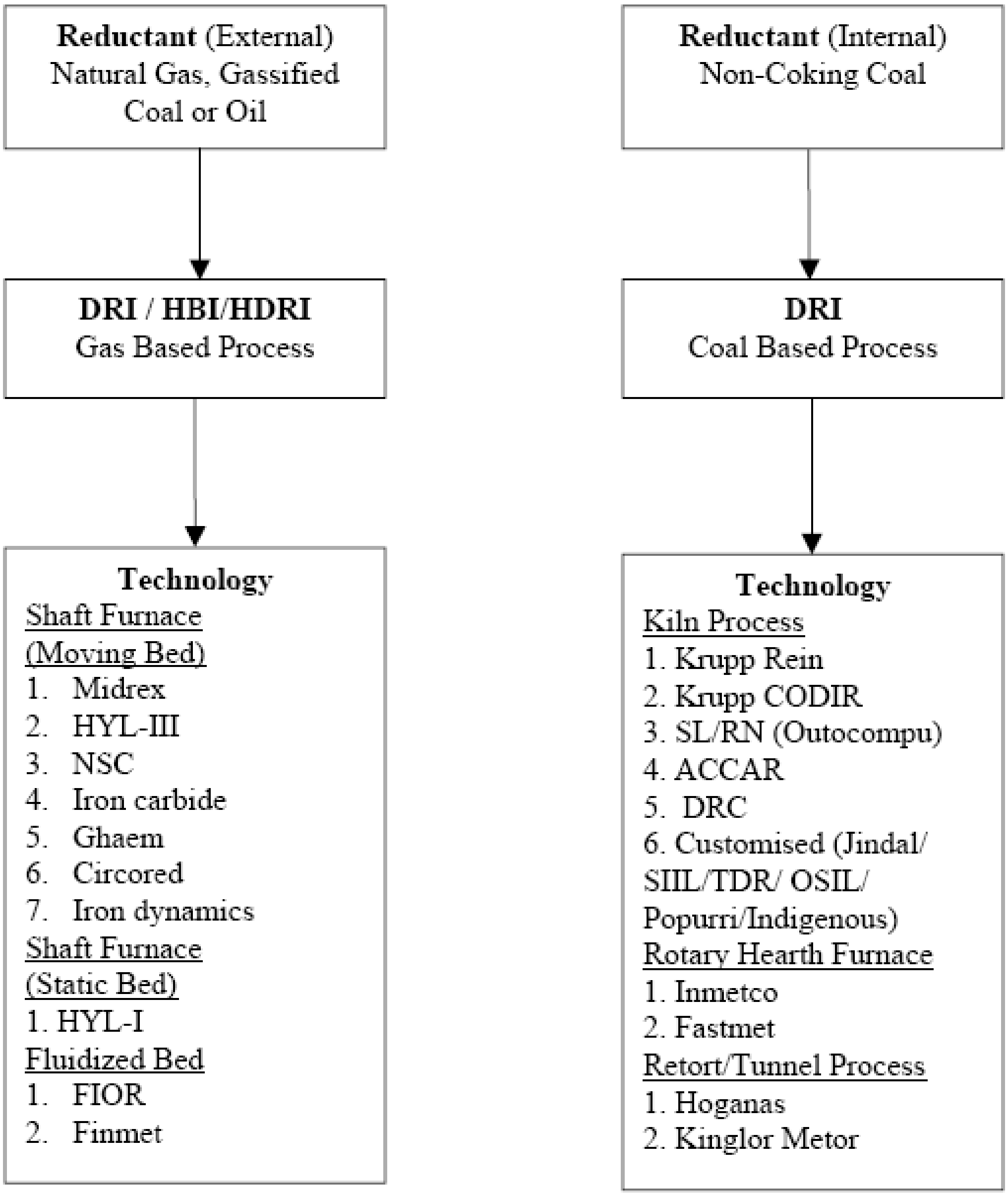
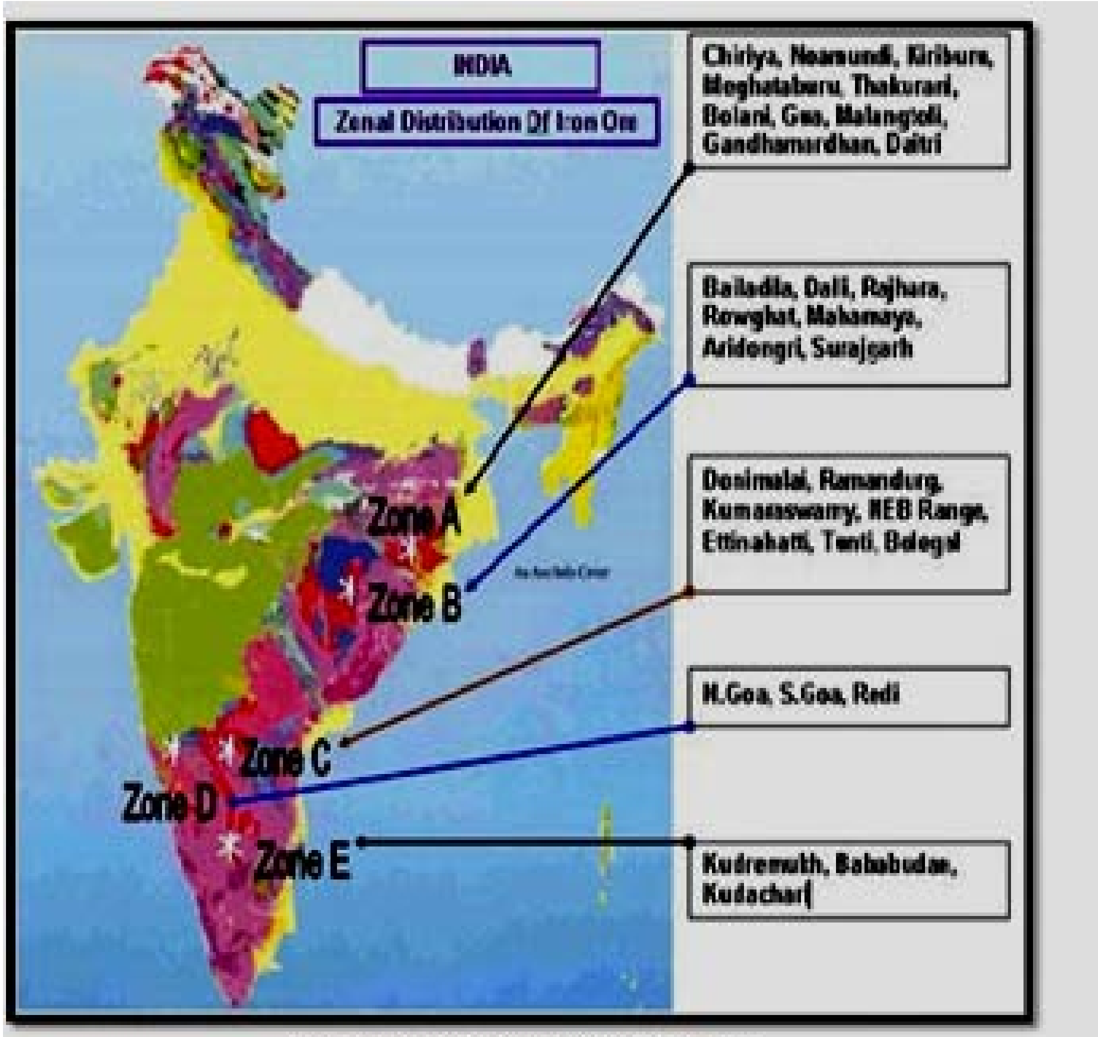
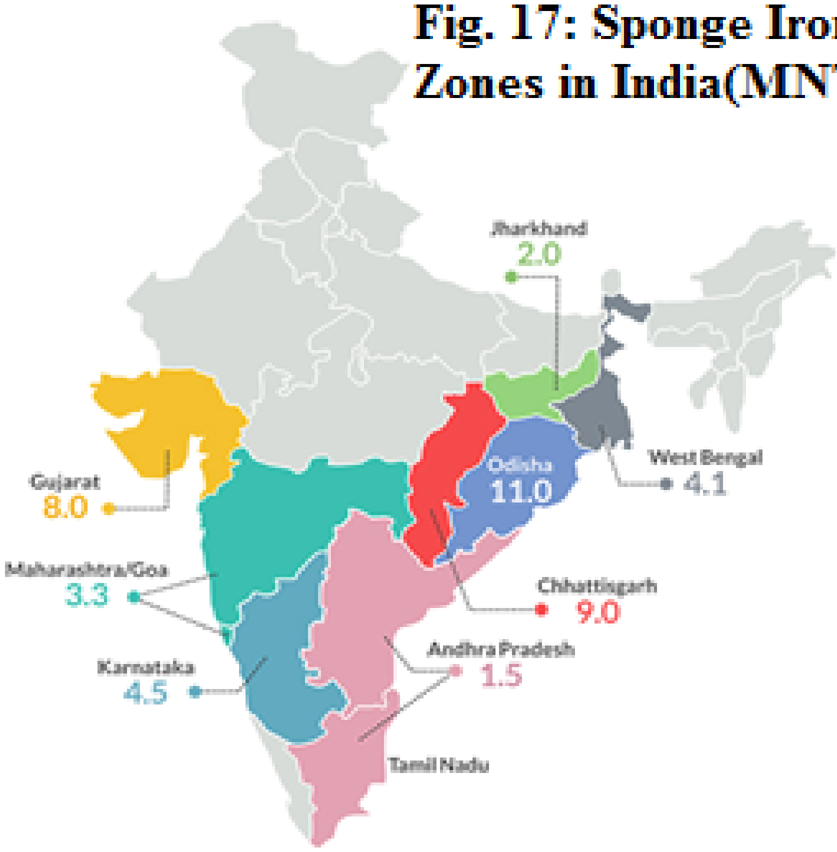


Figure 16: Zonal Distribution of Iron Ore In India



Zonal Distribution of iron ore in India

Fig. 17: Sponge Iron Producing Zones in India(MNT)



[4]

[4] MNT is Million Tonne

CHAPTER 4 : PROCESS DESCRIPTION OF SPONGE IRON PLANT

4.1 BRIEF DESCRIPTION OF SPONGE IRON PLANT PROCESS

Sponge iron, also known as "Direct Reduced Iron" (DRI) and its variant Hot Briquetted Iron (HBI) have emerged as prime feed stock which can replace steel scrap in EAF/IF as well as in other steel-making processes. It is the resulting product (with a metallization degree greater than 82%) of solid state reduction of iron ores or agglomerates (generally of high grade), the principal constituents of which are metallic iron, residual iron oxides, carbon and impurities such as phosphorus, sulphur and gangue (principally silica and alumina). The final product can be in the form of fines, lumps, briquettes or pellets. Sponge iron when briquetted in hot condition at elevated temperature is called hot briquetted iron (HBI).

Direct reduction processes available can be broadly grouped under two categories based on the type of reductant used. These are:

- Solid based processes
- Gas based processes

Solid Based Processes

From amongst various solid based processes, only a few have attained commercial significance. Most of the processes such as SL/RN, KRUPP-CODIR, DRC, TDR, SIIL, JINDAL, OSIL, Popuri utilise rotary kiln for reduction whereas Kinglor Metor process utilises an externally heated vertical retort.

Process Technology

Generally in any sponge iron process, reduction is conducted in a refractory lined rotary kiln. The kiln of suitable size, generally inclined at 2.5 % slope rest on two-four support stations, depending on the kiln size. The transport rate of materials through the kiln can be controlled by varying its slope and speed of rotation. There are inlet and outlet cones at opposite ends of the kiln that are cooled by individual fans. The kiln shell is provided with small sampling ports, as well as large ports for rapid removal of the contents in case of emergency or for lining repairs. The longitudinal positioning of the kiln on its riding rings is controlled hydraulically.

The coal and iron ore are metered into the high end of the inclined kiln. A portion of the coal is also injected pneumatically from the discharge end of the kiln. The burden first passes through a pre-heating zone where coal de-volatilization takes place and iron ore is heated to pre-heating temperature for reduction.

Temperature and process control in the kiln are carried out by installing suitable no. of air injection tubes made of heat-resistant steel spaced evenly along the kiln length and countercurrent to the flow of iron ore. Tips of the air tubes are equipped with special internal swirlers to improve uniformity of combustion. A central burner located at the kiln discharge end is used with Light Diesel Oil (LDO) for heating the cold kiln. After initial heating, the fuel supply is turned off and the burner is used to inject air for coal combustion.

The kiln temperatures are measured with fixed thermocouples and Quick Response Thermocouples (QRT). Fixed thermocouples are located along the length of the kiln so that temperatures at various sections of the kiln can be monitored. Fixed thermocouples, at times may give erratic readings in case they get coated with ash, ore or accretion. In such cases QRT are used for monitoring the kiln temperatures. The product (DRI) is discharged from the kiln at about 1000°C. An enclosed chute at the kiln discharge end equipped with a lump separator and an access door for removing lumps transfers the hot DRI to a rotary cooler. The cooler is a horizontal revolving cylinder of appropriate size. The DRI is cooled indirectly by water spray on the cooler upper surface. The cooling water is collected in troughs below the cooler and pumped to the cooling tower for recycling alongwith make-up water.

Solids discharged to the cooler through an enclosed chute are cooled to about 100°C without air contact. A grizzly in the chute removes accretions that are large to plug up or damage the cooler discharge mechanisms. The product is screened to remove the plus 30 mm DRI. The undersize – a mix of DRI, dolo char and coal ash are screened into +/- 3 mm fractions. Each fraction passes through a magnetic separator. The non-magnetic portion of the plus 3mm fraction is mostly char and can be recycled to the kiln if desired. The non-magnetic portion of – 3 mm fraction mostly spent lime, ash and fine char is discarded. The magnetic portion of each fraction is DRI. The plus 3mm fraction can be used directly for steel making and the finer fraction can be briquetted / collected in bags.

The kiln waste gases at about 850-900°C pass through a dust settling chamber where heavier dust particles settle down due to sudden decrease in velocity of gases. The flue gases then pass through an after burning chamber where un-burnt combustibles are burnt by blowing excess air. The temperature of the after burner chamber, at times, is controlled by water sprays. The burnt gases then pass through a down duct into a evaporation cooler where the temperature is brought down and through a pollution control equipment namely ESP / Bag filter/ scrubber where balance dust particles are separated. Then the gas is let off into the atmosphere through stack via ID fan.

In certain coal based large plant in India is equipped with waste heat recovery system, the flue gases after the after burning chamber pass through an elbow duct to waste heat boiler where sensible heat of the gases is extracted. The gas is then let off into the atmosphere after passing through pollution control equipment like ESP, ID fan and stack. In solid based processes, the non-coking coal and iron ore which are at intimate contact start reacting at the prevailing temperature.

Reaction mechanism

There are two major temperature zones in the kiln. The first pre-heat zone is where the charge is heated to 900 – 1000°C. The second metallization zone is held fairly constant at 1000-1050°C.
The charge into the kiln consists of a mixture of iron oxide lump, fluxes such as limestone and/or dolomite (amount depending of sulfur content of the coal) and medium volatile non-coking coal. In the pre-heating zone, the moisture is driven off first, and then the hydrocarbons and hydrogen evolve by thermal decomposition of the coal.
As the combustible gases rise from the bed of solid material, a portion of the gases is burnt in the free board above the bed by controlled quantities of air introduced through the air tubes. As the kiln rotates, the primary mode of heat transfer is by radiation to the tumbling charge and subsequently by internal solids mixing and renewal of the exposed bed surface.
In the pre-heat zone, the reduction of iron oxide proceeds only to ferrous oxide (FeO) (Equation I).

$Fe_2O_3 + CO = 2\ FeO + CO_2$ .... (I) Final reduction to metallic iron occurs in the metallization zone by reaction of CO with FeO to form CO_2 and metallic iron (Equation II).

$FeO + CO = Fe + CO_2$ .... (II) Most of the CO_2 reacts with the excess solid fuel in the kiln and is converted to CO according to the Boudouard reaction (Equation III).

$CO_2 + C = 2\ CO$ .... (III)

Coals with higher reactivity are preferred as they provide rapid conversion of CO_2 to CO, thereby maintaining reducing conditions in the kiln metallization zone. The highly endothermic reaction of coal with CO_2 prevents the bed from overheating and attaining high temperature that could lead to melting or sticking of the charge.

High coal reactivity decreases the reduction zone bed temperature but increases the relative capacity. Desired bed and gas temperature in the freeboard can be achieved with high reactivity fuels even with very high throughput rates. Air admitted to the ports below the bed in the pre-heat zone will burn some of the gases that otherwise leave the kiln unburnt to improve fuel consumption

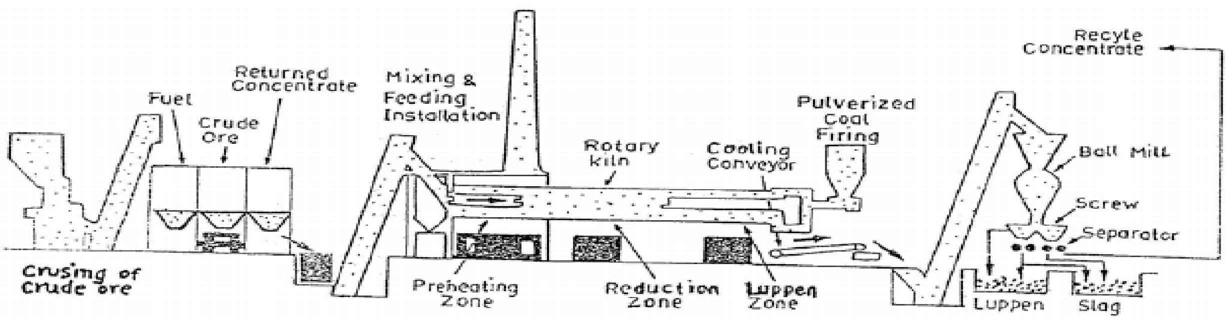
4.2 TECHNOLOGICAL OPTIONS FOR COAL BASED PLANTS

Krupp Renn process: An annual production of 450000 metric ton (500000 net ton) of DRI has been achieved by using the Krupp Renn process. The Krupp –Renn process was developed in the 1930's to treat high silica ore with a basicity ratio as low as 0.2 to 0.3, with the addition of limestone. In this process a mixture of minus 64 mm (2.5 inch) ore and fine grained carboneous reducing agent (coke breeze or bituminous coal fines) is fed continuously in rotary kiln.

