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Aluminium Vision Document

The Government of India's Ministry of Mines has recently released an *Aluminium Vision Document* aimed at transforming the Indian aluminium sector and aligning it with the vision of a "Viksit Bharat" (Developed India) by 2047.

Summary of the key objectives and aspects of the Aluminium Vision Document:

- Scaling Production: Aims to significantly increase aluminium production sixfold by 2047.
- Expanding Bauxite Capacity: Plans to expand bauxite production capacity to 150 MTPA.
- Boosting Recycling: Focuses on doubling the national aluminium recycling rate, reducing dependence on primary raw materials.
- Promoting Low-Carbon Technologies: Emphasizes the adoption of low-carbon and energy-efficient technologies to align with net-zero goals and sustainable development.
- Strengthening Raw Material Security: Seeks to enhance raw material security through targeted policy reforms and institutional mechanisms.
- Strategic Importance: Highlights the crucial role of aluminium in areas such as clean energy systems, electric mobility, and modern infrastructure, including the power sector.
- Government Initiatives: The vision document aligns with various government initiatives like "Make in India", "Smart Cities", and schemes promoting renewable energy and electric vehicles.
- Stakeholder Consultation: The document was developed through extensive consultations with industry players like NALCO, Hindalco, Vedanta, and associations like the Aluminium Association of India.

The Aluminium industry in India started in the 1930s when ALCAN set up its first smelter in Kerala through its subsidiary INDAL. Since then, India has reached a stage where it produces 4.16 MTPA of primary aluminium and 1.8 MTPA in the secondary sector. India today stands at the cusp of a major transformation. It has moved on from being called a developing nation to the leader of the Global South to harbouring ambitions of becoming a Developed economy by 2047. There are significant implications of this on per-capita income, quality of life and citizen-amenities, not to mention on overall GDP.

Aluminium is catalytic to the transformation we seek in the transportation, infrastructure and defence manufacturing sector. Its importance to the new economy is captured in the points below:

- It is lightweight and its application in transportation, construction etc. can bring down India's oil import bill.
- It is at the core of strategic sectors like space, missile defence, and aerospace and is of imperative importance in a world full of increasing strife.
- It melts at about 660°C compared to iron's 1538°C or silica (i.e. glass cullet) at 1700°C thereby making it less energy-intensive to re-cycle.
- Its electrical conductivity makes it the most important ingredient for the upcoming RE grid-connectivity projects, electric mobility etc.

India's GDP today stands at about USD 4 Trillion, seventy years since our Independence. The Government's vision is to take it to USD 30 Trillion in the next 23 years. From its inception till now, Indian per-capita Aluminium consumption has reached about 3.5 Kg (FY24) which is significantly short of the global average of 12 Kg. To achieve even the current global average by 2047, Indian per-capita consumption needs to grow at a CAGR of ~6%. The CAGR will need to be even more if India hopes to touch the per-capita consumption levels of nations like China, USA, and France etc. The economic progress of India will inevitably involve more Aluminium consumption than in the past. The incremental demand will come from the following three broad sources –

- Increased population – traditional applications at historical consumption intensity (e.g. electricals, utensils etc.): 1 – 1.5 MT
- Traditional applications but at higher consumption intensity (e.g. more airframes for India's growing defence-aviation industry, increased consumption of packaged food and drinks): 15 – 18 MT
- New-to-India applications at global average rate of consumption (e.g. greater component penetration in automobiles, transport etc. by Aluminium): 4 – 6 MT

The path to incremental demand will not be one strewn with roses. Cutting corners and compromising on product quality by some producers has resulted in either the discontinuation of aluminium use in certain products or the replacement of these domestic products with imports. For example, there is an urgent need to enunciate standards relevant to Aluminium in building and construction or e-scooters. Otherwise, these too will earn Aluminium a bad name. There is always competition forthcoming from alternate material from wood to steel to carbon composites. This can only be solved if the MSME sector is enabled to upgrade through professional guidance and aid through research and financial support. Luckily the existing players in the Aluminium industry have the line of sight into which of their MSME business partners are more capable than others. Their wisdom and knowledge base should be tapped to develop key MSME players to become the vanguard of high-quality downstream thrust.

While it will not be a one-way growth story, with competition from other materials, geo-political instability, global growth slow-down etc., it is estimated that India's domestic Aluminium demand will be –

- Short-term (FY24-FY30) : 8.5 MT by FY30
- Medium-term (FY31-FY40) : 18 MT by FY40
- Long-term (FY41-FY47) : 28 MT by FY47

India's vision in the Aluminium sector should not be restricted to meeting just the domestic demand. Today India is a fringe player in global Aluminium trade of 67 MT with a market share of only 3.8% whereas China has a share of 12.6%. Key competing geographies like China, Russia, North America are partially constrained to meet the future global demand. If India plays its hand well, it is not beyond the realm of possibility to aim to get a 10% market share by FY47. To address this overall demand, India's capacity should scale up to 37 MTPA by FY47.

This translates into a CAGR of about 7% for domestic demand driven growth and a CAGR of approximately 8.3% of overall capacity growth (including capture of export market share) which has to be covered in a gallop by the suppliers. This is in contrast to how the sector has grown in the past. Indian Aluminium sector growth has followed a step-function with long periods of gap between successive capacity additions. In the last 10 years, the sector has been in wait-and-watch mode. With high-capacity utilization in the last 3 years and in response to the increasing domestic demand, domestic producers have initiated expansion plans for their alumina refineries and Aluminium smelters. NALCO, Hindalco, and Vedanta aim to increase the country's alumina refinery capacity by approximately 10 MT and primary Aluminium smelter capacity by around 3 MT over the next 5 to 6 years.

However, these additional capacities for primary and Secondary Aluminium producers will not suffice to meet the projected short-term capacity requirement, **leaving India with a shortfall of another ~1.6 MT** of Aluminium production capacity by FY30. Similarly, the secondary sector growth plans are not supported by domestic scrap collection plans. To support India's goal of self-reliance, more scrap collection should be focused upon. These gaps will lead to potential import of Aluminium into the country. Alternatively, the Aluminium industry will go slow in pushing market-development.

Not only in the immediate term, even in the long-run, India will have to literally move mountains to stay '*Atmanirbhar*'. To meet the projected Aluminium demand, India must ensure a robust supply chain for Bauxite and Alumina, alongside sufficient capacity for both primary and secondary Aluminium production. Domestic primary Aluminium production is anticipated to satisfy domestic consumption needs and significantly boost export volumes. However, securing a steady supply of Bauxite is crucial. As per announced capacity by Primary Producers, Bauxite requirement is projected to reach at least 42 MT by FY30 whereas Alumina requirement is projected to reach 14 MT by FY30.

Also, assuming 85% Aluminium content in scrap (based on scrap import quality standard set by different countries), as per announced Secondary Aluminium Production Capacity, India's scrap demand will be as follows-

Year	Announced Secondary Aluminium Production Capacity (MT)	Scrap demand (MT)
FY30	3.5	4.12

Demand Supply Gap Assessment

India's current domestic self-reliant Aluminium production capacity is 4.2 MT, with secondary capacity of ~2.0 MT is largely dependent on imported scrap. With new bauxite capacity, an additional 3 MTPA of primary Aluminium production can be added. If the rate of mining from existing bauxite reserves can be increased by 50%, another 3 MTPA of primary Aluminium can be supported. Untapped domestic bauxite resources of 4.95 BnT, if proved can support another 14 MTPA of primary Aluminium. By FY47, secondary Aluminium production from domestic scrap is projected to reach an incremental 6 MTPA. However, to meet the projected Aluminium production capacity requirement of 37 MTPA **by FY47, there will still be a shortfall of at least 7 MTPA**, the raw material for which will need to be met from international sources of bauxite or scrap or discovering more bauxite resources within India. Depending on the assumption of a lease-period or life of mine, this gap might even increase. In any case, the process of transitioning 4.95 BnT of resources to proven reserves should happen on a mission-mode to ensure that the pathway to 2047 is clear. This is the biggest chunk of opportunity on which incremental Aluminium capacity can be planned.

Even the growth from 6.2 MTPA (4.2 primary and ~2.0 secondary) melting capacity to 28 MTPA of domestic demand-justified capacity is not a foregone conclusion.

There is no indication from the domestic Aluminium sector that they are planning to put up incremental capacity of the order of magnitude of 20 - 22 MTPA basis their current pronouncements. The Western world will not give India the Aluminium it needs because they are already on a journey towards decarbonizing their economies. Unless India thinks up a way to work around this current conundrum, there is a great likelihood that uncontrolled quality of Aluminium from rest of the geographies will find their way into India or India will just stop short of achieving its potential due to supply side constraints.

Even with massive jumps, some part of the plan is still not baked in. Each of these demand and supply side issues has to be addressed at the micro and macro level.

As was mentioned earlier, domestic demand growth would be about 7% CAGR and capacity growth required, considering export demand, would need to be about 8.3% CAGR. This is more than what Aluminium sector has achieved in the past 50 years. Also, the long gaps between sequential capacity growth in the sector is directly attributable to very few large-capacity players in the country. This is unlike the steel sector, which has seen continuous capacity growth on account of multiple large capacity players, each on their own track of capacity addition. The main reasons behind low capacity CAGR of Aluminium industry compared to steel are:

- Relatively underdeveloped end-use industry (like Aerospace manufacturing) and low penetration of Aluminium in standard segments (like Automotive) vis-à-vis global standards
- High capex per-tonne of capacity – especially in the primary Aluminium sector compared to steel
- Difficult raw material security scenario (unlike iron ore which has multiple commercial/ merchant miners)
- Lack of clarity around evolving regulations related to energy and carbon transition around the globe and India

The 37 MTPA capacity is not only the need of India but also an opportunity which will get frittered away if the difficult issues impeding the growth of the sector are not addressed in a comprehensive manner. Before delving into the nature of the challenge and its potential solutions, it might be useful to learn from the experience of countries that have been ahead of India in the curve and are of comparative size.

Global Lessons

There are several lessons to be taken from USA’s and China’s Aluminium sector strategy. In 1980, US primary Aluminium production peaked at 4.65 MT from about

30 smelters. By 2000, USA was down to about 23 primary Aluminium smelters. Currently USA produces less than 1 MT of primary Aluminium in about 4 operating smelters. The rest of the US production of over 4 MT comes from the secondary sector which processes scrap. There is a limit to which scrap based secondary production can go because it is limited by the amount of scrap generated in the first place and then collected. The main reason given by US primary producers behind closure of the smelters has been the high cost of energy. Also, the bauxite for US refineries was predominantly imported. Today, US meets about half of its Aluminium demand from imports. Over half of these imports come in from Canada which enjoys low production cost due to its access to hydropower. It is a matter of great irony because ALCAN of Canada (now part of Rio Tinto) was born out of ALCOA. Between 2018 and 2022, USA has to impose import tariffs and tariff rate quotas on Aluminium and its derivative products to protect whatever little capacity remains in that country. US industry’s denouement shows that not managing raw material availability and energy price led to a situation where the domestic production is in a non-competitive downward spiral compared to imports.

On the other hand, China’s Aluminium production today is overwhelmingly through the primary route. The Chinese primary Aluminium industry grew from just 0.4 MT in the 1980s to over 40 MT in 2023. This remarkable growth can be attributed to several factors. While the USA shifted its focus away from primary Aluminium, China promoted its primary industry through substantial government support in terms of policies and subsidies. In 2006, China recognized Aluminium as a “Pillar Industry,” emphasizing the government’s significant role. Investments in infrastructure and energy projects, along with heavy investments by Chinese companies in modernizing production facilities and adopting advanced technologies, increased efficiency and output, making Chinese Aluminium more competitive globally. By focusing on large-scale production, China reduced costs and increased production capacity, allowing its companies to dominate the global market.

