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INDIAN REFRACTORY MAKERS ASSOCIATION
Duckback House, Flat No. - 2B, 2nd Floor,
41, Shakespeare Sarani, Kolkata 700017
Phone: 033 4003-2748
E-mail: support@irmaindia.org
Website: www.irmaindia.org

CONTENTS

MESSAGE FROM THE CHAIRMAN 21

ASSOCIATION ACTIVITIES 23

IN THE NEWS 24

OVERSEAS NEWS 25

MEMBERSCAN 25

BUSINESS SECTION 27
Decarbonization Challenges for Steel Industry
– A Special Correspondent

TECHNICAL SECTION 36
Effect of Antioxidants on The Properties and Life of Magnesia Carbon Refractory: A Short review
– Arup Ghosh

STATISTICS 41

MESSAGE FROM THE CHAIRMAN

Dear Colleagues,

The past financial year 2021-22 was fairly good for the refractory industry as many of us could post decent profits. This has been due to phenomenal performance of iron and steel, cement etc sectors. There have been moments of difficulties as well when we faced difficulties in sourcing of raw materials like WFA especially from China due to their internal regulations.

This brings before us a much bigger issue of securing raw material security. India's plan to reach 300 million tonnes of crude steel production by 2030 seems doable provided there is no significant physical disruption to rattle our economy. Tata Steel plans to increase its capacity to 40 million tonnes by 2030 for which expansion of its existing steel making capacity at Jamshedpur, Kalinganagar and Angul seems adequate. JSW Steel plans expansion of its capacity to 36 million tonnes. SAIL will look at expanding capacity by 12-14 MTPA in the first phase at its units in Bokaro, Burnpur (IISCO) and Rourkela. We need to ponder over the question, where will the additional demand for calcined bauxite, fused alumina, fused & dead burnt magnesite come from? At around 146 million tonnes of current crude steel production capacity, we are sometimes at our wit's end to cope with the supply vagaries of imported raw materials, causes range from unavailability of containers, environmental restrictions in China etc. Not just refractories minerals, prices of iron ore, ferro alloys, coke have behaved in such a manner stumping many a Pundits of commodity trade.

Another issue that we will increasingly feel is the need to reduce carbon footprint. Being a responsible industry, it is obligatory on our part to leave a greener earth for our progeny. If we couple both the issues, it leads us to increased usage of recycled raw materials. The refractory recycling industry in India is mostly controlled by grey market players. This is where the steel industry needs to play a critical role by helping us sort the bricks as per grades and ease various logistic constraints in lifting the used materials. I request you all to sensitize the steel plants about the need to sort main refractory material classes and sub-classes from a stream of undefined used refractory products. It will ensure functional efficiency on our part as well as better quality products which will ultimately benefit the steel plants.

Parmod Sagar
Chairman

ASSOCIATION ACTIVITIES

IRMA Board of Directors Meeting

A meeting of IRMA Board of Directors was held on virtual platform on 28th May 2022 under the chairmanship of Mr P. Sagar. Issues discussed were market conditions, review of WRA activities and IRMA's support, IREFCON 2022 etc.

IRMA Communications Committee

A Communications Committee has been formed by IRMA Board of Directors to be headed by Mr Ish Garg. The other members are Mr Kamal Sarda and Mr Abhijit Borah (of RHI Magnesita India Ltd). The main task of the Committee is to streamline the various activities of IRMA in social media.

IREFCON 2022

IREFCON22 will be held at Hotel Westin, Kolkata from 16-18 November 2022. It will be in hybrid mode ie both physical as well as digital.

IREFCON22 Organizing Committee comprises

- Sameer Nagpal (Chairman) (Dalmia Bharat Refractories Ltd.)
- Sunanda Sengupta (Co-Chairman) (TRL Krosaki Refractories Ltd.)
- Parmod Sagar(RHI Magnesita India Ltd.)
- Ish Garg (Calderys India Refractories Ltd.)
- Arup Kumar Chattopadhyay (National Refractories)
- Udaya Shankar (Refratechnik India Pvt Ltd)
- Kamal Sarda (IFGL Refractories Ltd.)
- Nitin Jain (Vesuvius India Ltd.)

IREFCON22 Technical Committee comprises

- Indra Nath Chakraborty (Chairman) (Calderys India Refractories Ltd.)
- Sk. Bashir Mohammad (Dalmia Bharat Refractories Ltd.)
- Sukumar Adak(Mahakoshal Refractories)
- Arup Samanta(TRL Krosaki Refractories Ltd.)
- N K Mishra (RHI Magnesita India Ltd.)
- Soumen Sinha(Calderys India Refractories Ltd.)
- Shankha Chatterjee (Almatis Alumina Pvt Ltd)
- Ujjwal Sengupta (Refratechnik India Pvt Ltd.)
- S D Majumdar(IFGL Refractories Ltd.)
- Gautam Bhattacharya(Imerys India)
- H S Tripathi (CSIR – CGCRI)
- Brijender Singh (Tata Steel Ltd.)
- Premanshu Jana (Vesuvius India Ltd.)

The Keynote Speeches finalized are:

- Key Note Speech 1 (Technology for Refractory Industry) – Heiki Miki, Shinagawa Refractories (Mr Nagpal to confirm)
- Key Note Speech 2 (Tools for Refractory Industry) – Rinus Siebring, Tata Steel Europe
- Key Note Speech 3 (Talent for Refractory Industry) - Rainer Gaebel, Refratechnik

IREFCON22 Organizing Committee meetings were held on 11th April 2022 and 30th April 2022 under the chairmanship of Mr Sameer Nagpal. The issues discussed were constitution of Technical Committee, selection of Keynote &Theme Lectures, sponsorship and exhibition charges, CEO meet etc.

IREFCON22 Technical Committee meetings were held on 9th May, 23rd May and 6th June 2022. The issues discussed were criteria for selection of technical papers and case studies, spread of technical sessions, follow up on abstract submissions etc.

Workshop at IREFCON22

A workshop on refractories application will be organized on the side-line of IREFCONON22 for the employees of member companies. It will be conducted by reputed refractories expert Mr Tom Vert. Further detail follows.

IN THE NEWS

Tata Steel

As per media reports, post-acquisition, Tata Steel will endeavour to ramp up the operations of NINL to its rated capacity of 1.1 million ton per annum within the next 1 year, subject to obtaining statutory clearances. Tata Steel arm, Tata Steel Long Products, in January this year won the bid to acquire a 93.71 per cent stake in NINL at an enterprise value of Rs 12,100 crore.

Cut in Steel Production

Amidst falling demand, both locally and in the export market, the domestic steel majors have not just cut down their production, but preponed their maintenance shutdown work at some facilities to rein in the rising inventory and also to keep the plant future-ready. As a fall out of the Russia-Ukraine that started in late February, domestic steel prices started falling after reaching their peak in the first week of April.

Ultratech

UltraTech Cement has announced an investment of Rs. 12,886 crores for a 22.6 MTPA capacity increase at a cost of US$ 76 per tonne of cement. An increase in capacity of 22.6 million tonnes per year (mtpa) has been approved by the Board of Directors with a combination of brown field and green field expansion. By putting up integrated and grinding equipment and bulk terminals, the goal will be achieved. All around the country, more capacity will be built to meet the increased demand.

Adani to be India's No. 2 Cement Maker

Adani Group and Holcim have signed a binding agreement for the sale of the latter's cement business in India. The business comprises Holcim's 63.1 per cent stake in Ambuja Cements that owns a 50.1 per cent stake in ACC, and also a 4.5 per cent direct stake in the company. The acquisition would make Adani Group India's second-largest cement company in India with a capacity of 68 million tonnes.

Dalmia Cement

Cement-maker Dalmia Cement (Bharat) Ltd, has chalked out a Rs 2,600-crore investment plan spread over the next four years to take up expansion of its existing facilities and also set up new manufacturing units in Tamil Nadu. The company would set up two greenfield grinding units with a capacity of producing two million tonne per annum each.

Indian Mineral Output

The country's mineral production rose by 7.8 per cent in April 2022 over the same month a year ago. The index of mineral production of mining and quarrying sector for the month stood at 116, which was 7.8 per cent higher as compared to the level in April last year,

As per the provisional figures of the Indian Bureau of Mines (IBM), production level of important minerals in April includes coal at 665 lakh tonnes, lignite 40 lakh tonnes, natural gas (utilised) 2,748 million cubic metre, petroleum (crude) 25 lakh tonnes and bauxite 2,054 thousand tonnes.

Manganese ore, coal, lignite, bauxite and phosphorite were some of the minerals that showed positive growth in April. The production of other important minerals showing negative growth included petroleum (crude), limestone, copper concentrate, iron ore, lead concentrate, chromite and gold.

Hindalco

As a result of increased capacity at the Utkal alumina refinery in India's eastern state of Odisha, Hindalco Industries has increased its alumina output by 20% for FY22.

OVERSEAS NEWS

RHI Magnesita

RHI Magnesita's Technical Data Sheets include a field "Environmental Indicators" in which the CO2 equivalent emission of one metric ton of the product is listed. The calculation method for these indicators is developed with and supervised ongoingly by external experts under the principles of ISO standards. All greenhouse gases "cradle-to-gate", from raw material extraction to production to packaging to gate are considered in these CO2 footprint calculations.