The maximum temperature of kiln is kept at 1230 to 1260^{o}C (2250 to 2300°F), which is sufficient to convert the gangue in the ore to a very viscous high silica sludge and also to effect coalescence the sponge iron obtained from the reduction of the iron ore. The reduced iron welds into nodule called "luppen" which become embedded in the pasty sludge. This product is discharged from the kiln. After cooling it is crushed and luppen are magnetically separated from the sludge. Recovery of iron in the luppen varies between 94% to 97.5%.

High Titania ore can also be used in this process and iron can be separated from titanium since the latter is not reduced. Almost any solid carboneous fuel can be use as a reducing agent. Since a large part of the sulphur contained in the reducing agent goes in the luppen, the sulfur content of the metal becomes high and difficult for economically conversion of the luppen into steel by the conventional steel making practices. In some places, the process is used to concentrate low grade iron ores containing up to 30% silica, and the luppen been fed in to blast furnaces.

The process flow diagram of Krupp Renn process is shown in Figure 18.



Krupp – CODIR process

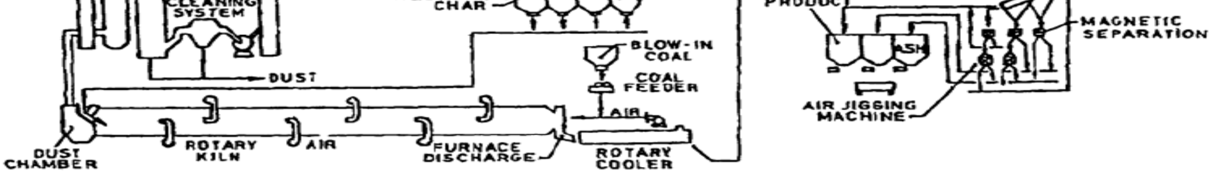
The Krupp – CODIR process of Krupp Industries, West Germany, seems similar to original Krupp – Renn process. The process operates at a lower temperature then the Krupp – Renn thus producing a standard DRI product. Furthermore, limestone or dolomite in the furnace charge absorb a substantial part of the sulfur introduced with fuel.

A Krupp CODIR plant designed for a facility of 150000 metric ton (165000 net tons) started operation 1973 at the Dunswart Iron and Steel Works Ltd. at Benoni, Rpublic of South Africa. The reduction kiln in this plant is about 4.0 meter (13 feet) inside diameter and 74 meters (243 feet) long. The energy consumption is about 15.9 million kilojoules per metric ton (13.7 million BTU per net ton) of DRI when low volatile anthracite is used for the reduction coal. As mentioned previously, the gross energy requirement increases when high volatile matter coals is used.In this process lump ore or oxide pellets, solid reductant, dolomite or limestone as flux is needed. The feed size of the solids is closely controlled to expedite separation. Typically, the preheating zone extends from 25% to 40% along the CODIR process kiln.

Primary heat is supplied to the kiln by the combustion of pulverized coal injected at the solids discharge end of the kiln. Secondary heat is supplied by in injecting air into the kiln gas space through tubes spaced along the entire length of the kiln. The secondary air is introduced axially (along the kilns centre line). In this way, a uniform charge temperature profile between 950 and 1050^{o}C (1740 and 1925°F) is achieved in the reaction zone of the kiln.The DRI, char, coal ash and spent flux are discharged via an enclosed chute from the rotary kiln burner hood into a shield rotary cooler. Cooling is accomplished by spraying a controlled amount of water directly into the hot solids and by spraying additional water on the outside of the cooler shell. The cooled solids are discharge over a 5 mm screen The minus 5 mm fraction is processed through further screening at 3 mm and magnetic separation to separate the final DRI from recycled char, spent flux and coal ash. Minus 3 mm DRI is separated as cold briquettes and 5-3 mm DRI is combined with plus 5 mm fraction. Char is separated by gravity for return to the kiln feed, and ash and spent flux are separated for disposal.

The process flow diagram of Krupp CODIR process is shown in Figure 19.

Figure 19: Krupp CODIR process



SL / RN Process (Outcompete)

A forerunner to the SL / RN process, RN process (for Republic Steel Company and Nations Lead Corporation) was developed originally in Norway, primarily to recover TiO2 from titanium bearing ore for the production of paint pigments. However, further development showed that other iron bearing ores could also be treated successfully to produce iron. Subsequently, a pilot plant is built in the United State, and in 1964 Lurgi Chemie acquired the RN patents and developed the technology further with the Steel Company of Canada Ltd. (Stelco) to the SL/RN process.

The SL/RN process flow typically rotary kiln operation described earlier. The largest commercial SL/RN plant, design to produce 360000 metric ton (400,000 net ton) of DRI per year was installed by Stelco at Griffith Mine in Ontario, Canada and began operating in 1975. The reduction kiln in this plant is 6 meters (19.7 feet) inside diameter and 125 meters (410 feet) long. The energy consumption at this plant is about 22 million kilojoules per metric ton (19 million BTU per ton) of product when the process is operated with high volatile sub-bituminous coal. This relatively high consumption occurs because most of the volatile matter in the reductant coal leaves the kiln and is not recovered.

Other commercial installations based on the SL / RN process include one installed in 1970 by New Zealand Steel Ltd. in Glenbrook, Auckland, New Zealand for recovery of iron from native iron sands and another plant installed at the Fukuyama Works of Nippon Steel in Japan in 1974. The New Zealand Steel Limited plant was subsequently modified to included a multiple hearth furnace for reheating the iron sand feed and charging the reduction coal. The Fukuyama plant was designed to process waste oxides generates at the Fukuyama Works. Other plants have been constructed the more recent plant are operating or under construction in Peru, and South Africa.

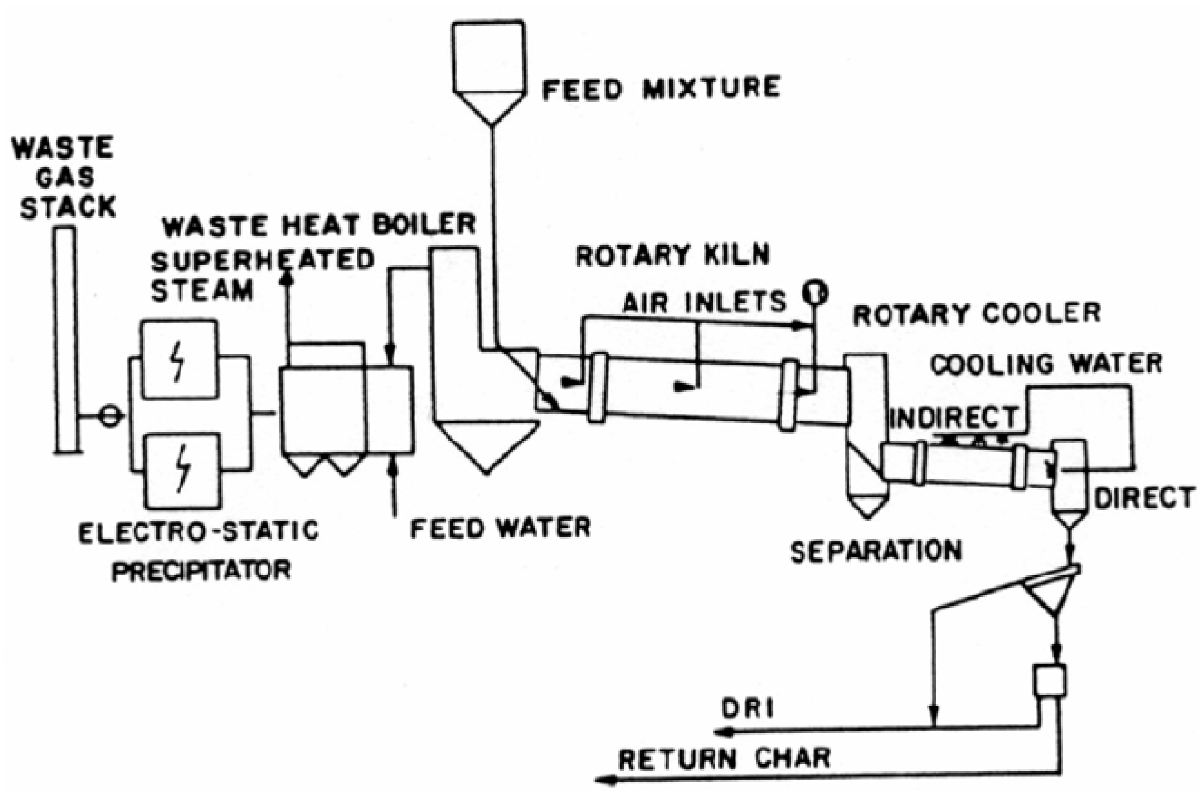
The SL / RN process consists of lump ore or pellets, coal, recycle char, and flux need to scavenge sulphur from the coal. In the kiln preheat zone, the charge is heated to about 980°C (1800°F) by counter flowing hot freeboard gases. For high kiln efficiency the reheated zone is made as short as possible usually 40 to 50% of kiln length. Reduction begins when the charge reaches temperature in excess of 900°C (1650°F) when the carbon gasification reaction starts generating carbon monoxide. To maintain a uniform reduction zone temperature by burning combustibles released from the bed, air is blown by shell, mounted fans, feed air into the freeboard gas stream, through burner tube space uniformly along the length of the kiln. Air is introduced axially in to the kiln and additional combustion air is blown into the kiln through a central airport of the discharge end.

The solids are discharged forms the rotary kiln via transfer chute into a sealed rotary cooler. Water sprays on the cooler shell reduces the temperature of solids to about 95°C (200°F) in a non-oxidizing atmosphere. External lifter aid heat transfer in the cooler discharge material that are continuously separated into DRI, DRI fines, non magnetic by a system of screen and magnetic separation. Char is separated from the waste by gravity separation.

The SL /RN process kilns are now equipped with nozzles for under-bed injection of about 25% of the process air in the preheating zone of kiln. The air is available for combustion of the volatile matter in the coal within the bed in the preheating zone. As a result, the length of preheating zone of the kiln is reduced because of improved heat transfer and fuel utilization. More of the kiln length can therefore be used as a reduction zone.

The process flow of SL/RN process is shown in Figure 20.

Figure 20: SL/RN process



ACCAR Process

The Allis Chalamers Controlled Atmosphere Reactor (ACCAR) produces highly metabolized DRI in a rotary kiln. Liquid, solid and gaseous fuels singly or in combination are used directly in the kiln with an external reformer or gasifying plan. The ACCAR kiln is equipped with an intricate port system and with valves arranged radically around the circumference of the kiln and spaced uniformly along its length, for liquid or gases fuel injection. Versatility in the use of fuel is claimed as an advantage for this process as it permits use of the most economical fuels available.

The original ACCAR development work started in the late 1960 and was based on hydrocarbon gases and liquids. Work was started in a 0.6 meter (2 feet) diameter by 7 meter (23 feet) long pilot plant at Milwaakee and continued in a 2.5 meter (8 feet) diameter by 45 meter (148 feet) long demonstration plant at Niagara Fall, Ontario, Canada.

The first commercial ACCAR plant for operation with natural gas and fuel oil was established through modification of an existing SL /NR plant in Sudbury, Ontario. The plant started operating in 1976. The reduction kiln is 5 meter (16.4 feet) inside diameter and 50 meters (164 feet) long and is claimed to be capable of producing 233,000 metric ton (257,000 net tons) of DRI per year with a total energy consumption of 15.7 million kilojoules per metric ton (13.5 million BTU per net ton) of DRI.

A second ACCAR plant of 150,000 metric ton (165.000 net ton) per year capacity start operation in 1983 in India. The plant operates with coal and oil. The oil can be injected under the bed for two third of the kiln length. The kiln design was modified to permit the addition of fine coal from the discharge end.

With 80% of the hydrocarbon fuel is released by coal, ACCAR has projected that a reduction kiln 6 meters (19.5 feet) inside diameter by 122 meter (400 feet) long will be capable of reducing 600,000 metric ton (660,00 net tons) per year of DRI. The total energy consumption is predicted to be about 18.6 million kilojoules per metric ton (16 million BTU per net ton) of DRI.

Because gases and liquid fuels are in short supply, operation of the ACCAR process with coal is popular. Coal has been used successfully to supply from 80 to 90% of the fuel for the ACCAR kiln, with the remaining fuel requirement being supplied by liquid and gaseous fuels. Coal and lump ore and or oxide pellets are fed into the fed end of the rotary kiln. The solids are heated to reduction temperature by the counter-current flow of hot gas. Volatile matter is released from the coal during heat up and carried out along the kiln exhaust gas. As the coal and iron oxide travel through the kiln, reduction is accomplished by the carbon and carbon monoxide reduction mechanism. The coal feed is controlled so that it is essentially consumed as the burden enters the final stage of the reduction. Combustibles released from the bed are burned in the kiln freeboard with air introduced through the port in the kiln shell.

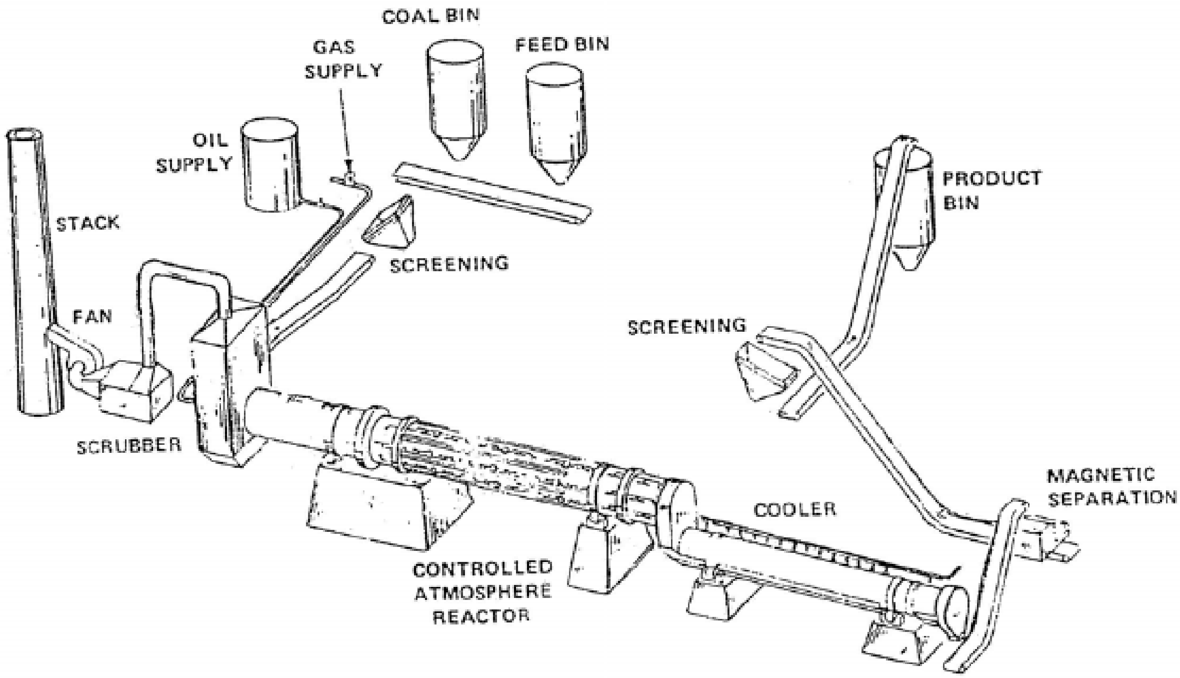
The final degree of reduction is achieved by introducing liquid and or gaseous fuel through the kiln shell port near the product end of the kiln as they pass under the solid bed. In passing through bed, this fuel is corrected to form hydrogen and carbon monoxide to complete the iron oxide reduction and to provide a protective atmosphere for the highly metalized product. This method of fuel injection permits operation with the excess of coal required to maintain a reducing atmosphere in the bed in other coal based DR process. Thus char recycling is eliminated.

Solids are discharged from the rotary kiln into a rotary cooler where cooling is accomplished with external water spray. The DRI is separated from the coal ash by magnetic separator, and is then screened to achieve coarse and fine product separation.

If waste heat recovery is not practiced, the kiln gas is cleaned and the heavier solids are removed in dry dust collector, and the fine solids are removed in a wet scrubber, which also cool the gas before it released to the atmosphere.

The process flow diagram of ACCAR process is shown in Figure 21.

Figure 21 ACCAR Process



DRC Process

The DRC process of the DAVY Reduction Corporation (DRC), a Division of Davy Mckee, stems from the Hockin process of Western Titanium Ltd. of Australia, Formerly Azion, DRC operate a pilot in Rockwood, Tennessee as a member of the Amcon group of Consolidated Gold Fields. The first commercial furnace was constructed for Scaw Metals in Germiston, South Africa.

Operations at Scaw Metals started in July of 1983. The kiln size is 4.5 metres (14.75 feet) shell diameter by 60 metres (197 feet) long. The rated annual capacity is 75000 metric tons (83000net tons). Reportedly, the plant exceeds this capacity. The coal consumption is 0.72 ton per ton of DRI based on 55 per cent fixed carbon. Davy / DRC anticipates construction of larger kilns in the future. They also stress high operability and control of their plant (including sulfur in the product) through complex consideration regarding raw material and proprietary design and operating future for the rotary kilns and ancillaries.

Ore, coal, recycled char, and flux if required, are continuously fed into the rotary kiln. Passage of the burden through a preheat zone and a reducing zone in the kiln flows typically rotary kiln operation. Some minus 9.5 mm coal (about 12.5 % of the total coal is blown by low pressure air into the discharge end of the kiln. Process heat is supplied by burning combustible in the kiln freeboard combustion air is blown in to the kiln shell mounted fans via tubes spaced along the length of the kiln. The bed and gas temperature profiles are controlled by adjustment of the air input through the tube.