Additionally, many Chinese Aluminium producers integrated their operations vertically, controlling everything from bauxite mining to Aluminium smelting and processing, which streamlined operations and reduced costs. Since the coal-based power costs in China are also high, they have continuously sought newer manufacturing and digital technologies to reduce the per-ton power consumption. Today when the world looks to become greener, China has accumulated sufficient scrap-worthy Aluminium in its economy which it can use to sustain a shift to secondary route. Still China looks to stay invested in primary Aluminium. All it now needs to do is to retain a relevant tax proposal that keeps its Aluminium scrap in the country. China is a good example of a timely and well-thought-through capacity expansion story that will sustain its leadership position in Aluminium for years to come.

It can be seen from the debacle of the US Aluminium industry (more in historical context section) how its dependence on scrap based secondary Aluminium and imported bauxite led to a downward spiral. Reliance on scrap can reduce carbon footprint but it puts a limit on production. There is no way any country can produce Aluminium beyond the quantum of scrap available, which itself is less than the quantum of production done previously. This is a vicious cycle. There are only three ways of expanding production:

- Promoting primary Aluminium with domestic resources with progressively increased availability of these resources over time
- Modernizing scrap tracing, collection and re-cycling domestically, popularizing and expanding closedloop scrap-based production method with progressively greater collection each year
- Mobilize scrap from beyond India – either as unprocessed scrap or as remelt ingots and secure domestic supply chains. It should be easier to pull off than getting green-field mines off the ground in foreign geographies as is being attempted now by several players including government companies. However, the modus operandi for such action should predominantly be private in nature to ensure agility. Support from government may be conceptualized for metal content brought back into India through such registered entities.

Way Forward for Indian Aluminium Sector: Its Strategic Objectives

India cannot emulate China's strategy now. When China grew, fossil fuels were not anathema to regulators, activists and shareholders. As India stands at the cusp of a take-off, it is saddled with this additional burden of carbon-footprint minimization. While NALCO is predominantly owned by Government of India, the other two large players are of an international nature. Global shareholders may prevent those companies from investing in coal-based capacities going forward. India should have more players in the large-capacity segment (> 500 kt) by 2047, if not by 2035. USA had about 14 companies producing ~4.5 MTPA of primary Aluminium in 1980s7. China had more than 30 primary Aluminium players in 20168. India on the other hand has only 3 primary producers. With more players, India will not only have a louder voice in policy framing for the country and globally but also foster a competitive market. India will also be able to fire on multiple cylinders and hustle their way around the global economy. More players with predominantly Indian shareholders may also have greater leeway with regard to fossil-fuel based capacities than current incumbents. However new players will only come in if India can solve for their line-of-sight to raw material and energy security.

In this scenario, India should focus on its innate advantages and follow the path described by our Hon'ble Prime Minister. Accordingly, its Vision and Mission may be articulated and worked upon by all the players in the sector. The demand and supply will not be achieved automatically. It has to be actively guided through policies and other enablement. The sector's vision and mission should be facilitated by the ministry and established in the following suggested tenets:

Copper Vision Document

The Government of India's Ministry of Mines has recently released **Copper Vision Document to Strengthen India's Clean Energy Infrastructure.**

Copper is vital for India's energy transition, infrastructure growth, and green technologies such as electric vehicles and solar power. Cu Vision Document provides a long-term strategy to meet growing domestic demand while ensuring raw material security. The document was developed through wide-ranging consultations with key stakeholders including Hindustan Copper Ltd. (HCL), Hindalco Industries Ltd., Kutch Copper Ltd., Vedanta Ltd., Indo-Asia Copper Ltd., Lohum, along with industry associations like Indian Primary Copper Producers Association (IPCPA) and International Copper Association (ICA).

The Copper Vision Document anticipates a six fold increase in demand by 2047 and outlines plans to add 5 million tonnes per annum of smelting and refining capacity by 2030. It focuses on scaling up secondary refining, enhancing domestic recycling, and reducing dependence on open-market imports by securing overseas mineral assets through global partnerships.

The Copper Vision Document is a step forward in creating a sustainable, resilient, and future-ready copper ecosystem for the nation.

The Copper Vision Document outlines a strategic roadmap for India's copper industry to support national growth, sustainability, and energy independence by 2047. Recognizing copper's pivotal role as a critical mineral, the document emphasizes copper's importance across vital sectors— such as renewable energy, electric vehicles, electronics, and infrastructure—which are essential for achieving India's ambitious economic and sustainable development targets.

Copper has been recognized as a critical mineral in India's resource strategy, playing a key role in advancing national goals for green energy and electric vehicle (EV) transition. The demand for copper is projected to surge as India accelerates its transition to clean energy technologies, transportation electrification, and digital infrastructure.

By 2050, global refined copper demand is expected to reach 53 million tonnes (MT) due to rapid urbanization, infrastructure expansion, and industrialization. In addition to traditional sectors, increased demand is anticipated from renewable energy, EVs, charging infrastructure, and AI.

Despite this growing demand, supply is expected to tighten due to factors such as the recent closure of the Cobre Panama mine and Indonesia's ban on copper concentrate exports. Additional challenges include declining ore grades, environmental oversight, resource nationalism, and escalated operational costs.

On a positive note, copper miners are taking steps to reduce emissions and make mining more environmentally friendly. Approximately 73% of carbon emissions in the copper industry occur during mining and beneficiation, with the remainder from smelting, refining, and transport. The largest emission source is the carbonized electricity used to process ore into copper. Miners are increasingly adopting renewable energy and energy-efficient technologies to minimize pollution, enhancing the industry's environmental sustainability.

The Kamoa-Kakula mine in the DRC (Democratic Republic of the Congo) has recently completed its Phase 3 expansion, achieving a copper production capacity of 650,000 tpa from concentrate and a smelter capacity of 0.5 MTPA.

Phase 4 expansion is underway, aiming for an annual ore throughput of 20 million tonnes. New smelter capacities are also emerging in Indonesia, India, the DRC, the USA, and China. However, the increase in smelter and refining capacities has led to a copper concentrate deficit, driving down TC/RC {*In the context of copper concentrate processing, TC/RC refers to Treatment Charges (TC) and Refining Charges (RC). These are fees paid by miners to smelters for processing copper concentrate (ore) into refined copper cathode. TC/RCs are a key revenue source for smelters and a significant cost for miners prices.*} In November 2023, a benchmark agreement between Chilean miner Antofagasta and Chinese smelter Jinchuan set the treatment charge (TC) at USD

80/t—9% lower than the previous year and the first drop in TCs in three years. Given the recent concentrate supply tightening and expanding smelter capacity in China, spot TCs have plunged to negative level.

India, the third-largest importer of copper scrap, imported 0.310 MT in CY23, while China imported 1.98 million tonnes. With an increasing focus by major scrap-exporting nations on domestic recycling, the global scrap supply chain is expected to face disruptions. Scrap trade dynamics are evolving as key scrap-producing economies consider restricting scrap exports to encourage domestic recycling.

In FY24, India's refined copper usage stood at 0.844 MT, while total copper apparent usage was 1.718 MT, with the remainder sourced from direct scrap melting and net imports of semi-finished products. Over 90% of copper concentrate requirements were met through imports. Additionally, anode net imports of copper anodes stood at 0.205 MT in FY24. Since the closure of the Sterlite Copper Tuticorin plant, India has been a net importer of copper cathodes, with a net import of 0.335 MT in FY24. Consequently, India's copper (HS code 74) trade deficit has grown from USD 0.76 billion in FY17 to USD 6 billion in FY23, with the copper concentrate trade deficit (HS code2603) reaching USD 3.4 billion. The three-month average LME copper price in October 2024 was USD 9,724/t, and it is expected to rise further in the long run due to increased demand and supply constraints, impacting the nation's forex reserves.

To address these challenges, the Indian government has introduced several initiatives, including the Exploration License (EL), Reverse Charge Mechanism (RCM) on scrap, Quality Control Order (QCO), and Extended Producer Responsibility (EPR). However, further action is required to stimulate domestic demand. For example, China has approximately 116.1 million tonnes of copper in use, which can be recycled within about 20 years to hedge against supply disruptions.

In contrast, India has only 15.2 million tonnes, making scrap copper relatively scarce. Policies to standardize copper content in end-use products and public awareness campaigns on copper's benefits could promote higher energy efficiency and living standards.

India's copper demand is projected to reach 3.0 – 3.3 million tonnes by 2030 and 8.9–9.8 million tonnes by 2047, reflecting a 2–2.2x increase by 2030 and a 5.9–6.5x increase by 2047. Demand is expected to grow at an elasticity of 1.1–1.3 relative to GDP growth until 2030 and 0.6 – 0.7 until 2047, spurred by the government's ambitious renewable energy targets (500 GW by 2030, with 50% of power from non-fossil sources) and EV goals (30% EV penetration by 2030), as well as India's potential role as a global manufacturing hub under the China+1 strategy. These projections should be reviewed and adjusted every 2–3 years as technologies will evolve and copper content in the finished product might vary due to technology change. For instance, copper content in EVs has dropped from 99.32 kgs in 2015 and is expected to be 61.7 kgs in 2030 marking a 38 kgs per car reduction from 2015 to 2030.

Such substantial demand increases necessitate a strategic approach to secure supply. By 2047, India must expand its refining capacities by an additional 1 MT by 203 0 and another 3.5 MT by 2047. Alongside overseas mine acquisitions, downstream integration near these assets should be prioritized. Furthermore, India must improve its scrap refining capabilities, currently negligible, aiming to refine 15–20% of available scrap in the long term.

Given the strategic role of scrap in achieving net-zero goals, major economies are contemplating scrap export bans. India should consider imposing similar restrictions on copper scrap while enhancing domestic scrap collection. Copper in buildings and infrastructure becomes available for recycling after 30–50 years, whereas consumer goods and vehicles provide scrap within 15– 20 years. Government initiatives should thus focus on increasing copper demand in consumer goods to leverage this shorter recycling cycle.

To ensure a stable supply of primary raw materials, India should prioritize expanding domestic mining capacity and acquiring or investing in foreign assets in copper-rich regions such as Australia, South America, and Africa. Increased imports from Africa may be feasible following the recent removal of copper concentrate import duties.

Hydrogen-based DRI Compared with Natural Gas-Based Reduction

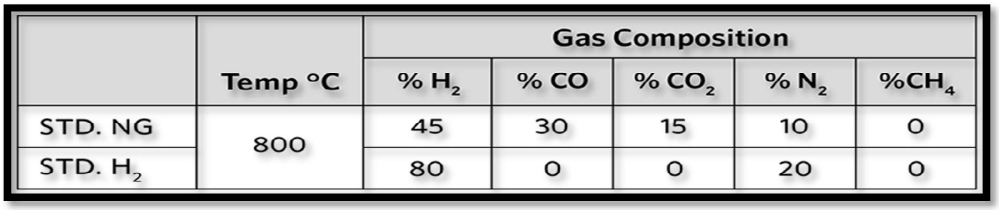
The mechanical properties of direct reduced iron (DRI), such as swelling behaviour and strength are influenced by reducing gas composition. Higher the carbon monoxide (CO) concentration in reducing gases, the more serious the swelling that occurs. relationship of the reduction disintegration tendency and the reduction mode has been examined and it has been concluded that the top chemical reduction *(top chemical reduction is a chemical reaction where a solid-state material is reduced, and the reaction occurs within the crystal structure of the material, maintaining the original* *structural topology)* in hydrogen (H_2) and CO mixture resulted in worse disintegration behaviour than the homogeneous reduction under pure H_2 atmosphere. These studies indicate that there is less possibility of swelling and disintegration when DRI is produced under H_2.