Nabaltec

The company has earned EUR 54.8 million in revenues in the first three months of the year, up 19.1% from the same quarter of last year, when revenues were EUR 46.0 million. Operating profit (EBIT) was EUR 7.1 million in the first quarter, up from EUR 3.9 million in the same period of 2021.

Elkem ASA

Elkem ASA has entered into an agreement to acquire KeyVest Belgium S.A, a specialist company in the sourcing of materials and production of metal powders to the refractory industry and other segments including advanced ceramics. This will expand Elkem's product portfolio and create a platform for further growth.

Chinese BFA Market

Due to low operating rate of Chinese steel plants, the demand for Chinese BFA remains weak in the short term. However as most producers hold the prices firm, experts say the prices of BFA will continue to remain strady.

China Refractory Raw Materials Index

According to Refwin, the China Refractory Raw Materials Price Index in March 2022 was 211.21, a month-on-month decrease of 0.62% and a year-on-year increase of 17.9%.

MEMBERSCAN

RHI Magnesita India

RHI Magnesita's net sales turnover for the FY 2021-22 was Rs 1990.71 crores while the reported PAT was Rs 267.92 crores. The company is listed in the 2022 edition of the coveted Fortune India Next 500 listing and recognized as Rising Star for making the biggest leap in the ranking by achieving the highest growth in 2021 among all ranked companies.

TRL Krosaki Refractories

TRL Krosaki has created a landmark with sales turnover crossing Rs 200 crores for the month of May 2022. The company recently received the coveted “Golden Peacock Corporate Social Responsibility Award for the year 2021.

Dalmia Bharat Refractories

Dalmia Bharat Refractories is looking at a capex of Rs.300 crore over the next three-four years as it plans a capacity ramp-up and investment towards R&D across units. Around 80-100 crore has been spent between FY19 and FY21.

IFGL Refractories

Net profit of IFGL Refractories rose to 18.14% to Rs 77.49 crore in the year ended March 2022 as against Rs 65.59 crore during the previous year ended March 2021.

Mahakoshal Refractories

Mahakoshal Refractories has recently been honoured by Industry Outlook as one of the top 10 refractory manufacturers of the country.

OBITUARY

Mr B N Ghosh, an eminent refractory technologist passed away on 20th May 2022. He was ex Head Refractories – Tata Steel and ex Director Technical Tata Refractories Ltd.

Known for his in depth knowledge on refractories for steel making, Late B N Ghosh was an extremely popular figure in refractory fraternity. He also served IRMA in the capacity of Technical Adviser. May His Soul Rest in Eternal Peace.

ECONOMY AT A GLANCE

- Growth this year is set to slow, but it will still be higher than it was before the pandemic. Consumption will be boosted by the relaxation of Covid-19 restrictions, while increased government spending will add impetus. That said, rising commodity prices pose a downside risk. While the direct impacts from trade and financial exposure to Russia and Ukraine are minimal, spill overs from rising commodity prices, higher borrowing costs, and weaker external demand are significant.
- Experts project the country's GDP to expand 6.3% in FY 2023.
- The Indian economy expanded 4.1% year-on-year in the first three months of 2022, slightly higher than market forecasts of 4%, but the least in a year, due to rising Omicron infections, elevated energy prices, and ongoing supply chain constraints. A slowdown was seen in mining and quarrying (6.7% vs 9.2% in Q4) and communication (5.3% vs 6.3%) while manufacturing output edged 0.2% lower (vs +0.3%). On the other hand, faster increases were seen for utilities (4.5% vs 3.7%) and the farm sector (4.1% vs 2.5%) while construction rebounded (2% vs -2.8%).
- The global economy is now projected to grow by only 3.1 per cent in 2022, down from the 4.0 per cent growth forecast released in January 2022. Global inflation is projected to increase to 6.7 per cent in 2022, twice the average of 2.9 per cent during 20102020, with sharp rises in food and energy prices. The war in Ukraine, lockdowns in China, supply-chain disruptions, and the risk of stagflation are hammering growth.
- Global inflation is expected to moderate next year but it will likely remain above inflation targets in many economies. The report notes that if inflation remains elevated, a repeat of the resolution of the earlier stagflation episode could translate into a sharp global downturn along with financial crises in some emerging market and developing economies.
- Growth in advanced economies is projected to sharply decelerate from 5.1 percent in 2021 to 2.6 percent in 2022—1.2 percentage point below projections in January. Growth is expected to further moderate to 2.2 percent in 2023, largely reflecting the further unwinding of the fiscal and monetary policy support provided during the pandemic.

BUSINESS SECTION

DECARBONIZATION CHALLENGES FOR STEEL INDUSTRY

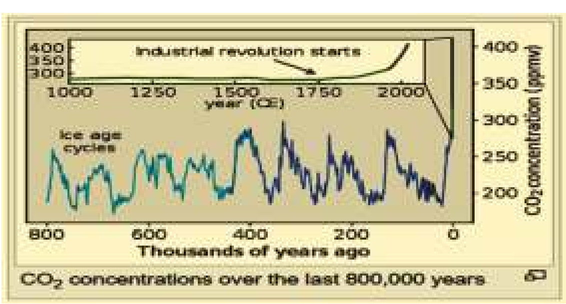
By a Special Correspondent

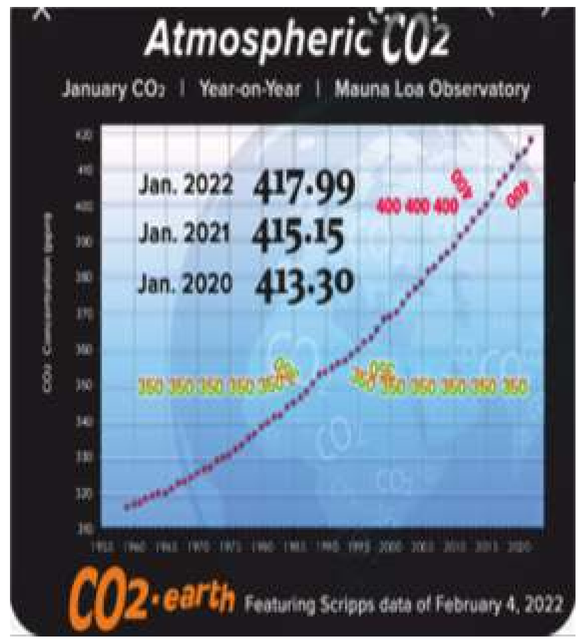
Introduction

The iron and steel industry is the largest coal consumer after thermal power and is a greenhouse gas intensive industry. It consumes about 7% of global energy supply, and conservative estimates report that it is responsible for 7–9% of global greenhouse gas emissions. Decarbonization of the iron and steel industry is thus vital to meet climate change mitigation targets and achieve a sustainable future for the industry.

The Present Situation

The concentration of carbon dioxide in Earth's atmosphere is currently at nearly 412 parts per million (ppm) and rising. This represents a 47 percent increase since the beginning of the Industrial Age, when the concentration was near 280 ppm, and an 11 percent increase since 2000, when it was near 370 ppm. (Source: NOAA)

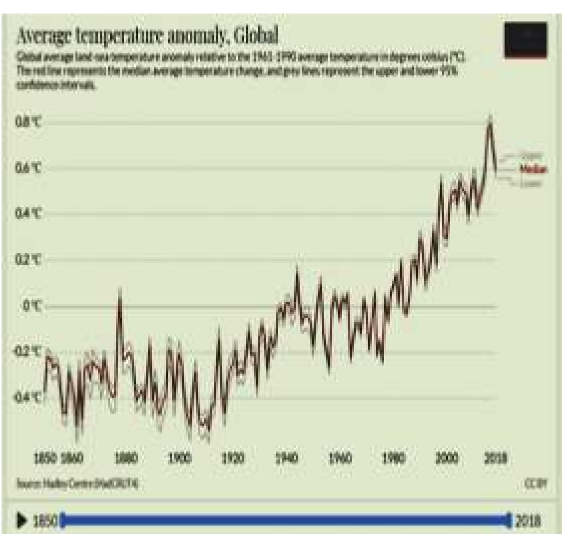




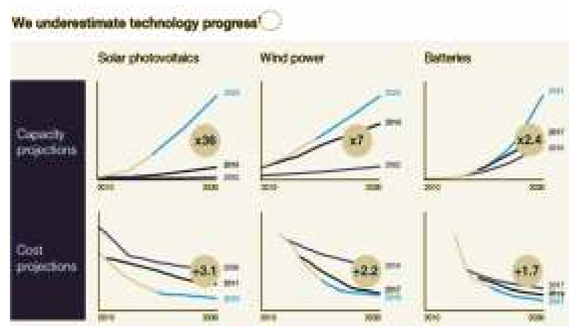
Carbon cycle experts estimate that natural “sinks”—processes that remove carbon from the atmosphere—on land and in the ocean absorbed the equivalent of about half of the carbon dioxide we emitted each year in the 2011-2020 decade. Because human activities add more carbon dioxide into the atmosphere than natural processes can remove, the amount of carbon dioxide in the atmosphere increases every year. The more we overshoot what natural processes can remove in a given year, the faster the atmospheric concentration of carbon dioxide rises. In the 1960s, the global growth rate of atmospheric carbon dioxide was roughly 0.8± 0.1 ppm per year. Over the next half century, the annual growth rate tripled, reaching 2.4 ppm per year during the 2010s. The annual rate of increase in atmospheric carbon dioxide over the past 60 years is about 100 times faster than previous natural increases, such as those that occurred at the end of the last ice age 11,000-17,000 years ago.