In the reduction zone iron oxide is reduced by carbon from the coal, with reaction (2), (4), (6) and (9) controlling the complex gas solid reactions

$3Fe_2O_3 + H_2 = 2Fe_3O_4 + H_2O$ (1)

$3Fe_2O_3 + CO = 2Fe_3O_4 + CO_2$ (2)

$Fe_3O_4 + H_2 = 3FeO + H_2O$ (3)

$Fe_3O_4 + CO = 3FeO + CO_2$ (4)

$FeO + H_2 = Fe + H_2O$ (5)

$FeO + CO = Fe + CO_2$ (6)

$3Fe + CO + H_2 = Fe_3C + H_2O$ (7)

$3Fe + 2CO = Fe_3C + CO_2$ (8)

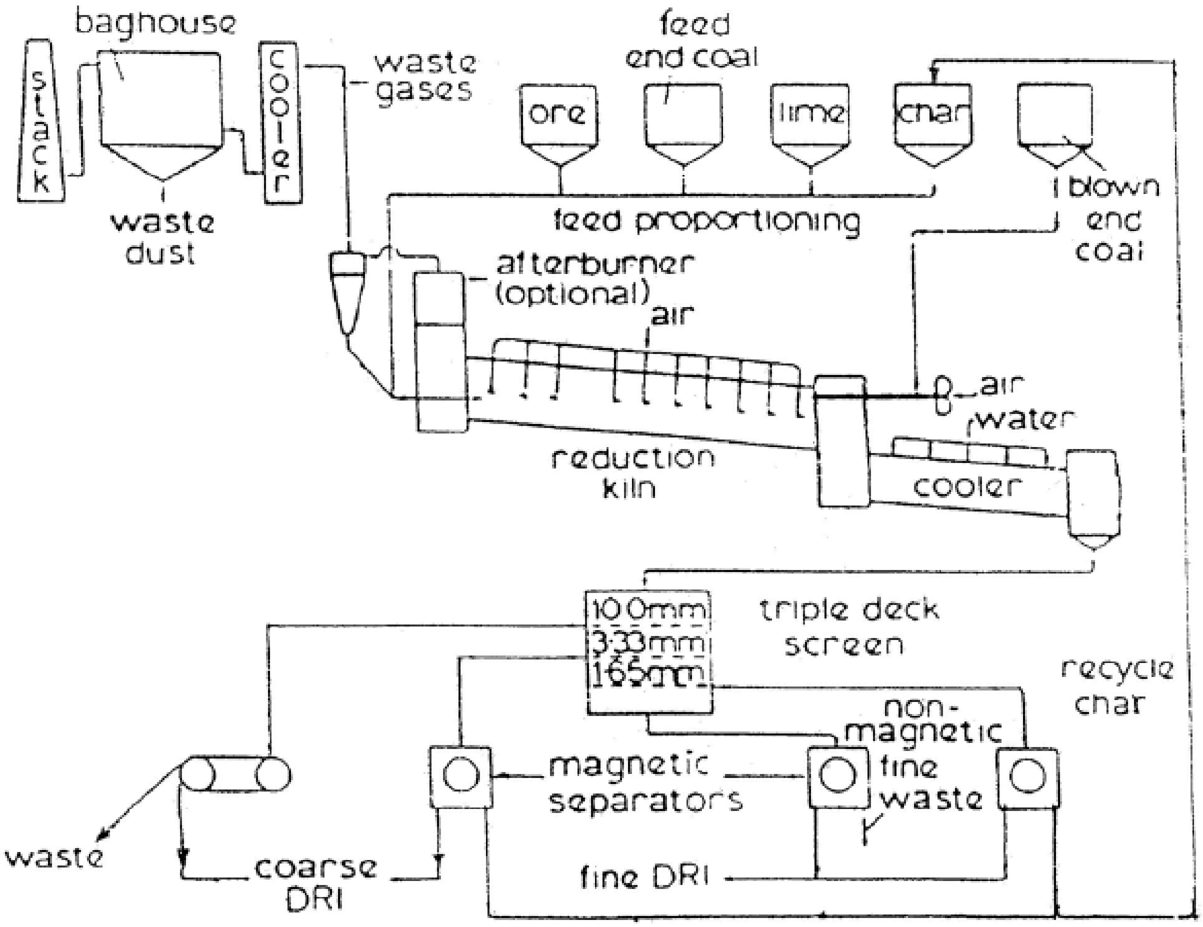
$CO_2 + C = 2CO$ (9)

The maximum kiln bed temperature in the reduction zone is about 1060^oC (1940^oF) with a maximum kiln gas temperature of about 1160^oC (2120^oF). Emphasis is placed on maintaining a high ratio of carbon monoxide to carbon dioxide in the kiln bed to achieve a high degree of reduction. Control of the rate of the heat transfer to the bed and control of the bed temperature are also critical for steady operation of the kiln, the achieve stable process chemistry and favourable reaction kinetics. The hot waste gases leave the kiln of about 800^{o}C (1470^{o}F).

Solids are discharged from the kiln via a sealed transfer chute in to a sealed rotary cooler. Cooling is achieved by spraying water on the outside shell of the screening and magnetic separation circuits. Pores and fine DRI and charge that is recycled are thus separated from the fine waste.

The process flow diagram of DRC process is shown in Figure 22.

Figure 22: DRC Process Flow Diagram



Customized or Indigenous Process

In India, the standard DRI processes are modified in a minor way and thereafter referred to as customized / indigenous technology. Only trivial changes in terms of the feed ratio, length and the diameter of the kiln are made in the name of customized technology. These customized technologies are dominating the coal based sponge iron process in India. Jindal, TDR, Sponge Iron India Limited (SIIL), Orissa Sponge Iron Limited (OSIL), Popurri Engineering, etc have customized and adopted and market such technology.

In India, the coal based DRI production process employs a rotary klin as the main reactor wherein the process of reduction of the iron oxide is carried out with coal as reductant. Refractory lining of about 150-200 mm thickness is given inside the kiln to protect the shell. The kiln has a general slope of 2.5 - 3% down towards the discharge end. There are air blowers mounted on the kiln shell having dampers to provide required air for combustion at different heating zones.

Sized iron ore and coal in required proportion are fed in to the kiln with the help of the weigh feeders at the feed end. Due to the rotational motion of the kiln and due to the slope provided, the charge moves forward to the discharge end. Thermocouples are mounted on the kiln to measure and control the temperature of the different heating zones. Fine coal is also injected through the discharge end of the kiln with the help of the coal injector machines & lobe compressor, to meet the additional carbon and volatile matter requirement of the reaction.

Kiln discharge material which is a mixture of sponge iron and char (mixture of unreduced iron, uncalcinated limestone, gangue and semi burnt coal) is taken to a rotary cooler. Water is sprayed on the cooler shell to indirectly cool the kiln discharge mix to about 120^{o}C. The cooler also has a slope of about 2.5%. The cooler discharge falls onto a hopper and taken through conveyors for screening of fines and coarse materials. After separating the -3 mm and +3 mm sizes in the product screen, the cooler discharge mix is subjected to magnetic separation where sponge iron is separated from char. Sponge iron and char of coarse and fine sizes are stored in separate silos or hoppers.

The reducing gases generated from the combustion of the coal, flow counter current to the direction followed by the solids and emerge from the feed end. The kiln is maintained at a positive pressure of about +5 mm water column. The flue gases then passes through the gravitational Dust Settling Chamber (DSC) and pass on to the After Burner Chamber (ABC) located right above the DSC. In the ABC, the CO is converted to non toxic CO_2. Therefore, in ABC the off-gas laden with combustible matter is burnt. On the top of the ABC, there is an emergency cap to maintain the kiln pressure by letting out the accumulated gases.

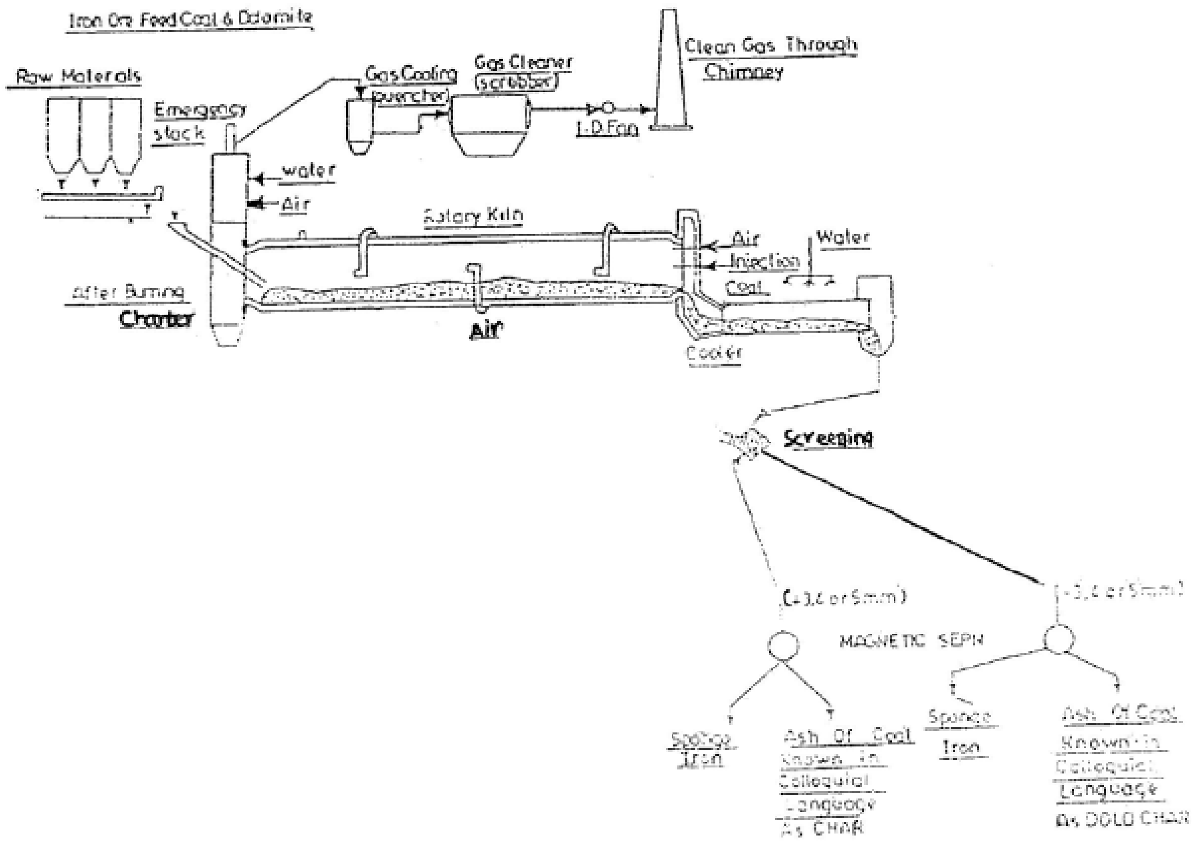
The DRI plants installed in early eighties and nineties uses quenching through Wet Scrubber to treat the dust bearing flue gases. In this system the huge amount of sludge is generated, which is disposed in ash ponds. The latest trend in DRI plant is to use Electrostatic Precipitator for dust trapping. In this system, the flue gas, at about 900^{o}C - 950^{o}C, is taken to a Gas Conditioning

Tower (GCT) where quenching water is added to cool the gas to about 150°C. The cooled gas then travels to the Electrostatic Precipitator (ESP). Dust is trapped in the ESP and the flue gas is let out using chimney.

Off late, some large DRI plants have installed Waste Heat Recovery Boiler (WHRB) after the ABC, to utilise the waste heat content of the flue gas. The WHRB generates steam at high pressure and use it to run turbines and produce electricity. The general technology followed in all the coal based DRI plants is similar to that of SL/RN (Lurgi process).

The process flow diagram is shown in Figure 23.

Figure 23: Flow Diagram of Coal Based Customized / Indigenous Technology



Sponge Iron India Limited: In India, the first sponge iron plant of 100 tons/day capacity was constructed in 1979 by a Company styled as Sponge Iron India Limited (SIIL) at Paloncha in Khammam District of Andhra Pradesh. SIIL is a joint venture between Govt. of India, Govt. of AP, UNDP and UNIDO. The technology supplier to this plant was Lurgi (SL/RN Technology). In this plant, the kiln is 3 m in diameter and 40 m length. The feed rate of iron ore was fixed at 6.7-7.0 tons/hour and coal feed rate at 3.5-5.0 tons/hour. The feed was retained in the kiln for 4-6 hours and the temperature of the preheating zone was 650-800^{o}C, reduction zone was 900-1000^{o}C. The production started in 1980 and the DRI output was 100 tons/day. Wet scrubber was used to clean the dust laden gases.

The SIIL plant was meant to demonstrate production of DRI from iron ore and non-coking coal available in abundance in India and to establish the suitability of Indian raw material for DRI making. The initial shortcomings in the process were overcome by SIIL engineers and the operation streamlined. Based on the results of operation of these units, other DRI plants started coming up in India. Similar plant was established in 1990s by HEG Ltd. at Durg, Bellary Steel & Alloy Limited at Anantapur Road, Bellary in Karnataka and Raipur Alloys Ltd. at Siltara in Chhattisgarh.

Popurri Engineering: Mr. Popurri Ankineedu was one of the engineers associated with the SIIL project, who later left SIIL and started marketing this process knowhow under the brand name of Popurri Engineering. Today there are over 50 small DRI plants all over India, which are based on process knowhow supplied by Popurri Engineering. Some other engineers who were also associated with the earlier DRI plants also started supplying the process knowhow to the upcoming DRI plants, thereby closing the flow of standard technologies into Indian DRI market. Large Indian steel majors however did not support these small time freelancing engineering endeavours driven by the desire to establish their own brand knowhow and market them for profits. The steel majors like Jindal and TISCO have also made minor modifications to the original Lurgi technology and came up with their own brand of Jindal Technology and TDR technology.

Jindal Technology: Jindal Steel & Power Limited started their first kiln of 300 tons/day capacity in 1991 at Raigarh in Chattisgarh. Subsequently they have established five similar kilns till 2000. Today they are the worlds largest producer of coal based DRI with an installed capacity of 620,000 tons/annum. They have successfully provided the Jindal Technology to Monnet Ispat, Nalwa Sponge, Vallabh Steel, and Rexon Strips. The kilns of Jindal Technology are having diameter of 3.8 m and length of 70.8 m. The feed rate is 9-10 tons/hour and the size of feed is 5-20 mm for iron ore and 3-20 mm for coal. Coal injection is done from the discharge end of the kiln having lump size of 3-20 mm and fines of –3 mm. The temperature at the feed end is maintained at 750-900^{o}C, middle of kiln at 990-1040^{o}C and discharge end at 1010-1050^{o}C.

TDR Technology: Tata Steel established a sponge iron plant in 1983 at Beliapada, near Joda of Keonjhar District in Orissa named Tata Sponge Iron Limited. The process is similar to SIIL. Lurgi provided technical support. The process was called TISCO Direct Reduction (TDR). The first kiln was established in 1986 having DRI output of 300-350 tons/day. The kiln diameter is

4.2 m and the length is 72 m. The feed rate is 21 tons/hour and the kiln retention time is 8-9 hours. The size of the feed is 5-20 mm for iron ore and 0-15 mm for coal. At the feed end the temperature is kept about 800^{o}C and at the discharge end it is about 1000^{o}C. The second kiln of 350 tons/day was established in 1998. TSIL appointed Dastur and Lurgi GMbH for providing technical support so that certain shortcomings, inherent in the design of the first kiln, could be rectified. Emphasis was laid on the general lay-out of the plant. The working point at kiln inlet was reduced from 14.9m to 12.9 m .ESP was used for dust trapping compared to wet scrubber in the first kiln, and the plant was totally automated through the PLC system. The length of the rotary cooler was increased to 42 m against 35 m of the first kiln, at a discharge end a weigh hopper with a variable discharge system has been installed to ensure positive sealing. In order to increase productivity a counter current iron ore fines injection system of 2.5 tons/hour was installed. Castable refractory lining was done in Dust Settling Chamber. The third kiln of 500 tons/day was established in 2004.

Orissa Sponge Iron Limited: Orissa Sponge Iron Limited (OSIL) was set up in 1983 in Palaspanga of District Keonjhar in Orissa. It was based on ACCAR process having an underbed injection of diesel from the discharge end. OSIL later used coal fines in place of diesel and patented it as OSIL technology. In 1995 OSIL supplied the technology to Llyods sponge iron plant at Ghuggus in Chandrapur district of Maharashtra. In OSIL, the diameter of kiln is 4.0 m and the length is 84 m, having refractory thickness of 230 mm rendering an effective diameter of 3.54 m. The kiln output is 300 tons/day. Non-coking coal is fed from the feed and discharge end as reductant, whereas provision for injecting solid, gaseous and liquid fuels are provided through the 300 portholes located on the kiln shell. OSIL uses a unique patented reactor for production of sponge Iron called a ported reactor. The reactor is a rotary kiln and is the heart of the reduction process. It is lined with castable refractory. The reactor is supported on three piers and is driven by two DC drive motors through a common girth gear. Located along and around the reactor are a series of ports and air tubes which can deliver combustion air into the reactor. Process air is provided by air fans through two manifolds. The reactor is at a slope of 2.5%. The temperature of reactor is maintained at around 10500C. The coal fed into the reactor is heated and gasified to form a reducing CO which in atmosphere inside the reactor. Iron ore is reduced to DRI. After passing through the reactor the reduced iron ore (Sponge Iron) and coal char drop through a transition chute to a rotary cooler. The hot DRI is cooled in the cooler by indirect means. The cooler is supplied on two piers at 2.5% slope driven by a single AC drive motor.

