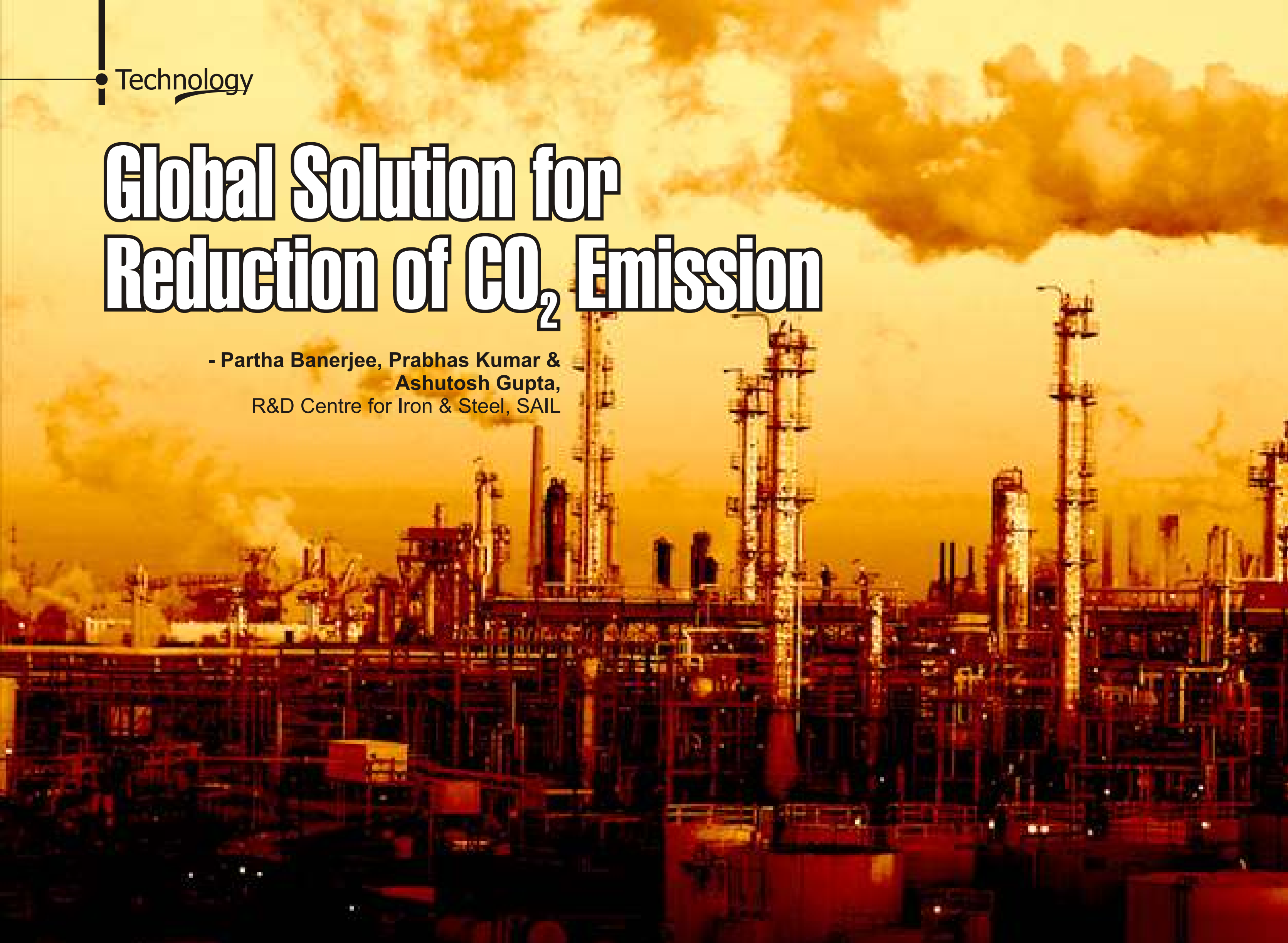

Global Solution for Reduction of CO_2 Emission

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Iron and steel production emits enormous quantities of Carbon Dioxide (CO2), especially in developing countries where outdated, inefficient technologies are still used to produce iron and steel. CO2 emission for steel production in key developing countries (Brazil, China, India, Mexico, and South Africa), will continue to grow as these countries develop and as demand for steel products increases. In this paper, typical solutions for CO2 emission intensity reduction in the key steel production processes are discussed. Some of the technologies that can be adopted to reduce energy consumption dependant CO2 emission in the steel industry are described in short and savings of energy use and CO2 emission achieved internationally has been presented. New breakthrough technologies that are being pursued for reducing CO2 emission intensity are also discussed.

Although some plants have adopted some of the technological innovations, more emphasis is needed to adopt and optimize these technologies in developing countries.

Introduction

In 2007, the Intergovernmental Panel on Climate Change (IPCC) affirmed that warming of the climate system due to increase in concentration of Green House Gases (GHGs) in the atmosphere, is unequivocal; with effects such as increasing land and ocean temperatures, rising global average sea level, and reduced snow and ice already being observed.The GHG of most relevance to the world steel industry is CO2, as it makes up approximately 93 % (on CO2 equivalent basis) of all steel industry GHG emissions (including direct emissions from steel production and indirect emissions from energy consumption). Over 90 % of steel industry emissions come from iron production in nine countries or regions Brazil, China, European Union (EU) - 27, India, Japan, Korea, Russia, Ukraine and the USA.

Technological advancements over the past 25 years have enabled substantial reductions in

CO_2 emissions from steel production. These advancements include:

- Enhanced energy efficiency
- Gas-based iron making
- Recycling of steel

As a result of systematic technological improvements, Blast Furnaces (BFs) in EU currently consume an average of around 490 kg of carbon-containing materials per ton hot metal (thm) produced. The best European and Japanese steel plants are operating at the limits of what is presently technically possible.To break through this barrier, potential new technologies have been identified through the following breakthrough programmes.

