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RESEARCH IN IRON MAKING IN INDIA - PAVING THE WAY FOR A GREAT FUTURE OF THE STEEL INDUSTRY [1]

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Abstract

The Indian steel industry is likely to witness tumultuous activity in the expansion of existing plants as well as in the installation of new green field projects in different part of the country. These projects comprise conventional, non-conventional and alternative ironmaking processes. While blast furnace iron making is central to the production of steel, the secondary steel sector has uniquely included electric induction furnace steel making in addition to the electric arc furnace units. Both these units depend mainly on scrap or direct reduced iron for metallic input. It entailed large numbers of coal/gas based direct reduced iron units, mini blast furnaces and COREX plants for hot metal (pig iron). Several direct reduction-smelting reduction eco-friendly technologies to directly use iron ore fines, and non-coking coal as reducing agent and energy source are under development. India has adequate raw material resources for the production of iron and steel and a comfortable market opportunity and an inherent urge to 'achieve' and add values to indigenous raw materials through research and innovation. The paper highlights the research and development efforts undertaken in the area of iron making specifically with respect to reducing energy consumption and CO_2 emissions. The paper further focuses on some research areas likely to be undertaken for developing and or adopting new apt iron making processes/ technology under Indian conditions to sustain in the competitive steel growth and global economy.

Key words: Blast furnace iron making; Direct reduced iron; Direct reduction – smelting reduction; Environment and economic synergy in ironmaking.

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1 INTRODUCTION

Iron making in India is believed to have begun as early as late 2nd millennium BC. The most striking evidence of the skill attained by the early iron – makers is found in the Iron Pillar of Delhi India near Kutub Minar. It was built in 4th century AD. This was probably erected at Delhi in 1050 AD. During 16th century AD, the iron guns / cannons were made from iron bars in India. Figure1 highlights that the Indian tribal preserved the technology of ancient iron making up to the 21st Century.

Figure 1 Primitive Indian iron making technology .

1.1. Where we stand

Prior to liberalization, conventional, blast furnace (BF)-basic oxygen furnace (BOF)/twin hearth furnace (THF) based steel plants dominated the steel production (70%) in the country and the contribution of electric steel making, particularly electric arc furnace (EAF) was limited to around 30%. In 1991 when the economy was opened up, the older steel plants in the public and private sector phased out several obsolete facilities by modern and state-of-the-art technologies and began to expand their capacity. Figure 2[1] depicts the driving, pulling and the limiting forces. These forces comprise technological advancements, market and economic growth, and energy, environment and natural resources, respectively.

The present Indian steel production of about 70 MT per annum is spread over the 11 integrated steel plants and a large number of mini steel plants comprising the electric arc furnace (EAF) / energy optimising furnace (EOF) and electric induction furnace (EIF) units. Iron production would, seemingly continue to remain from blast furnace in 21st century. Earlier blast furnaces in India were smaller in size. The situation is now changing dramatically in India in terms of installing so many large size (around 4000m^3 in size) blast furnaces. The steel production is likely to be doubled by 2020. The integrated steel plants include different process routes *viz*, BF-BOF/OHF, BF/COREX-BOF, dueling metallics (DM)-EAF/EIF plants. The dueling

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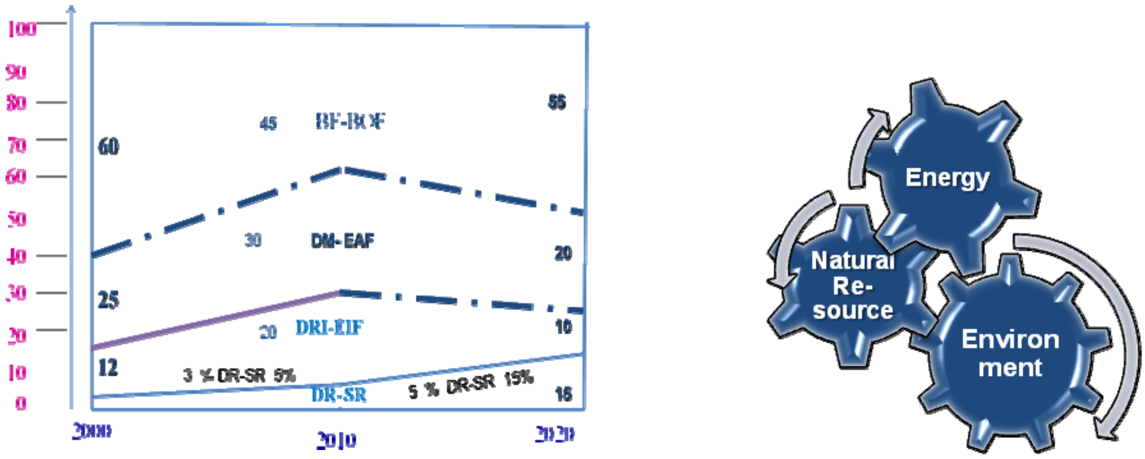
metallics (DM) normally comprise steel scrap, direct reduced iron(DRI), hot briquetted iron (HBI), pig iron (PI), hot metal) (HM).