Global Warming

The current warming trend is of particular significance because it is unequivocally the result of human activity since the mid-20th century and proceeding at a rate that is unprecedented over millennia. It is undeniable that human activities have warmed the atmosphere, ocean, and land and that widespread and rapid changes in the atmosphere, ocean, cryosphere, and biosphere have occurred. Ice cores drawn from Greenland, Antarctica, and tropical mountain glaciers show that Earth's climate responds to changes in greenhouse gas levels. Ancient evidence can also be found in tree rings, ocean sediments, coral reefs, and layers of sedimentary rocks. This ancient, or paleoclimate, evidence reveals that current warming is occurring roughly ten times faster than the average rate of ice-age-recovery warming. Carbon dioxide from human activity is increasing more than 250 times faster than it did from natural sources after the last Ice Age. The ocean has absorbed much of this increased heat, with the top 100 meters (about 328 feet) of ocean showing warming of more than 0.6 degrees Fahrenheit (0.33 degrees Celsius) since 1969.6 Earth stores 90% of the extra energy in the ocean.



Technologies To Prevent Global Warming



Mitsubishi Heavy Industries (MHI) Group, a Japan-based leader in decarbonization technology, has identified three areas that are primed for innovation and investment.

1. Alternative energy sources

Reaching net zero at a global scale will take a variety of renewable energy sources – more than just wind and solar power. The need for post-carbon solutions has grown particularly acute in areas that have had few viable alternatives, such as commercial vehicle fleets, maritime shipping and energy-intensive industry applications like steel and cement production.

New energy sources, from green hydrogen to synthetic fuels, is expected to enable broader decarbonization, including in industries typically reliant on fossil fuels. In 2019, transporting freight by road was responsible for more than 40% of global oil demand, making commercial vehicle fleets a prime target for decarbonization. Electrification has been a challenge, however, because the batteries produced for electric vehicles haven't been light enough or powerful enough to move large vehicles over long distances.

In the near term, synthetic fuels, such as electrofuels, have the potential to make an immediate, positive impact. Infinium, a leading e-fuel provider in Sacramento, can power the production process with renewables and utilize captured carbon dioxide as a raw material for fuel – a net zero carbon alternative. Electrofuels work with existing engine technology, meaning transportation and freight companies could reduce emissions without immediately upgrading their fleets. Electrofuels could play a key role in reducing emissions in aviation as well.

As alternative renewable energy sources come online, they will have applications across other sectors as well. In steel production, hydrogen is applicable for the direct reduction process, which enables decarbonization of the blast furnace. In maritime shipping, green ammonia produced by companies such as Starfire Energy is seen as a remedy for an industry responsible for 2.5% of greenhouse gas emissions worldwide.

Every new energy source, from synthetic fuels to green hydrogen, adds to the potential to reduce emissions more broadly, not just in transportation but also in other traditionally carbon-dependent industries.

2. The carbon value chain

Carbon capture isn't a new concept. The technology has been around since the late 1970s, when oil and gas companies wanted to capture carbon dioxide from the natural gas production process so they could inject it into oil wells to improve recovery. As these technologies continue to become more robust and sophisticated, investors have begun focusing on methods to use that stored carbon productively and profitably.

Investments in vegetation and soil storage could make these carbon management options a major part of decarbonization in the near future. The United Nations estimates that these solutions could generate $800 billion in annual revenues by 2050, giving them a net present value greater than the total market capitalization of today's oil and gas majors.

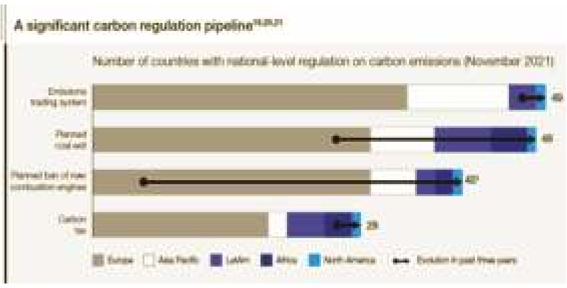
The carbon value chain is poised to grow as carbon capture technology becomes more widely used in decarbonization efforts around the world.

With the commoditization of captured carbon, analyst projections for products that use carbon dioxide range from $800 billion to $1 trillion by 2030. Possibilities range from incorporating the gas into building materials such as concrete to using it as a feedstock for chemicals like solvents or plastics to new, as-yet unimagined applications.

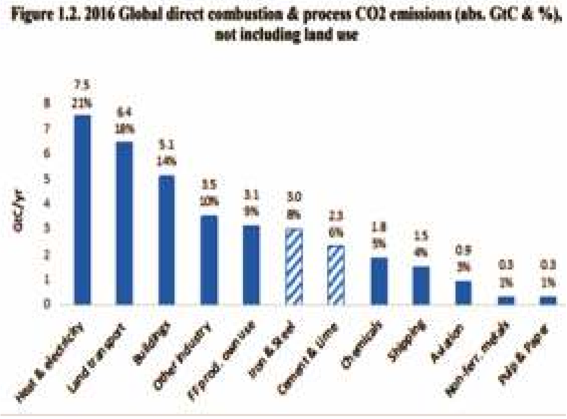
3. Short- and long-term renewable energy storage

Existing renewable technologies continue to offer innovation and investing opportunities given the need to decarbonize the grid globally. Consider batteries, which have been around for more than two centuries. Recent advances have made storing electricity from vast solar arrays in batteries during the day economically viable. Storing renewable power helps utilities bridge the gap between the time green electricity is generated and the moment it's used. A report from IHS Markit projects that global utility-scale energy storage installations will surpass 10 gigawatts for the first time this year – more than double the 4.5 gigawatts installed in 2020. And venture capital, public market and debt financing of battery companies jumped 136% last year, to $6.6 billion, suggesting more growth to come. Meanwhile, interest and investment in green hydrogen as a long-term storage solution is also rising rapidly.

Storing renewable power helps utilities bridge the gap between the time green electricity is generated and the moment it's used, so they can supply clean power when it's dark or when the wind isn't blowing. As storage technology improves and becomes more widely adopted, these developments will enable utilities to retire redundant emissions-generating equipment, and will allow solar and wind power producers to take advantage of higher prices when electrons are scarce.



In 2014, the top carbon dioxide (CO_2) emitters were China, the United States, the European Union, India, the Russian Federation, and Japan. These data include CO_2 emissions from fossil fuel combustion, as well as cement manufacturing and gas flaring. Together, these sources represent a large proportion of total global CO_2 emissions.



Decarbonization of Steel Industry:

As steel is essential for modern economies and developing technologies, steel demand is expected to grow substantially in the coming years due to its direct relationship to population, GDP growth, and overall industrialization. Economic expansion of emerging economies in India, ASEAN countries, and Africa will add to the demand trends already exhibited by the US, Europe, and China.

As steel is essential for modern economies and developing technologies, steel demand is expected to grow substantially in the coming years due to its direct relationship to population, GDP growth, and overall industrialization. Economic expansion of emerging economies in India, ASEAN countries, and Africa will add to the demand trends already exhibited by the US, Europe, and China. Thus, it is perhaps inevitable that the iron and steel industry is highly responsible for global greenhouse gases (GHGs) emissions and thus contributions to climate change. The iron and steel sector emits 2.6 Gt CO_2e annually, which is 7% of the global emissions from the energy use and 7–9% of global anthropogenic CO_2 emissions—the highest among heavy industries.