- ULCOS
- COURSE-50

Enhanced Energy Efficiency

Steel production is energy intensive. On an average, about 95 % of an integrated facility's energy input comes from solid fuel (mainly coal), 3-4% from gaseous fuels and 1-2 % from liquid fuels.Coke, made by carburising the coal or coal is the primary reducing agent of iron ore, and most other fuels are used to substitute a portion of coke / coal. Among the many human activities that produce GHGs, the use of energy represents by far the largest source of emissions 68.6 % in 2010. Smaller shares correspond to agriculture, producing mainly CH_4 and N_2O from domestic livestock and rice cultivation, and to industrial processes not related to energy, producing mainly fluorinated gases and N_2O. The scenario is similar for India, with the use of energy responsible for 66.9 % of GHG emissions in 2010.

The global problem of climate change requires a global solution. Policies to encourage improved energy efficiency and reduced CO_2 emissions are important in all regions.India released the National Action Plan on Climate Change (NAPCC) on 30th June 2008 to outline its strategy to meet the challenge of Climate Change. Under this, National Mission on Enhanced Energy Efficiency (NMEEE) ushers in four new initiatives to significantly scale up implementation of energy efficiency in India. The flagship of the Mission is the Perform, Achieve and Trade (PAT) mechanism, which is a market-based mechanism, to make improvements in energy efficiency of energy intensive large industries, like the steel industry, more cost-effective; by certification of energy savings that could be traded. Recently, Ministry of Power, Government of India had specified an overall specific energy consumption reduction target of 5.9 % for the Indian steel plants that consumed more than 30,000 Gcal / annum / plant during 2007-10, as a part of NAPCC. The targets were to be achieved by the year 2014-15].The data is being verified in 2015-16. Failure in meeting the target will result in monetary penalisation, while overachieving will result in issuance of certificates that can be traded. Sophisticated energy management systems ensure efficient use and recovery of energy throughout the steelmaking process for reuse, wherever possible.The impact of major energy efficiency technologies in reducing CO2 emission intensity in steel industry is given in Table – 1.