a: BF-BOF,DM-EAF,Scrap/DRI-EIF,DR-SR Process (%)

b: Energy-Economy-Environment synergy

Figure 2 Emerging iron and steel making scenario : green *Vs* economic growth

Strengths
- Increase Demand
- Availability of labour at low-wage rates
- Huge Resources Of Raw material
- Environment laws

Weaknesses
- High cost of capital
- Lack of infrastructure
- Slow decision making
- Low labour productivity
- Insufficient transport system

Opportunities
- High potential to be tapped
- Unexplored rural market
- Export market penetration
- Consolidation

Threats
- Cheap Imports
- Slow Industry Growth and Technological changes
- Price sensitivity and demand volatility
- Threat from substitute

Figure 3 Indian iron making scenario SWOT analysis

Figure 3 surmises the factors arising out of SWOT analysis. It tends to show that the natural resources and global environment through reduction of emission will govern the technological progress for development of steel industry in the 21st century[2,3]. Based on the experiences of blast furnace, iron making would need modifications to reduce the energy consumption and to minimize the emission of green house gases (GHG). The other approach would perhaps be to adopt suitable alternative iron making processes, which can use low quality iron ore/ fines and non-metallurgical coal. Based on current conditions of alternative iron making, it is, inevitable to look for a new iron making processes which are at different stages of their developments viz FINEX, FASTMET, ITmk3 etc.

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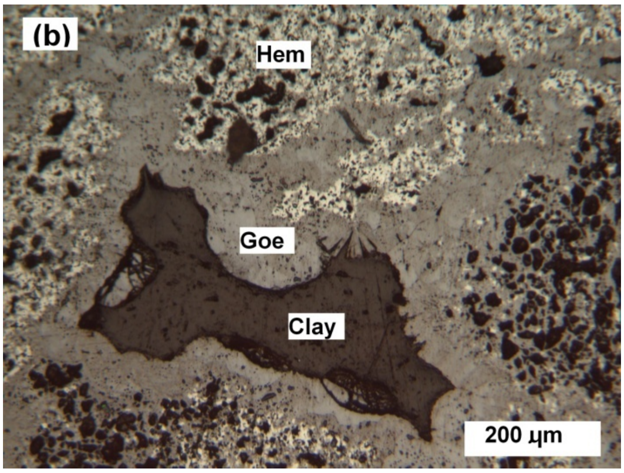
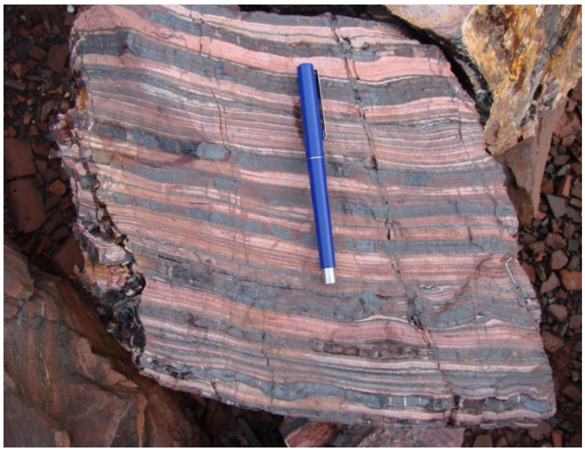
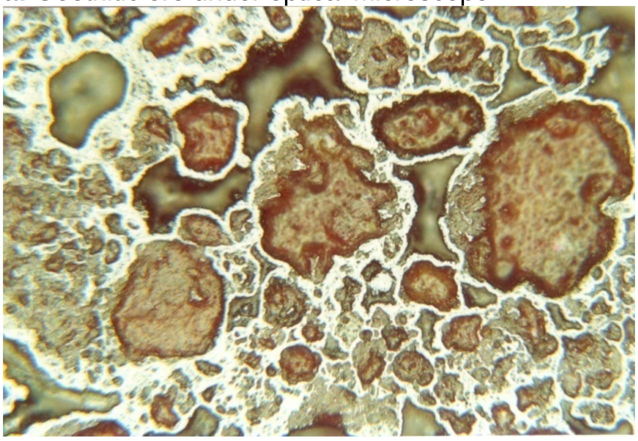