The use of pure hydrogen (H_2) as direct reduction reducing gas gives rise to the question whether the as-produced cold DRI (CDRI) will reach the same targeted parameters, such as product strength, when compared to CDRI produced from reformed natural gas (NG). Investigations were conducted at the Midrex Research & Development Technology Center to examine and compare the effects of gas composition on the apparent density, porosity, reduction swelling, cold crush strength, and fines generation of carburized and non-carburized CDRI when using either H_2 or reformed NG as the reducing gas. It was determined that the structure and physical properties of CDRI are influenced by the reducing gas composition and subsequently may affect plant operation or cause materials loss during processing and transportation.

Testing and Calculating Methodology

Five direct reduction grade-pellets, with total Fe ranging between 67.6% and 68.3%, were selected and subjected to two modified ISO 11258 reducibility tests. Two types of reducing gas were employed for the reducibility tests (labeled Standard NG and Standard H2). The gas compositions of the Standard NG and Standard H_2 reducing gases are shown in *Table 1*.

Table I: Gas Composition Standard NG and Standard H_2 reducing gas



		Gas Composition				
	Temp °C	% H_2	% CO	% CO_2	% N_2	%CH_4
STD. NG	800	45	30	15	10	0
STD. H_2		80	0	0	20	0

The pellets reduced under Standard NG reducing gas were further carburized to achieve around 2% carbon level to mimic industrial DRI. After the pellets completed the reduction process under Standard NG conditions, the NG-reduced DRI was immediately subjected to 30 minutes of cooling under nitrogen (N_2) flow to a temperature of 700°C, followed by carburization under a continuous flow of a mixture of H_2 and CH_4 (methane) gas, maintained at 700°C during the carburization process.

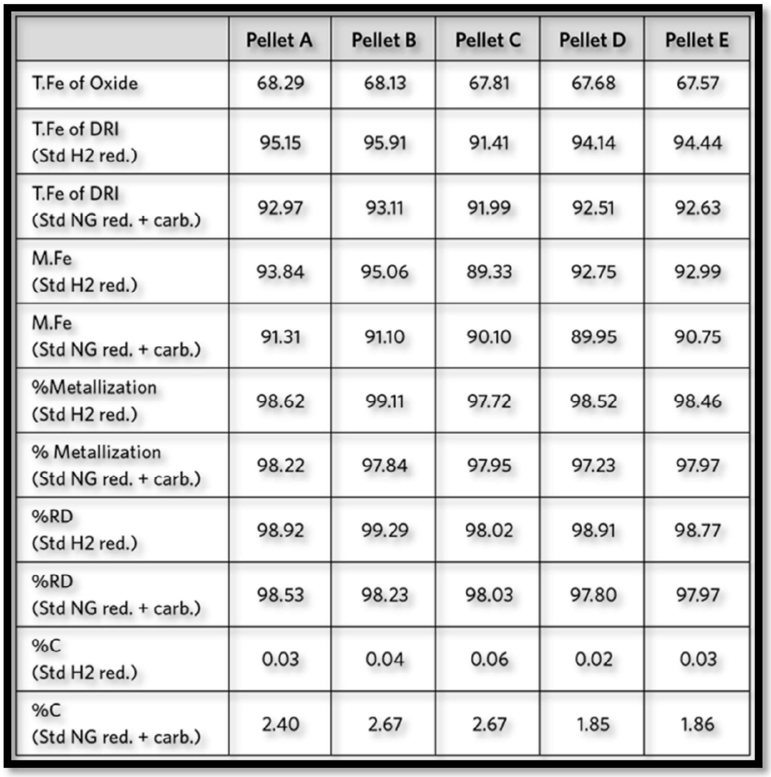
The physical properties of the H_2-DRI and the carburized NG-DRI, such as apparent density, porosity, volume expansion, cold crushing strength, and tumble strength were measured using methods developed in-house. The reduction degree of the pellets at any given time was determined by weight loss of the samples during reduction based on reduction degree at a set time, weight change in load cell at a set time during the reduction test, and total weight change of sample after the completion of the reduction test.

The reduction degree of the DRI was determined by measuring the concentration of total Fe (% Fe_t), metallic Fe (%M. Fe), and FeO (% FeO) via chemical analysis. The carburizing percentage of NG-DRI was determined by weight gain of the samples during carburization. The volume expansion ratio of DRI was determined with a series of equations that considered volume of sample, sample weight after reduction and carburization, weight of oxygen combined with iron as Fe_2O_3 and Fe_3O_4 in oxide pellet, weight of oxygen removed by reduction, sample weight after reduction, apparent density of sample, and oxygen concentration of the oxide pellet.

Results

Chemical analysis and reduction curves of oxide pellets and DRI

Table II: Typical DR-grade oxide pellets characteristics



	Pellet A	Pellet B	Pellet C	Pellet D	Pellet E
T.Fe of Oxide	68.29	68.13	67.81	67.68	67.57
T.Fe of DRI (Std H2 red.)	95.15	95.91	91.41	94.14	94.44
T.Fe of DRI (Std NG red. + carb.)	92.97	93.11	91.99	92.51	92.63
M.Fe (Std H2 red.)	93.84	95.06	89.33	92.75	92.99
M.Fe (Std NG red. + carb.)	91.31	91.10	90.10	89.95	90.75
%Metallization (Std H2 red.)	98.62	99.11	97.72	98.52	98.46
% Metallization (Std NG red. + carb.)	98.22	97.84	97.95	97.23	97.97
%RD (Std H2 red.)	98.92	99.29	98.02	98.91	98.77
%RD (Std NG red. + carb.)	98.53	98.23	98.03	97.80	97.97
%C (Std H2 red.)	0.03	0.04	0.06	0.02	0.03
%C (Std NG red. + carb.)	2.40	2.67	2.67	1.85	1.86

Table II shows the chemical analysis of the five selected pellets in their initial oxide state after Standard H2 reduction and after Standard NG reduction followed by carburization, respectively.

The reduction curves of the five oxide pellets that were reduced under Standard H2 and Standard NG reduction conditions are shown in *Figure 1A* and *Figure 1B*.

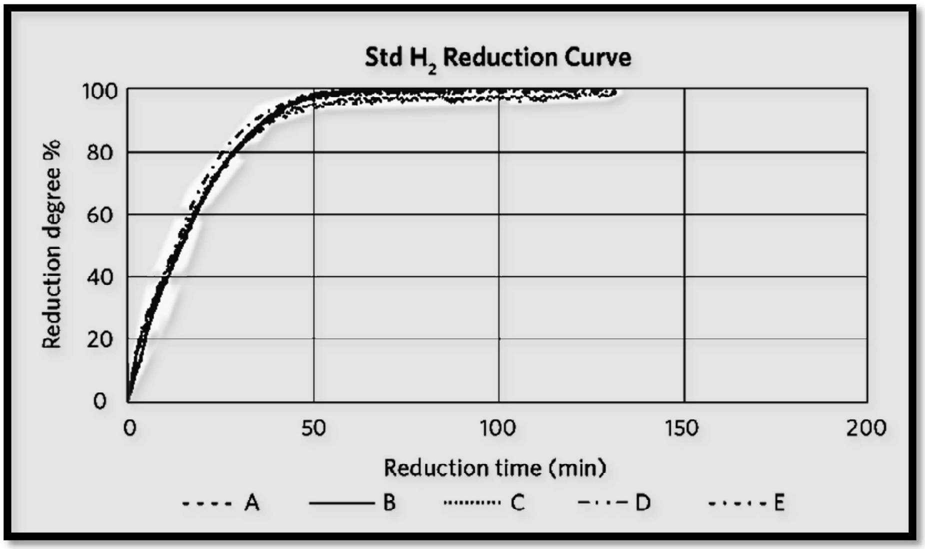


Figure 1A: Reduction curves under Standard H_2 conditions at 800°C

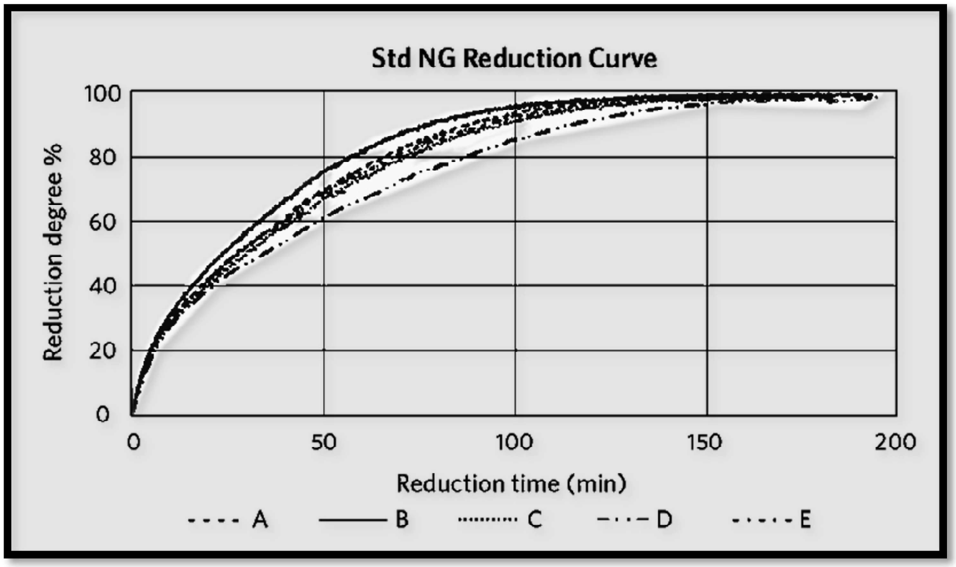


Figure 1B: Reduction curves under Standard NG condition at 800°C

The reduction curves indicate that under the same reduction temperature (800°C), the reduction rate (i.e., for achieving a given reduction degree) was the fastest for the pellets reduced under the Standard H_2 reduction condition. We also observed that there was not much difference in the reduction behaviour of the different oxide pellets when they were reduced under the Standard H_2 condition. On the other hand, the reduction rate varied among the different oxide pellets when they were subjected to Standard NG reduction condition. The reason for the different reduction behaviours between the oxide pellets and reduction conditions is not clear, as there are many factors that can affect the reduction curve of oxide pellet including pellet size distribution, iron oxide grain size distribution, size of pores, pores complexity inside the pellet, slag phase, bonding strength of oxide grains, and pelletizing temperature.

Apparent density and porosity comparison

Figure 2 and *Figure 3* show the average apparent density and porosity of oxide pellets, H_2-DRI, and carburized NG-DRI. There is no noticeable difference between the H_2-DRI and NG-DRI.