Steel Industry: Low-Carbon Approach

✓CDA (Carbon Direct Avoidance): Steel
- I. Existing BF/BOF route: Use of LNG/Syngas/H_2 as reductant
- II. DRI/EAF route: Use of LNG/Syngas/H_2 as reductant in DRI, Midrex with H_2 injection

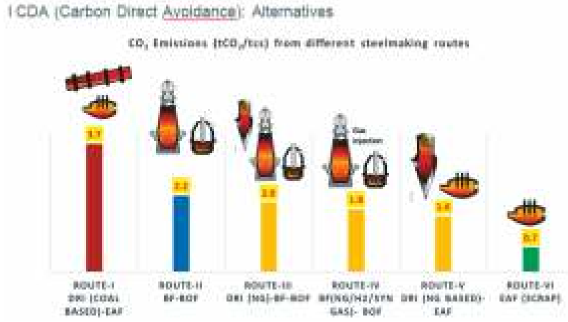
✓CCS (Carbon Capture and Storage):
- I. CO_2 Absorption by ammines
- II. Adsorption using Pressure Swing Adsorption

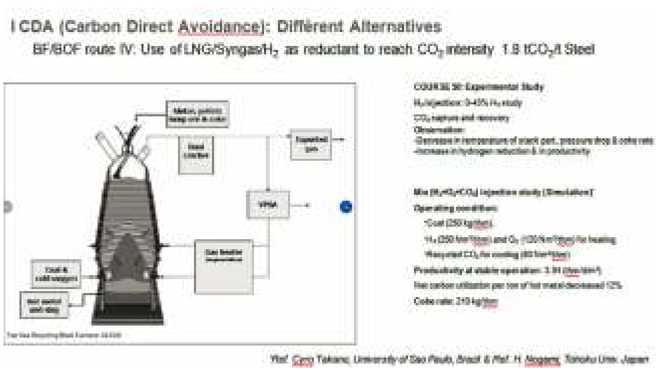
✓CCU (Carbon Capture and Usage):
- I. Conversion of CO_2 to chemicals with H_2 sources
- II. Conversion of CO_2 to chemicals through biological route
- III. Chemical Looping Combustion technology

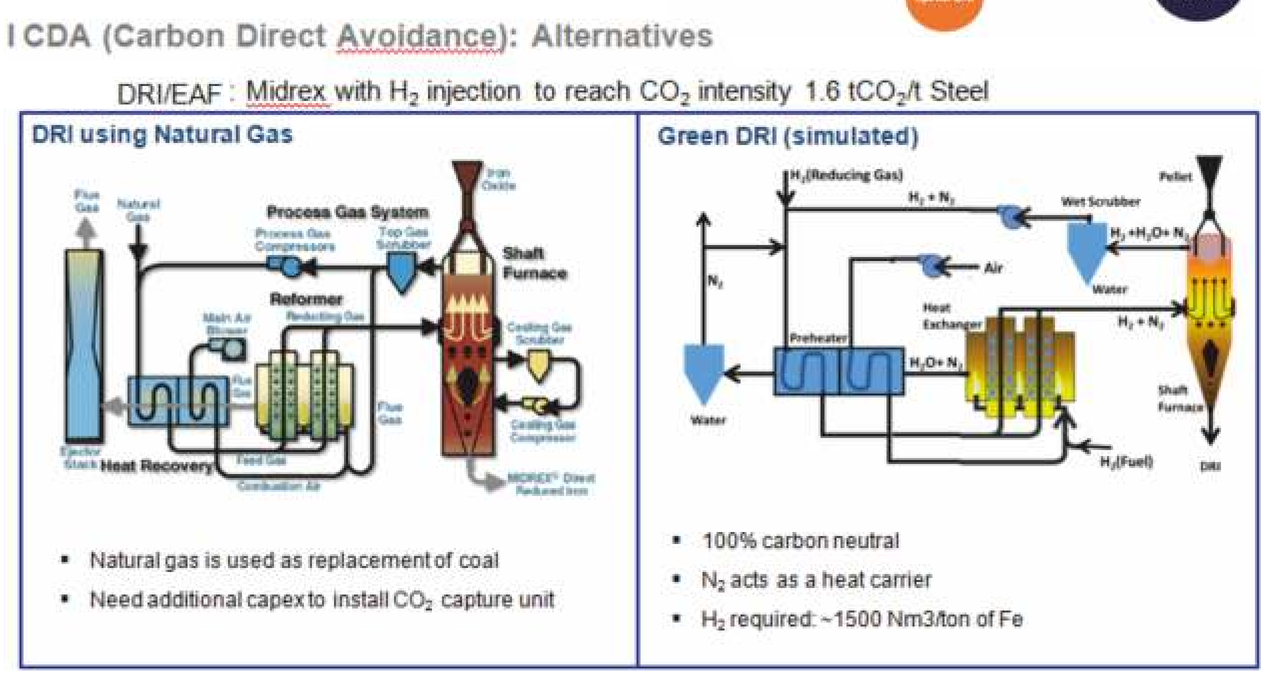
Iron and steel are also considered as one of hardest industries to decarbonize due to high heat requirements, using carbon as a process input, low profit margins, high capital intensity, long asset life, and trade challenges. Many institutions, such as the International Energy Agency (IEA), European Steel Association, Lawrence Berkeley National Laboratory, Boston Consulting Group, and WSP and Parsons Brinckerhoff/ DNV GL, have published carbon mitigation options and technology roadmaps for the industry's decarbonization.

CDA (Carbon Direct Avoidance): Steel

I CDA (Carbon Direct Avoidance): Alternatives

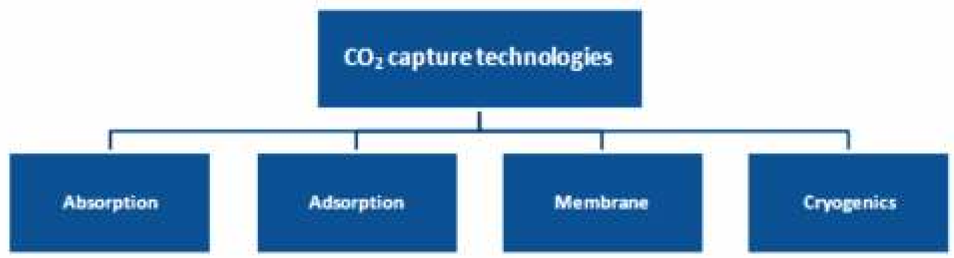






While the next decade will likely see process modifications such as carbon capture and storage (CCS) and carbon capture and usage (CCU), implementation of new processes will be critical. One lever for these transitions will be the reduction of iron ore with hydrogen instead of coal. However, the determining factor for the success of this technology will be the availability of hydrogen at economic level and at scale.

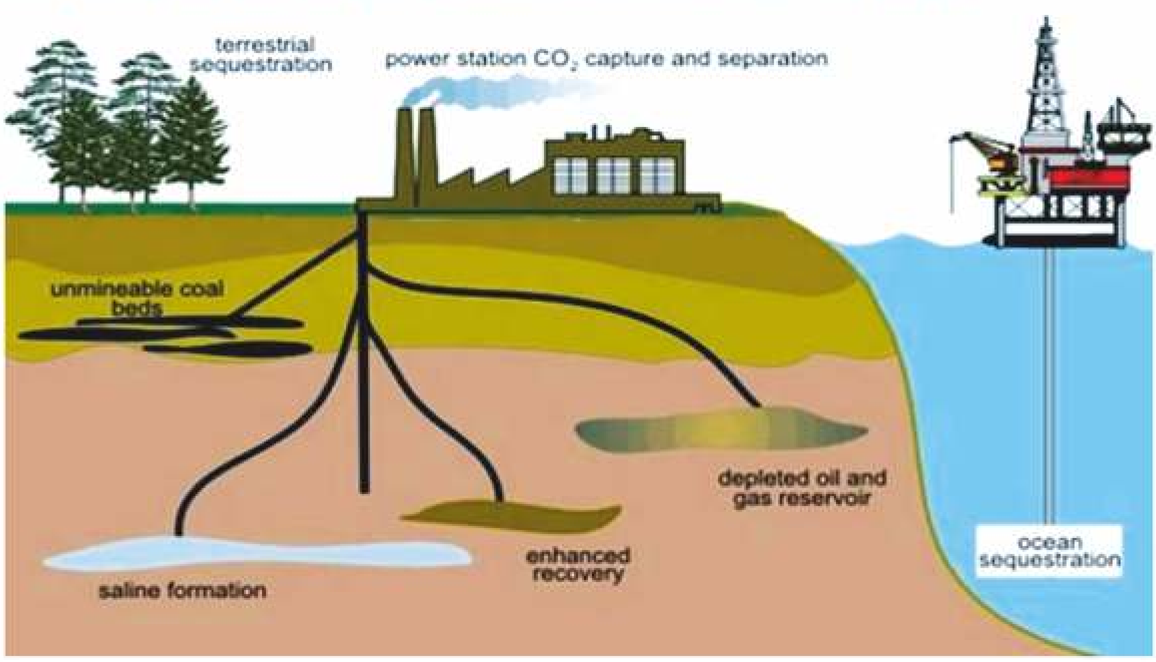
CCS (Carbon Capture and Storage): State of research/technology CO_2 capture