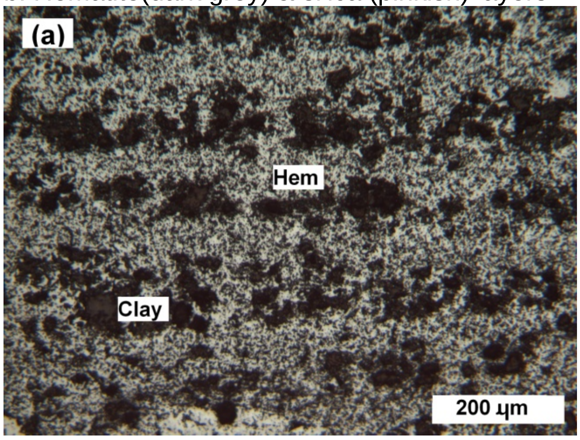
a: Goethitic ore under optical microscope



b: Hematite(dark grey) & silica (pinkish) layers



c: Lateritic ore under optical microscope



d: Clay impurities under optical microscope

Figure 4 Typical Indian iron ores

Some of the Indian iron ores as typically shown in Figure 4 can be used with or without beneficiation, others may not be economically viable to be used with beneficiation. There is, therefore, a scope for a technology [4, 5] that can directly use such ores that are in abundance and cannot otherwise be used in existing iron making processes. The quality of sinter, pellet, lump ore and ore fines as well as quality of coke need to be improved [2, 3]. Under this scenario, the Indian steel companies are making a decisive competitive edge to stay in the market place by addressing internal resources and external economic factors. It is therefore imperative for Indian steel companies to adopt technologies to use such raw materials [6, 7] in a cost effective manner that cannot otherwise be used by the existing routes for steel production, *viz*. BF-BOF, DM-EAF, Scrap/DRI-EIF routes.

Table 1 shows a typical structure of iron and steel in India. It classifies[8] steel production by its process/ technology route, the BOF route accounts for about 45% of the total crude steel production. BOF route is followed by EIF route which accounted for 32% and EAF route accounting for 23%. The remarkably large contribution of the EIF sector is one of the unique features of the Indian Steel Industry.

Table 1 Indian Iron making units

Type of Plant	Number of Units	Total Capacity (million tonnes per year)
BF-BOF based Integrated Steel Plant	8	29.997
Eaf based integrated steel plant	3	10.600
EIF based plant	1170	28.833

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EAF/ EOF based mini steel plant	37+2	9.500
Gas Based DRI plant	3	8.000
Coal Based DRI plant	418	26.600
Mini BF based Pig Iron plant	42	Consumed in EAF steelmaking
Ferro alloy units	173	4.045

2. INDIAN IRONMAKING: PERSPECTIVES AND OPTIONS

Indian blast furnaces productivity is (1.5-2.5 tonnes/m^3/day) as against the global benchmark of (2.5-3.5 tonnes/m^3/day). Similarly, coke rate in Indian blast furnaces is (400-520 Kg/tHM) [8] as compared to the global benchmark of (350-400 Kg/tHM) with extensive coal dust injection(CDI) exceeding 150 kg/tHM (even up to 250 kg/tHM adopting oxy-coal injection technology). These are attributable mainly to very high alumina (2-4% in lumps and 4-6% in fines on an average) and silica besides higher alumina/silica ratio in iron ore and high ash (15-20%) in BF coke. While, high ash coke results in high energy consumption coke oven and BF, high alumina and silica content in iron ore result in the formation of a very viscous slag [9-11]. It severely affects the performance of BF. Besides, it increases the energy consumption. Application of sophisticated probes and computerized expert system will help unravel mysteries associated with BF phenomena and make the operation more predictable and more versatile [12-15].