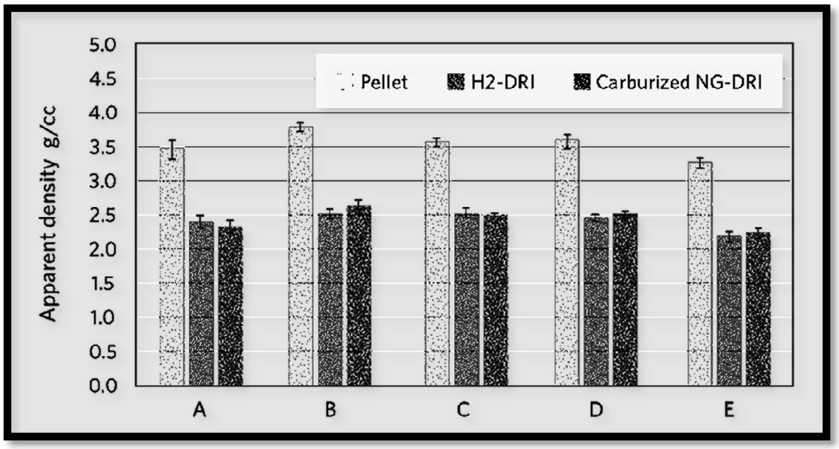


Figure 2: Apparent density of oxide pellet, H_2-DRI, and carburized NG-DRI

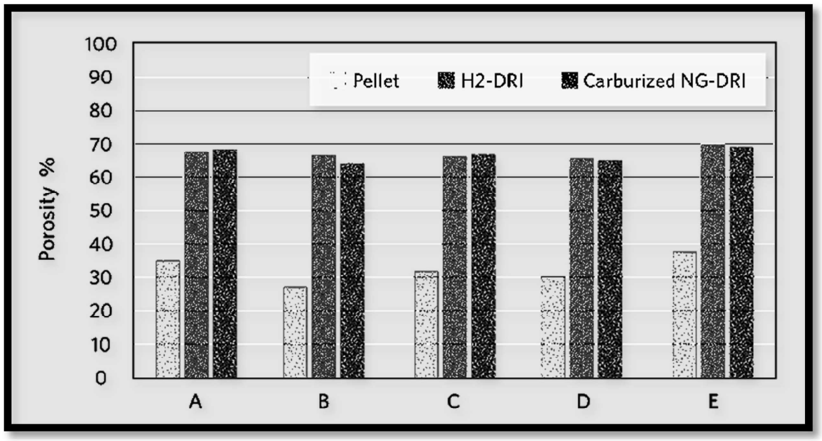


Figure 3: Porosity of oxide pellet, H2-DRI and carburized NG-DRI

Figure 4 shows the relationship between the porosity of oxide pellets and DRI. As can be seen in *Figure 4*, the porosity of DRI trends with the porosity of the respective oxide pellets and this suggests that the porosity change during the reduction process, or the final porosity of the reduced pellets, is mainly governed by the pre-reduced oxide pellets.

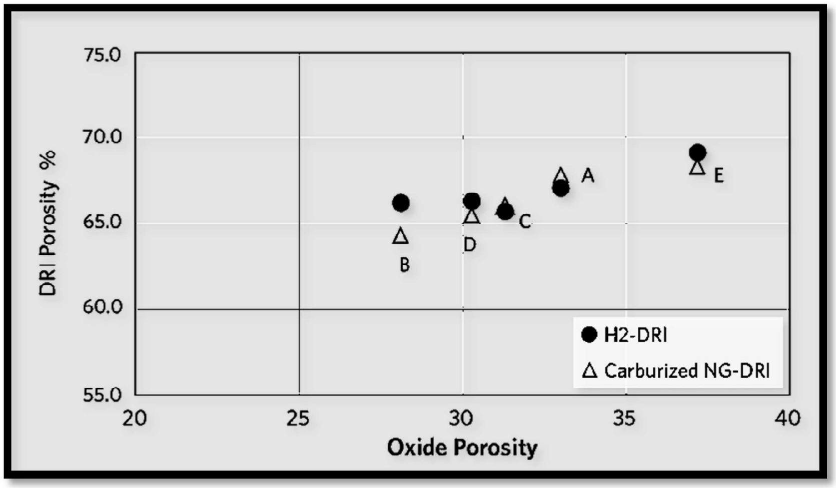


Figure 4: Comparison between porosity of oxide pellet, H2-DRI and carburized NG-DRI

Volume expansion comparison

Figure 5 shows the volume expansion comparison between H2-DRI and carburized NG-DRI of each pellet brand. For all oxide pellet brands, hydrogen reduction produced comparable or smaller volume expansion than reformed natural gas reduction.

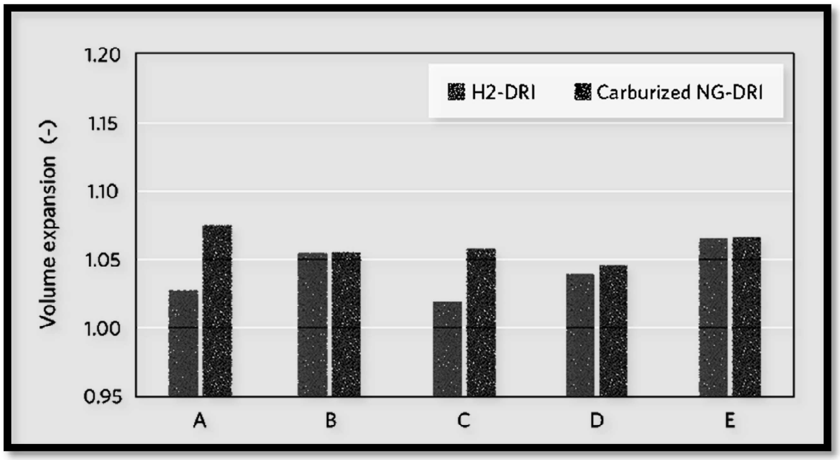


Figure 5: Volume expansion comparison between H2-DRI and carburized NG-DRI

Cold Crushing Strength (CCS comparison)

Figure 6 shows the average CCS (kgf/ piece) of H2-DRI and NG-DRI. For all pellet brands, H2-DRI has slightly higher CCS than NG-DRI. Based on this result, we can expect CDRI produced from H2 reduction to have less cracks or breakage during handling or transportation compared to NG-CDRI.

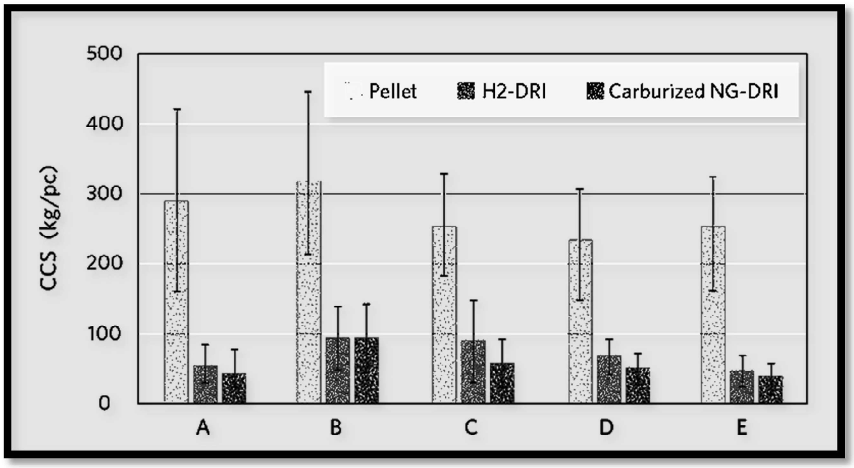


Figure 6: CCS comparison between oxide pellet, H2-DRI and carburized NG-DRI

Tumble Strength (CCS comparison)

Figure 7A and *Figure 7B* show the average weight ratio of fines at -3.35 mm and -1.0 mm generated H_2-DRI and NG-DRI, respectively. For all the pellet brands, H_2-DRI generated less fines compared to carburized NG-DRI. Based on this result, we can expect that cold H_2-DRI would generate less fines during handling than NG-DRI. One possible reason for the higher fines generation by carburized NG-DRI could be that the Fe3C (iron carbide) phase has less resistance to abrasion than metallic iron.

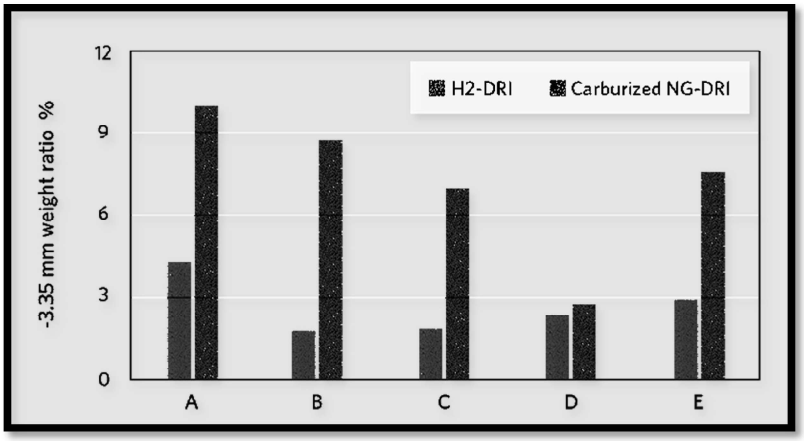


Figure 7A: Weight ratio of -3.35 mm fines generated by H2-DRI and carburized NG-DRI

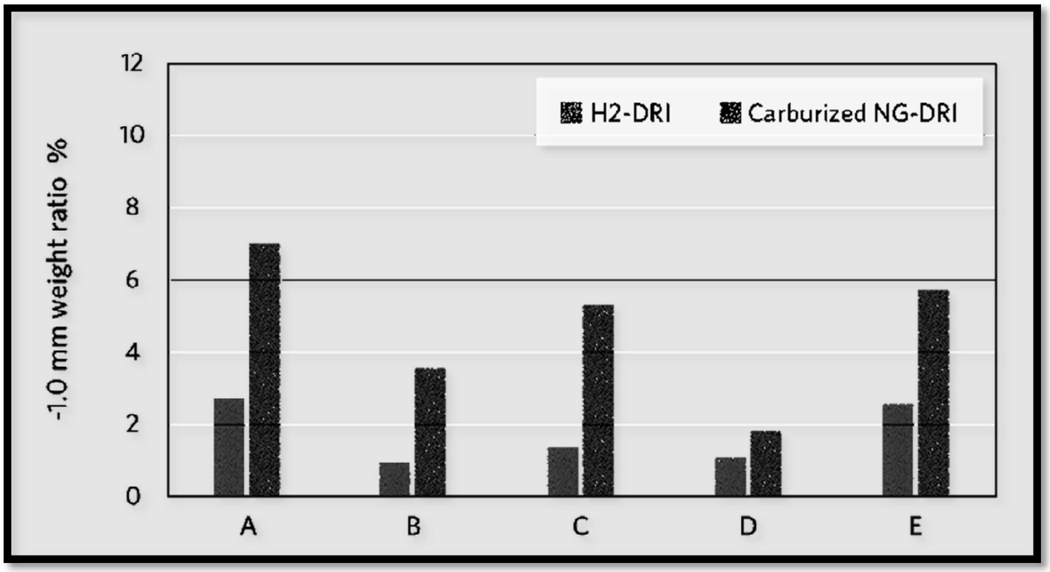


Figure 7B: Weight ratio of -1.0 mm fines generated by H2-DRI and carburized NG-DRI

Discussion

Effect of reduction gas composition on physical properties

To better understand the effect of H_2 reduction on the physical properties of DRI, the CCS and weight ratio of fines, results were compared with respect to DRI porosity. *Figure 8A* and *Figure 8B* show the relationship between porosity and CCS of H_2-DRI and carburized NG-DRI, respectively. The result shows that for a given porosity, the CCS of H_2-DRI is stronger than carburized NG-DRI and the compression strength decreases with increasing porosity.