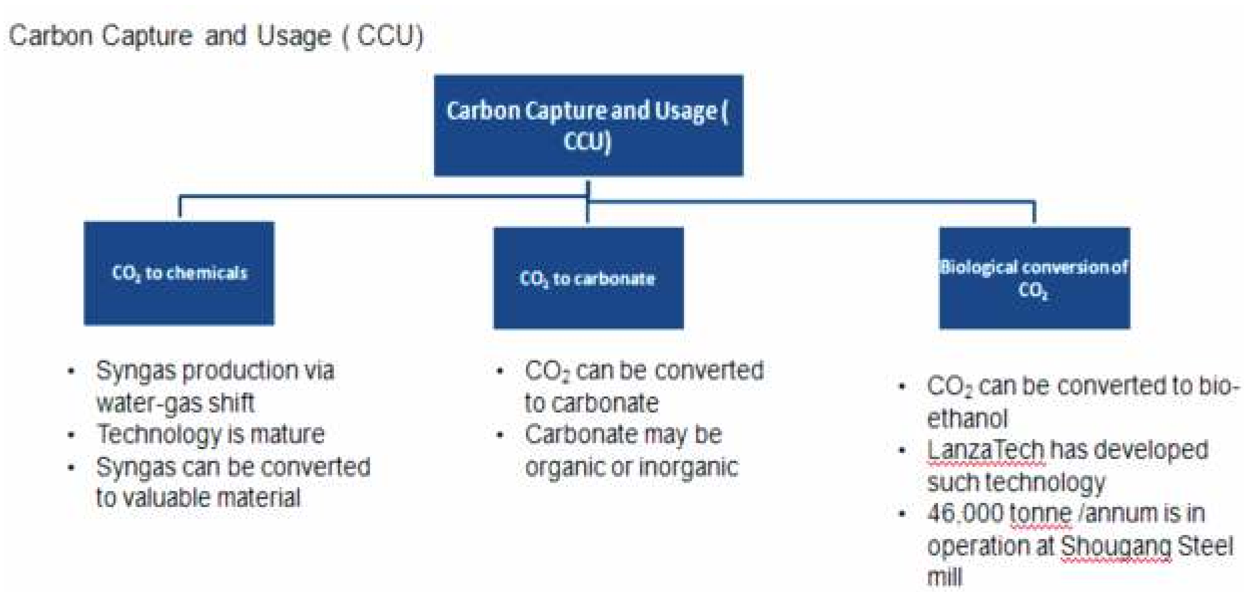


Technology	Pros	Cons
Absorption	Recovery rate >95% Product purity >99%	Solvent degradation Equipment corrosion
Adsorption	Low utility consumption and adsorbent is easily available	Hydrocarbons are co-absorbed Economical at high pressures.
Membrane	No regeneration energy Simple modular system	Membranes plugged by impurity Membrane wetting
Cryogenics	Purity>99%	Energy intensive CO_2 concentration in feed>50%

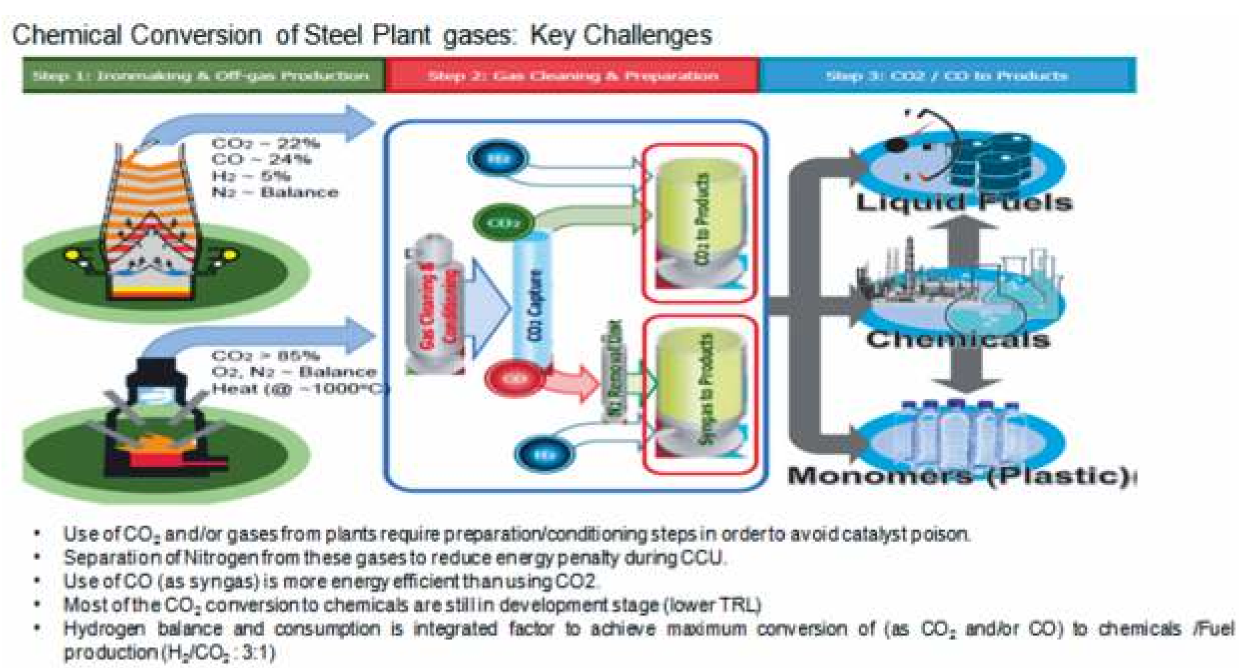
CCS (Carbon Capture and Storage)

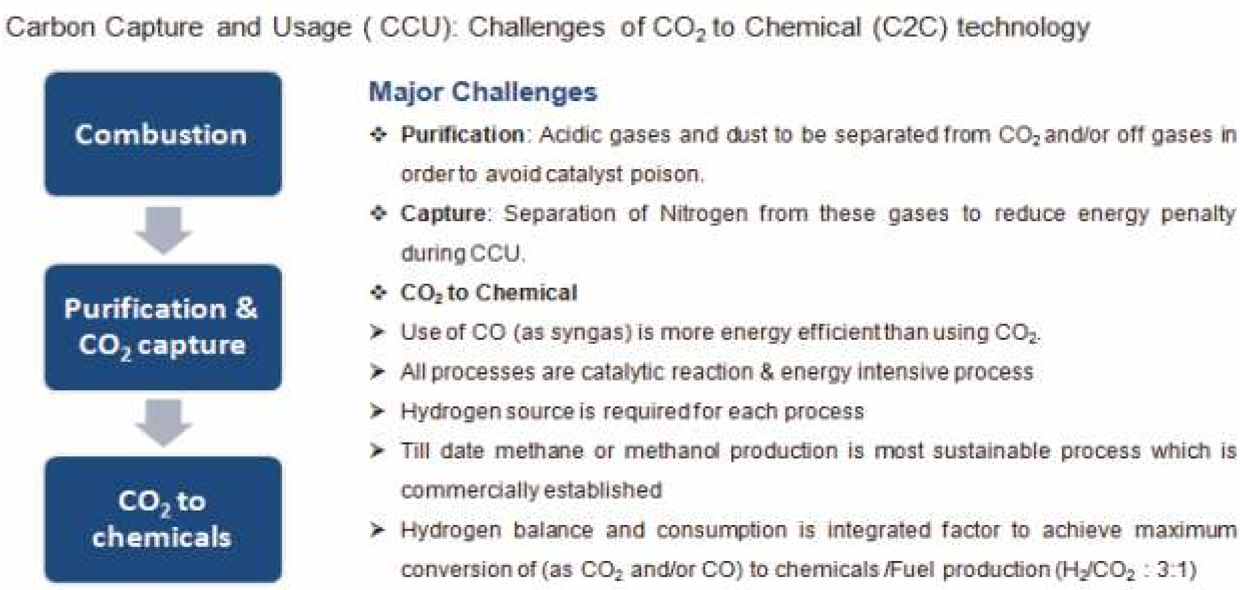
CCS (Carbon Capture and Storage): State of research/technology CO_2 Storage





While CCS and CCU are both medium- and long-term economic options, hydrogen is a growing opportunity in the face of ambitious international climate targets. It is one of the few options for reducing emissions in steelmaking and could provide renewable developers a competitive advantage in the current paradigm. According to McKinsey's Steel Lens, hydrogen-based steel production could enable steel production that is nearly carbon-neutral.





Role of Hydrogen in Low-Carbon Approach

While the next decade will likely see process modifications such as carbon capture and storage (CCS) and carbon capture and usage (CCU), implementation of new processes will be critical. One lever for these transitions will be the reduction of iron ore with hydrogen instead of coal. However, the determining factor for the success of this technology will be the availability of hydrogen at economic level and at scale.

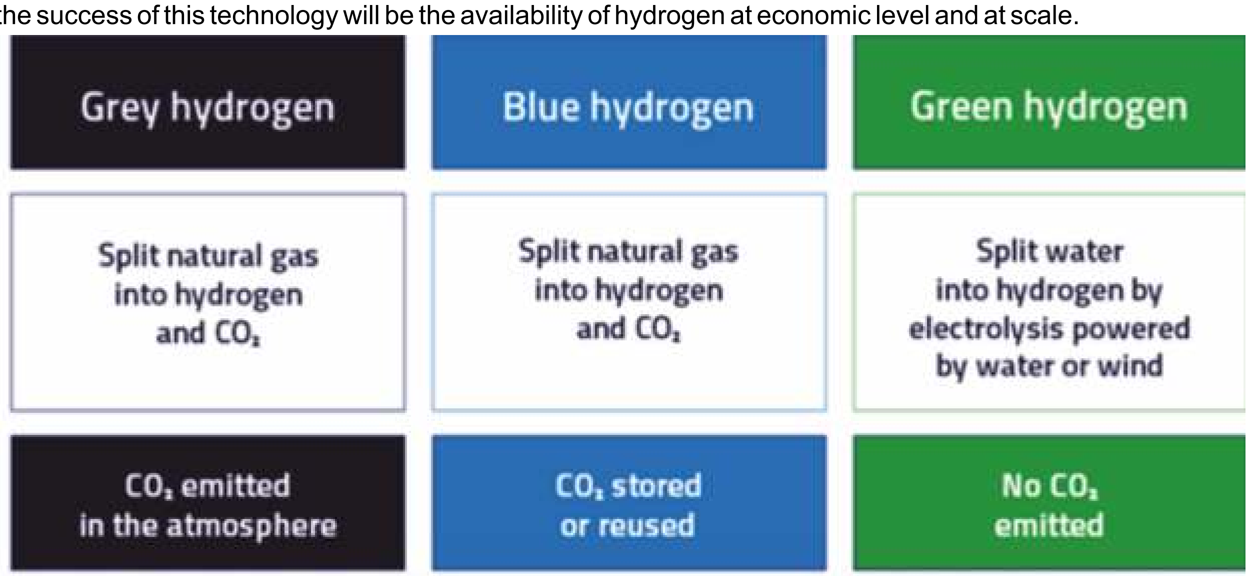


Figure. Differences between hydrogen types.

