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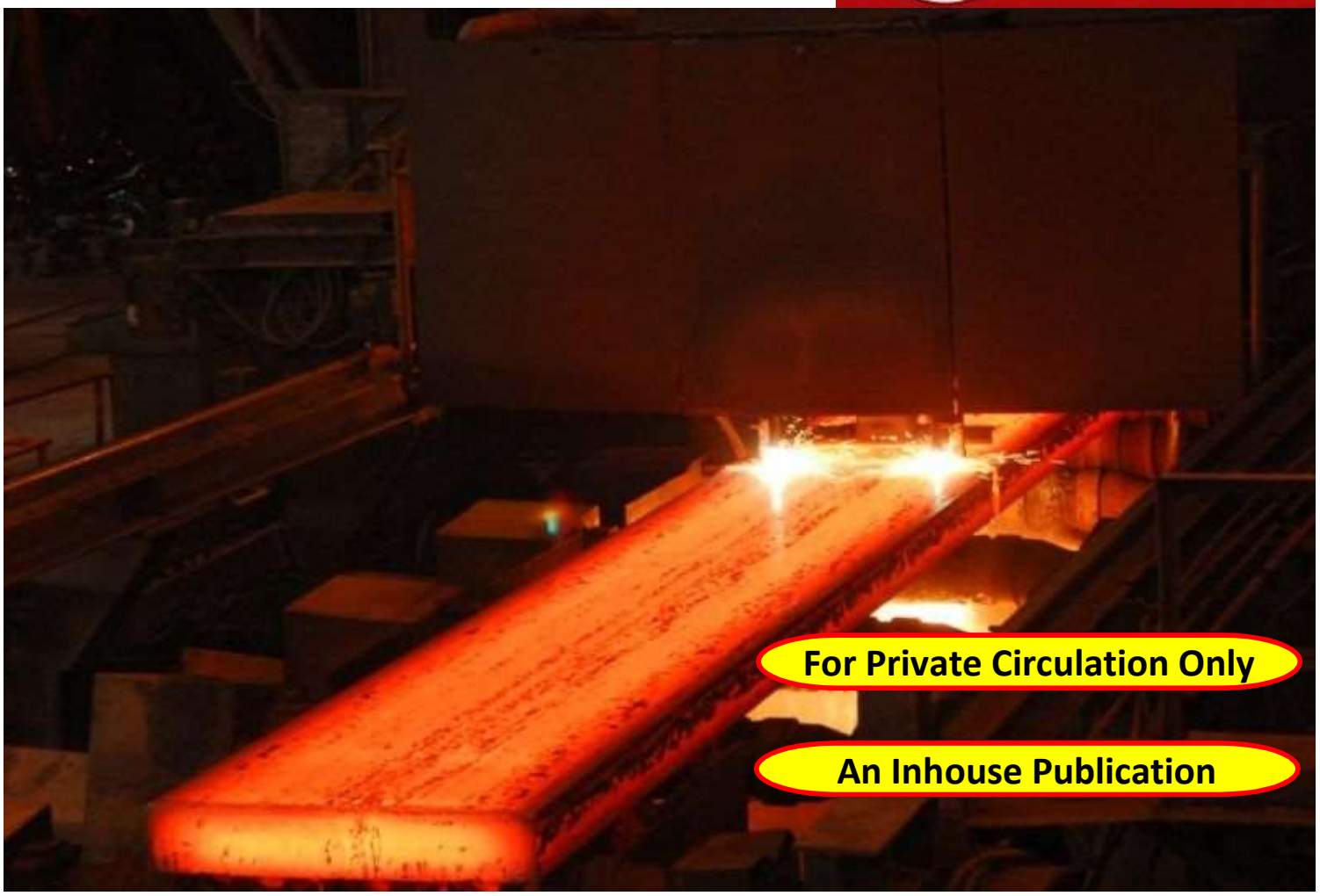

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IIM Delhi Chapter Newsletter Issue No.57, April 2024

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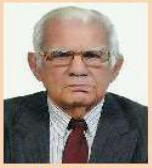
 B D Jethra	 Anil Gupta	 S C Suri	 K L Mehrotra	 K K Mehrotra

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XCarb Innovation Fund

To support broader decarbonisation efforts, in March 2021 ArcelorMittal launched XCarb® Innovation Fund, the intention of which was to invest in the best and brightest technologies that hold the potential to support the decarbonisation of steelmaking.