TABLE 1 : ENERGY EFFICIENT TECHNOLOGIES / PRACTICES & THEIR IMPACT ON CO2 EMISSION IN STEEL INDUSTRY

TECHNOLOGY	ESTIMATED CO2 REDUCTION
Controlled Program Heating of Coke Ovens	13.4 kgCO2 / t Dry Coke
Coke Oven Gas Sensible Heat Recovery	3.2 kg CO2 / t Dry Coal
Carbonisation Control of Coke Ovens	15 kg CO2 / t Dry Coke
Coke Dry Cooling	Reduction by 73 kg CO2 / t Dry Coke
Super Coke Oven for Productivity and Environment Enhancement towards the 21st Century (SCOPE 21) project	21 kg CO2 / t Dry Coke
Moisture Control of Coal to Ovens	Reduction by 15 kg CO2 / t Dry Coke
Segregation of Raw Materials while Charging Sinter-mix on Pellets	0.5 kg CO2 / t Gross Sinter
Sinter Cooler Exhaust Gas Waste Heat Recovery	8 kg CO2 / t Gross Sinter
Sinter Main Exhaust Gas Waste Heat Recovery	Reduction by 7 kg CO2 / t Gross Sinter
Curtain Flame Ignition System for Sinter Ignition Hood	0.8 kg CO2 / t Gross Sinter
Reduction of Air Leaks in Sinter Plant	2 kg CO2 / t Gross Sinter
Sinter Plant Fans - capacity Optimisation and Control	0.7 kg CO2 / t Gross Sinter
Improved Raw Material Quality for BF	2.3 kg CO2 per 10 kg / thm Reduction in Slag Rate
Top Pressure Recovery Turbine in BF	5.5 kg CO2 / t Hot Metal
Blast Furnace Solid or Liquid Fuel Injection	205 kg CO2 / t Coke Replaced
BF Stove Waste Heat Recovery	15.4 kg CO2 / t Hot Metal
BFG Recovery for 2-bell System	2 kg CO2 / t Hot Metal
Hot Metal to Crude Steel Ratio	10 kg CO2 / tcs for Every 1% Reduction in Ratio
BOF Gas Recovery	36 kg CO2 / t Liquid Steel
BOF Combined Blowing	7 kg CO2 / t Liquid Steel
BOF Gas Heat Recovery	reduction by 47 kg CO2 / t Liquid Steel
Heat Recovery from Semis	15 kg CO2 / t Liquid Steel
Scrap Preheating with EAF off-gas	41 kg CO2 / t Liquid Steel
Hot DRI / HBI Charging to EAF	77 kg CO2 / t Crude Steel
Hot Metal Charging to EAF	43.5 kgCO2 / t Liquid Steel
Conversion of Ingot Route to Continuous Casting Route	64.5 kg CO2 / t Product
Reducing Ingot Track Time	7.5 kg CO2 / t Ingot for 1 hr track Time Reduction
Thin Slab Casting and Rolling	47 kg CO2 / t Product
Evaporative Cooling System in Reheating Furnaces	19 kg CO2 / t Input
Hot/warm Charging in Reheating Furnaces	16.4 kg CO2 / t Input for Charge Temperature Raised to 330 OC
Maximising Hearth Coverage in Reheating Furnaces	1.5 kg CO2 / t Input for 1 % Increase In Hearth Coverage

Gas-based Iron Making

The relation between CO_2 emission and energy consumption through different primary energy sources used in steel industry is given in Table – 2. It can be noticed that over and above energy efficiency, the CO_2 emission intensity is also dependant on the energy mix. Replacing coal by NG reduces CO_2 emission by 41 % for the same heat input.

The main primary production route of steel (73.9 %) is BF – BOF, where Specific Energy Consumption varies between 4.73 and 7.45 Gcal/tcs. Up to 75 % of the energy consumption at an integrated facility is consumed for iron making. Replacing BF injectants like coal, tar or oil, with NG, reduces emission by ~740 kg CO_2 / t coke replaced.