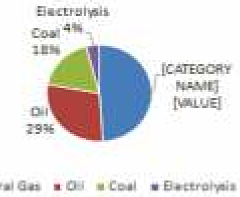
Hydrogen Production and utilization

Billions, Nm³/an		World (2018)	
Fossil	Natural Gas	309,1	49%
	Oil	182,9	29%
	Coal	113,9	18%
	Electrolysis	25,2	4%
	Total	630,8	100%

Global Production: 50 million tonnes / yr
Growing 10% / yr

Major Hydrogen Programs

Japan	Set up hydrogen fueling stations. Plans to spend $20 billion by 2020
Germany	Largest number of demonstration of hydrogen based applications; Hydrogen fueling stations
Iceland	Iceland plans to be world's first hydrogen economy
USA	Annual spending around $ 30M Hydrogen Freedom Fuel Initiative announced in January, 2003 with budget of US $ 2.2 billion. IPHE set up in November 2003



Source: Report on "Technology Roadmap on Hydrogen and Fuel Cells", pg. No. 10, IEA, 2018

Green hydrogen-based steelmaking can reduce our import dependence on coking/non-coking coal and make India self-reliant. Any investment in blast furnaces today will lock in imported coal demand for mid-century and beyond. Replacing coal by hydrogen generated with renewable energy (Green Hydrogen) would make it possible to largely decarbonise the industry. At current price levels, replacing coal with hydrogen would drive up the price of steel. This gap will likely narrow in the coming years, and could disappear by 2030, as carbon and carbon-emission pricing could drive up the cost associated with the use of coal on one side, while, on the other side, the decreasing costs of renewable electricity, efficiency gains resulting from larger-scale production of hydrogen, and optimisation of the hydrogen-based steel-making processes will drive down the costs of this alternative. India can become a leader in Green Steel production with groups like Reliance and Adani entering Green Hydrogen sector.

Conclusion

India has the target of producing 5 MTPA green hydrogen by 2030. It will need a renewable energy capacity of at least 100 GW, electrolyser deployment of 40 GW, and an investment of about $100 billion. With this, it would potentially reduce carbon emissions by 1.6 per cent, natural gas imports by 68 per cent, and save about Rs 40,000 crore on annual energy import bills.

India can also target green hydrogen use across other sectors of the economy. The country can blend green hydrogen in existing steel plants, use it across the mobility sector and also blend in existing natural gas pipelines. We expect that these sectors can create an additional green hydrogen demand of 3.5 MTPA, which will need the deployment of another 70 GW of renewable energy, 28 GW of electrolyser capacity and an investment of $78 billion. (ET Energyworld, 18 Jul, 2022). The upcoming National Green Hydrogen Mission is expected to have targets related to incremental blending of green hydrogen in refineries and fertiliser plants. It is expected that the mission will have a production-linked incentive scheme for the manufacturing of electrolysers. It might also have targets on pilots across sectors like mobility and steel. In short, interesting days ahead for Indian steel industry in terms of technology change, the impact of which will certainly be felt by the Indian refractory industry.

Reference

1. Decarbonizing the iron and steel industry: A systematic review of sociotechnical systems, technological innovations, and policy options: Jinsoo Kima, Benjamin K.Sovacoo et al (Energy Research & Social Science Volume 89, July 2022, 102565)

2. Tackling the challenge of decarbonizing steelmaking : (May 18, 2021)

TECHNICAL SECTION

EFFECT OF ANTIOXIDANTS ON THE PROPERTIES AND LIFE OF MAGNESIA CARBON REFRACTORY: A SHORT REVIEW

Arup Ghosh
Former Chief Scientist & Head Refractory, CSIR-Central Glass & Ceramic Research Institute, Kolkata, India, E-mail: arupcgcri1@gmail.com

Abstract

Technological advancement in refractories is closely related to the transitions in steelmaking technology with ever increasing operating conditions. Since the last few decades magnesia carbon refractory is being used as lining materials in primary as well as secondary steelmaking. This paper describes the effect of different antioxidants on the properties of MgO-C refractory. The role of antioxidants is also reviewed on the lining life of convertors and ladles. Use of nano carbon on the properties of carbon based refractory is illustrated in this review paper.

Refractory technological development started during the era of industrial revolution (18th to 19th centuries) [1]. Undoubtedly, the driving force of this advancement was the steel industry. A series of steelmaking furnaces were developed during this period, which includes i) Open hearth furnace - a reverbatory furnace for steel production, which employs regenerative heat exchangers to utilize its own waste heat; ii) Converter - a steelmaking furnace functions with the burning of impurities present in molten pig iron through air blown from the bottom of the furnace to use them as the heat source. Some of the refractories developed during that period include i) Tar bonded dolomite brick produced for Thomas (basic) converter, silica brick developed for the Bessemer (acidic) converter and open-hearth furnace etc.

The most significant advancement in steel making and refractory technology took place after World War II. Some of the innovations in steel production processes were oxygen blowing into open hearth and electric hearth furnaces, oxygen blown from the top of convertors, vacuum degassing and continuous casting of steel. The performance of refractories in those furnaces significantly improved with time. The remarkable trends were more use of high pure basic materials and expanded use of oxide carbon composite refractories.

The development of carbon based composite refractory originated with MgO-C brick in 1980's. These refractories are mainly used in basic oxygen furnaces, electric arc furnaces, steel ladles and functional components in continuous casting of steel. The importance of introducing carbon in oxide refractory is to reduce wear by lowering the slag / metal infiltration in the refractory. At the same time thermal shock resistance improves with the increase of thermal conductivity and decrease of thermal expansion of the product [2]. Additionally the higher sublimation temperature of carbon (4000°C) acts as super refractory.

In the primary steelmaking practise the slag is highly basic in nature and in this condition MgO-C refractory is the best option to resist the slag corrosion and other operating condition. The average lining life of BOF converters improved dramatically from 200-300 heats to around 5000 heats, when Dolomite products were replaced by MgO-C refractory along with periodical gunning and slag splashing in the lining. MgO-C bricks are produced by mixing size graded sintered / fused magnesia, along with antioxidants and pitch or phenolic resin as binders. In case of pitch, mixing temperature is between 100-200°C and for resin bonded products mixing is done in ambient conditions. The mixed mass is pressed in a heavy duty press followed by tempering to improve the strength through polymerisation of binders. Tempering for pitch bonded MgO-C is generally carried out between 250 to 350°C and for resin binders the temperature is between 180 to 220°C.

The MgO-C refractory in steelmaking received continuous R&D attention, the variables being quality of magnesia, graphite, metal additives, binders, etc. The enhancement of properties was with respect to hot strength, resistance to oxidation, slag attack, thermal shock resistance, thermal conductivity, modulus of elasticity etc. The addition of different metal powders (Al, Si, Mg, Al-Mg) to MgO-C system showed improved oxidation resistance and increase in hot strength [3]. The importance of carbon additions can be seen in the wear reduction by lowering infiltration depth and by increasing high temperature bonding. Thermal shock resistance is also improved by increasing thermal conductivity and decreasing thermal expansion [4]. Oxidation of carbon-containing refractories is either due to direct oxygen contact at elevated temperature or directly by oxides like FeO and MnO in the slag that are reduced to metals and oxidise carbon to gaseous CO. The antioxidants reacts with oxygen earlier than carbon due to their higher reactivity, which ultimately suppress the oxidation of carbon. The reaction products of the antioxidants and oxygen clogged the open pores of refractory, which ultimately restricts the oxygen ingress to stop carbon oxidation. Metals are added due to their higher affinity to oxygen than that of carbon, at the critical temperature range. Therefore, the carbides and nitrides, formed with the metallic antioxidants, protect the graphite against oxidation. Additionally, the presence of antioxidants improves the high temperature strength in air and under reducing atmospheres.