Therefore, besides technological up gradation, raw material up gradation/ beneficiation would be the key issues for the future steel industry in India. Indian integrated steel plants have installed stamp charge coke oven batteries [3, 16] to ensure higher utilization of medium coking coal and semi soft coals with an aim to reduce the cost of coke and hence iron & steel. Conforming to the environmental norms, the industry has begun to adopting coke dry quenching (CDQ) technology to recover the sensible heat of hot coke for steam/power generation. It helps in improving coke quality, BF operation and its productivity. The trend of new investments in top charge batteries involves establishing taller/wider/longer, high productive and environment friendly batteries. Further, on-line, Level-II computerized controlled battery heating and automation system essentially improves coke quality and reduces energy consumption in coke making.

Many plants have now started setting up pellet plants to use large share of pellets in place of iron ore lumps. Besides, a few companies have set up modern sintering plants (Area:180-400 m^2 and productivity: 1.4-1.5 t/m^2/hr) to match the sinter capacity with large BFs (~4000 M3) being set up. There are also several recent technological innovations in sintering area like micro pellet sintering process, multi-slit (COG) burners in ignition furnace, recovery of sinter cooler for preheating combustion air, sinter plant waste heat recovery (SCWHR) for steam/power generation.

2.1. Non- Conventional Iron Making

Direct Reduction/Smelting Reduction technologies mainly involve pre-reduction of iron bearing oxides and the smelting of these pre-reduced materials into hot metal. These are carried out in two separate but integrated units and are known for their eco-friendliness and direct use of iron ore fines, and non-coking coal as reducing agent and energy source [16, 17]. These technologies appear to make iron without coke making or separate agglomeration facilities [18] and fulfill the requirement

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of sustainable development with regard to environmental control, pollution control and safety.

The COREX process has inherent limitations with respect to direct use of iron ore fines and non-coking coal to make liquid iron. The FINEX process developed by POSCO at Pohang, in South Korea comprises preheating of iron ore fines, which are reduced to DRI in a four stage fluidised bed system. It is hot compacted and charged into the melter-gasifier along with the non-coking coal fines briquettes. A 2 MTPA module is likely to be commissioned by end of 2013. Other commercial modules under joint venture with POSCO in India may also come up in future. However, like COREX, this technology also has limited modular size.

ITmk3, is seemingly a flexible, green and environment friendly technology developed and owned by Kobe Steel Limited, Japan for smelting of iron ore fines. It uses non-coking coal without agglomeration to produce premium grade iron in the form of nuggets with 96-97% iron in a rotary hearth furnace. The sensible heat of off-gas could be recovered and recycled as a preheated air. The CO_2 of the ITmk3-EAF process steel making is claimed to be 25-30% lower than BF-BOF route. However, natural gas or similar fuel being an issue, alternative fuels like coal gas needs to be explored for the process to be a successful in Indian context.

The FASTMET process envisages reduction of ore-coal composite pellets in rotary hearth furnace (RHF). The FASTMELT process is a direct combination of the FASTMET process with a DRI melter. The hot metal from FASTMELT can produce very similar chemistry as obtained through BF process.

2.2. Alternative Ironmaking: Embargoes and Plans

The rapid growth of world steel production has though emanated from the dramatic growth of iron making capacity; some countries have abundant steel scrap storage where iron to steel ration is the lowest (0.70-0.65)[1]. It (iron to steel ratio) is however, the second highest (Figure 5) in India. Because of the growing deficit of steel scrap and non-availability of good quality of coking coal , the future expansion of steel capacity of the country would be based on the use of dueling iron metallic (*viz*., direct reduced iron/sponge iron, hot metal, hot briquetted iron) as the electric furnace steelmaking process input charge mix[17]..