Rotary Hearth Process

Inmetco Process

The INMETCO process is currently operated by the International Mettle Reclamation Co. Inc. in Ellwood City Pennsylvania for the recovery of waste iron ore dust. The oxide pellets are fed into a rotary heath furnace, which is separated by air curtains into oxidizing, reducing, and natural discharge zones. Burners above the bed are fired with oil or natural gas (coal burners have been tested and can be used as well). The shallow bed depth results in high heat transfer rates. Residence time for the pellets in the bed is approximately 15 to 30 minutes.

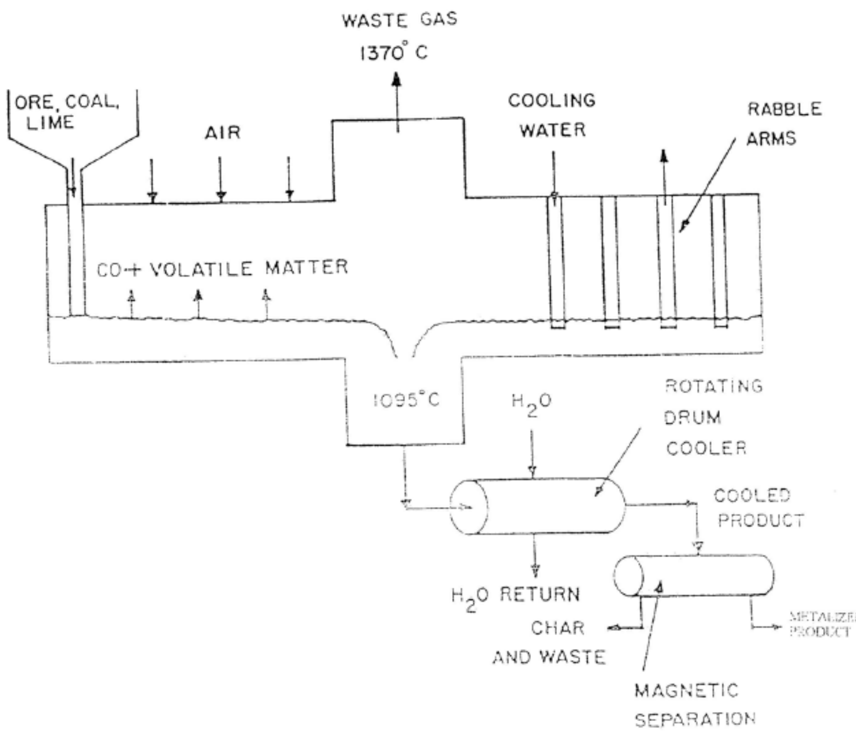
As of 1980, the process operated at 80000 metric tons (88000 net tons) of feed per year in the recovery of metal from waste dusts. An operating rate up to 250000 metric tons (275 000 net tons) of feed per year per single unit has been proposed.

Salem Direct Reduction Process

To avoid accretion problem common in rotary kiln direct reduction processes, the Salem Furnace Company proposes using a rotary heath furnace as the reduction reactor. For the Salem DR process the rotary heath is surmounted by a stationary roof, which is fitted with a series of water-cooled rabble arms fixed across one radius. Lump ore, or pellets, and coal, are fed through a chute at the periphery of the heath. As the heath rotates several times, the rabble arms toward a central discharge heat-soaking pit move the burden. In this manner the material that is turned and displaced by a rabble makes one completes revolution as a quiescent bed before a reach the next rabble.

Volatile matter in the coal and combustible released from the bed are burned in the freeboard between the roof and the hearth layer to provide the heat for the charge. Combustion air preheated by the process exhaust gases, is admitted to the freeboard through port in the root and side walls. The reduced product is discharged through the currently locate soaking pit in to rotary cooler, cooled by external water spray. The DRI is separated from the coal ash and residual char by screening and magnetic separation. The process flow diagram of Salem DR Process is shown in Figure 24.

Figure 24: process flow diagram of Salem DR process



Retort Process

Hoganas Process

The E. Sieurin Hoganas process was developed at Hoganas in Sweden in 1910 and is still in commercial use. Alternate layers of fine-grained high-grade iron ore, dry coke breeze, and limestone are charged into cylindrical ceramic containers called saggers are then heated to a maximum temperature of 1260°C (2300°F) in a furnace of the tunnel-kiln type used for burning brick. The furnace is heated by burning producer gas and the carbon monoxide evolved by the reduction of the ore. The containers are cooled in the furnace, removed, and the reduced iron is separated and cleaned. Total retention time of a container in the tunnel kiln is about 80 hours. Most of the DRI produced is sold as iron powder. The largest Hoganas plant in operation has two tunnel kilns and is capable of producing 38000 metric tons (41000 net tons) annually.

Kinglor Metor Process

The Konglor-Metror process is based on the concept of producing DRI continuingly by heating mixture of ore and coal in an externally fired rectangular shaft or retort. Earlier attempts to implement this concept failed because the reduction reaction are highly endothermic and the production was severely limited by the slow rate of heat flow into the charge through the retort walls which were made of firebrick. Kinglor Metor overcame this limitation by constructing the wall of the retort with highly conductive silicon carbide and by burning reduction with in a preheating zone in the upper part of the retort a schematic flowsheet of the process.

Danieli & Cie Limited installed a pilot plant comprising tow reactor at Buttrio, Italy. The reactors are essentially vertical shaft of conical shape about 11 m (33 feet) high with top diameter of 0.4 m (1.3 feet) and bottom diameter of 0.7 m (2.3 feet). The energy consumption is claimed to be about 16 million kilojoules per metric ton (13.8 million kilojoules per metric ton (0.43 million BTU per net ton). The pilot-plant operations demonstrated the process to be simple to construct, easy to operate, and flexible with respect to feed and reluctant requirements.

A commercial plant capable of producing 40000 metric tons (44000 net tons) per year has been installed by Ferriere Arvedi & Cie in Cremona, Italy. The plant consists of two identical 20000 metric tons (22000 net tons) per year modules. Each module contains six vertical retorts 13 m (43 feet) high, 12.5 m (41 feet) long, and 3 m (8.8 feet) wide. Ore and coal are fed continuously into a silicon- carbide reactor that is heated to about 1100°C (2010°F) with natural gas radiant burners. Solid fuel requirements of about 8.5 kilojoules per metric ton (7.4 million BTU per net ton) of DRI and gaseous fuel requirement of about 7.9 kilojoules per metric ton (6.8 million BTU per net ton) are claimed for the process.

Gas Based Processes

Today gas based DR plants subscribe to more than 90% of installed DR capacity in the world, of which MIDREX and HYL together have about 85 % of the total capacity to their credit.In the gas based processes, the reduction of iron oxide is carried out by a mixture of CO & H_2 at a temperature of about 750-950°C.

The reducing gas is produced by reformation of natural gas. The reformation is partial oxidation of hydro-carbons. To enhance the reformation process, normally a catalyst is used.

Major Facilities of Gas Based Plant

a) Direct reduction furnace
b) Hot briquetting system (OPTIONAL)
c) Process dust collection system
d) Reformer
e) Recuperator and flue gas system
f) Gas scrubber and cooler
g) Process gas compressors and blowers
h) Water system
i) Effluent treatment system
j) Natural gas system
k) Inert gas/seal gas system
l) Compressed air system
m) Steam facilities (for HYL-III plant only)
n) Electrical equipment
o) Instrumentation
p) Raw material, product storage & handling system
q) Repair shop and laboratory
r) Ventilation and dedusting system

Midrex Process

Surface combustion division of Midland developed the Midrex Process. In the mid-1960s the Midrex division became a subsidiary of Korf industries. In 1974 Midrex was acquired by Kobe Steel Limited in 1983. The first commercial midrex plant was intalled near Portland Oregon and started production in 1969. The plant included two shaft reduction furnaces of 3.4 m (11.2 feet) inside diameter and had a total capacity of 300000 metric tons per year. The average energy consumption of this plant was about 15 million kilojoules per metric ton (12.9 million BTU per ton of DRI). Many difficult engineering and operating problems were solved during the first several years of operation of this plant.

The Midrex DRI plants of 1970s comprise the 4.88 m (16 feet) inside diameter midrex series 400 and the 5.5 m (18 feet) inside diameter series 600 shaft furnace modules. The number of the series originally designated the DRI capacity in thousand of metric tons per year. By 1983, more than twenty Midrex modules were installed having a total capacity of about 9 million metric ton per year (9.9 million net ton per year).

The main components of the process are the DRI shaft furnace, the gas reformer, and the cooling gas system. Solid and gas flows are monitored and the process variables are controlled within the operating limits. The temperature and composition of each gas stream to the shaft furnace are controlled within specification limits to maintain optimum bed temperature for reduction, degree of metallization, carbonization level (Fe_3C contents), and to ensure the most efficient utilization of the reducing gas.

The DRI furnace is steel vessel with an internal refractory lining in the reducing zone. The charge solids flow continuously in to the top of the furnace through seal legs. The reduction furnace is designed for uniform mass movement of the burden by gravity feed, through the preheat, reduction, and cooling zones of the furnace. The cooled DRI is continuously discharged through seal legs at the bottom of the furnace. The use of seal legs for feeding and discharge solids eliminates the need for complex lock hoppers. Inert gas is injected into the seal legs to prevent escape of process gases. On discharge from the shaft, the DRI is screened for removal of fines. Special precautions are undertaken to minimize any danger of spontaneous ignition of the pyrophoric DRI product during extended storage or shipment. Either the patented Midrex CHEMAIRE process or a Hot Briquetted Iron Process is employed to protect the DRI.

Reducing process gas, about 95% combined hydrogen + carbon monoxide, enters the reducing furnace through a bustle pipe and ports located at the bottom of the reduction zone. The reducing gas temperature ranges between 760 & 950^{O} C. The reducing gas flows countercurrent to the descending solids. Iron oxide reduction takes place according to reaction following.

$3Fe_2O_3 + H_2 = 2Fe_3O_4 + H_2O$ (1)

$3Fe_2O_3 + CO = 2Fe_3O_4 + CO_2$ (2)

$Fe_3O_4 + H_2 = 3FeO + H_2O$ (3)

$Fe_3O_4 + CO = 3FeO + CO_2$ (4)

$FeO + H_2 = Fe + H_2O$ (5)

$FeO + CO = Fe + CO_2$ (6)

The partially spent reducing top gas, containing about 70% carbon monoxide plus hydrogen, flow from an outlet pipe located near the top of the DRI furnace into the top gas scrubber where it is cooled and scrubbeed to remove the dust particle. The largest portion (about two third) of the top gas recompressed, enriched with natural gas, preheated to about 400^{O}C (750^{O}F) and piped into the reformer tubes. In the catalyst tubes, the gas mixture is purified to form carbon monoxide and hydrogen. The hot reformed gas (over 900^{O}C or 1650 ^{O}F), which has been restored to about 95% carbon monoxide plus hydrogen is then recycled to the DRI furnace.

The reformation reactions are as follows:

$CH4 + CO_2 = 2CO + 2\ H_2$ (1)

$CH4 + H_2O = CO + 3H_2$ (2)

The balance top gas (about one third) provides fuel for the burner in the reformer. Hot flue gas from the reformer is used in the heat recuperates to reheat combustion air for the reformer burners and also to preheat the process gas before reforming. The addition of heat recuperates to these gas streams has enhanced process efficiency, helping to decrease annual fuel to a full usage reported low figure of 11.4 to 11.6 million kilojoules per metric ton of DRI.

Cooling gases flow countercurrent to the burden in the cooling zone of shaft furnace.The gas then leaves at the top of the cooling zone and flow through the cooling gas scrubber. The cleaned and cooled gas is compressed, passed through a demister, and is recycled to the cooling zone.

An alternative flowsheet uses cold shaft furnace top gas for cooling prior to it introduction into the reformer. The DRI absorbs sulphur in the top gas that comes from the raw material. This helps to prevent sulphur poisoning of the catalyst.

The process flow diagarm of Midrex process is shown in Figure 25.

Typically Midrex offers the following module sizes :

i) 400 Series modules

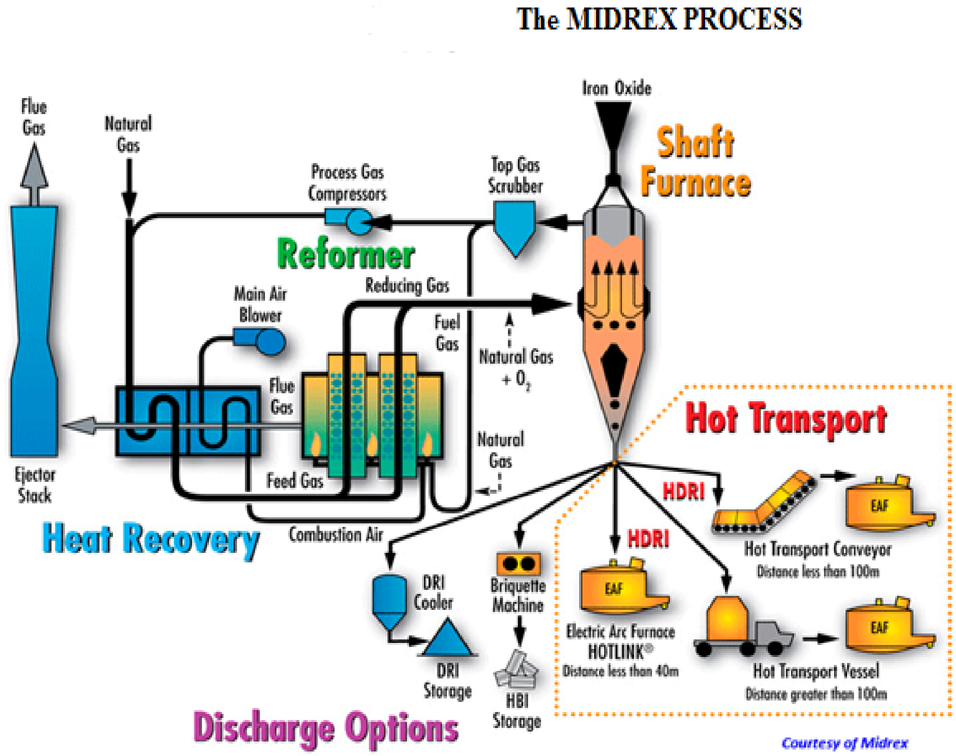
ii) 600 Series modules

iii) 800 Series modules

iv) Midrex Mega Module

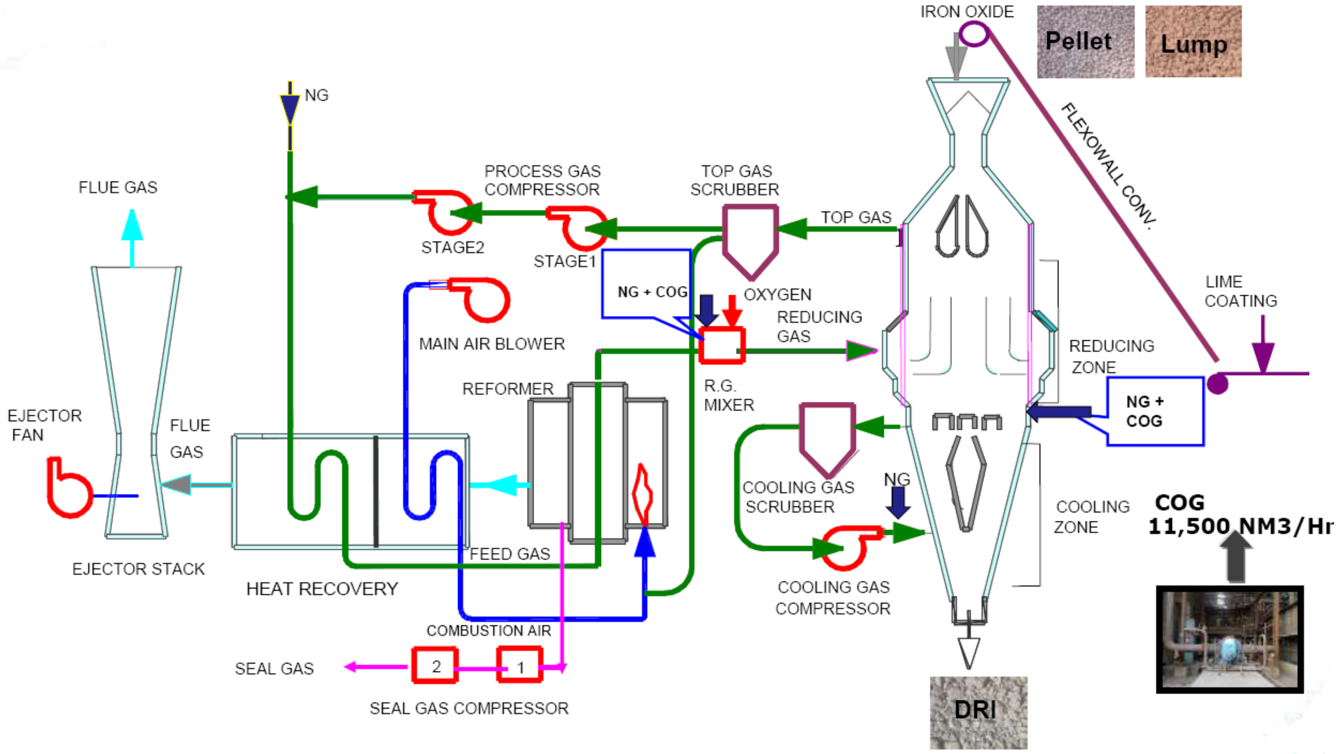
v) Midrex Super Mega Module

Figure 25


The MIDREX PROCESS
Iron Oxide
Shaft Furnace
Flue Gas
Natural Gas
Process Gas Compressors
Top Gas Scrubber
Reformer
Reducing Gas
Main Air Blower
Fuel Gas
Natural Gas + O2
Flue Gas
Natural Gas
Hot Transport
Ejector Stack
Feed Gas
HDRI
HDRI
Heat Recovery
Combustion Air
Hot Transport Conveyor
Distance less than 100m
EAF
DRI Cooler
Briquette Machine
EAF
Electric Arc Furnace
HOTLINK®
Distance less than 40m
EAF
DRI Storage
HBI Storage
Hot Transport Vessel
Distance greater than 100m
Discharge Options
Courtesy of Midrex

JSW Steel Ltd, Dolvi

- Technology MIDREX, Gas based
- Commissioned -1994
- Original capacity-1.0 MTPA
- World's first mega module DRI plant.
- After De bottlenecking in 2005 capacity 1.6 MTPA
- Designed to use only Natural gas as a source of hydrocarbons for Production of Hydrogen & Carbon mono-oxide by catalytic reforming.