Almost three years on, the fund has invested a total of $188.5 million in 7 different companies developing technologies that range from carbon capture and utilisation to long-term battery storage solutions to hydrogen production and more. Through the fund ArcelorMittal also became a founding partner of the Bill Gates-led *Breakthrough Energy Catalyst Programme*, a platform in which ArcelorMittal have committed $100m over 5 years, that seeks to accelerate the adoption of decarbonisation technologies by investing in early stage projects. The fund have also launched two successful Accelerator Programmes, one global and one focused on India, providing mentorship and development opportunities for businesses that are typically viewed as being too early stage for the XCarb® Innovation Fund.

A lot has been achieved in the Fund's three short years of life, with 2023 typifying the progress that both the Fund and its portfolio have made.

In 2023, the Fund made three investments totalling $66 million, doubling down on a previous bet, bringing one of the most exciting technologies on the market into its portfolio and crowning the winner of its inaugural Accelerator Programme.

The year got off to a fast start with a $36 million investment in *Boston Metal* in January. *Boston Metal* is commercialising one of the most talked about decarbonisation technologies in steel circles – a *molten oxide electrolysis (MOE) technology* that transforms iron ore into iron, using clean electricity, thereby removing carbon from the steelmaking process.

The investment was followed up in June when the Fund injected a further $25 million into nuclear innovation company, *TerraPower*, founded by Bill Gates in 2008, bringing its total investment to $50 million and making it the Fund's single largest investment.

To wrap up its investments for the year, in July, ArcelorMittal announced the results of the Fund's inaugural Accelerator programme, selecting Ontario-based *CHAR Technologies* as the winner and investing $5 million in the company. *CHAR* has been collaborating with Canadian flat steel making operation, ArcelorMittal Dofasco, to test the use of its bio-carbon solutions as a partial replacement for fossil coal in the

steelmaking process. In addition to *CHAR*, strategic partnerships were also formed with *Carbon Upcycling* and *D-CRBN* to wrap up a successful first Accelerator Programme.

ArcelorMittal also saw various updates and milestones achieved by several companies.

- Boston Metal had a busy year. In Brazil, it signed a cooperation agreement with the state of *Minas Gerais* where its subsidiary, *Boston Metal do Brasil*, is developing the first commercial application of its MOE technology, using MOE to recover high-value metals from mining waste. It is targeting commercial production of its first high-value metals this year and expects to bring MOE to the steel market by 2026.

- Another of the Fund's investments, *Form Energy*, progressed construction at its flagship production factory in Weirton, West Virginia. Following the ground-breaking in May last year, progress continued apace and is set to complete in the early part of this year, with commercial production of their 100 hours duration battery storage solutions anticipated to start mid-2024. *Form* also had a strong end to 2023, securing a $30 million grant from the *California Energy Commission* to build its first project in California, a 5MW/500MWh iron-air battery capable of discharging energy to the grid for 100 hours.

- *H2Pro* and ArcelorMittal advanced their study of the implementation of a 12 MW electrolyser in *Sestao, Spain. H2Pro* also partnered with *Doral* on a large green hydrogen project pipeline worldwide and has secured access to 200 MW of *H2Pro* electrolysers for its projects in Europe, the United States, and Israel. They have also partnered with Morocco's renewable energy developer, *Gaia Energy*, to develop a 10-20MW demonstration green hydrogen project in Morocco.

- *LanzaTech*, has had great success with its technology in China, where it now operates four plants, each producing between 46,000 and 60,000 tonnes of ethanol a year from carbon rich waste gases. Last year, *LanzaTech*'s partner *Indian Oil* also started its first facility in India using *LanzaTech*'s technology, which produces 33,500 tonnes of ethanol a year from its *Panipat Refinery*.

- Nuclear power innovator *TerraPower* advanced its plans to build its *Natrium™ Reactor Demonstration Project* in *Kemmerer, Wyoming*, purchasing land and announcing contracts for suppliers which will support the development of the

Natrium™ reactor. The demonstration plant will validate the design, construction, and operational features of the Natrium™ technology. The project features a 345MW sodium-cooled fast reactor with a molten salt-based energy storage system. The storage technology can boost the system's output to 500MW of power when needed, which is equivalent to the energy required to power around 400,000 homes. In a further boost, in December, it signed a MoU with the UAE's nuclear energy development organization, *Emirates Nuclear Energy Corporation (ENEC)* to explore opportunities for the commercialization and global deployment of its Natrium™ technology.