Direct Reduced Iron (DRI) processes reduce iron ore to a highly metalized product, but there is no melting of this material as is the case in BF. This is achieved with either NG based (MIDREX process) or coal-based (SL/RN process) reducing agents or a mixture of the two. MIDREX is a NG based, continuous process carried out in a shaft furnace with a non-fluidized moving bed for the reduction of lump ore or pellet. SL/RN is a coal based, continuous process carried out in an inclined rotary kiln, where the iron ores are first preheated and then reduced as they travel down the shaft. An energy efficient SL/RN process, consumes about 3.55 Gcal / t DRI [8] of net energy while emitting 1.6 t CO_2 /t DRI, on the other hand, an energy efficient MIDREX process consumes 2.83 Gcal / t DRI of net energy while emitting only 0.66 t CO_2 / t DRI.

Thus, changing the process from coal-based to NG-based reduction of iron ore is a solution for reducing GHG. However, scarcity of local cheaper gas, reluctance of consumers to pay for pricey imports and inadequate infrastructure for gas distribution has clouded the prospects, especially for a country like India. Essar Steel, Hazira, India is a live example.

Recycling of Steel

Once steel is produced it becomes a permanent resource because it is 100 % recyclable, has an infinite life cycle and can be easily recovered with magnets. Infinite recyclability without loss of properties makes steel unique and valuable. Secondary steel is produced by recycling steel in an Electric Arc Furnace (EAF) or Electric Induction Furnace (EIF). The main inputs are recycled steel and electricity. The energy consumption in secondary steel production varies between 2.17 and 2.99 Gcal/tcs , resulting in emission of only 0.55 +0.09 t CO_2 / tcs; much less than that emitted for producing primary steel. This is mainly because of the elimination of the requirement of reducing agents for separating iron from its oxides. As a result, international trade in ferrous scrap has been steadily increasing over the years keeping pace with crude steel production.

Most steel products remain in use for decades before they can be recycled. Therefore, there is not enough recycled steel to meet growing demand using the secondary steelmaking route alone. Demand is met through a combined use of the primary and secondary production methods. In Japan, scrap based steel accounted for 42 % of materials for crude steel production in 2007. Europe currently recycles more than 90 % of the steel used in automobiles. Even for primary steel production, scrap input in the BOF can be as high as 25 to 30%, as is the case in United States and some European countries.

But scrap generation depends on regional steel usage. One of the reasons why steel production has high CO_2 emission in developing countries like India is extremely low per capita steel consumption levels (59.4 kg finished steel / capita) in contrast to the world average of 216.6 kg finished steel / capita which renders availability of ferro-scrap for steel production scarce. As markets get saturated with steel products, they will return to a recycling path depending on products made from steel, from a few weeks ago in steel packaging, to vehicles which may last up to 15 to 20 years or infrastructure and buildings which may last up to 50 to 100 years.The economics of recovering material is usually aligned with the price of raw materials, if they reduce in price they are used more and scrap prices drop as well, if scrap is scarce the prices increase.

Governments around the world at national and regional levels need to prioritise, promote and encourage a circular economy approach leading to encouragement for the collection and recycling of end-of-life steel products, thereby preventing its end up in landfill. Junking of old vehicles is a norm in developed nations. All nations, conscious of CO_2 emission, like USA, Germany, UK, Japan, France, Italy and even China have 'cash for clunkers' programme for scrapping old cars. How to dismantle the vehicles in an environment friendly manner, so that steel

TABLE – 2 : SPECIFIC CO2 EMISSION OF DIFFERENT PRIMARY ENERGY SOURCES USED IN STEEL INDUSTRY

ITEM	SPECIFIC CO2 EMISSION IN KGCO2 / GCAL	REFERENCE
Coal (Coking / BF Injection / Sinter / BOF / Steam)	398	International Energy Agency
Coal (SR / DRI)	398	World Steel Association
Coal (EAF)	453	International Energy Agency
Coke	453	World Steel Association
Heavy Oil	323	International Energy Agency
Light Oil	310	International Energy Agency
Kerosene	299	International Energy Agency
Liquefied Petroleum Gas	264	International Energy Agency
Natural Gas	234	International Energy Agency
Coke Oven Gas	184	World Steel Association
Blast Furnace Gas	1,130	World Steel Association
LD Gas	754	World Steel Association
Coal Tar	385	World Resources India
Benzole	348	World Steel Association

parts can be easily recycled, is another area for which organised infrastructure are to be in place.