Flow Chart of Sponge Iron Plant

Process Description

HYL-III process:

The HYL-III process of Hylsa of Monterrey, Mexico evolved from the original HYL process by retaining the catalytic reformer, the gas reheater, and the off gas handling system which condenses water and remove particulate in a scheme that recycles the reduce–reactor off-gas. In the HYL III process, a single shaft furnace with a moving bed is used in place of the four original fixed bed reactors.

The HYL plants operated with iron ore, iron oxide pellets or mixture of the two, natural gas consumption equivalent to about 10.7 million kilojoules per metric ton of DRI is quoted for green field construction. The power consumption of gas compression is 90 kWh per metric tons of DRI.

The main equipment of HYL-III comprises a DR shaft furnace, a gas reformer, and a gas reheated. The principles of operation of the furnace are similar to the midrex shaft furnace described previously. Continuously descending iron- bearing material is reduced in an upper zone by the countercurrent flow of gas, which is rich in carbon monoxide and hydrogen. Reduction is accomplished by reaction of the reducing gas which is introduced through a distribution system about the circumference of the shaft at an intermediate height. The main reactions are as follows:

Reforming reactions

$$CH_4 + H_2O = CO + 3H_2$$

Reduction reactions

$$3Fe_2O_3 + H_2 = 2Fe_3O_4 + H_2O \qquad (1)$$

$$3Fe_2O_3 + CO = 2Fe_3O_4 + CO_2 \qquad (2)$$

$$Fe_3O_4 + H_2 = 3FeO + H_2O \qquad (3)$$

$$Fe_3O_4 + CO = 3FeO + CO_2 \qquad (4)$$

$$FeO + H_2 = Fe + H_2O \qquad (5)$$

$$FeO + CO = Fe + CO_2 \qquad (6)$$

A proper selection of iron oxide feed stock permit operation at 950°C. The addition of 5 per cent non-sticking ore alters the sticking tendency of iron oxide pellets and improves performance by promoting uniform descent of the burden. This increases productivity and decreases fuel consumption.

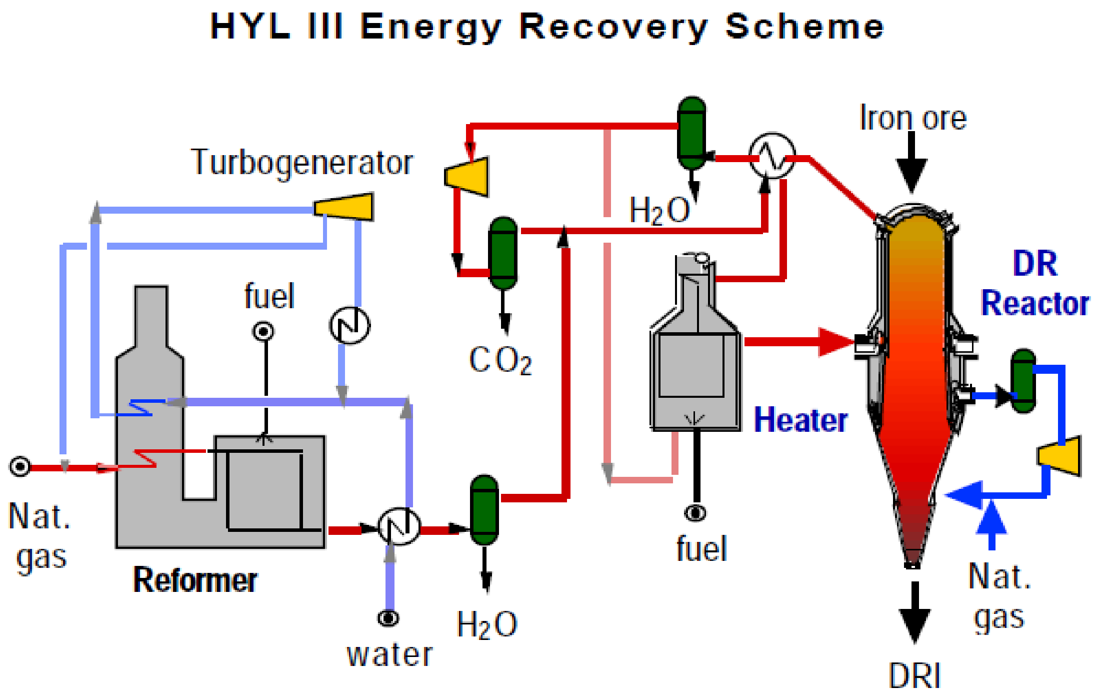
After reduction, the hot DRI continues to descend through a constant pressure zone, which separates the upper reducing zone form, the lower cooling zone. The DRI is cooled to below 50°C by an independent gas stream. The cooling gas is withdrawn at the top of the cooling zone. After cooling, cleaning and compressing. This gas is recalculated at the bottom of the shaft furnace. The composition and temperature of gas flow to the shaft furnace are carefully controlled to permit independent control of the metallization and carbon content of the DRI. It is claimed that a high reduction temperature and the formation of an iron carbide shell protect the DRI from spontaneous rexidation. Like Midrex, there is provision of hot briquetting facilities in the system.

The HYL III shaft furnace operates ***at medium pressure*** for this reason, the design incorporates special pressure lock system for charging iron oxide feed materials at the roof and for discharging cold DRI at the bottom. Possible advantages of high pressure operation are enhanced reduction kinetics, higher gas throughput, and condensation at elevated pressure which lowers the moisture content of the recirculated top gas.

Insofar as reducing gas is concerned, the HYL III process employs catalytic steam reforming of natural gas. As in the original HYL process excess steam is used, the reformed gas is cooled to condense water, which increases the carbon monoxide plus hydrogen content to a high percentage.

The sensible energy of the reformed gas is recovered during cooling by heat exchangers to the steam system. The usual heat recovery system in the flue gas stack of the reformer and gas reheater is also used. The cold reformed gas is mixed with compressed top gas from the shaft furnace This top gas had previously been processed to remove a substantial part of its moisture and particulates. The mixed reducing gas is then reheated introduced in to the shaft furnace along with natural gas, excess shaft furnace of gas (over that amount recirculated the process) is used as fuel in the reformer and gas heater.

Fig. 26: HYL III Process



NSC Process

The Nippon Steel Corporation (NSC) began fundamental research on their shaft furnace DRI process on a small scale in 1970 in conjunction with the Iron and Steel Institute of Japan. At the same time, the Hirohata Works and Texaco, Inc were jointly developing a fuel oil partial-oxidation gasifier for producing reducing gas for blast furnace injection. These efforts formed the basic for the design and construction of a shaft furnace pilot plant that started operation in 1971. Reducing gas was generated by the partial oxidation of fuel oil.

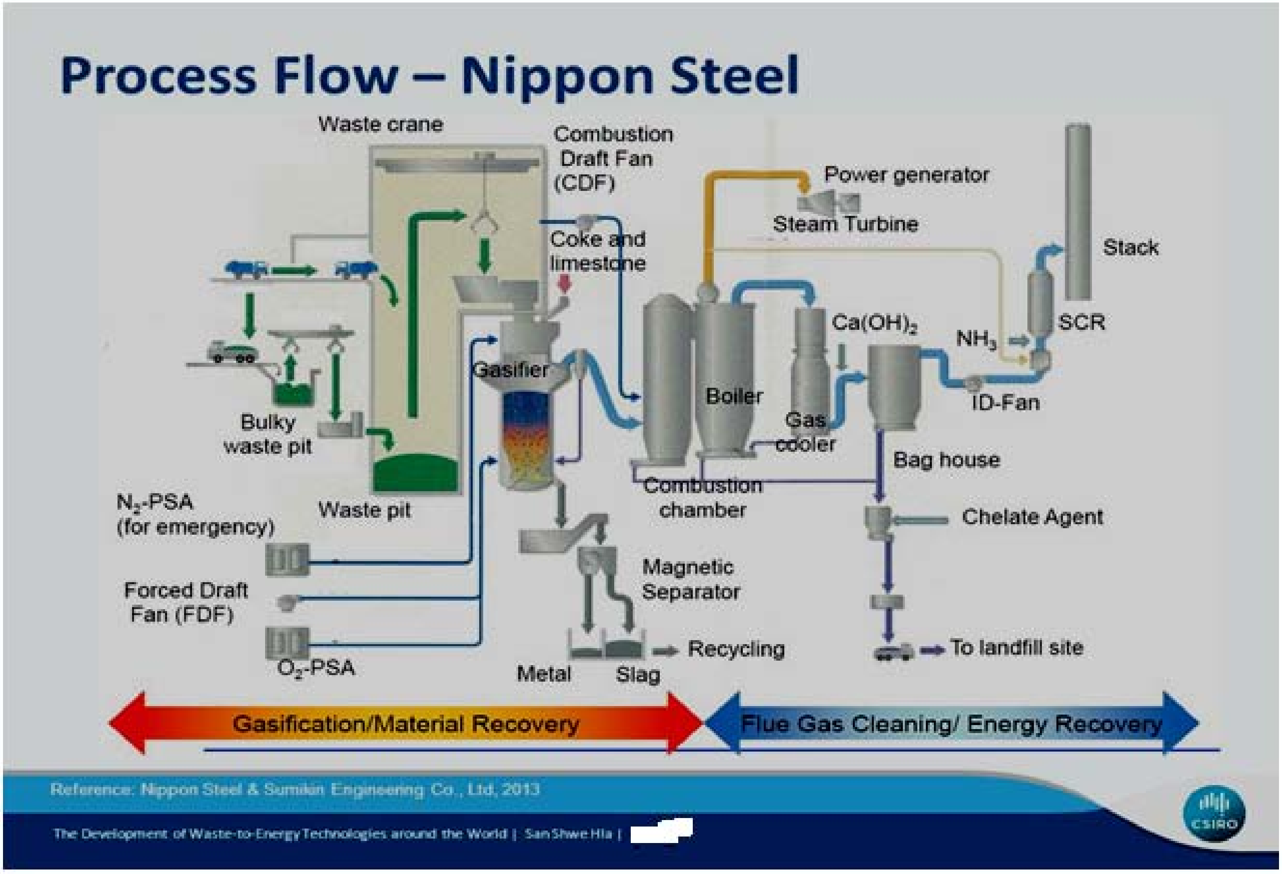
A demonstration plant with a design capacity of 150000 metric ton (165000 net ton) per year of DRI was built by NSC at their Hirohata works. The plant was operated in 1977. The shaft furnace, which exhibits lines similar to the blast furnace, has a 2.1 m (6.9 feet) inner diameter at the lower gas injection point, and is 9 m (29.5 feet) high. The shaft furnace is pressurized up to 5 bars (5 atmospheres) to gain advantage in the recycled system and blowing rate of gas a discussed previously for HYL III. The shaft furnace is equipped with lock hopper charging system, which is pressurized with seal gas to prevent leakage of reducing gas. The burden in the shaft furnace is supported at thew bottom by a table. Hot DRI is removed periodically by the controlled action of scrapers. The DRI collect in an underlying conical section below the table and subsequently flow in to a separate but connected cooling vessel. A flow of recirculated gas cool the DRI to below 100°C (212°F). Carburization is effected in the same unit. NSC proposed briquetting to protect their DRI product from reoxidation.

A Texaco partial oxidation gassifier is employed in the process. It is design for the production of 16700 Nm^3 per hour of gas from 5 metric tons (5.5 net ton) per hour of light oil. The generated gas temperature exceeds 1100^oC (2000^oF temperature) and contains about 87 % hydrogen and cabon monoxide in a ratio of about 10.5 to 1. Recycle shaft furnace of gas temper the generated gas temperature to between 800 and 1000^oC (1475 and 1830^oF) the mixed gas is then injected into the shaft furnace provision are made to remove carbon soot from the gasifier product. However certain amount of soot retards sticking and promote burden movement in the shaft furnace. The process operates with lump ores and oxide pellets, which are, reduce by reaction (1) to (6) as descend by gravity through the shaft furnace countercurrent to the upward flow of gas. Most of the lean gas from the top of the shaft is cooled in a recuperative heat exchanger, cleaned, recompressed, and stripped of CO_2. This gas is then reheated in the recuperated heater followed by a fixed heater is controlled to yield the desired temperature of the reducing gas entering the shaft furnace. The flow of process fuel to the gassifier is equivalent to 9.5 million kilojoules per metric ton (8.2 BTU million net per ton) of DRI additional fuel and power is required for heating and compressing gas and for operation of the unit for CO_2 removal.

The shaft furnace is equipped with a probe from sampling the solid and gas at various elevations. A computer assists in the precise control of operating variables of the plant. The operation confirms the result of single particle reduction studies which indicate that reduction kinetic level of after the pressure is increased by a few atmosphere with no further benefits as the pressure is raised higher.

The process flow diagram of NSC Process is shown in Figure 27.

Figure 27: Process Flow of NSC Process



Shaft Furnace Process (Static Bed)

HYL Process

The HYL process was developed by Hojalata y Lamina S.A. (HYLSA) of Monterrey, Mexico in the HYL process, lump ore and fired plates are produced in the fix bed retorts by performed natural gas.

The first commercial HYL plant was installed at Monterrey and started production late in 1957.this plant has a capacity of 200 metric tons per day (220 net tons per day) of DRI, and the reactor are about 2.5 meters (8 feet) in diameter and hold about 15 metric ton (16.5 net ton) of ore in a 1.5 meter (5 foot deep bed. By 1980, fifteen HYL plants with a total capacity of about 10 million metric ton (11 million net ton) per year of DRI were scheduled to be in operation in world wide. The reactor in the most recent plant are 5.4 meter (17.5 feet) in diameter and 15 meter (50 feet) high. Design capacity is about 1900 metric ton per day (2100 net ton per day) of DRI having a average reduction of about 90 %. The energy consumption in the most recent plant is 14.9 million kilojoules per metric ton (12.8 million Btu per net ton) of 90 % reduced DRI. The more recent plants of the HYL II design (1) use high temperature alloy tube in the reducing gas reheating furnace, which permits heating the gas to the higher temperature, and (2) reduced the number of heating furnace for the original four units to two units. This eliminates thermal cycling of the earlier designs.

In the HYL II process reducing gas (rich in carbon monoxide and hydrogen) is generated, typically by nickel based catalytic reforming of natural gas which is mixed with steam before entering the reformer, Commercial HYL operations use excess steam over stoichiometric requirements, to prevent carbon reformation and promote long catalyst life.

HYL's practice of using the cold reducing gas for both product cooling and carbonization negates any advantage of using catalytic that permit near to stoichiometric steam use.

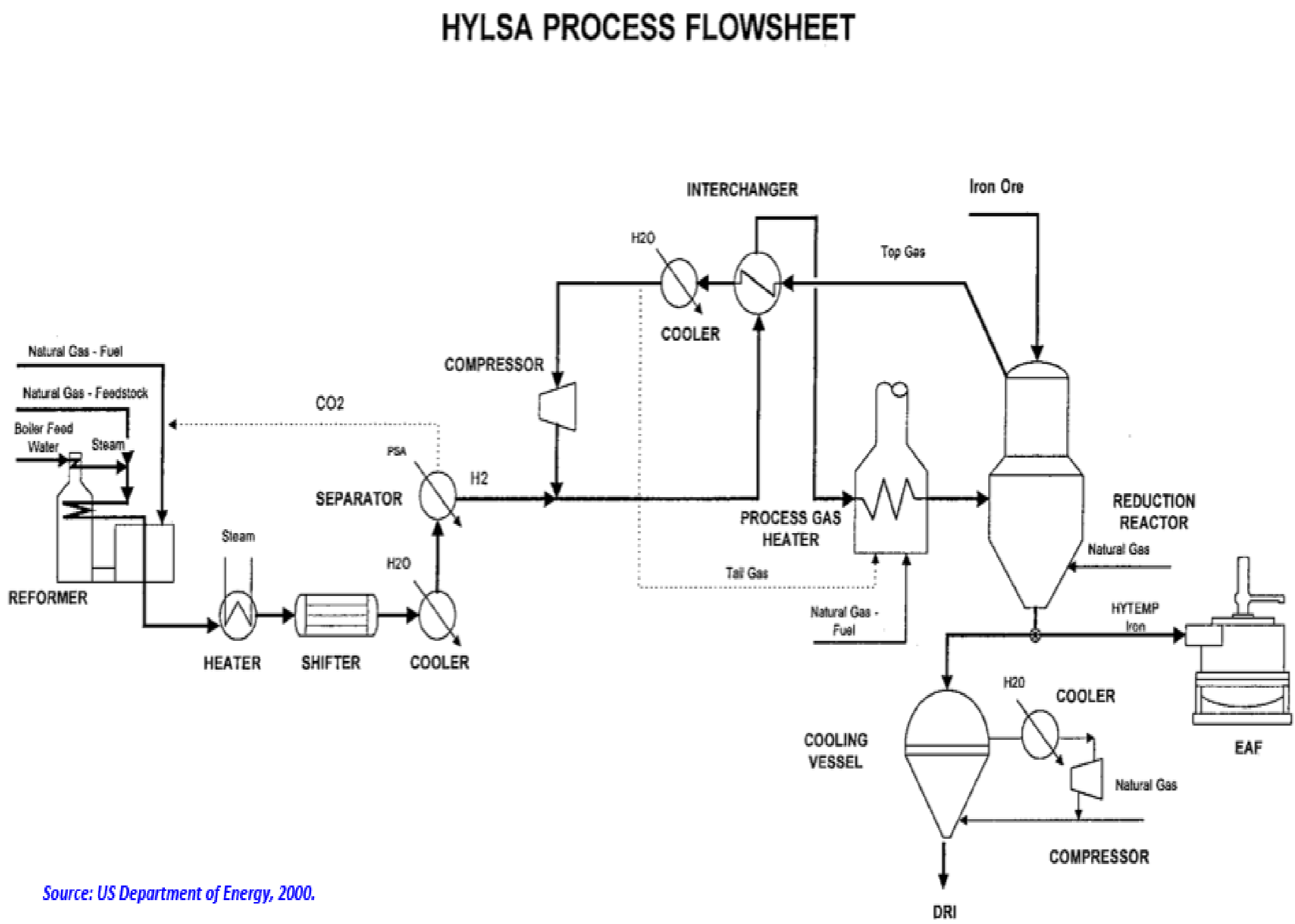
Much of the water vapor in the reformed gas must be removed and quenching is achieved by hydrogen – rich reducing gas. Reformer heat is supplied by the combustion of reduction process tail gas. Process steam for the reformer is produced in a west heat boiler, using the heat in the reformer flue gas. With added boiler capacity, additional steam can be generated to feed steam turbine – driven equipment, thus lowering the electrical energy requirements.