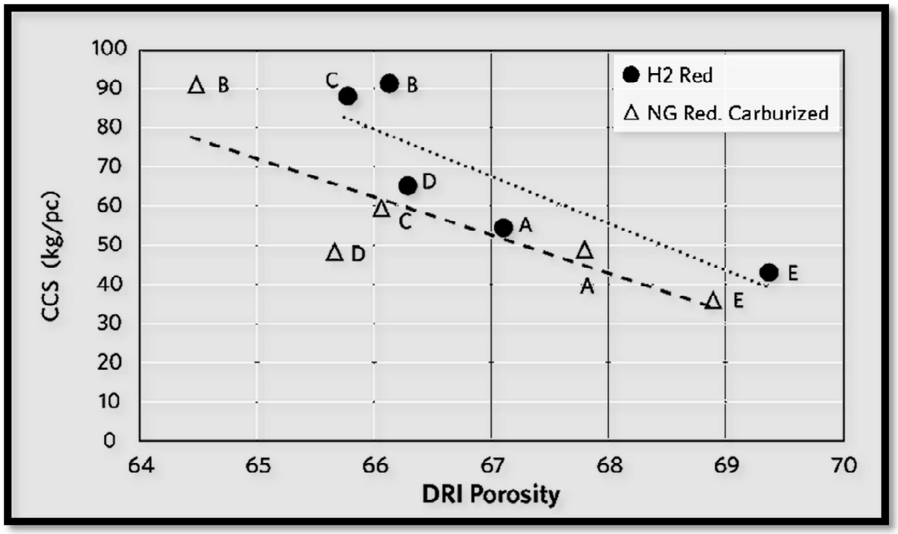


Figure 8A: Relationship between porosity and CCS of H2-DRI and carburized NG-DRI

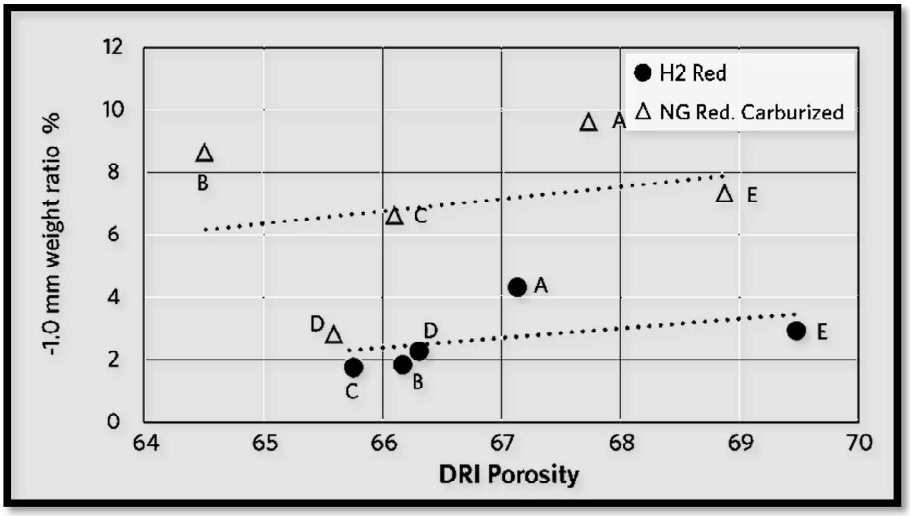


Figure 8B: Relationship between fines generated and CCS of H2-DRI and carburized NG-DRI

Furthermore, *Figure 9* shows the relationship between porosity and fines generation of H_2-DRI and carburized NG-DRI. Both conditions have exhibited linear relationship of fines generation over DRI porosity. However, H_2 reduction produced lower amount of fines generation than carburized NG-DRI.

Thus, we can conclude that hydrogen reduction allows higher strength and lower fines generation for CDRI than NG reduction with carburization. Among the different DR-grade pellet brands, oxide pellet porosity is key for determining CDRI physical properties.

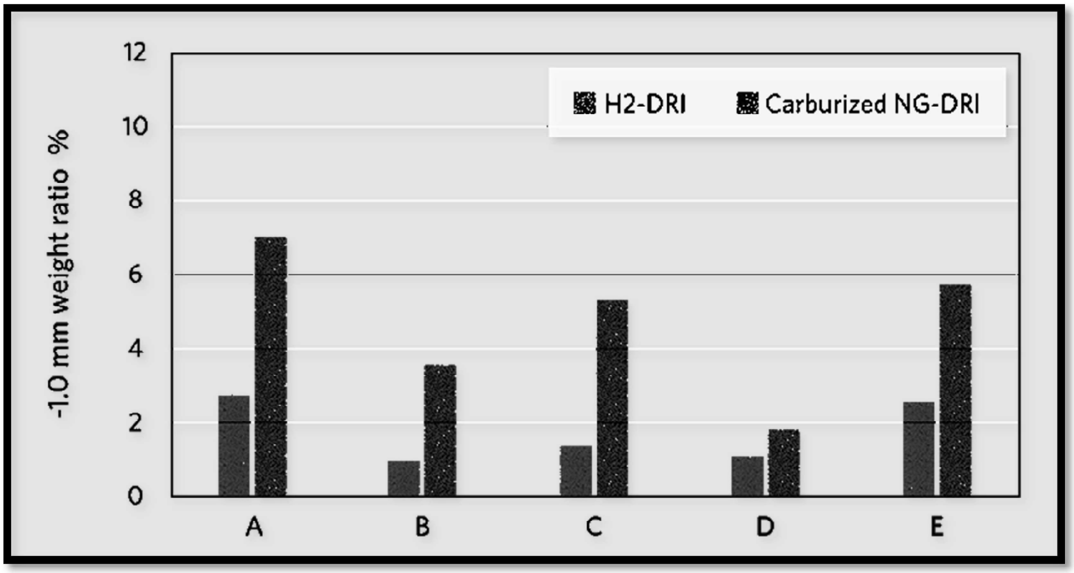


Figure 9: Weight ratio of -1 mm fines generated by H2-DRI and carburized NG-DRI

Conclusions

A detailed study and comparison of physical properties of H_2-DRI and carburized NG-DRI produced from five DR-grade oxide pellets was conducted. There was no apparent difference in apparent density, porosity, and CCS between H_2-DRI and carburized NG-DRI. Fines generation by H_2 reduction is comparable or lower than that by NG reduction. Specifically, H_2 reduction had lower <1mm fines generation than NG reduction. CCS and fines generation correlated with DRI porosity. The descending order of pellet brands for DRI porosity is similar with that for oxide pellet porosity. Thus, oxide porosity is a key factor determining the physical properties of CDRI.

India's New Hotspots for Mining Rare Earths

Papum and Pare – two little-known rivers winding through the hills of Arunachal Pradesh – may soon step into the national spotlight. The Papum Pare district, named after these rivers, has emerged as a promising frontier in India's quest for rare earth elements (REEs). A Ministry of Mines handbook released in June spotlighted the region's "notably high neodymium" content – a vital component in electric vehicles and advanced electronics. If tapped, these reserves could one day fuel EV and auto manufacturing hubs from Gurgaon to Pune to Chennai.

REE-enriched soils have also been identified in Assam's Karbi Anglong, while a bauxite-REE belt has surfaced in Meghalaya's Sung Valley. Adding to the momentum, is the newly discovered REE deposits of "promising" nature in the Singrauli coalfields of Madhya Pradesh.

Thus, the strategic metals the world is scrambling to secure are not limited to India's well-known beach sands, red sands, or alluvial deposits in states like Andhra Pradesh, Odisha, Tamil Nadu, Kerala, West Bengal, Gujarat, and Maharashtra. They lie deeper inland too – across the forests, hills, and even coalfields of India's unexplored heartlands. India has identified many of these new hotspots.

India's reliance on China for rare earth magnets remains strikingly high, with 85-90% of import volumes and 60-80% of import value in two key categories. This data underscores the depth and complexity of India's supply chain dependence.

REEs comprise a group of 17 elements, divided into two categories: light and heavy. Light REEs, such as neodymium and praseodymium, are essential for electric vehicle motors, wind turbines among others.

In contrast, heavy REEs like dysprosium and terbium are critical for high-performance applications, including fighter jets and other advanced defence systems that require enhanced magnetic stability.

While rare earths are classified as critical minerals, it's important to note that not all critical minerals are rare earths. Elements such as lithium and cobalt, also vital to the EV ecosystem, fall into the critical category but are not part of the rare earth family.

In 2024-25, the Geological Survey of India undertook 195 exploration projects to assess critical minerals including REEs.

While the discovery of new pockets of clean-tech metals offers hope for the future, what India urgently needs is a diversified and resilient supply chain. India may rank third globally in rare earth reserves – trailing only China and Brazil – but when it comes to actual production and refining, the numbers tell a stark story.

As of 2024, China mines nearly 70% of the world's rare earth and controls an overwhelming 90% of refining capacity, according to US Geological Survey's data. India's production share is less than 1%.

India must adopt a multi-pronged strategy to navigate the rare earth crisis. There is a need to boost domestic production, especially given India's considerable reserves – 8.52 million tonnes (MT) of rare earths, including 7.23 MT of Rare Earth Oxide contained in monazite.

In 2024, Myanmar emerged as the world's third-largest producer of REEs, trailing only China and the US, a surge largely driven at China's behest, with much of the supply coming from the Kachin region.

Khanij Bidesh India Ltd. (KABIL), a government-owned entity established in 2019, is actively scouting for overseas critical mineral assets, particularly lithium and cobalt. The company is currently pursuing projects in Argentina, Australia, and Chile.

Simultaneously, it is desirable that domestic players like IREL (India) ramp up mining operations and develop a comprehensive rare earth value chain within the country. But such an ecosystem could take years to materialize. IREL – a state-run enterprise under the department of atomic energy has been exporting rare earth for years instead of supplying domestically, as there simply weren't any takers from the auto sector. IREL has recently suspended its REEs exports to Japan, aiming to conserve strategic resources for domestic consumption as India moves to insulate itself from global supply shocks.

Meanwhile, companies like Vedanta and Hindustan Zinc are positioning themselves to play a central role. In May, Hindustan Zinc secured a rare earth block in Uttar Pradesh's Sonbhadra district, marking a significant step toward diversifying the country's strategic mineral base. Vedanta, too, is aggressively pursuing critical mineral assets across Maharashtra, Rajasthan, Bihar, Arunachal Pradesh, Karnataka, and Chhattisgarh.

India's rare earth strategy must emphasize need to develop new technology for indigenous production, and also to pioneer alternatives to traditional REEs. There is a need to develop a new class of materials with properties similar to rare earths. India must take the lead on this.

There are early signs of indigenization. One such initiative is a Rs 250-crore project backed by the Technology Development Board, a statutory body under the department of science and technology – which last year partnered with Pune-based Midwest Advanced Materials to support the indigenous commercial production of neodymium materials and rare earth permanent magnets.

Source: The Economics Time, 17th August 2025

Laser Ultrasonics can Assist the Green Steel Transition

The steel industry is on the brink of a transformative shift towards greener, more sustainable practices. One promising advancement in this journey is the introduction of a new laser ultrasonic (LUS) based grain size gauge. This cutting-edge technology offers unprecedented insights into the microstructure of steel, paving the way for more efficient and environmentally friendly production methods.

What is laser ultrasonics?

Laser ultrasonics is a non-contact measurement technique that uses lasers to generate and detect ultrasonic waves in materials. In simple terms, it involves firing a short laser pulse at the surface of a material to create ultrasonic waves, which then travel through the material. Another laser then detects the response of these waves, allowing scientists to analyze the material's properties and microstructure. A schematic illustration of the ultrasonic measurement principle is given in Figure 1 below.