a: year wise iron/steel ratios   b: country wise iron/steel ratio

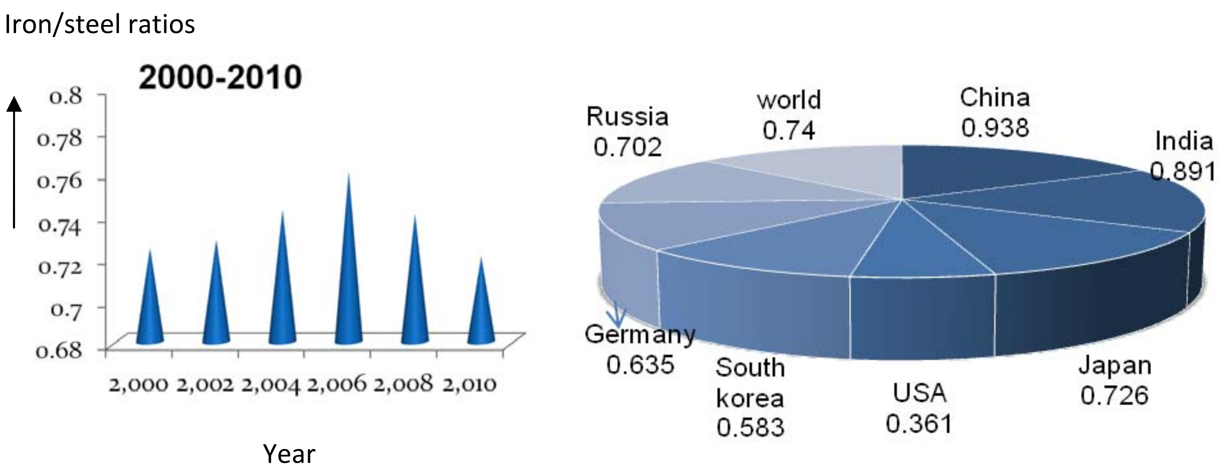

Figure 5 Iron/Steel ratios

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The COREX technology was developed in pursuit of producing hot metal utilizing non coking coal as a substitute to BF iron making. But it partially depends on coke and essentially on lumpy ore and/or iron ore pellet. The COREX plants utilise the rich and voluminous by-product gas for power generation and/or heating purposes, including for production of sponge iron. The COREX process entails economic and optimum utilization of coal fines generated in the plant.

Of the total production of DRI of 26.32 million tonnes in India, 25% is shared by the gas based and the balance 75% by coal based technologies. The metallurgical usage of natural gas being an issue, non-coking coal gasification and use of the synthesis gas can alternatively be used as the reductant in vertical shaft furnace to produce gas based DRI. Coal based sponge iron are mostly scattered in the iron ore belt in different modular size of DRI rotary kilns in the range of 50 TPD - 500 TPD. These DRI plants (>300 TPD) recover the waste heat from the kiln, which substantially improves the energy efficiency, environment friendliness and also reduces the cost of operation.

3 ENERGY AND ENVIRONMENT: PUSH AND PULL FACTORS

The intensity of CO_2 emission may vary from country to country or plant to plant due to differences in technology adopted, product mix, plant operation efficiencies, quality of raw material, type of energy etc. The iron and steel industry in India is not sparing any efforts to limit its footprint. Even though the specific energy consumption (SEC) values in Indian plants have declined from 42 GJ/MT in 1990 and 36.4 GJ/MT in 1995 to 28.9 GJ/MT in 2007 and are still decreasing (27.3 GJ/MT in 2009), they compare rather poorly against the SEC values in countries like Japan (23.3 GJ/MT - 2004), US (20.1 GJ/MT - 2001) & China (25.6 GJ/MT - 2001).

Table 2 Energy conservation technologies and reduction potential

Technology	Potential reduction
Sinter cooler – waste heat recovery	550-650 MCal/ton of sinter
Coke dry quenching	250-300 Mcal/ton of coke
Coal moisture control in coke ovens	50-70 Mcal/ton of coal
BF Top pressure Recovery Turbine (TRT)	40-80 kwh/ton of iron
Waste heat recovery from BF Stove Waste gases	15-25 Mcal/ ton of iron

Table 2 shows huge potential for saving, if the energy efficiency in Indian integrated steel plants is to be improved and carbon dioxide emission intensity is to be reduced. The energy and carbon intensity of steel production from iron ore is lowest for gas based DRI-EAF route, followed by BF-BOF route and with the coal DRI-EAF/EIF route being the highest. Globally, scrap contributes to around 30% of total steel production, bypassing the energy intensive primary steel production route. However, in India, there are a very few number of scrap based EAFs. Best available technologies indicate specific energy consumption of around 4.5 Gcal/tcs for BF-BOF route and about 4.0 G cal/tcs for gas based DRI-EAF unit. Thus the average energy consumption (6-6.2 G cal/tcs) for the two sectors in Indian plants indicates an energy saving potential of about 50%. Similar conclusion also holds good in respect of

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carbon-di-oxide emission (10% reduction in energy is approximately equivalent to 09% CO_2 emission reduction).