The reducing section consists of a set of four reactors, three of which are in operation while the fourth is engaged in discharging and charging operation. The HYL process is a cyclical batch operation, and three on line reactors operates in series. The reduction of the charge is performed in two stages, an initial reduction stage and main reduction stage. Cooling and carbonization (Fe_3C) and the final adjustment of metallization are performed in the third stage. Each stage of operation takes about three hours. An intricate system of valves permits the reactors to be connected in any desired order so that any one reactor can be connected in its correct process stage.

The flow of reducing gas is counter-current of the iron oxide change stages. The quenched fresh gas from the reformer is used first in the reactor, in the cooling stage that will be discharge as its next operation. The gas then flow through the reactor that is in the main reduction stage, and finally through the reactor that has most recently been charged for the initial reduction stage. Reduction is accomplished according to reduction (1) to (6). Because water is performed during reduction, the reducing gas is quenched when it leaves each reactor to condense the water and enhance the reduction potential of the gas. Before entering the reactors in the reduction stage, the quenched process gas is heated to about 815°C (1500°F) in an indirectly heated gas fired furnace. The gas is further heated to about 1050°C (1925°F) by the combustion of residuals unreformed hydrocarbons with the controlled injection of air at the entrance to the reactor. The process tail gases used to provide fuel for the reformer and for the gas-heating furnace. The reducing temperature in the HYL process is above 980°C. The advantages of using this high reducing temperature are improved reduction efficiency for a hydrogen-rich reduction pyrophoric tendency.

As the product in the cooling stage passes through the temperature zone of about 550°C (1020°F) carbon deposited on the reduced product as Fe_3C (cementite), see reaction (7) and (8). The advantage cited for this cementites shell is protection against reoxidation. HYL practices carbon- level control between 1.0 and 2.5 per cent by adjusting the time that the product remains at this carburization is attained by controlling cooling- gas composition.

Figure 28: HYL Process



Source: US Department of Energy, 2000.

CHAPTER 5 :STATUS OF SPONGE IRON PLANTS IN INDIA

5.1 Questionnaire Survey

Project specific questionnaire was prepared that includes information like name, address, capacity, technology, process details, production details, Energy consumption pattern and raw materials consumption, GHG Estimates etc. Relevant environmental information related to water consumption and wastewater management, air pollution and management, solid waste generation and management, hazardous waste management, plant safety measures were also included in the questionnaire.

Joint Plant Committee (JPC), Ministry of Steel, Kolkata & Sponge Iron Manufacturers Association (SIMA) was contacted for obtaining the list of sponge Iron plants in India. Subsequently, a meeting was held with JPC at Kolkata and Directory of Sponge Iron Units in India was obtained. The questionnaires (Annexure-I) were sent by post/ couriered to the sponge iron plants registered with Sponge Iron Manufacturers Association (SIMA). The questionnaires were sent to all the units on 15th January, 2015. The last date for receipt of the questionnaire was fixed as 15th March,2015.

5.2 Identified stakeholders for consultations

Sl.No.	Name of the Agency/Organization	Focus Area
1	Department of Industrial Policy and Promotion (DIPP)	Department under Ministry of Commerce & Industry, Govt. of India. Apart from regulation and administration of the industrial sector, the role of the Department has been transformed into facilitating investment and technology flows and monitoring industrial development in the liberalized environment.
2	Central Pollution Control Board (CPCB)	Regulatory Body responsible for enforcement of emission norms.
3	Bureau of Energy Efficiency (BEE)	Regulatory body for setting up norms for energy usage pattern as per Energy Conservation Act, 2001.
4	Sponge Iron Manufacturers Association (SIMA)	SIMA represents the Indian DRI Industry and provides a common platform for regular interface with the Government of India and other regulatory authorities. The Association is a common forum for its members to share and exchange each other's experience, views and problems. The Association concentrates on market development, compilation and dissemination of industrial data and technical and commercial information, essential for decision making in the current fast changing business environment.
5	Coal India Ltd (CIL)	Leading supplier of coal in India.
6	Institute of Mineral & Materials Technology (CSIR-IMMT)	Provide R&D support for process and product development with special emphasis on conservation and sustainable utilization of natural resources.
7	NMDC Ltd.	Supplier of Iron Ore in India.
8	National Institute of Secondary Steel Technology (NISST)	Provide trained technical manpower to the secondary steel sector and conduct research, development and design work in frontier areas for providing updated technology to this sector.
9	M/s Orissa Sponge Iron Ltd.(OSIL)	First Sponge Iron Plant in India.
10	M/s Lurgi India Company Pvt. Ltd.	Leading technology provider for sponge Iron units of India.

5.3 Questionnaire Survey analysis

Based on the filled in Questionnaires received from the units, following analysis was done:

Sponge iron, also referred as Direct Reduced Iron (DRI), is mostly used for steel making through conventional melting and treatment process in Electric Arc Furnace or Induction Furnace. It is used widely as substitute to steel scrap. Due to shortage of steel scrap in the country coupled with the extremely volatile international pricing of steel scrap, more and more DRI is now used for steel making in India. Raw materials like iron ore, coal and dolomite are available at competitive prices in the country, hence coal based DRI plants are being established in large numbers. Due to availability of natural gas in western coast of the country, some large DRI plants have been also established. The gas based DRI plants produces DRI and use it spontaneously for steel making or convert the DRI to Hot Briquetted Iron (HBI) for storage and sale. Today India is the largest hub of coal based DRI plants in the world. Production-wise India ranks first in the world. In the present scenario, every week new DRI plants are being established in the country.

Categorization

The coal based DRI plants can be categorized into three classes, namely large, medium and small. Some Plants are having one to two 100 tons/day kilns produce about 33000 tons/annum of DRI. These plants do not have Waste Heat Recovery Boilers (WHRB) or Fluidized Bed Combustion (FBC) Boilers to utilize the char and coal fines for producing steam / power. Due to their small size and lack of capability to utilize waste heat and char (solid waste), they are categorized as small DRI plants. Plants having more than two numbers of 100 TPD kilns, producing more than 165000 tons/annum of DRI are categorized as large DRI plants or having one to two 500 TPD kilns. Plants producing in between 33000 Tons/annum and 165000 tons/annum or having one or two 300/350 TPD kilns in combination are categorized as Medium DRI plants.

Location

The DRI plants in India are mainly located close to the source of raw material. The DRI plants are located in the following districts:

a. Durg, Raipur, Bilaspur, Raigarh in Chattisgarh (Coal from South Eastern Coalfields and Iron Ore from Northern Orissa)

b. Bhandara, Chandrapur and Nagpur in Maharastra (Coal from Western Coalfields and Iron Ore from Northern Orissa)

c. Jharsuguda, Sundergarh, Rourkela, Barbil, Joda, Keonjhar in Orissa (Coal from Mahanadi Coalfields and Iron Ore from Keonjhar District)

d. Jhargram, Ranigunj, Durgapur, Bankura, Purulia in West Bengal (Coal from Eastern Coalfields and Iron Ore from Northern Orissa)

e. Jamshedpur, Chandil, Chaibasa, Giridih, Koderma, Hazaribagh in Jharkhand (Coal from Central Coal fields and Iron Ore from Northern Orissa)

f. Khammam, Kurnool in Andhrapradesh ((Coal from Southern Coalfields and Iron Ore from Karnataka)

g. Hospet, Bellary in Karnataka (Coal from Southern Coalfields and Iron Ore from Karnataka)

h. Goa (Coal from Southern Coalfields and Iron Ore from Goa)

i. Hazira [Gujarat Coast] and Raigad [Maharashtra coast] (Natural Gas from Bombay High and Tapi Estuary and Iron Ore lump from Karnataka by sea route and Iron Ore pellet from Pellet Plants near Visag in Andhra Pradesh by sea route.

Easy availability of raw material : The distribution of the iron ore and non-coking coal in India is restricted chiefly to the Eastern, South-Eastern and in some parts of the Deccan Plateau. This is the reason behind the boom of coal based DRI plants in the Orissa-Chattisgarh-Jharkhand-West Bengal region. The location of the iron ore mines in Banspani - Barjamda, in the Keonjhar– Sundergarh area of northern Orissa and the Gua-Chiria mines in Jharkhand have additionally helped the coal based DRI Plants to come up in this area. Coal based DRI units in the western Maharashtra-Goa-Karnatak region have come up depending on the proximity of the iron ores mines in Goa and Bellary - Hospet -Chikamglur region (Karnataka).

Easy availability of Gas : Whereas the presence of the Natural Gas fields in the Gujarat and Bombay high area have played the key role in the development of the gas based DRI plants in this area. Iron ore lump and pellet from the East coast is transported by ships and delivered to convenient ports in Gujarat and Maharashtra. This very reason prevents certain portions of the country like the North, North West and South region from becoming the hub of coal or gas based DRI plants.

Proximity of Market and other Infrastructure : The setting of a DRI plant is also dependent on the proximity of the secondary steel making market and related infrastructure like road, rail and ports. For example, the future boom of DRI plants in Gujarat can be attributed to the availability of the port facility in the Arabian sea which are used to bring the raw material in from the interiors of the country as well as for the dispatch of finished product. Another reason, which contributes significantly to the cause is the setting of many Induction Furnaces and Electric Arc Furnaces, which are essentially dependent on these DRI plants for supply of sponge iron. The North East, blessed with ample amount of natural gas, is yet to become a hot spot for DRI generation, which could be blamed to the lack of necessary infrastructure like ports, rail and road and more importantly the secondary steel making market.

Potential areas : The South Eastern coast line of India, viz. Tamil Nadu and Andhra Pradesh holds ample potential for the development of the coal based DRI plants, because of their proximity to the iron ore mines and coal fields as well as good connectivity. Few gas-based plants would come up in Krishna Godavari basin of Andhra Pradesh due to the availability of Natural Gas and iron pellets from Kudremukh, Mangalore and Bailadila. Gas based DRI plants will be equally possible in the western coast of India near the central to southern part of Karnataka or in the northern part of Kerala. The availability of iron ores in the Bellary-Hospet and in the Kudremukh and the supply of cheap natural gas from Bombay High through gas pipelines will make these plants viable.

Process Technology

The DRI is produced in India by two different process, namely the coal based and the gas based process. Numerous standard as well as customized technologies are available for both the processes. For coal based plants, SL/RN (Lurgi) technology has been widely used but later the promoters resorted to customized process (Rotary kiln type). OSIL uses a unique patented reactor for production of sponge Iron called a ported reactor. The reactor is a rotary kiln and is the heart of the reduction process. It is lined with castable refractory. The reactor is supported on three piers and is driven by two DC drive motors through a common girth gear. The customized process are minor modification of Lurgi Technology and are supplied under the style of Jindal process, TDR process, SIIL process, Popurri process, etc.

Available Module Size

Coal based plants are available in module sizes in the range of 100 tpd (30,000 tpa), 200 tpd, 300/350 tpd (100,000/120,000 tpa) and 500 tpd (150,000 tpa).

Preferred Raw Material Characteristics

It was found from the survey that the principal burden material used for production of steel making grade DRI in the sponge making process is iron oxide lump ore, non-coking coal and lime stone/dolomite. The iron ore should be preferably high in Fe content (>65% Fe) and non-decrepitating type. Coals with a high reactivity and high fusion temperature are preferred. The coal should also be non-coking. A low ash fusion temperature is undesirable as it promotes formation of accretions in the kiln. The coal ash composition is also important as a siliceous ash might react with ferrous oxide to form low melting ferrous silicate and interfere with the reduction to metallic iron.

TYPICAL RAW MATERIAL CHARACTERISTICS

i) Iron ore lump

Fe : 65 % (min.)

SiO2 + Al2O3 : 3.5 % (max.)

S : 0.02 %(max.)

P : 0.035%(max.)

Size : 5-20 mm

ii) Coal (dry basis)

Fixed C : 42.5 % (min.)
Ash : 27.5 % (max.)
VM : 30 %
S : 1.0 % (max.)
Moisture : 7 % (Max.)
Reactivity : 1.75 cc of CO/gmC/sec
Caking index : 3 max.
Size : 0 - 20 mm

iii) Limestone

SiO_2 : 8 % (max.)
CaO : 46 % (min.)
MgO : 8-10 %

iv) Dolomite

SiO_2 : 5 % (max.)
CaO : 28 % (min.)
MgO : 20 %

3.32 Typical Product Charachteristics

The typical sponge iron (coal based) characteristics are as follows:

Fe (total) : 92 % (min.)
Fe (Met.) : 83 % (min.)
Metallization : 90 % (min.)
Carbon : 0.25 % (max.)
S : 0.025 % (max.)
P : 0.06 % (max.)
Re-oxidation : Non-pyrophoric characteristics

Major Facilities of Coal Based DR Plant

a) Reactor
b) Cooler
c) Off gas handling
d) Reactor feed system
e) Product processing
f) Briquetting (Optional)
g) Instrumentation & control
h) Electrics
i) Dust collection and disposal system
j) Water system
k) Compressed air system
l) Fuel oil facility
m) Fire fighting
n) Air-conditioning & ventilation
o) Emergency DG set
p) Raw material, product storage and handling
q) Repair shop and store
r) Laboratory

5.4 Key Performance Indicators and The Existing Scenerio

The details of questionnaire survey pertaining to four critical parameters are given in the table below.The analysis of the data received for medium sized annual capacity sponge iron plants and comparison with benchmark level is summarized in the following table.

Sl. No.	Specific Consumption	Unit Value	Benchmark Level	Actual Data*
1	**Iron Ore**	**T/Ton**	**1.55**	**1.65**
2	**Coal**	**T/Ton**	**1.50**	**1.55**
3	**Electricity**	**kWh/Ton**	**100**	**217**
4	**Thermal Energy**	**G.Cal/Ton**	**5.75**	**5.80**

***Note:The Actual data is computed on the basis of received questionnaire data**

5.4.1 General outlook of green house emission measures and practice adopted in India

Inside the rotary kiln, the DRI gases flow counter-current to the kiln feed. The temperature at the product discharge end in a rotary kiln is about 950-1050^{o}C compared to 750-900^{o}C towards the feed end. The counter-current flow of hot DRI gases enable it to remove the moisture content from feed. The hot DRI gases contains huge amount of fine dust comprising oxides and unburnt carbon and toxic carbon monoxide. It needs treatment before discharging into the atmosphere.

The raw material feed side of rotary DRI Kiln has a natural structure below the After Burner Chamber (ABC) that acts as Dust Settling Chamber (DSC). About 15-20% coarse dust settles in DSC by means of gravity. In ABC, the CO content of gases is converted to CO_2. This conversion process is exothermic and the temperature of gases rises to 1000-1050^{0}C.

Some plants (very few) have Gas Conditioning Tower (GCT) followed by pollution control equipment and cleaned gas is emitted through stacks mostly of 30 m in height.

In most of the Plants where Popuri technology is involved there is no pollution control equipment provided to clean the waste gas. Some of the plants are adding pollution control facilities to clean the gas at present to comply with statutory requirements and is under erection stage.

In some of the bigger size plants, the heat content of hot gases is utilized to generate steam through Waste Heat Recovery Boilers (WHRB). The steam is used to operate small size turbines to produce electricity. The exhaust gases coming out of WHRB, having temperature around 150-175^{o}C is taken to pollution control equipment for particle separation. Different industries using different type of pollution control equipment like Bag filter, scrubber and some also have Electrostatic Precipitators (ESP). The clean gas is let out through stacks. There is no basis for calculation of stack height.

The old rotary kiln DRI plants have used Gas Cleaning Plant (GCP) based on Venturi Scrubbers (wet cleaning) for the treatment of DRI gases. This system generates dust bearing sludge, that needs separate handling and disposal. However, this system can take care of particulate matter as well as gaseous pollutants. No new plants are using GCP.

The Suspended Particulate Matter (SPM) content of treated DRI gases of rotary kiln have been reported by these industries to State Pollution Control Board (SPCB) of their state as to be less than 150 mg/Nm^3 in all the plants, irrespective of the pollution control devices applied. Rotary kiln DRI plants have emergency stack/safety cap above the ABC of feed end column. The safety cap is required to maintain the positive pressure inside the kiln and avoid chances of CO related explosion. In many of the plants it is observed that continuous black smoke was discharged from this cap. At night the flame cum black smoke is more visible. The owners resort to this practice of discharging untreated emissions from the cap and bypassing GCP /GCT + ESP which pollutes the atmosphere.

5.5 Issues & Challenges faced by the Sponge Iron Industry

Indian Sponge Iron sector faces some serious challenges which affect the energy efficiency of the industry. Though certain problems can be solved by the industry itself, some factors are beyond the control of the industry.

Factors which are beyond the control of the industry and which affects the energy efficiency to a large extent are:

Inferior quality of coal

Quality of coal, in terms of calorific value and ash percentage, available to iron & steel industry is deteriorating by day which in turn decreases the energy efficiency of the industry.