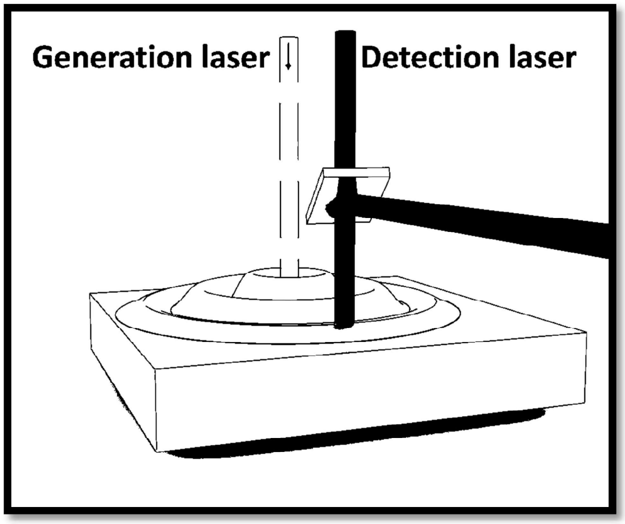


Figure 1: Schematic illustration of how laser ultrasound works

The pulsed green laser generates the ultrasound, and the response is then measured with the red detection laser.

The process begins with a short-pulsed laser, known as a Q-switched laser, which generates the ultrasound by creating a plasma on the material's surface. This plasma causes a thermal expansion that generates an ultrasonic shockwave. The response of the ultrasonic wave is then measured by analysing the Doppler shift of the surface reflection using another laser. This technique, developed in the 1980s and 1990s, has been commercially employed in the metal industry since early the 2000s for monitoring wall thickness during the production of seamless steel tubes.

LUS-based grain size gauge

The new LUS-based grain size gauge represents a significant leap forward in steel production technology. Installed in the hot strip mill at Borlänge, Sweden, this system is the first permanent setup to monitor the microstructure of steel during hot rolling. The gauge is positioned after the last stand and before the run-out table, ensuring it captures critical data during the production process.

One of the key features of this gauge is its ability to measure the grain size of steel in real-time. Grain size is a crucial factor in determining the properties of high-strength steel and other types of steel. Traditionally, measuring grain size during the hot rolling process has been challenging due to the extreme conditions, with temperatures ranging from 800-1200°C and material moving at speeds of up to 10 m/s. The LUS-based grain size gauge is the only technique to overcomes these challenges, while providing accurate and reliable measurements.

How it works?

The LUS-based grain size gauge operates by analyzing the frequency-dependent attenuation of ultrasonic waves as they pass through the steel. Here is a simplified breakdown of the process:

1. Generation of ultrasound: A laser pulse hits the surface of the steel, creating an ultrasonic shockwave.
2. Detection of response: Another laser detects the response of the ultrasonic waves that travels inside the steel.
3. Frequency analysis: The system analyzes the frequency-dependent attenuation of these waves. Higher frequencies are attenuated more than lower frequencies, and this attenuation is related to the grain size of the steel.
4. Grain size calculation: Using a calibration curve, the system translates the measured attenuation into an average grain size value.

This method allows for real-time monitoring of the steel's microstructure, providing valuable data that can be used to optimize the production process.

Impact on the green steel transition

The introduction of the LUS-based grain size gauge is particularly significant in the context of the green steel transition. As the industry moves towards more sustainable practices, there is a growing emphasis on using scrap-based and hydrogen-reduced steel. These new methods aim to reduce the carbon footprint of steel production, but it is crucial to ensure that the resulting steel has the same properties as traditional steel made from iron ore.

The LUS-based grain size gauge plays a vital role in this verification process. By providing accurate measurements of the steel's microstructure, it ensures that the new, greener steel meets the required standards. This capability is essential for gaining industry acceptance and driving widespread adoption of sustainable steel production methods.

Real-world applications and benefits

The LUS-based grain size gauge has already been installed and tested in the SSAB mill in Borlänge, Sweden. The system has demonstrated its ability to provide reliable measurements in the harsh environment of a hot strip mill. The gauge's robust design includes optics for a long working distance of more than half a meter and suitable protection against the harsh conditions.

In practical terms, the gauge offers several benefits:

- ***Enhanced quality control***: By monitoring the grain size in real-time, the gauge helps identify deviations in the production process, allowing for immediate adjustments and ensuring consistent quality. For some steel grades the Hall-Petch relation can also be utilized to measure the mechanical properties without need for destructive testing. Hence, facilitating mechanical data over the entire length of the strip/coil without the need for costly and time consuming destructive testing while at the same time increasing the yield.
- ***Process optimization***: The data collected by the gauge can be used to optimize the production process, in both feed-back/forward control loops as well as assisting the setup calculation in between strips leading to more efficient and cost-effective production.
- ***Accelerated material development***: The real-time and detailed microstructure data provided by the gauge can be used to develop new alloying concepts and to improve existing materials, and materials models, thus accelerating the pace of innovation in the steel industry.

Conclusions

The new LUS-based grain size gauge is a ground-breaking technology that has the potential to revolutionize the steel industry. By providing real-time, accurate measurements of the steel's microstructure, it supports the transition to greener production methods and ensures the quality and consistency of the resulting steel. As more steel companies adopt this technology, we can expect to see significant advancements in both the efficiency and sustainability of steel production.

Source: Green Steel World News Update, 10th July, 2025

Stegra's Green Hydrogen Plant

With the four central electrolyzer buildings nearing completion, installation of the process equipment that will produce green hydrogen, the lifeblood of Stegra's green iron and steel plants, is moving forward at pace. The goal is to install one electrolyzer per week. The first steel was raised in late 2024, and just six months later, all four of the massive electrolyzer buildings are nearing completion and the first process equipment has been installed.

The 20 megawatt electrolyzers from thyssenkrupp nucera are an impressive sight, each measuring 40 meters long and nine meters high. Using alkaline water electrolysis (AWE), they will split water into hydrogen and oxygen using 100% renewable electricity, producing more than 100,000 tonnes of green hydrogen annually. The green hydrogen will then be used to purify iron ore in the green iron plant. In a direct reduction process, the green hydrogen reacts with the oxygen in the iron ore, producing green direct reduced iron that is then used to make green steel. The main by-product is water, rather than the large amounts of CO_2 emitted in traditional ironmaking processes. Reliable delivery of over 700 megawatts were needed, and alkaline water electrolysis was the best solution. While some technologies offer more flexibility, what is needed was something that could deliver a reliable supply 24 hours a day.

AWE also has a larger footprint than some other technologies. That was not really an issue plenty of space was available there at Stegra's 70-hectare hydrogen site.

Today, the green hydrogen facility is dominated by the four electrolyzer buildings that will form its beating heart. In the coming months, they will be joined by additional structures that will contain, among other things, an electrical substation, purifiers, and compressors.

Stegra's first steel production lines will go live in 2026 using recycled steel scrap as raw material, with green hydrogen-based iron and steelmaking beginning shortly thereafter and a full-scale ramp in 2027. By 2028, the company aims to reach steady-state operations across the green hydrogen, green iron, and green steel plants.

Source: Green Steel World News Update, 10th July, 2025

Steelmaking in Europe

- **EAF Transition Stalled by High Electricity Costs**

Limited Renewables, renewable demand to quadruple by 2050 -Steelmaking in Europe is transitioning to cleaner technologies like EAFs, but this shift is hindered by high electricity costs & the need for accessible renewable energy. Energy demand for green steel production is expected to quadruple by 2050.

- **Limited Green Steel**

Production Green Steel Adoption Slows Amid High Costs and Low Buyer Willingness -Green steel production remains limited and costly, with buyers hesitant to pay premiums. Tradeable values for green steel are significantly lower than initial offers, and weak market conditions have slowed decarbonization projects.

• EU Steel Faces Overcapacity

Low Demand, and Import Competition the EU steel industry struggles with overcapacity, falling demand and competition from low-cost imports. Existing safeguard measures will remain until 2026, with new trade defense measures expected to address these challenges.

• CBAM to Curb Carbon Leakage but Adds Compliance Burden

CBAM, set to take full effect in 2027, aims to reduce carbon leakage by imposing costs on imported steel with high emissions. It is expected to support domestic steel prices but poses bureaucratic challenges for implementation.

• Structural Cost Pressures and Raw Material Dependence Challenge Decarbonization

The industry faces structural cost disadvantages, reliance on imported raw materials and the need for long-term decarbonization strategies. Initiatives like CBAM and renewable energy projects are critical to its sustainability and competitiveness.

• CBAM & Steel imports by EU

Additional costs of around €56 per tonne Extras will have to be paid for imported steel with higher emissions, "Assuming this benchmark and imported steel with embedded CO2 emissions of 2.1 tonnes, and a current EUA price of €76, CBAM is estimated to cost an additional €56 per tonne of steel," Julian Verden, managing director for Europe at steel services provider Stemcor, said.

Source: Key takeaways from the 75th Anniversary of Eurometal

HBIS is Producing DRI by Using More than 60% of Hydrogen

Chinese HBZX High Tech, part of Hebei Iron & Steel Group – HBIS, is the first worldwide steelmaker producing DRI using more than 60% Hydrogen in the feed gas mix, on industrial basis.

At HBZX plant, in Xuan Hua, Zhangjiakou, Hebei province, a new, 600,000 tpy, Zero Reformer, Energiron® direct reduction plant has been supplied, which has achieved continuous, stable, and safely production with outstanding quality.

The plant is the first hydrogen-enriched gas-powered DRI industrial production facility in the world, and is also the first green gas-based DRI plant in the country, paving the way to the transition from the carbon-based BF route to gas-based DRI technology and electric steelmaking.

With a CO_2 release as low as 250 kg/ton of DRI, the HBIS plant claims to be the greenest industrial DRI plant in the world.

Furthermore, the carbon dioxide is selectively recovered by a CO_2 removal unit included in the basic Energiron® DR technology process scheme, and part of it will be reutilized in downstream processes (carbon capture and use or storage CCU/CCS). This would lead to a final net emission of just about 125 kg of CO_2 per ton of DRI.

Solar-powered Steel Mill in America

Rocky Mountain Steel gets most of its electricity from a 300-MW solar project in Colorado. The 300-megawatt Bighorn Solar project provides most of the power for the Rocky Mountain Steel mill.

An enormous array of over 750,000 solar panels blankets the prairie landscape in Pueblo, Colorado, providing clean energy to one of the largest electricity-based steel mills in the country.

The Rocky Mountain Steel mill, which opened in 1881, today uses electricity instead of coal to produce steel rails and pipes. In late 2021, it became the first and largest solar-powered steel plant in the United States — and possibly the world — when electricity began flowing from the 300-megawatt Bighorn Solar project next door, supplying roughly 90% of the power used by the facility’s electric arc furnace.

Recent U.S. efforts to build cutting-edge, low-emissions ironmaking facilities that use green hydrogen — made with renewable power — have all but vanished due to challenging economics. Building large clean-energy projects like Bighorn Solar to power industrial sites just got much harder to do under the megabill signed into law this month, which slashes incentives for and imposes restrictions on wind and solar.

At the same time, the nation's steel industry is slowly getting cleaner as manufacturers invest in new capacity that relies on electricity and fossil gas, not coal. And Rocky Mountain Steel is no longer the country's only solar-powered steel plant. U.S. Steel's Big River Steel mill in Arkansas draws from the 250-MW Driver Solar project, while steelmaker Nucor Corp. has a deal to buy 250 MW of power from the Sebree Solar farm under construction in Kentucky.