3.1. Air Water and Solid Environment

The environmental concern of iron making involves[19] particulate emissions (dust) from process and non process operations, the emissions of volatile matter associated with coke oven and dioxins from sinter plant operations, other gaseous pollutants like oxides of sulphur and nitrogen due to the steel plants located in the vicinity of large thermal power plants. The high dust emissions from the sponge iron units based on coal is underway adopting Best Available Technology (BAT).

Over the years, the fresh water (make-up water) consumption for steel production has been brought down to less than 5 m^3/tcs, with some integrated steel plants operating at volumes less than 3.0 m^3/tcs. The volume of solid wastes (slag, sludge and dust) of Indian iron making plants has successfully been converted into useful byproducts by recycling or use as a raw material in other industries.

Figure 6 Paving blocks from synergistic use of granulated blast furnace slag and fly ash

4 RESEARCH AND DEVELOPMENT IN IRON MAKING: CHURNING SYNERGIES

Although the science of iron making is more than 100 years old, it is still beset with uncertainties. There are inconsistent experimental data and conflicting theories. The practical application of many present day theories has been limited severely because most of the research on iron making has been confined to idealized systems.

Aggressive R&D efforts would focus towards the prime objectives of improving the quality of the iron ore, coal and other inputs with or without beneficiation and agglomeration. Besides, the R&D inputs intend to synergise and adopt such technologies that are relevant to optimizing natural resources, minimize damage to the environment, and that achieve global productivity and efficiency standards. Against the above back drop, the issues of utmost importance are the R&D intervention to find out techno-economic solutions to use indigenous raw material resources. Fulfilling these objectives and the growing Indian steel demands requires multi-pronged innovation centric research and technology development.

4.1 Iron Making Technological Developments: Onus on India

Quality of basic input/raw materials: These would include lower grade iron ores including slimes, high ash coking coal/non-coking coals and raw materials for refractory, pulverized coal injection and ferroalloy and involve

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development / adoption of suitable beneficiation technologies. It would entail micro-alloying of beneficiated fines and adopting relevant agglomeration techniques viz sintering and pelletisation. Emphasis would be on water conservation in beneficiation by exploring dry beneficiation techniques

Alternative iron making technology: Direct reduction and smelting reduction by processing both lumps and fines of low grade high alumina iron ore and high ash Indian non-coking coal to suit Indian conditions.

Non-coking to coking coal: Aiming at optimum coke consumption in blast furnace**, i**t would involve synthetic production of coking coal and technology for modification of coal blending by utilizing high ash non-coking coal, waste plastics (1Mt corresponds to 1.5 % CO_2 emission reduction). It would entail developing strategies and practices for improving rate of pulverised coal injection (PCI) in blast furnace to a level of at least 100-150 kg/tHM in the next five years in all blast furnaces and above 200 kgs/tHM including injection of natural gas, coal bed methane in next ten years.

Alternative energy source: It would involve developing/adopting such technologies/practices which have an impact in reducing energy consumption and carbon dioxide emission including alternative energy sources for integrated iron-steel making viz. coal bed methane, natural gas, hydrogen etc. Emphasis would be on coal gasification to produce synthetic gas for sponge iron production utilizing the sensible heat of hot gases from iron and steel making plants.

Reduction in waste generation: with a view to reduce waste generation in all stages from mining to steelmaking would involve total utilization of generated wastes and zero waste (air, water and solid) discharge. It would explore effluent control in coke ovens through bio-chemical/microbial treatments.

5 CLOSURE

Most of the technological challenges we face in India are country specific: high alumina in ore; high ash in coal. Appropriate solutions to improve techno-economics lie in phasing out old/obsolete production facilities and technologies and adoption of modern state-of-art relevant energy efficient and environmentally benign commercially best available technologies. The processes of sintering, pelletising and coking have to be improved by implementing or adapting innovative technologies. The utilization of non-coking coal and weak coking coal by upgrading their metallurgical characteristics will be one of the most important issues for coke making. This may be supplemented by R&D support particularly directed towards utilisation of Indian iron and carbon bearing natural resources. It is imperative to carry out a comparative evaluation of BF and smelting reduction technologies to determine whether DR-SR processes having no coke oven and sinter plants tend to be less capital intensive and more environment friendly, particularly, in terms of SOx, NOx and dust emission.

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