Raw material price volatility

The price of raw materials has become a major factor of concern for the Indian sponge Iron producers. All the major steel producers in India are trying to secure raw material for their future needs by acquiring mines or entering into joint ventures. Strict land acquisition laws can slow the process. The volatility in price of raw materials has also increased the cost of steel making.

Vintage of the plants

Vintage of the plants has a key role in higher energy consumption of Indian plants. Many of the public sector units are old plants with vintage technologies. Introduction of new technologies in these plants proves to be very tedious and thus hindering the progress of energy efficiency activities.

Cost of energy efficiency

Any modification in the process for energy efficiency activities in steel plant is capital intensive. Therefore, several plants are apprehensive to go ahead with energy efficiency activities. The industrial lending rates of the banks are very high in India and thus the Internal Rate of Return (IRR) is also high. This makes projects less attractive. In addition to this, there are no separate funds available for energy efficiency activities.

CHAPTER 6: BEST PRACTICES TO REDUCE GHG EMISSIONS

6.1 Improving Energy Efficiency: The sponge Iron (DRI) units use coal for process requirement and for heat requirement. Electricity is used for all motive loads for process equipments. Fuel oil is used for transportation in the plant & Emergency power through DG Sets. Raw material like Iron Ore, Coal & Dolomite are procured from nearby mines or are imported. All the units are utilizing horizontal kilns in combination of kiln capacities of 100 tpd, 300/350 tpd & 500 tpd. The following Energy Conservation options have been identified/implemented by the units so as to reduce Green House Gases Reduction:

a. **Generate Electrical Power from Waste Gas of DRI Kiln:**In the sample sponge iron production process produces Sponge Iron through Direct Reduced Iron (DRI) process and has a kiln with production capacity of 350 TPD, flue gases of about 90,000 Nm^3/hr at 950 to 1100^{0}C are generated. The volume of the flue gases depends on the production of the DRI kiln. Under normal process operations, this heat is lost to the atmosphere as the gases are vented to atmosphere without heat recovery. A Waste Heat Recovery (WHR) based power project can be installed on the new Direct Reduction Iron (DRI) kiln. The project activity is installation of a Waste Heat Recovery Boiler (WHRB) with a steam generation capacity of 38 tons per hour (TPH) by recovery of latent heat from in the flue gases of the DRI kiln. The waste flue gases of sponge iron kiln are passed through WHRB and steam is generated at a pressure of 66 kg/cm^2 and temperature of 490^{0}C. The exhaust gases after heat recovery at 160 - 180 ^{0}C are passed through Electrostatic Precipitator (ESP) and released to the atmosphere. The steam produced in WHRB can produce power of about 8 MW, when the DRI kiln is operated at its rated capacity. The plant can also install a 24 TPH rated Atmospheric Fluidized Bed Combustion (AFBC) boiler, where char and coal rejects are used as fuel. Steam generated by both WHRB and AFBC boilers is combined at a common header and supplied to steam turbine generator set of 12 MW for electricity generation which is used for captive consumption. In the absence of the project activity, the flue gases at high temperature would have been released to the atmosphere, which is a common practice in the sponge iron industries and the equivalent amount of electricity would have been generated by coal based power plant or imported from grid. Hence, the utilization of waste heat by project activity will reduce greenhouse gas emissions.

Case Study-1: Generate Electrical Power from Waste Gas of DRI Kiln		
Parameters	**Unit**	**Value**
Actual Gas Flow rate	**Nm^3/Hour**	**90,0000**
Temp. of Flue Gas	**^{0}C**	**950-1100**
Actual Steam Generation	**MT/Hr**	**38**
Steam Pressure	**Kg/cm^2**	**66**
Steam Temp.	**^{0}C**	**490**
Power Generated	**MW**	**8**
Total Energy Generation in One Day	**UNITS(Kwh)**	**192000**
Daily GHG saving (kg CO_2)	**kg CO_2 /Day**	**192000*.537=103104**
Annual GHG saving	**TCO_2/Year***	**25776**
Sponge Iron Sector Annual GHG saving (T CO_{2e}) for Total 12** Such Plants	**Million TCO_2/Year**	**0.31**
***Note: Total Operating Days in One year are assumed to be 250 days**		
****Note:As per CPCB data There are around 12 such plants with capacity of 100,000 to 120,000 tpa**		

b. Use Heat of Kiln Exhaust Gas to Produce Chilled Water For Retrofiting Absorption Chiller

From DRI kiln off gas available, a part of this kiln exhaust gas can be used to generate steam at 8.00 Kg/cm^2 and this can be used to run absorption chiller-which will meet administrative office as well as plant control room A/c load. In tropical zone, the average temperature during summer months shoots up to above 42^{0}C and falls in hot and dry zone for about ten months causing human discomfort. It is recommended to use DRI kiln off gas partially to generate steam at 8 Kg/cm^2 in a waste heat boiler. The steam thus produced will be driving force for absorption chiller replacing the energy consuming air conditioners. The chilled water at 5^{0}C if circulated through AHUs will provide desirable comfort without appreciable consumption of electricity. However, the payback period depends on the cost of electricity per unit.

c. Install cogged type Flat Belt for motor Drives

Most of the drives in this sponge iron plant are V-belt drive. The Vee belt use trapizodial cross section to create wedging action on the pulleys to increase friction and improve the belts power transfer capability. Vee blets drive can have peak efficiency of 95-98% at the time of installation. The transmission efficiency drops over time if slippage occurs because Vee belts are not periodically tensioned apart from increase in electricity consumption due to higher resistance and frictional losses. Cogged belts have slots that run perpendicular to the belts length. The slots reduce the interface resistance of the belts without compromising the transmission efficiency and at the same time reducing the electricity consumption. Cogged belts can be used with the same pulley as equivalent rated V belts. They run & lasts longer and have an efficiency margin of at least 2% over vee belts.

Case Study- Install cogged type Flat Belt for motor Drives		
Parameters	**Unit**	**Value**
***Specific Power Consumption**	**Kwh/Ton**	**217**
****Annual Production**	**Tonnes/Year**	**100,000**
Annual Power Consumption for Belt Driven Equipments	**Units(Kwh)**	**217X10^5**
Power saving by Installing Cogged Type Belts	**Units/Year**	**4.34X10^5**
Annual GHG saving	**TCO$_2$/Year**	**233**
***Note: Specific Power Consumption as per Section 5.4 of report**		
****Note:As per Available Module sizes Section 5.1 of report**		

d. Waste Heat Utilization by Iron Ore preheating in Sponge Iron Plant

Proportionate amount of Iron Ore along with feed coal and dolomite is fed at ambient temperature to the kiln through a feed pipe. It is recommended to install iron ore pre-heater (rotary drier) to utilize a part of heat content of kiln off gases released during manufacture of sponge iron in rotary kiln. The charge pre-heater will utilize sensible heat content of flue gas released at 950^{0}C from individual kiln to preheat incoming iron ore from 400C to 750^{0}C, thus reducing coal consumption.

Case Study- Waste Heat Utilization by Iron Ore preheating in Sponge Iron Plant		
Parameters	**Unit**	**Value**
***Specific Iron Ore Requirement**	***T/Ton***	**1.65**
****Daily Iron Ore feeding rate for 350 TPD capacity Plant**	**Tonnes/day**	**1.65X350=577**
****Hourly Iron Ore feeding rate for 350 TPD capacity Plant**	**T/Hr**	**24**
****Hourly Coal feeding rate for 350 TPD capacity Plant**	**T/Hr**	**23**
Specific Heat of Iron Ore	**Kcal/Kg/^{0}C**	**0.140**
Temp Range Iron ore required to Heated	**^{0}C**	**750-45=705^{0}C**
Total heat Energy Utilized & Required from Klin Exhaust Gas	**Kcal/Hr**	**24X10^{3}X.140X705=2.36X10^6**
Total Heat supplied by Burning Coal at Existing Rate	**Kcal/Hr**	**23X1000X4100***=94.3X10^6**
Total quantity of coal saved by Pre-Heating Ore	**T/Hr**	**0.575**
Annual Coal savings	**T/Year**	**0.575X24X250=3454**
Annual GHG Emission Reduction Potential	**TCO_2/Year**	**3454X2.6****=8980**
***Note: Specific Iron ore Consumption as per Section 5.4 of report**		
****Note:As per Available Module sizes Section 5.1 of report**		
*****Note: GCV of Coal is Taken 4100 Kcal/Kg for calculation**		
******GHG Emission Equivalence for Coal is 2.6 TCO_2/Ton of Coal**		

e. Removal of Moisture from iron ore by waste gas

DRI kiln off gas is available at 24000 Nm^3/hr and 950^{0}C, while iron ore contains around 1.29% moisture. This wet iron ore is fed to the DRI kiln. A part of kiln off gas can be used counter currently to remove moisture from Iron Ore. It is recommended to remove moisture in iron ore up to bone dry condition. It is also recommended to divert a part of the off gas through a rotary drier and counter currently admit iron ore against gas stream. Rotary feeder may be used to avoid false air entry.

f. Injecting oxygen with combustion air in the kiln

Oxygen enrichment is a flexible, efficient, and cost-effective technology that can improve combustion in all types of kilns. Oxygen enhances the combustion of all fuels, enabling improved burning zone control, greater kiln stability, and lower emissions. By increasing the oxygen concentration of combustion air through the addition of relatively pure oxygen, flame temperatures rise, heat transfer rates improve, and overall combustion efficiency increases.

g. **Install Energy Efficient Motor :**Motors are used in most buildings for compressors, HVAC systems, and pumps. A motor is considered energy efficient if it meets or surpasses the efficiency value. What sets efficient motors and regular motors apart are design, materials, and manufacturing techniques. These improved features help motors obtain a higher level of efficiency and perform tasks using less energy than their less efficient counterparts. The upfront cost of an energy efficient motor is higher than a conventional motor, but the payback is relatively quick, roughly 1-2 years, depending on the model. Because these motors are made with better designs, materials, and manufacturing techniques, they need to be replaced less and are more reliable. Thus, upgrading the motors leads to both cost and energy savings.

h. Suitable options towards Installation of variable speed drive for major electrical drives such as kiln & cooler main drive motor, lobe compressor, volumetric feeder, coal crusher, kiln shell air fans, ID fan etc

A variable-frequency drive (VFD) (also termed adjustable-frequency drive, variable speed drive, AC drive, micro drive or inverter drive) is a type of adjustable-speed drive used in electro-mechanical drive systems to control AC motor speed and torque by varying motor input frequency and voltage. VFDs may be installed for major electrical drives such as kiln & cooler main drive motor, lobe compressor, volumetric feeder, coal crusher, kiln shell air fans, ID fan etc thus reducing the Energy consumption.

i. Kiln Shell Painting with heat resistant Paint to reduce the radiation temperature

The thermal losses depend largely on the surface temperature. Every 25 ^{o}C increase in the surface temperature will increase the thermal loss by approximately 17% with the same surface emissivity at 0.9. The paint emissivity has a significant effect on the kiln surface heat transfer. Lower emissivity paint decreases thermal losses but increases the kiln surface temperature. A large increase of the kiln surface temperature is not ideal because it will cause structure problems induced by large differential thermal expansion between the metal shell and the bricklayer. Therefore, the proposed paint with an emissivity of 0.65 is appropriate to reduce the paint temperature.

Figure 29: Application of Heat Shield Paint on the outer surface

j. Use of "Thermact" as additives in feed coals for proper combustion of coal inside the Kiln(efficiency improvement)

Cost of Coal forms the major part of the total production cost of sponge Iron. With the continued escalation in the price of coal, the generation cost has been going upward. The higher unburnts in fly and bottom ash, SPM & SOx levels have been the major problems for DRI units from the environmental point of view. This acts as a major constraint in selection of coal , especially in situations where the company is forced to go for low ranking coal. In such a scenario, the need of the hour is to reduce the cost of fuel as well as the emission levels and overcome operational problems.

THERMACT, a multifunctional solid fuel additive, specially developed to improve the combustion efficiency of solid fuels and contains proprietary combustion catalyst, which help in complete combustion of coal thereby reducing the unburnt particles in ash. THERMACT also helps in reduction of SPM. The unique catalyst present in THERMACT takes advantage of the inherent moisture present in solid fuels to generate gases like CO , H_2 and Oxygen which help in extraction of more heat from the fuel. THERMACT also helps in reduction of excess air requirement thereby preventing heat losses. This helps in reduction of problems related to combustion and associated costs of energy generation, thereby resulting in Efficiency Improvement.

Figure 30: Arrangement showing feeding of Thermact (catalyst) inside the kiln

k. Covering the coal heap at yard to reduce wind loss

The stockpiles in the coal yard area should be kept limited to reduce the number of exposed surfaces from prevailing wind. This will reduce the quantity of coal from being carried away by wind thereby reducing the wind losses.

l. Covering coal in transit (wagon & truck) to reduce loss

The procurement of coal in most of the Sponge Iron units is done through truck, train or conveyor. As a result, loss of coal occurs during transit of coal to the plant. It is recommended to cover the coal in transit (wagon & truck) to reduce coal loss.

m. Robust preventive and Predictive maintenance

Frequent kiln breakdown due to mechanical, electrical and operational interruptions have a significant effect on Kiln availability which also leads to poor efficiency. It can be overcome by implementing best maintenance planning and Robust Preventive and Predictive Maintenance.

n. Improving campaign life

Frequent kiln shutdown due to accretion formation, DSC clinker formation and refractory damage affects its capacity utilization and also consume more energy in reviving the kiln.

This can be overwhelmed by Better Process Control and monitoring, Selection and Application of quality refractory material and Restriction of Undersize in feed material.

o. Improving Production Rate

Reasons for Low Production rate identified leading to low capacity utilization are Low Yield, Process Interruptions at Central Burner, Feeding and Injection systems which can lead to increase energy consumptions.

This can be achieved by

- Proper blending of Imported & Domestic coal to maintain required F.C.
- Utilization of high TI Pellet
- Conducted Fe Balancing to analyze yield losses.
- Fabrication of CB & Coal Injector Trolley for fast operation.
- Restriction of Undersize in material

p. Improvement in Operational losses

There are various operational losses which needs to be saved for efficient energy conservation. These are Major Losses, Emission of flue gas from slip seal, Cooler Discharge and stack cap, Radiation losses, Spillages from feed and injection area and Yield Losses. Various initiatives can be taken to minimize the same. These initiatives are

- Better sealing done in stack cap to capture fugitive emission;
- For Better sealing, pneumatic cylinders installed at slip seal to maintain gaps in seals;
- Thorough inspection of old and worn out refractory and application of best quality refractory which reduced in radiation losses;
- Inspection of spillages if any and arresting;
- Using minimum coal during Shut down & Light up and following Ramp up plans;
- D.P. Valve Installation at Cooler Discharge.

6.2 Waste Minimization/Pollution Control Measures

6.2.1 Air Pollution

Stack Emission from Kiln

Adequately designed ESP or any other adequate air pollution control system/combination of system should be installed to achieve the prescribed stack emission standards.

As installation and operation of Pollution Control Equipment for plants with less than 100 TPD capacity is not economically viable, therefore, it is recommended that plants with less than 100 TPD shall not be permitted in future.

i. Program for phasing out old plants having capacity less than 100 TPD shall be worked out by the State Pollution Control Board.

ii. All Pollution control equipment should be provided with separate electricity meter and totaliser for continuous recording of power consumption. The amperage of the ID fan should also be recorded continuously. Non-functioning of Pollution control equipment should be recorded in the same logbook along with reasons for not running the Pollution Control Equipment.

iii. The safety cap/emergency stack of rotary kiln type plant, which is generally installed above the After Burner Chamber (ABC) of feed end column, should not be used for discharging untreated emission, bypassing the air pollution control device.

iv. In order to prevent bypassing of emissions through safety cap and non-operation of ESP or any other pollution control device, software controlled interlocking facility should be provided on the basis of real time data from the plant control system, to ensure stoppage of feed conveyor, so that, feed to the kiln would stop automatically, if safety cap of the rotary kiln is opened or ESP is not in operation. The system should be able to take care of multiple operating parameters and their inter relations to prevent any possibility of defeating the basic objective of the interlock. The system should be foolproof to prevent any kind of tempering. The software based interlocking system, proposed to be installed by industry should be get approved by the concerned State Pollution Control Board, for its adequacy, before installation by the industry.

v. Mechanical operated system for timely collection and removal of the flue dust generated in ESP or any other pollution control device shall be installed.

Stack Emission from de-dusting units

All de-dusting units should be connected to a stack having a minimum stack height of 30 m. Sampling porthole and platform etc. shall be provided as per CPCB emission regulation to facilitate stack monitoring. De-dusting units can also be connected to ABC Chamber and finally emitted through common stack with kiln off-gas emissions.

Fugitive Emission

The measurement may be done, preferably on 8-hour basis with high volume sampler. However, depending upon the prevalent conditions at the site, the period of measurement can be reduced.

6.2.2 Effluent Discharge

i. All efforts should be made to reuse and re-circulate the water and to maintain zero effluent discharge.

ii. Storm water / garland drain should be provided in the plant.

6.2.3 Noise Control

The industry should take measures to control the Noise Pollution so that the noise level standards already notified for Industrial area are complied.

6.2.4 Solid Waste Management

Char

- Char should be mixed with coal or coal washery rejects and used as fuel in Fluidized Bed Combustion Boilers (FBC) for generation of power. The plants having capacity 200 TPD and above should install Fluidized Bed Combustion Boilers (FBC) for generation of power. Also the smaller capacity individual Sponge Iron Plants (Capacity upto 100 TPD) and operating in cluster can collectively install common Fluidized Bed Combustion Boilers (FBC) for power generation. The Sponge Iron Plant are free to explore other options / possibilities to use char for generation of power. Char can be sold to local entrepreneurs for making coal briquettes. It can also be mixed with coal fines, converted to briquettes and used in brick kilns.
- Under no circumstances char should be disposed off in agricultural fields/other areas. Logbook for daily record, of Char production and usage must be maintained by the industry and the record shall be made available to officials of CPCB/SPCB/PCC during inspection.