- *Breakthrough Energy Catalyst* announced a project equity investment of $75 million in Infinium's first-of-a-kind commercial-scale Power-to-Liquids eFuels facility, expected to be the largest in North America. The facility will convert waste carbon dioxide and renewable power into sustainable aviation fuel and other low-carbon fuels. Funding commitments of €240 million to accelerate high impact climate solutions in Europe were also announced in 2023. These commitments are made alongside the European Commission and the European Investment Bank into two projects: a 15% equity interest in the *Ørsted FlagshipONE project*, the largest e-Methanol project in Europe, and a project-level grant of €35 million to support the construction of *Energy Dome's Ottana CO2 Battery Project*, a first-of-a-kind long duration energy storage project.

Furthermore, to support the Fund's ambitions, last year ArcelorMittal joined *Launchpad*, an initiative from the *Earthshot Prize*, that will connect funders to current and former Finalists and nominees and support their funding needs and growth journey.

And finally, the work the ArcelorMittal team is doing has started to receive external recognition… ArcelorMittal was named the Impact Fund of the Year, recognizing their strong commitment to supporting clean technologies, advancing the growth of the hydrogen economy and promoting sustainable development.

Source: ArcelorMittal News, Feb 20, 2024

Electric Hot Metal from Renewable Energy

- First green electricity supply contract to supply the direct reduction plant.
- Renewable energy is a cornerstone of the tkH2Steel transformation project.

- Close cooperation between thyssenkrupp Steel and RWE to achieve climate goals.
- Energy is generated at RWE's Kaskasi offshore wind farm in the North Sea

thyssenkrupp Steel and RWE have signed a long-term Power Purchase Agreement (PPA) to supply green electricity to the first direct reduction plant at the Duisburg location with electrically powered melters. The contract, with a term of 10 years, provides for a delivery volume of 112 GWh per year. The electricity will be generated at RWE's Nordsee Kaskasi offshore wind farm, 35 kilometers off the coast of Heligoland. This means offshore wind energy will make a significant contribution to supplying the energy for the tkH2Steel transformation project in future, and will help in achieving climate goals. Additional contracts with green electricity producers will be required to fully supply the system with green electricity.

Electric hot metal from renewable energy: primary steel production will be climate-friendly

In conjunction with the two electrically operated melters, the direct reduction plant will be integrated into Europe's biggest iron and steel plant as a technologically new plant combination. The direct reduction plant which is 100% hydrogen-capable produces directly reduced iron (DRI), referred to as sponge iron, from iron ore. The DRI is melted into hot metal using CO_2-free electricity in the two identical melters. With a capacity of 2.3 million metric tons of regeneratively produced hot metal per year, up to 3.5 million metric tons of CO_2 emissions can be avoided annually. This innovative approach is a significant step on the path to sustainable and carbon-neutral steel production.

Green electricity is the foundation of a sustainable industry

The partnership with RWE is an important building block in the company's energy strategy, as part of the tkH2Steel transformation project, with the goal of sustainable steelmaking. This strategy envisages successively increasing the requirement for electricity generated from renewable sources, and thus paving the way for carbon-neutral production.

Source: thyssenkrupp Press Release, Feb 19, 2024

H_2 Green Steel Raises Debt Financing for the World's First Large-scale Green Steel Plant

H2 Green Steel is driving one of the largest climate impact initiatives globally. The company was founded in 2020 with the purpose to decarbonize hard-to-abate industries, starting by producing steel with up to 95% lower CO_2 emissions than steel made with blast furnaces. The construction of the flagship green steel plant in Boden, with integrated green hydrogen and green iron production, is well under way. The supply contracts for the hydrogen-, iron- and steel equipment are in place. A large portion of the electricity needed has been secured in long-term power purchase agreements, and half of the initial yearly volumes of 2.5 million tonnes of near zero steel have been sold in binding five- to seven-year customer agreements.

H_2 Green Steel announced a massive milestone on its journey to accelerate the decarbonization of the steel industry, which is still one of the world's dirtiest. The company has signed debt financing of €4.2 billion, added equity of close to €300 million and been awarded a €250 million grant from the Innovation Fund. Funding amounts to €6.5 billion in total.