The commonly used antioxidants in carbon based refractory are Al, Si, B_4C or their combination [2]. Different reaction products formed with these antioxidants hinders carbon oxidation. The most commonly used antioxidant Al tends to form Al_4C_3 at intermediate temperature, which is relatively hygroscopic and disintegrate the refractory. However, at high temperature due to spinel formation it improves different properties. Ghosh et. al. [5] reveals that the oxidation resistance of Al containing MgO-C bricks is better than the Si containing one, at 1200–1550 °C. B_4C is a carbide based excellent antioxidant, which ultimately reacts with MgO to form low melting compound 3MgO B_2O_3 (M_3B) [6]. M_3B is liquid at high temperature, blocks the open pores and covers the carbon surface to suppress its oxidation. Another study reveals that best results were obtained with a combination of Al and B_4C or CaB_6 [7]. However the liquid phase formation at elevated temperature will be responsible for poor corrosion resistance and hot strength.

The oxidation resistance with and without antioxidants of MgO-C samples tested at 1500°C for 2 hrs is given in Table 1 [2, 6]. The % weight loss for the sample without antioxidants shows highest loss of 17% and the loss for the sample with B_4C is lowest (11%). The carbon weight loss for Al and Si antioxidants are higher (13-14%) compared to B_4C sample. From the results, it can be concluded that B_4C is the most efficient antioxidant to control weight loss followed by Si and Al in MgO-C samples. The phase development study evaluated by XRD analysis shows that the major phases are periclase and graphite and the minor phase for Al antioxidant is magnesium aluminate spinel ($MgAl_2O_4$), for Si sample is Forsterite (Mg_2 SiO_4) and for B_4C sample is Magnesium Borate ($Mg_3B_2O_6$).

Table I: Oxidation weight loss at 1500°C, phase development and HMOR of different MgO-C samples. [2, 6]

Sample	% wt. Loss	Minor phases	HMOR
MgO-C without additive	16.7	--	49
MgO-C with 2% Al	14.4	MA	81
MgO-C with 2% Si	13.2	M_2S	65
MgO-C with 2% B_4C	11.2	M_3B	40
MgO-C with Al (1%) + Si (1%)	14.0	MA, M_2S	88
MgO-C with Al (1%) + B_4C (1%)	12.9	M_3B, MA	87

It has been observed that the antioxidants in addition to suppress carbon oxidation have other function in these composite refractories particularly enhancing bonding effect to improve thermo-mechanical properties. It creates additional bonding in the product by forming oxides and deposited in pockets and grain boundary. It is reflected in the hot MOR of MgO-C refractory. This extra bonding effect of some antioxidant makes the product rigid and increases the young's modulus and finally causes brittleness of MgO-C brick. Therefore, though HMOR increases with some antioxidant, due to rigidity it is under higher stress and resulted in structural spalling.

Hot Modulus of Rupture test results of MgO-C sample without additive develops minimum strength [2, 6]. The higher weight loss of carbon in this sample increases the porosity at elevated temperature, which is responsible for low hot strength. The HMOR value of combined additive (Al + Si) containing sample were much higher when compared with other antioxidants. The reason for improved hot strength is due to transformation of Al to spinel and Si to Mg_2SiO_4 (Forsterite). All these bond phases are high temperature melting. The high melting phases along with low carbon loss contributed to the high hot strength of this sample.

Table 2: Slag corrosion resistance (Wear Index) of different MgO-C samples at 1650°C [6, 8]

Sample	Wear Index, %	
	Tripathi, Ghosh et. al. [6]	Zhang et. al. [8]
No additive	100	100
Additive - Al	79	90
Additive – Si	96	125
Additive – Al + Si	68	120
Additive – B_4C	146	190
Additive – Al + B_4C	76	75

Table 3: Slag corrosion resistance (Wear Index) of different MgO-C samples at 1650°C [6]

Sample	Wear Index, %
No additive	100
Additive - Al	79
MgO-C [SM + FM] SM – Dead burned MgO FM – Fused MgO	48

The results of dynamic corrosion test by Rotary Drum method is tabulated in Table 2 [6, 8]. The results show that the slag resistance of antioxidant added sample are much better compared to without antioxidant sample. When the wear index of sample without additive is 100, the same for (Al + Si) sample is 68 and Al sample is 79. The additive suppresses the carbon oxidation by blocking the open pores thus restricting slag infiltration and MgO corrosion. Zhang et al [8] reveals that out of all antioxidants ($Al+B_4C$) shows maximum corrosion resistance. He interpreted that B_4C develops low melting M_3B, which in turn favours the crystal growth of MA developed from Al antioxidant. The bigger size MA eventually protects the graphite to oxidise and ultimately improves corrosion property. The maximum corrosion resistance with minimum wear index occurs in sample having a combination of sea water magnesia and fused magnesia [SM + FM] along with Al antioxidant (Table 3) [2]. Here apart from the low carbon loss due to oxidation, the presence of bigger crystal fused magnesia improves the corrosion resistance substantially.

Refractory materials containing combination of fused and sintered magnesia and mixtures of metallic antioxidants shows optimum hot MOR and corrosion resistance (Table 3). MgO-C refractory (CSIR-CGCRI & RINL developed technology) with antioxidants on application in LD Converter shows a lining life of around 7000 heats [9].

According to H. Jansen [10] antioxidants added MgO-C brick shows some inferior properties compared to bricks without addition. The RUL / creep diagram of MgO-C brick with and without Al addition is shown in Fig 1. It reveals that both linear expansion (RUL) and volume expansion (creep) is higher for Al added samples due to insitu spinel formation. The higher expansion of Al containing bricks leads to higher stress, which may be responsible to develop cracks and poor thermal shock resistance.

MgO-C bricks with antioxidants in Steel ladle shows wear at slag line after certain heats. This is particularly seen for boron containing additives. Fig 2 shows that the fused MgO and spinel grains of the bricks are washed away in presence of by CA and CS containing slags. However, for Al antioxidants the results are not shown in this particular study.

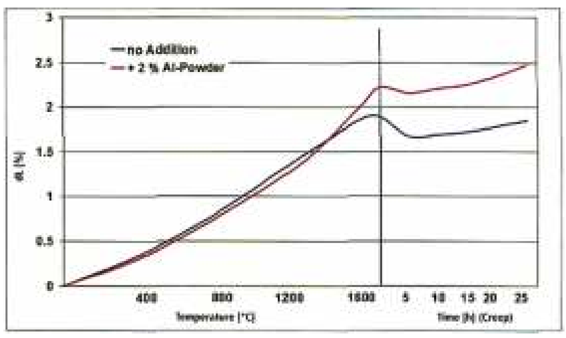


Fig 1. RUL and creep of MgO-C brick with and without 2% Al addition [10]

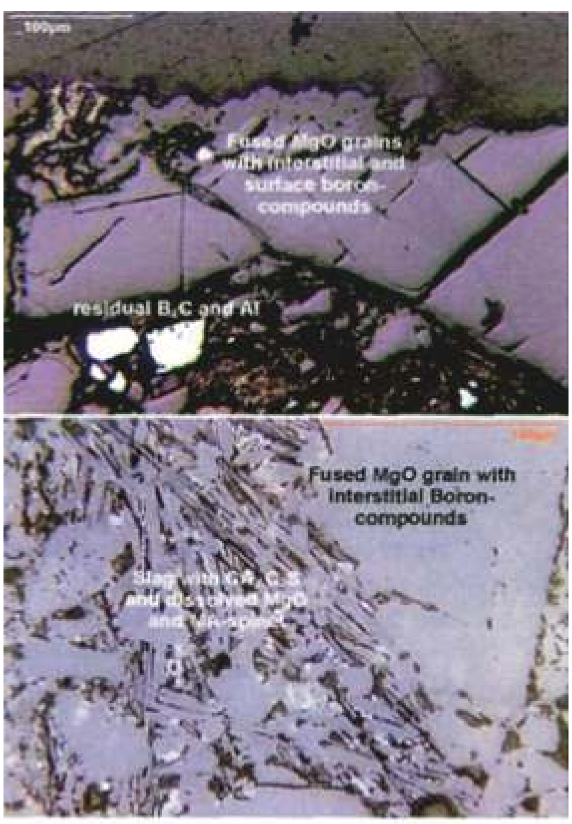


Fig 2. Microstructure of boron containing MgO-C brick and its dissolution CA and CS slag [10]

In the slag zone of steel ladle corrosion and oxidation is predominant factors, whereas thermal shock and abrasion resistance is negligible. The impact pad zone is subected to abrasion, erosion and spalling but slag corrosion is much less in this area. Tapping temperature is one of the major factor in MgO-C brick life with and without Al addition. At a higher temperature (1735°C) Al added MgO-C brick decomposes faster compared to without addition bricks. Al containing MgO-C refractory decomposes in a low O_2 atmosphere along with higher tapping temperature, which is responsible for relatively low lining life.

In MgO-C brick, the higher carbon content obstructs the steel refining process, since the objective of steelmaking process is to reduce the carbon content of steel through decarburisation. Therefore, since the last decade research is going on to reduce carbon content in refractory. One of the routes may be to use of nano carbon in refractory to reduce the graphite content substantially. Researchers are trying to reduce the carbon content of MgO-C refractory for reducing thermal conductivity, without compromising its critical thermo-mechanical and chemical properties. This can be done by making the structure denser, by using carbon black nanoparticles [11]. Research is also going on to develop in-situ carbon nanotube in the matrix through catalytic pyrolysis of organic binder used in the refractory. Properties of MgO-C refractories with and without nano carbon is given in Table 4 [12, 13]. Incorporation of nano carbon black improves the physical and thermo-mechanical properties of MgO-C refractory to that of conventional MgO-C refractory. It is also noticed that, for nano carbon bonded MgO-C refractory, the MOE is much less compared to that of conventional MgO-C refractory. The lower MOE value of nano carbon bonded MgO-C refractory indicates that the addition of nano carbon helps reduce the stress generation, which increases its flexibility and thermal shock resistance than conventional MgO-C refractory.