Making cleaner steel with clean power

Steel is an essential material used to make everything from railroads, bridges, and buildings to solar-panel racks, electric vehicles, and grid components. Producing the high-strength metal is an emission intensive business, responsible for as much as 9% of global carbon dioxide emissions and a significant amount of harmful local air pollution. That's because most steel production globally involves use of copious amounts of coke/injection coal in a blast furnace to turn raw iron ore into iron; the iron is then made into steel in a separate furnace. The United States still operates a dozen blast furnaces, which account for roughly 30% of the country's annual steel production.

The remaining 70% of U.S. steel output comes from electric arc furnaces, including the hulking unit at Rocky Mountain Steel's facility, which is capable of producing 1.1 million tons of steel per year. These power-hungry furnaces turn scrap metal into a glowing orange liquid that is then transformed into recycled steel parts.

Producing steel this way can curb CO_2 emissions by up to 75% compared to traditional coal-based methods. However, the carbon intensity of steel made in an electric arc furnace depends on the electricity used — and most of the 100-plus such facilities operating in the U.S. rely primarily on coal- and gas-fired electric grids.

Until a few years ago, Rocky Mountain Steel got its power from Xcel Energy's coal-fired power plant in Pueblo. Lightsource bp financed, owns, and operates the neighboring $285 million Bighorn Solar project. The developer sells the electricity it generates to Xcel under a 20-year power purchase agreement; the utility then provides power to Evraz North America for the steel mill. When the 1,800-acre solar array came online in late 2021, Bighorn became the nation's largest on-site solar facility dedicated to a single customer.

This project proves that even hard-to-abate sectors like steel can be decarbonized when companies come together with innovative solutions.

Source: Canary Media Daily, 16th July, 2025

AM/NS Getting Ready for Introduction Green Steel Rating Scheme

India's push to cut industrial emissions is gaining traction with the rollout of a first-of-its-kind Green Steel Taxonomy—ushering in a new era for steel procurement in sectors like automotive, where emissions accountability is becoming critical. ArcelorMittal Nippon Steel India (AM/NS India), one of the country's leading integrated steelmakers, is preparing to be the first in line for certification under the new system, which classifies steel based on its carbon footprint. As climate regulations tighten and sustainability climbs the corporate agenda, the Indian government's newly introduced Green Steel Taxonomy is poised to be a game-changer. Finalized in December 2024, and likely to take effect in April 2026, the framework will rate steelmakers based on the carbon intensity of their production—setting a standard in an industry long criticized for its emissions. For automotive companies, the implications are significant.

As they transition to electric vehicles and face rising scrutiny over Scope 3 emissions—the indirect footprint of their supply chains—steel sourcing is becoming a strategic concern. Flat steel, a core material for auto manufacturing, must now align not only with performance requirements, but also with environmental expectations. ArcelorMittal Nippon Steel India, a joint venture between ArcelorMittal and Nippon Steel, believes it's ready and announced that it is on track to become the country's first integrated steel producer to earn at least a three-star certification under the new framework.

The taxonomy is managed by the National Institute of Secondary Steel Technology (NISST), which oversees the certification process and star ratings. Green steel, as defined in this context, refers to production with emissions below the 2.2 tCO_2 threshold. Top-rated producers—those emitting less than 1.6—can earn a five-star rating.

AM/NS India achieved a CO_2 intensity of 2.17 tCO_2/tcs (tons of carbon dioxide equivalent per tonne of crude steel) in FY 23— 14% lower than the national average and aims to achieve 20% reduction in carbon emissions intensity by 2030 to 1.8 tCO_2/tcs from the 2021 baseline. The company has already reduced its carbon emissions intensity by over 35% since 2015. Currently, 65% of AM/NS India's steel capacity is derived from the Direct Reduced Iron (DRI) route that uses natural gas. This process has a low carbon footprint. The ongoing expansion incorporates state-of-the-art technologies that focus on lowering carbon emissions.

Green Steel 2027

It’s not just about steel—AM/NS India is also building out the infrastructure to back its green ambitions. In Andhra Pradesh, it is developing a renewable energy facility with pumped hydro storage. It’s also expanding its scrap processing capabilities to raise the recycled content in its products. By 2027, the company expects 70% of its production to be classified as green steel.

The idea is not just for the company to come out with green steel. But it is also making the product of the customers green. Nowhere is that more relevant than in the automotive industry. Vehicle makers currently account for 17–18% of AM/NS India’s revenue, and that number could double in coming years. To meet demand, the company is ramping up capacity—from 9–10 million tons per year today to 15.6 million tons by 2027.

Two new production lines, tailored for automotive-grade steel, are expected to be operational by 2025. The company sees the auto sector as central to its expansion strategy. Green steel, however, is still a loosely defined term. Globally, there’s no single standard. Most definitions center on emissions intensity and production methods—such as electric arc furnaces or hydrogen-based reduction using recycled materials.

In India, where adoption is nascent, automakers still largely focus on high-strength steels for weight reduction, which improves fuel efficiency and EV range but doesn’t necessarily mean the steel itself is green. While the world is grappling with many things, India has some clarity on green steel definition and parameters.

Green Steel Surge

Green steel movement is gaining pace. Major steel producers like Tata Steel and JSW Steel are developing low-carbon production strategies. Tata is exploring nuclear-powered steelmaking and ramping up renewables. JSW has targeted Europe with its green steel plans, aiming to meet the EU’s strict Carbon Border Adjustment Mechanism (CBAM) regulation in addition to catering to the domestic markets. In the broader market, demand for flat steel in auto manufacturing is already at 7.8 million tonnes annually and growing 6–7% each year. Meanwhile, the Indian hot-rolled and cold-rolled steel market is projected to reach $270.5 billion by 2030, up from $171.1 billion in 2024.

Road Ahead

With clear government definitions and rising global demand, industrial giants like AM/NS India, Tata Steel and JSW are taking the lead and laying the foundations for a supply chain transformation. For automakers, adapting to these new standards may be complex—but the long-term payoff lies in building vehicles that are genuinely greener from the ground up.

Source: https://share.google/66T1zt72TFg1nhVvd

The Helios Cycle™: A Zero-Emission, Novel Method for Processing Iron Ore and Ore Residuals Using Sodium Looping

As the steel industry accelerates its decarbonisation journey, breakthrough technologies like the *Helios Cycle*™ are redefining what's possible. Initially developed for oxygen production on the Moon, the *Helios Cycle*™ can revolutionise green ironmaking on Earth. This zero-emission process replaces carbon with sodium in the reduction of iron ore, using a closed-loop sodium system that eliminates direct CO_2 emissions while enabling the use of low-grade ores and tailings—without pre-treatment.

Key Principles:

- **Sodium Reduction:** Instead of carbon (coal, natural gas, or hydrogen) to reduce iron oxide (iron ore) to metallic iron, the Helios Cycle utilizes metallic sodium (Na).
- **Closed-Loop System:** The sodium oxide (Na2O) by product of the reaction is then decomposed back into sodium and oxygen, allowing for the continuous reuse of sodium.
- **Low Temperature Operation:** The reaction occurs at relatively low temperatures (350-750°C), making it more energy-efficient than traditional methods like the blast furnace, which operates at much higher temperatures.
- **Zero Direct Emissions:** The process produces only iron and oxygen, with no direct CO2 emissions, making it a sustainable alternative to conventional steelmaking.

How it works:

1. **Iron Ore Reduction:** Iron ore (e.g., Fe2O3) is mixed with sodium metal in a reactor.

2. **Reaction:** The sodium reacts with the oxygen in the iron ore, forming sodium oxide (Na2O) and leaving behind metallic iron.

3. Sodium Recycling: The sodium oxide is then processed to recover the metallic sodium and oxygen, closing the cycle.

4. Iron Output: The metallic iron produced can be further processed into steel using either electric arc furnaces (EAFs) or basic oxygen furnaces (BOFs).

Advantages of the Helios Cycle:

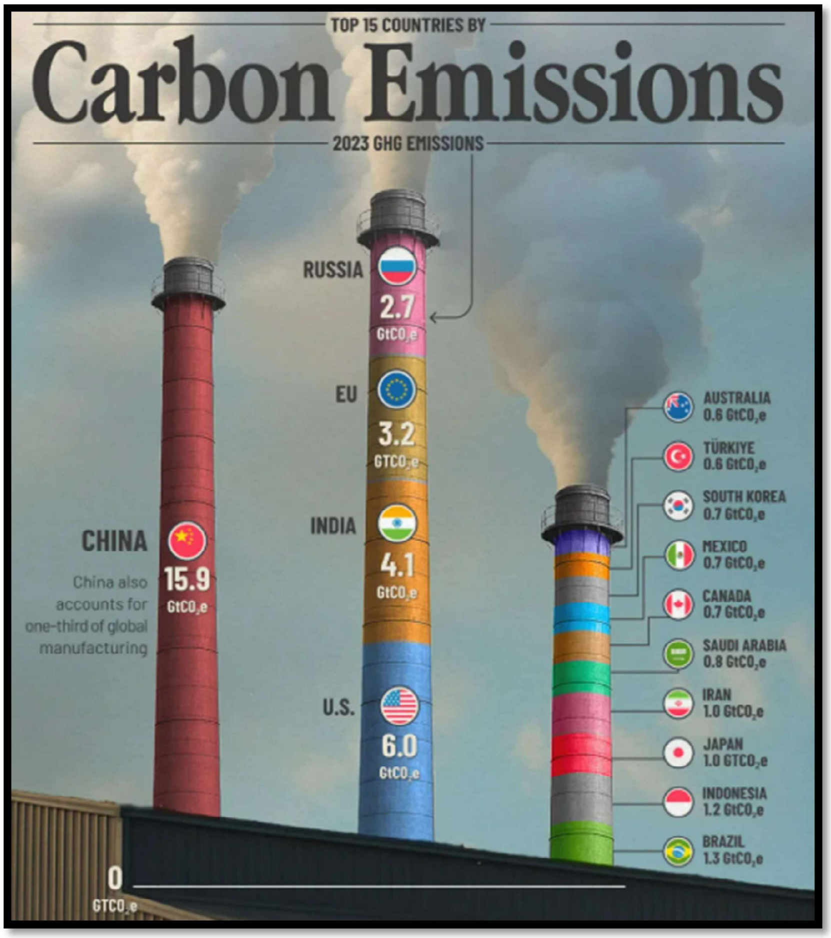
- **Decarbonization:** Eliminates direct CO2 emissions, a major advantage in the fight against climate change.
- **Cost Competitiveness:** Claims to be cost-competitive with traditional blast furnace methods, potentially reducing the "green premium" for sustainable steel.
- **Energy Efficiency:** Operates at lower temperatures, potentially reducing energy consumption by up to 30% compared to blast furnaces.
- **Flexibility:** Can utilize a wider range of iron ore feedstocks, including low-grade ores and tailings, without pre-treatment.
- **Modular Design:** The technology is designed for modular furnaces, allowing for potential on-site iron production and reduced reliance on large, centralized steel plants.

In essence, the Helios Cycle offers a promising pathway towards a more sustainable and cost-effective steel industry by leveraging a novel chemical process and a closed-loop system for sodium recycling.

Source: Steel Talk, Expert lectures for the ***steel*** *industry, 22nd July, 2025*

Top 15 Countries by Carbon Emission

- **China** accounts for nearly one-third of global greenhouse gas emissions at 15.9 Gt CO_2e in 2023.
- But this also reflects its extensive industry that is essentially the world's factory.
- Meanwhile **the U.S.** (6.0 Gt CO_2e) shrinks its own footprint by importing carbon-intensive goods.
- Fast-growing **India** and **Indonesia** emit heavily as they industrialize and consume—echoing the path wealthier nations took before widespread prosperity.
- Cheap energy and extraction industries emissions in **Saudi Arabia**, **Canada**, and **Australia** well above expectations despite smaller populations.