H_2 Green Steel has signed definitive financing documentation for €3.5 billion in senior debt and an up-to-€600 million junior debt facility:

- Consistent with project financings, international banks providing the senior debt will be lending in part under cover provided by *Riksgälden* (Swedish National Debt Office), as a green credit guarantee and Euler Hermes as an export credit cover for €1.2 billion each. The guarantees cover 80% and 95% of the loan amount respectively, and are provided in accordance with market pricing.
- The group of over 20 lenders includes *Svensk Exportkredit (SEK)* and the European Investment Bank together with commercial banks, led by *BNP Paribas, ING, KfW IPEX-Bank, Societe Generale* and *UniCredit*.
- The junior debt consortium is led by AIP Management and comprises European and international investment banks and funds.

H_2 Green Steel has also raised close to €300 million more in equity, bringing the private placement in the project to a total of €2.1 billion. New shareholders include *Microsoft Climate Innovation Fund, Mubea* and *Siemens Financial Services*. Additionally, *IMAS Foundation* and *Just Climate* are some of the existing shareholders which are increasing

their investments in *H_2 Green Steel*.

In September 2023, *H_2 Green Steel* announced it had raised €1.5 billion in equity, making it the largest private placement round in 2023 in Europe. Before that, the company closed its series A equity round of €86 million in May 2021 and announced the close of its series B1 round of €260 million in October 2022.

H_2 Green Steel has also signed a €250 million grant agreement under the *Innovation Fund through the European Climate, Infrastructure and Environment Executive Agency (CINEA).* The Innovation Fund is financed by the European Union's *Emissions Trading System* and supports innovative projects that aim to speed up decarbonization of European industry and accelerate the green transition.

The steel industry is a strategic sector, being at the heart of the EU economy. Commitment to reach net zero by 2050 requires this sector to undergo transformative changes. The project paves the way for the development of environmentally friendly steel - crucial for the decarbonisation efforts of the so-called "hard to abate sectors", of which steel is an important one.

Source: H2 Green Steel website Jan. 22, 2024

KIRCHHOFF Automotive and H_2 Green Steel in Deal for Supply of Near Zero Emissions Steel

Global supplier to the automotive industry, *KIRCHHOFF Automotive*, signs 7-year agreement with *H_2 Green Steel* for the delivery of near zero emissions steel from Boden.

By teaming up with the Swedish impact company *H_2 Green Steel, KIRCHHOFF Automotive* takes further steps to decarbonize its supply chain and to achieving its sustainability goals.

KIRCHHOFF Automotive works ambitiously with sustainability, including its supply chain where steel is the main component in its products, accounting for circa 50% of its material purchases. 90% of its carbon footprint is currently determined by the use of conventionally produced steel and aluminium. Based on orders for upcoming generations of vehicles from international car manufacturers, *KIRCHHOFF Automotive* sees that the demand for safe and sustainable body-in-white parts will increase strongly in the coming years. The order from *KIRCHHOFF Automotive* will see

deliveries of green steel from *H_2 Green Steel's* Boden plant starting 2027, to *KIRCHHOFF Automotive's* plants across Europe. As early as 2022, *KIRCHHOFF Automotive* began a process of determining the location of greenhouse gas emissions in their supply chain (Scope 3), both upstream at suppliers and downstream at customers. The company also has an overall goal to establish a high level of sustainability in the automotive industry's supply chains.

H_2 Green Steel is committed to the Scope 1, 2 and upstream Scope 3 requirements as defined in the GHG Protocol. The company has a gross embodied carbon emission intensity obligation per tonne of steel included in its customer contracts and the continuous work to reduce emissions will impact *KIRCHHOFF Automotive's* material supply chain and its upstream Scope 3 emissions.

The two companies will also work together on a circularity initiative where the aim is to send at least 30% of the steel scrap volumes back to *H_2 Green Steel*'s electric arc furnaces in Boden for recycling.

Source: H2 Green Steel website, January 16, 2024

Natural Hydrogen

There is enough natural hydrogen underground to meet all demand for hundreds of years', says US government agency. Geologists expect 'gold rush' for natural H_2 resources.

There are trillions of tonnes of naturally occurring hydrogen in underground reservoirs, a tiny percentage of which would meet all the world's H_2 needs for hundreds of years. A "gold rush" to exploit reserves is about to start.