Kiln Accretions

The kiln accretions are heavy solid lumps and can be used as sub- base material for road construction or landfill, after ascertaining the composition for its suitability and ensuring that it should not have any adverse environmental impact.

Gas Cleaning Plant (GCP)/Scrubber Sludge

The sludge should be compacted and suitably disposed off after ascertaining the composition for its suitability and ensuring that it should not have any adverse environmental impact.

Flue Dust / Fly ash

i. Flue dust is generated from air pollution control system i.e. ESP or any other air pollution control system installed with kiln. Secondary flue dust is also generated from Bag Filters or any other air pollution control equipment installed with Raw Material Handling, Coal Crusher, Cooler Discharge and Product house unit. The reuse/ recycling of the flue dust generated / collected may be explored and suitably implemented.

ii. Fly ash brick manufacturing plant should be install for fly ash utilization. Fly ash can be utilized in cement making by Cement industry also.

Bottom Ash

Bottom ash may have objectionable metallic compounds, therefore should be stored in properly designed landfills as per CPCB guidelines to prevent leaching to the sub-soil and underground aquifer.

General

Solid waste management program should be prepared with thrust on reuse and recycling. Solid waste disposal site should be earmarked within the plant premises. The storage site of solid waste should be scientifically designed keeping in view that the storage of solid waste should not have any adverse impact on the air quality or water regime, in any way.

The various types of solid wastes generated should be stored separately as per CPCB guidelines so that it should not adversely affect the air quality, becoming air borne by wind or water regime during rainy season by flowing along with the storm water.

6.2.5 Raw Material handling and Preparation

i. Unloading of coal by trucks or wagons should be carried out with proper care avoiding dropping of the materials from height. It is advisable to moist the material by sprinkling water while unloading.

ii. Crushing and screening operation should be carried out in enclosed area. Centralized de-dusting facility (collection hood and suction arrangements followed by de-dusting unit like bag filter or ESP or equally effective method or wet scrubber and finally discharge of emission through a stack) should be provided to control Fugitive Particulate Matter Emissions. The stack should confirm to the emission standards notified for de-dusting units. Water sprinkling arrangement should be provided at raw material heaps and on land around the crushing and screening units.

iii. Work area including the roads surrounding the plant shall be asphalted or concreted.

iv. Enclosure should be provided for belt conveyors and transfer points of belt conveyors.

The above enclosures shall be rigid and permanent (and not of flexible/ cloth type enclosures) and fitted with self- closing doors and close fitting entrances and exits, where conveyors pass through the enclosures. Flexible covers shall be installed at entry and exit of the conveyor to the enclosures, minimizing the gaps around the conveyors.

In the wet system, water sprays/ sprinklers shall be provided at the following strategic locations for dust suppression during raw material transfer:

- Belt conveyor discharge/ transfer point
- Crusher/screen discharge locations

6.2.6 Waste Heat Recovery Boiler (WHRB)

Sponge Iron Plants of capacity more than 100 TPD kilns shall use Waste Heat Recovery Boiler (WHRB) for generation of power.

6.2.7 Cooler Discharge and Product Separation Unit

Permanent and rigid enclosures shall be provided for belt conveyors and transfer points of belt conveyors. Dust extraction cum control system preferably bag filters or ESP to arrest product loss in cooler discharge and product separation area shall be installed.

6.2.8 Char based Power Plant

For plant having capacity of 200 TPD of cumulative kiln capacity, the power production through FBC boiler using char as a part of fuel, is a viable option. Power generation through FBC boiler using char as a part of fuel be implemented in a phased manner within 4 years of commissioning and targeting for 100% utilization of char.

Individual Sponge Iron Plants of capacity upto 100 TPD and located in cluster can install a common char based power plant collectively.

6.2.9 New Sponge Iron Plants

i. No New Sponge Iron Plant will be commissioned without installation of Pollution control systems as stipulated in the Standards. The concerned State Pollution Control Board will accord consent to operate only after Physical verification of the adequacy of the Installed pollution control systems for meeting the standards and stipulated conditions in the consent to establish.

ii. All new kilns shall have the independent stack with the kiln or multi-flue stacks in case two or more kilns are joining the same stack for better dispersion of pollutants.

iii. Any entrepreneur having more than 2x100 TPD kiln may install WHRB for power generation, as it's a techno-economic viable option. For plants having capacity of 200 TPD or more, power generation using char in FBC Boiler as part of fuel is techno-economic viable option, therefore, new plants must install FBC boiler for power generation at the time of installation of the industry.

iv. Any new sponge iron plant being installed along with the other downstream facilities of converting the sponge iron into steel with/without further processing the steel should meet the target of 100% utilization of sensible heat of DR (Direct Reduction) Gas and Char for power generation. Wet scrubbing system for kiln off-gas treatment for such plants should not be opted.

6.2.10 General Guidelines

i. Extensive plantation/Green belt shall be developed along the roads and boundary line of the industry. A minimum 15 m width Green Belt along the boundary shall be maintained. However, the green belt may be designed scientifically depending upon the requirement and local and mix species of plants may be selected for the green belt.

ii. Monitoring of stack emissions, fugitive emissions, trade effluent and noise level shall be done as per CPCB regulations.

iii. Pollution control systems shall be operated as an integral part of production to ensure minimum emissions. Pollution Control System shall start before conveyor operation/operation of plant. Similarly pollution control system shall be stopped only after completion of conveyor operation/operation of plant so that possibility of dust settlement in ducts can be eliminated. Continuous evacuation of dust (from Dust catchers, ESPs, Bag filter hopper etc.) shall be organized.

6.2.11 Siting Guideline for Sponge Iron Plants

i. Siting of new sponge iron plants shall be as per respective State Pollution Control Board guidelines. However the following aspects shall also be considered:

ii. Residential habitation (residential localities/ village) and ecologically and/or otherwise sensitive areas: A minimum distance of at least 1000 m (1.0 km) to be maintained.

iii. The location of Sponge Iron Plant should be at least 500 m away from National Highway and State Highway .

iv. Radial distance between two Sponge Iron Plants should be 5 km for plants having capacity 1000 TPD or more.

v. Sponge Iron Plants can be established in designated industrial areas / Estates as notified by State Govt.

vi. If any plant/clusters of plants are located within 1 km from any residential area/ village they may be shifted by State Pollution Control Board/ State Govt. in a phased manner for which a time bound action plan is to be prepared by SPCBs.

6.3 Occupational Health and Safety

DRI Plants falls under 1st Schedule of the Factories Act. 2nd Schedule prescribes the following limits for pollutants in the work environment (time weighted average for 8-hours continuous exposure).

- Silica (in quartz and amorphous form-fly ash having more than 50% silica content and counted as total dust) - Permissible level of silica (in amorphous form, counted as total dust) is 10 mg/m^3
- Coal dust (respirable fraction <10 μ size; containing less than 5% quartz) - Permissible level of silica (in amorphous form, counted as total dust) is 2 mg/m^3
- Iron oxide fumes - Permissible level is 5 mg/m^3
- Carbon Monoxide CO - Permissible level is 55 mg/m^3 (TWA for 8 hours), 440 mg/m^3 (STEL for 5-minutes)

The occupational health envisaged in DRI plants are respiratory problems due to dust and CO poisoning due to accidental exposure to untreated DRI gases. The following safety measures shall be undertaken in sponge Iron plants:

- Workers working in areas like RMH yard and Product House that generates fugitive dust should wear nose masks / dust filters.

- CO probes with electrochemical sensors should be installed after the ABC, at stack and at kiln discharge end.

- In case a person inhales CO, he should be removed to fresh air and given mediated oxygen through a mask for 30 minutes and if required cardiopulmonary resuscitation should be performed. Thereafter, supportive treatment if required should be given in the nearest hospital. In order to cater to routine mechanical injury to body parts, first aid boxes equipped with medicines should be kept handy.

- The employees exposed to dusty environment should be subjected to regular health check-up. The workers should be diagnosed for respiratory functions at periodic intervals and during specific complaints for lung function test, sputum test, X-ray test, etc.

6.4 Implementing the concept of Lean Management for productivity Enhancement

Lean was generally practiced with manufacturing industries but now it is being applied with equal emphasis in service as well as administration processes. It was developed by the Japanese automotive industry following the challenge to re-build the Japanese economy after World War II. It is not a tactic or a cost reduction program, but a way of thinking and acting for an entire organization.

Lean is all about customer focus. Value is defined by the customer and the entity develops and maintains processes to provide this value. Processes are run by people. The support, proper leadership and guidance drive people to continuously improve the processes that add value to the customer. The system that helps to achieve this is a Lean Management system. Lean Management system uses various tools to connect the purpose (providing value to customer) to the process and people. Some of the lean management tools which are commonly used are Leader standard work, visual control boards, 5S, and daily accountability.

Lean management is characterized by its drive toward achieving profitability and productivity through continuous improvement and resource waste elimination. It is an organizational culture as well as specific practices with clear goals. Thousands of organization worldwide have achieved tremendous productivity and return on investments by implementing lean practices and techniques.

Lean Management System works on the following 5 principles:

1. Value - specify what creates value from the customer's perspective.
2. The value stream – identify all the steps along the process chain.
3. Flow - make the value process flow.
4. Pull - make only what is needed by the customer (short term response to the customer's rate of demand).
5. Perfection - strive for perfection by continually attempting to produce exactly what the customer wants.

Lean Management System considers the following 7 types of manufacturing wastes (muda):

1. Overproduction – occurs when production should have stopped.
2. Waiting time – periods of inactivity.
3. Transport – unnecessary movement of materials.
4. Extra processing – rework and reprocessing.
5. Inventory – excess inventory not directly required for current orders.
6. Motion – extra steps taken by employees due to inefficient layout
7. Defective goods – don't conform to specifications or expectations.

And the following 7 types of service wastes (muda):

1. Delay – customers waiting for service.
2. Duplication – having to re-enter data, repeat details etc.
3. Unnecessary movement - poor ergonomics in the service encounter.
4. Unclear communication – having to seek clarification, confusion over use of product/service.
5. Incorrect inventory – out of stock.
6. Opportunity lost – to retain or win customers.

7. Errors – in the transaction, lost/damaged goods.

The lean management leads to the following benefits at all levels.

1. Company – It ensures less waste which means low expenditure and investment. The reduction of waste will ensure improved product quality, profitability and optimized production.

2. Customers – It ensures improved customer care services and efficient supply of goods and services to clients.

3. Employees – It ensures motivated employees due to the safe working environment that the method avails to them.

Lean Management is applicable to all government organizations as well. Around the world, government organizations from local law enforcement to national benefits administration have realized the benefits of Lean Management – a new approach. They have realized its benefits and started implementing within their organization to streamline complex processes, offer better services to customers, shrinking wastes, and to realize real improvements.

Lean Management helps public sector/organizations streamline processes by addressing the causes of organizational inefficiency, building the management systems and capabilities to sustain new ways of working, and engaging managers and staff to make continuous improvement a part of everyone's day-to-day job.

That's one reason lean management succeeds where other approaches fail: while experts and change agents can kick-start the lean process, it is only when people in line organization feel fully accountable and have learned the right capabilities that improvements are sustainable.

Lean management programs generally start with pilots to accelerate organizational learning and quickly build a foundation for organization wide change. Teams diagnose problems in a small area, and then design and implement solutions, refining them along the way so they can be scaled up to the larger organization. Within 6 to 18 months, this approach can deliver genuine transformations: typical improvements include better employee engagement and development and 15 to 30 percent rises in personnel productivity; 30 to 50 percent higher quality and service-level adherence; and dramatically faster turnaround times and more customer satisfaction.

Lean management also offers substantial risk-management benefits. When managers understand more about the real needs of stakeholders and customers and eliminate non-value-added activities, organizations can deploy human and financial resources to the areas where they can make more of difference. With rapid test-and-learn events, managers understand the implications of changes before rolling them out across the organization – and can make course corrections early and often. Standardizing work increases the predictability of outcomes and captures best practices. Creating a culture of transparency and constructive problem solving encourages staff to identify and mitigate risks and inefficiencies.

In spite of all the above benefits, lean management in India is still in infancy and the Indian firms are far away from enjoying its complete benefits. The awareness level in Indian context on lean manufacturing is very low. The concept is largely adopted only by the big firms popularly known as Indian MNCs. One such example is Tata Motors which has created a success story by launching Nano implementing lean manufacturing. Lean philosophy helped to reduce the cost without compromising on size and comfort. Recently many apparel firms have also opted for lean manufacturing owing to reduction in order-to-delivery time from European importers.

The implementation of lean philosophy demands a motivated and trained work-force and committed top management. The competition is very tough and lean principles can prove very beneficial not only to the Indian manufacturing firms but, also the organizations in service sector like hospitals, academics, Government and State establishments etc. to compete globally. It will help them to improve upon product & service quality and reduce the costs along with speeding up the delivery.

The organizations can make game-changing advances by improving a wide range of processes, from hiring and procurement to customer services. Focusing on a single process can yield incremental progress, but it often fails short of real and lasting transformation as Lean Management is a continuous improvement process where it focuses on incremental improvement of products, processes, or services over time, with the goal of reducing waste to improve workplace functionally, customer service, or product performance.

CHAPTER 7: CONCLUSION AND WAY FORWARD

7.1 Conclusion

The following are the critical comments on factors affecting Specific Energy Consumption (SEC), Issues & challenges w.r.t sponge Iron Industry:

- Plant Specific Energy Conservation (SEC) can be improved by enforcing feed mix of consistent quality over a period of time, proper control of process parameters and with a high degree of technological discipline;
- The regular mechanism for conducting the Energy Audits and drawing up action plan will improve energy utilization practices and reduce wastages;
- The present coal price and its quality is adversely affecting plant economics. This sometimes may come in the way of implementing new schemes alongwith slowdown in domestic market;
- Identification of right technology and equipments to improve the energy efficiency of the plant. There are financial support available under various Government schemes through banks/financial Institutions for upgrading and improvement of Energy Efficiency;
- Awareness generation, sensitization on relevant technologies ,with service providers/ equipment suppliers within the SIPs on cluster basis , Scale of operation , vintage of plant & technologies;
- Specialized and focused training towards skill up gradation of unskilled man power by the service providers on improved operation and maintenance of equipments, importance of energy, its use during the process , energy conservation measures among industry owners and workforce will result in efficient operation of plant resulting improving the productivity & Energy Efficiency. Institutions of National repute like NPC, PCRA, TERI etc. which work in the skill developments and capacity building can be approached for the same.

7.2 Way Forward

As far as the global steel consumption figures, Indians lag far behind the rest of the World. Against the world average of 215 kg, per person steel consumption in India is just 50 kg a year. This consumption gap is likely to reduce in coming years. With rapid economic growth, steel requirement for housing, infrastructure and industry is poised to grow significantly.

Post liberalisation, steel production in India has grown seven to eight per cent annually. At this rate, which many experts consider sustainable, steel production will jump to 300 MT in 2030 from 60 MT at present. Traditionally, steel was manufactured from pig iron using blast furnace. India does not have reserves of coking coal, an important raw material for blast furnace route to make steel, and presently imports about 70 per cent of its coking coal requirement. Therefore, blast furnace route cannot meet the 300 MT target.

The other way to produce steel is by recycling used steel via the steel scrap route. Currently, about 15 per cent of steel production in India is from scrap. Due to limited scrap availability and ever increasing prices of imported scrap, not more than 10 per cent of steel can be produced from scrap by 2030.

The only option left is production of steel through DRI (sponge iron) route. DRI can be produced using gas but it is expensive and gas availability is not assured. So, the real option is to produce steel using non-coking coal, through DRI. In 2030, more than 60 per cent of the steel produced in India will come from coal-based sponge iron. This means more than 200 MT of sponge iron and hundreds of sponge iron factories. Hence, there is an urgent need to develop an action plan for the sector to contain its Energy & environmental impact.

Many states offer tax holidays and incentives in their industrial policy, which has further triggered the growth of this sector. There are direct incentives provided for industrial investment in the form of interest subsidy, infrastructure development/capital investment subsidy, exemption from electricity duty, exemption from stamp duty, exemption from entry tax, allotment of plots at concessional premium in industrial areas, exemption from land diversion fee, reimbursement of project report expenses and quality certification subsidy. As a result of mushrooming of sponge Iron Industry, it has brought the curse of environmental degradation in the form of air pollution, pressure on local resources, degradation of land and adverse health impact. Industries will pollute as there is no credible deterrence for non-compliance. Hence, there is an urgent need of tighten technology and Energy & emission benchmarking for this sector.

Material handling is a major source of fugitive dust and needs to be tackled by implementing mandatory technology and management norms. Ultimately, there has to be further technology development in this sector as the current technology, even with all refinements, is still polluting. We need a technology mission for the sponge iron sector.

Bibliography

1. Energy Statistics, Ministry of Statistics and Programme Implementation, Twenty Third Issue, 2016
2. PAT Booklet, Bureau of Energy Efficiency (BEE), Ministry of Power, Page No. 15, July 2012 edition
3. www.knowledgeplatform.in, 2015, NEPA
4. Manual on Energy Conservation Measures in Sponge Iron Manufacturing Cluster, Orissa, Bureau of Energy Efficiency
5. Comprehensive Industry Document Series (COINDS), Sponge Iron Industry, Central Pollution Control Board, 2006-07
6. Guidelines for Pollution Control in Sponge Iron Industry, MoEF
7. Technology Compendium on Energy Savings Opportunities, Iron & Steel Sector, Published by CII, November 2012
8. GreenHouse Gas Emissions- Estimation and Reduction, Asian Productivity Organization (APO) Publication, 2009 edition
9. Baseline Energy Audit Reports for PAT cycle, NPC, 2009-10, Iron & Steel Sector
10. www.steel.nic.in, Ministry of Steel website
11. Perry's Chemical Engineering Handbook
12. Journal of Indian School of Political Economy
13. Manual of Environment Protection Agency (EPA,USA)
14. Reports of Competition Commission of India
15. CPCB Manuals
16. www.beeindia.gov.in, Bureau of Energy Efficiency website, PAT Scheme & presentations