Table 4: Properties of MgO-C bricks with and without nano carbon [12, 13]

Properties	10% carbon containing conventional MgO-C refractory	0.9% Nano C+ 3% graphite containing MgO-C refractory
Apparent porosity (%)	3.3	5.2
Bulk density (g/cm^3)	3.03	3.05
Cold Crushing Strength (MPa)	37.5	59
Hot MOR at 1400^0C (MPa)	2.3	3.7
Modulus of Elasticity (GPa) [MOE]	76	71
Thermal Conductivity at 1000^0C (W/m^0K)	9.3	6.4

Using Nano carbon improves Hot MOR due to better densification and less oxidation of carbon. Finally, the higher thermal shock resistance is related to the lower residual fracture energy of nano carbon added bricks. Use of nano-carbon black also reduces total carbon content thus reducing heat loss and thermal stress to the steel shell. It is also reported [14] that, compared to conventional MgO-C bricks (with 20% flake graphite), bricks containing 3 wt.% carbon black (50 nm size) show similar thermal shock, but lower, thermal conductivity, wear and oxidation rates. Carbon black forms whiskers with antioxidants, fills the pores and increases the toughness. The oxidation of nano carbon generates small pores, which resist slag infiltration and thereafter wear.

Conclusions

In general antioxidants improve the oxidation resistance, HMOR and slag corrosion resistance of magnesia carbon refractories. However, in case of Al antioxidant RUL and creep properties deteriorate. Combination of Al and B_4C proved to be most effective additive in enhancing MgO-C properties. In the LD convertor antioxidants improve lining life in certain cases, but for steel ladles with higher tapping temperature and low oxygen level, MgO-C tends to decompose and may affect lining life. Nano carbon addition in MgO-C improves the properties compared to conventional graphite added bricks. It also facilitates production of clean steel as carbon pickup from refractory is limited. However, application of nano carbon based MgO-C refractory is not gaining popularity may be due to health concern of using nano materials in solid form, heterogeneity of mixing, cost etc.

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STATISTICS

Export of Refractory Products (2021-22)

EXPORT OF REFRACTORY ITEMS	m.t.	Rs. Lakhs
FIRE CLAY BRICKS & SHAPES	245910.00	9050.12
HIGH ALUMINA BRICKS & SHAPES	239930.00	92974.41
SILICA BRICKS & SHAPES	30720.00	2048.78
BASIC BRICKS & SHAPES	260641.44	21633.15
MONOLITHICS/CASTABLES	6707.72	47298.63
SPECIAL PRODUCTS	159710.00	69456.58
CERAMIC FIBRES ETC	106760.00	16005.34
OTHERS	89620.00	19361.52
TOTAL	1139999.15	277828.53

(Source: Min. of Commerce, Govt of India)

Import of Refractory Products (2021-22)

IMPORT OF REFRACTORY ITEMS	m.t.	Rs. Lakhs
FIRE CLAY BRICKS & SHAPES	2140.00	1161.32
HIGH ALUMINA BRICKS & SHAPES	1374450.00	54204.16
SILICA BRICKS & SHAPES	604550.00	6494.78
BASIC BRICKS & SHAPES	12190527.05	140586.69
MONOLITHICS/CASTABLES	348.45	108711.30
SPECIAL PRODUCTS	1840.00	3150.55
CERAAMIC FIBRES & OTHERS	334440.00	31625.55
OTHERS	844590.00	28808.78
TOTAL	15352885.50	374743.13

(Source: Min. of Commerce, Govt of India)

Technical Articles for IRMA Journal

Indian Refractory Makers Association extends an earnest request to all readers of IRMA Journal for their co-operation in providing technical notes and articles concerning raw materials development, introduction of novel inputs, refractory products and their design, selection, application engineering and performance for a better exchange of technical information and experiences amongst producers and user of refractories. The full paper can be mailed to support@irmaindia.org with the title “Technical Article for IRMA Journal”.

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3. The print area shall be 16cm width X 24.5 cm height.

4. The title of the paper is to be in 14 point “Arial” Bold and Italics, al Capitals, brief but informative e.g.

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5. The authors name and organization shall be printed in 10 point “Arial” Italic, e.g. *A.Dasgupta*

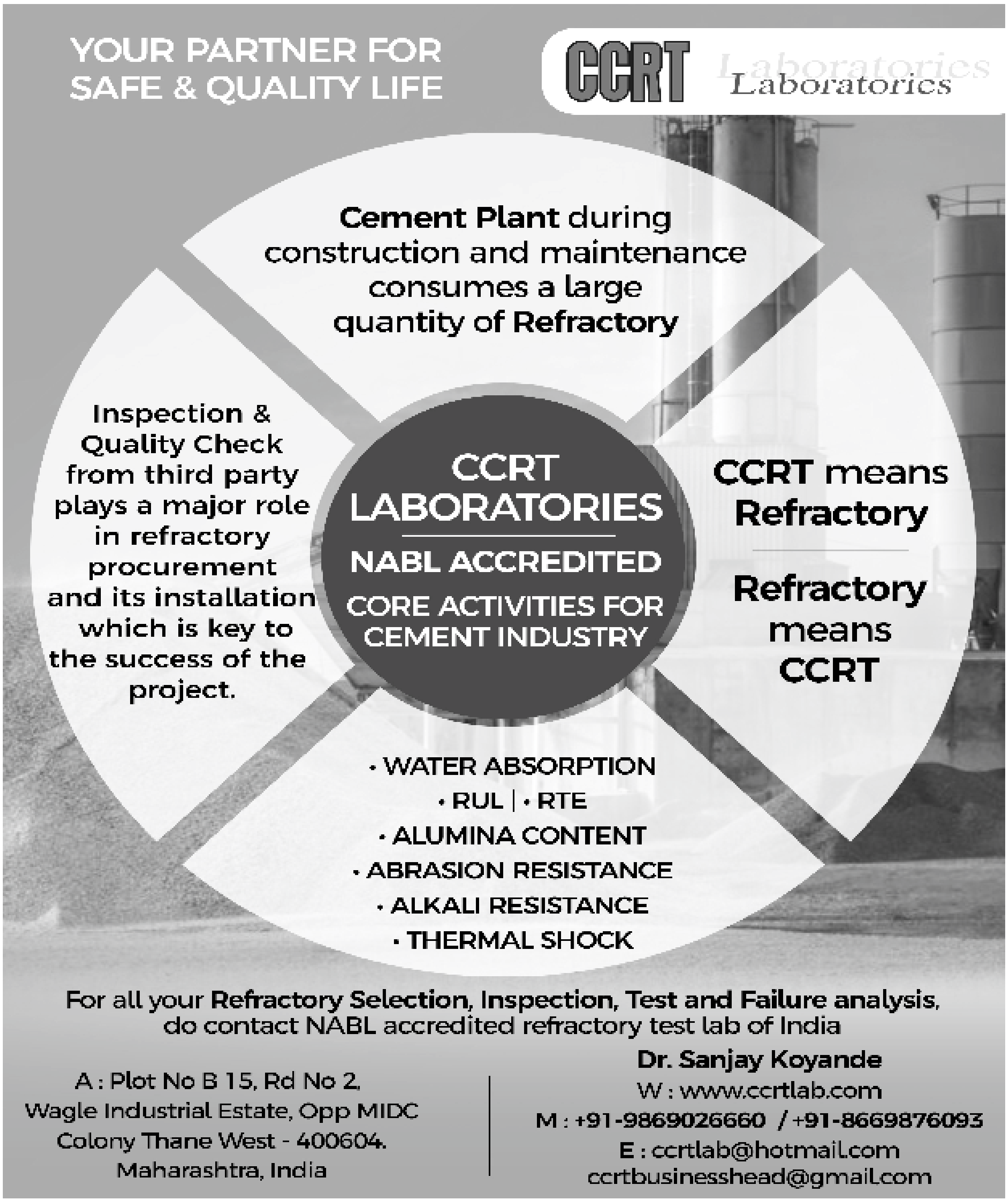
6. The sectional or sub-heading should be 10 point “Arial” Bold, e.g. **Effect of High Temperature**.

7. The body typing should be 10 point “Arial” Normal, e.g. The factor affecting the lining life

8. References are to be numbered in chronological order as cited in the text and should be given in 10 point “Arial” Normal, at the end of the article. The format should be:- surname and name of the author first, followed by the title of the book/article, the title of the paper/ publication, volume number, issue number, page and year of publication.

9. An abstract of the paper containing important feature of the text should be sent in about 100 words, along with the paper.

10. Five reprints of each paper shall be supplied to the author, free of charges.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