However, impure substances contained in scrap become constraints on scrap usage. For automobile steel sheets, seamless steel pipes and other advanced steel products, the materials standards are very tough and hence, scrap used for these products is limited.

Technology Transfer

Technology transfer is also a part of the global solution for reduction of CO2 emission. Encouraging developing countries to use the hard lessons learned in the developed world and bringing all the major steel-producing companies up to the industry best practices as quickly as possible, without compromising the drive to improve their social and economic well-being or competitiveness, should be the objective of technology transfer. Regular exchange of information through projects, workshops, conferences and expert groups on technology; and also production of technical reports on major subjects should be the backbone of this technology transfer. The technical reports form the basis for internal online benchmarking systems and aim to contribute effectively to improving the economic and environmental performance of the global steel industry.

One such technology transfer initiative is the Asia Pacific Partnership (APP), which involves Australia, China, India, Japan, South Korea and the US. Together, these countries account for almost 60% of the world's crude steel production and almost half of its CO2 emissions (from all sources). In India, Operating Committee meetings are important sources of technology transfer information. Operators of the major steel producers regularly exchange information through presentations and working groups.

Conclusions

Steel is one of the most common materials in the world besides wood and concrete. It has been at the core of the economy for historical and pre-historical times and its discovery goes back to the onset of civilization. On the other hand, steel is a modern material which incorporates some of the newest concepts in material physics, including the nanotechnology paradigm. It is present everywhere and acts as the backbone of our material civilization, as it is present in infrastructure, buildings, transportation, packaging, machinery, etc. When an artefact does not include steel as a major component, it is made of parts which were produced with machines made of steel - such as smartphones, computers or aircraft. In other words steel is essential for the high standard of living in the developed world and for the growth of emerging economies.

The steel industry is relatively versatile in its fuel requirements, and can adapt its production processes and techniques to suit prevailing conditions. It had made considerable progress in substituting coal-based energy with oil before the oil price hikes of 1973 and 1979. In some countries, sizeable amounts of natural gas are used to reduce CO2 emissions, but in others, natural gas is priced as a premium fuel as its resources are limited, and in these areas the steel industry uses little natural gas.

The highest values of return on investment of CO2 emission reducing technologies are usually related to small low cost projects like installation of more efficient pumps, fans, compressors, burners; and improvements of insulation of furnaces & control instruments / systems, which have little effect on the overall CO2 emission intensity of a steel plant. Retrofitting of more energy-efficient technologies to reduce CO2 emission in existing plants is often very expensive; owing to which CO2 emission intensity of modern plants are lesser compared to older ones.

In 2010, with an average of 1.8 t CO2 / tcs emission and crude steel production of 1,433 Mt, the steel industry accounted for 5.2 % of the 49,503 Mt of world's CO2 equivalent GHG emissions directly or indirectly. With the large increase in steel production - 34.5% increase between 2009 and 2014 the steel industry is a major cause of concern to the global community for global warming. Hence solutions for reducing CO2 emission are a necessity.

One of the irony is that reduction in CO2 emission does not always correspond with the requirements imposed from technology. An example is the hot metal to crude steel ratio. From CO2 emission point of view, this should be as low as possible.

However, technical developments connected with optimisation of the refining process like hot metal treatment and vacuum degassing, result in an increase of the ratio. As a matter of fact the metallurgical requirements are imposed on the steel plants to achieve optimisation between process and CO2 emission.

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