Rank	Country	GHG Emissions (2023), *Gt* CO_2e	Share of Global Emissions %
1	China	15.9	30.1
2	U.S.	6.0	11.3
3	India	4.1	7.8
4	EU	3.2	6.1
5	Russia	2.7	5.0
6	Brazil	1.3	2.5
7	Indonesia	1.2	2.3
8	Japan	1.0	2.0
9	Iran	1.0	1.9
10	Saudi Arabia	0.8	1.5
11	Canada	0.7	1.4
12	Mexico	0.7	1.3
13	South Korea	0.7	1.2
14	Türkiye	0.6	1.1
15	Australia	0.6	1.1

Strategic Technological Revolution: Transforming US Steel Production

Nippon Steel's acquisition of U.S Steel represents more than a financial transaction – it marks the beginning of the most comprehensive technology transfer program in modern steel industry history. The Japanese giant's **advanced manufacturing technologies,** developed over decades of research and proven in operations across Asia, will fundamentally transform American steel production capabilities. These technological developments span revolutionary hydrogen-based steelmaking, advanced electrical steel production, and cutting-edge blast furnace optimization systems that position the combined entity at the forefront of global steel innovation.

The **COURSE50 technology program** stands as the centerpiece of Nippon Steel's technological contribution to U.S. Steel operations. This groundbreaking system uses **heated hydrogen injection** into blast furnaces to replace traditional coke-based reduction processes, achieving unprecedented carbon emissions reductions. Recent trails at Nippon Steel's Kimitsu test facility have demonstrated a **43% CO_2 reduction**–the world's highest achievement in hydrogen-based steelmaking technology. The technology maintains thermal balance within blast furnaces while dramatically reducing carbon footprint, proving that environmental sustainability and operational efficiency can coexist in heavy industry.

Hydrogen metallurgy advancement through the Super COURSE50 program represents Nippon Steel's most ambitious technological development for implementation at U.S. Steel facilities. The program targets **50% or greater CO_2 emissions reduction** by 2029 through advanced hydrogen direct reduction processes combined with sophisticated heat recovery systems. This technology addresses the fundamental challenge of hydrogen-based steelmaking–the endothermic nature of hydrogen reduction that traditionally requires external heat input. Nippon Steel's breakthrough involves heated hydrogen injection combined with optimized furnace operation that maintains production efficiency while achieving unprecedented environmental performance.

Nippon Steel's strategic technology deployment timeline for US Steel operations, spanning 2025-2029 with total investments exceeding $4 billion.

Commercial-scale implementation of these technologies at U.S. Steel facilities will begin immediately following the acquisition's completion. Nippon Steel has committed **$1.3 billion specifically for technology deployment** at Mon Valley Works and Gary Works, including complete modernization of Blast Furnace #14 at the Indiana facility. The Gary Works revamp will extend the facility's operational life by 20 years while implementing Japanese advanced technologies including hydrogen injection systems, copper stave cooling technology, and high-efficiency top charging systems that optimize fuel consumption and environmental performance.

The **NSCarbolex Neutral green steel program** will provide U.S. Steel with immediate access to premium low-carbon steel markets that command significant price premiums. This certified green steel product uses mass balance methodology to allocate CO_2 emissions reductions from Nippon Steel's decarbonization projects to specific steel products, enabling customers to reduce their Scope 3 emissions. The program has already secured contracts with major automotive manufacturers including partnerships for electric vehicle applications, demonstrating strong market demand for environmentally certified steel products in North America.

Advanced electrical steel production represents a strategic growth opportunity where Nippon Steel's technology leadership will directly benefit U.S. Steel's market positioning. The Japanese company's **non-directional electromagnetic steel sheets** are essential components for electric vehicle motors renewable energy generators, and advanced electrical applications. Technology transfer will enable U.S. Steel to serve the rapidly expanding American electric vehicle market with domestically produced high-performance electrical steel, reducing supply chain risks and capturing growing demand from automotive manufacturers transitioning to electrification.

Carbon Neutral Vision 2050: Environmental Strategy Amid Financial Constraints

Nippon Steel's Carbon Neutral Vision 2050 represents one of the steel industry's most ambitious decarbonization commitments, targeting **30% CO_2 emissions reduction by 2030** and complete carbon neutrality by 2050. The strategy encompasses two primary approaches: developing breakthrough technologies for low-emission steel production and providing high-performance products that enable customer emissions reductions across value chains. This environmental transformation is proceeding despite current financial constraints, reflecting management's belief that sustainability leadership will drive long-term competitiveness.

Technology investments focus on revolutionary steelmaking processes including the COURSE50 program, which uses hydrogen injection in blast furnaces to achieve significant emissions reductions. Recent trials have demonstrated **43% CO_2 reduction** in hydrogen-based blast furnace operations, representing a major breakthrough toward commercial viability. The company is also investing **¥870 billion ($6.05 billion)** to transition from traditional blast furnace technology to electric arc furnace (EAF) production at three Japanese facilities, fundamentally changing the carbon profile of steel production.

Electric Arc Furnace expansion represents the cornerstone of Nippon Steel's near-term decarbonization strategy. EAF technology enables steel production using recycled scrap metal with dramatically lower carbon emissions compared to traditional blast furnace operations. The company's EAF investment program will increase annual production capacity by **2.9 million tons** while positioning Nippon Steel as a leader in low-emission steelmaking. Government subsidies of ¥251.4 billion support these investments reflecting Japan's commitment to industrial decarbonization.

Hydrogen-based technologies offer the most promising path to deep emissions reductions in primary steel production. The Super COURSE50 program aims to achieve **50% CO_2 reduction by 2030** through advanced hydrogen direct reduction of iron (H_2-DRI) processes. The company's Hydreams R&D Center, representing a ¥1.7 billion investment, is accelerating commercialization of hydrogen technologies that could revolutionize steel production. However, technical challenges including hydrogen embrittlement and energy costs remain significant barriers to widespread deployment.

Integration challenges arise from balancing environmental objectives with financial constraints imposed by the U.S. Steel acquisition. The acquired American facilities include coal-based blast furnaces that may require decades of operation to justify investment costs, potentially conflicting with carbon neutrality goals. However, planned investments in U.S. operations include EAF facilities and hydrogen-ready infrastructure that will support long-term emissions reductions while maintaining production capacity and employment levels required by the National Security Agreement.

Rare Earth Plus One - Alternative EV Plan

There has been much noise – about opportunity and caution – over China lifting curbs on export of rare-earth (RE) magnets to India. Which is understandable since an overwhelming majority of EV motors use permanent magnets that contain RE elements. But RE use also exposes an inherent conflict in EV tech. The switch to fossil fuel alternatives is necessitated by sustainability, but mining RE minerals substantially degrades the environment. Which may be why countries have allowed

China to acquire its global dominance over producing RE minerals. The strategy is now being tested by vulnerability of supply chains. There is a global effort on now to gain resilience over RE mining, while securing consistent supply of permanent magnets from China. But there are alternatives to RE element magnets being tested for use in EV motors. The first approach persists with the use of permanent magnets in motors, but making them RE-free. These magnets are not as powerful, and the engineering challenge is to get more juice out of motors built with them. This typically makes the motor bulkier and more complex. Research on magnetic materials and motor design indicate alternatives are emerging. Another idea being tested is to eliminate the heavy RE elements, which are even more scarce, from permanent magnets. Degradation of magnetic properties is thereby contained and this requires a less intensive redesign of EV motors. The second approach is to do away with permanent magnets entirely and replace them with electromagnets. This is a more radical shift in terms of engineering because such motors need a continuous power supply to maintain the magnetic field. Electromagnetic motors that can be used in EVs are entering the market with performance to match those using permanent magnets. So, EV technology free of RE elements is already available. The engineering challenges are not as intense as the economic ones. Current EV tech has been subsidized by taxpayers. Its evolution may require additional support. Which is also where the excitement lies.

Source: The Economic Times, 21st August 2025

Aluminium Demand to Double in 10 Years

Hindalco Industries, expects aluminium consumption to double to 16 million tonnes per annum in the next 10 years on strong domestic demand. The company had initiated its highest-ever capex of ₹18,000 crore last fiscal to tap the growing opportunities. The momentum across transport, railways, energy and construction is fuelling demand for customised metal solutions. Aluminium and copper form the backbone of infrastructure, mobility and clean energy. India’s aluminium consumption, already at 5.5 million tonnes in FY25, is poised to double over the next decade, signalling unprecedented growth opportunities ahead. Copper demand is growing at an accelerated pace, powered by urbanisation, digitalization, clean energy adoption and electric vehicles. Hindalco is expanding its aluminium smelter at Aditya by 0.18 million tonnes per annum and further expanding to 0.36 million tonnes at Mahan. In addition, the company is setting up a greenfield 0.85 million tonne alumina refinery. Besides, the company’s resource security has been further strengthened with the allocation of the 12-million-tonne Meenakshi coal mine. In copper, a 0.3 million tonne smelter expansion is underway at Dahej, which, once completed, will make it the largest copper smelting complex in the world, outside China.

Source: The Hindu Businessline, 21st August 2025

Know Your Members

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Former Director (Engg.), AIR & DD
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Associate Members of Institution of Engineers (India) (AMIE) - Electrical Engg., Associate Member of Institution of Electronics & Telecommunication Engineers (AMIETE) - Electronics, Telecommunication & Computer Engg.,
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Shri Vijay Kumar Gupta retired as Director (Engineering), Sr. Administrate Grade (SAG), in 2001, after serving All India Radio and Doordarshan, Ministry of I & B, Govt. of India, for more than 37 years at different stations, in various capacities. He is presently rendering service as a Consulting & Chartered Engineer in various fields. Shri Gupta is a Fellow & Chartered Engineer, Institution of Electrical Engineers (IET) London, Fellow & Chartered Engineer, The Institution of Engineers (India) (IEI), Fellow & Chartered Engineer, Institution of Electronics & Telecommunication Engineers (IETE) and Senior Professional Engineer, Engineering Council of India (ECI).

He is a Life Member of The Indian Institute of Metals (IIM) *(LM-56521)*. He was Former Chairman of Institution of Electrical Engineers, Delhi Local Network (IET-DLN), and also Computer Society of India, Delhi Chapter (CSI-DC), Former Hon. Secretary, The Institution of Engineers (India), Delhi State Centre (IEI-DSC) and Former Treasurer, BESI.

Shri Gupta is recipient of the following Awards and Prizes:

- NATIONAL AWARD, announced on Republic Day'1975 and received on 4th August 1975 from the Hon'ble President of India, organized by NRDC, New Delhi, on inventing and making a working gadget on "TV DRY REHARSAL CAMERAS AND MECHANICALSWITCHER". Technical paper on the working of the gadget was published in the Educational Broadcasting International (A Journal of British Council) published from London in September,1974
- Received First and Third Prizes for the technical papers on "RELAY OF COMMENTARIES & PROGRMME" and "ROAD ILLUMNATION" respectively, which were published in IEI Bulletins of Delhi Centre during 1970 and 1972. These prizes were given by the Hon'ble Prime Minister of India and the Hon'ble Vice President of India respectively.
- Received an appreciation of valuable services to the Special Organizing Committee of IX Asian Games, held at Delhi in 1982.
- Received first Prize of the Indian Culture Exhibition at the "Festival Of Nations" at Minnesota, USA during May,2009.

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