An unpublished report from the US Geological Survey (USGS) — an agency of the US government — has found that there are as much as five trillion tonnes of natural hydrogen underground. And just a fraction of that would be enough to meet global H_2 demand for years to come.

Most hydrogen is likely inaccessible, but a few per cent recovery would still supply all projected demand — 500 million tonnes a year — for hundreds of years.

The Hydrogen Council estimates that global hydrogen demand will reach 375 million tonnes per year by 2050. This means that investment is likely to begin flowing into

natural hydrogen production imminently.

A gold rush for gold hydrogen is coming. Exploiting natural hydrogen — sometimes known as gold or white hydrogen — would be cleaner and cheaper than making H_2 via steam methane reforming or eletrolysis.

The news comes as the US government allocated the first tranche of a $20m subsidy programme for technologies to measure and produce natural H_2.

Until a few years ago, the scientific consensus was that naturally occurring hydrogen underground would be destroyed by microbes or chemical processes close to the Earth's surface.

But geologists now believe subterranean hydrogen is generated in large quantities when iron-rich minerals react with water.

Several exploration companies are already actively searching for H_2 resources, with the aim of commercialising them.

Natural hydrogen detected at Australia's second exploration well, pointing to 'likely' underground accumulation

Australia's *Gold Hydrogen* reported that it had found "elevated levels" H_2 in its South Australian well, while Bill Gates-back US explorer *Koloma* has been searching the US Midwest. Earlier this year, researchers found a "spring" of almost pure natural hydrogen in Albania, producing up to 200 tonnes per year.

However, it has yet to be proven that natural hydrogen can be commercially exploited at scale, partly due to the fact that it always seems to be mixed with other gases such as methane, from which it will need to be separated, and partly due to the size of the reserves discovered to date.

The only current use of natural hydrogen anywhere in the world is in a village in Mali, west Africa, where it is burned — unseparated from other gases — to generate electricity.

Source: Accelerate Hydrogen Newsletter, Feb. 20, 2024

Which Countries are Leading the Green Hydrogen Race?

Right now, the world produces almost no green hydrogen. But around the globe, that's set to change — here's where it's happening first.

Whether we believe green hydrogen to be fundamental to the clean energy transition or dismiss it as an overhyped technology, one thing is for certain — more of it is coming.

But where will most of this green hydrogen be produced? Besides China's enormous lead, the answer is a bit all over the map. According to the International Energy Agency's hydrogen projects database, there are the top 15 countries with the most green hydrogen capacity that's operational or under construction or has secured committed financing.

China is currently the world's largest consumer and producer of hydrogen. Most of the hydrogen it makes today is fossil-fuel-based, but the country has big plans to scale up its green hydrogen production and use the fuel to decarbonize sectors like steel and chemicals production.

Saudi Arabia is next on the list, thanks to the fact that it's currently building the world's largest green hydrogen project. A joint venture between *ACWA Power*, *Air Products* and *Neom*, the huge facility will include "up to 4 gigawatts of solar and wind energy to produce up to 600 tonnes" of green hydrogen per day. That would mean the facility will be capable of producing over 200 kilo tonnes of green hydrogen per year if it operates every day. For context, the largest existing green-hydrogen facility, in China's Xinjiang region, has a capacity of just over 44 kilo tonnes per year.

Sweden, which opened its largest electrolyzer facility last year, is up next, and fellow European Union members **Germany** and **France** also make the top 10. The EU has plans to "produce 10 million tonnes and import 10 million tonnes" of "renewable hydrogen" by 2030, and it has set ambitious targets to boost hydrogen use in industry and transport, positioning itself as a leader in demand-side policy incentives, which are lacking elsewhere.

The **United States** is just behind Sweden on green hydrogen plans. Thanks to the 2022 Inflation Reduction Act, which includes the world's most generous clean hydrogen subsidies, the country is expected to see a wave of new investment in green hydrogen production.

The **United Kingdom**, which has its own set of support measures for clean hydrogen, rounds out the top five countries.

In total, the world produces just 180 kilo tonnes of electrolysis-based hydrogen per

year right now. But that number could reach more than 14,000 kilo tonnes by 2030 if all projects currently under construction become operational — and that's not even counting the hundreds more that have been announced but don't have investment or permitting yet.

Source: Canary Media, 2 February 2024

Top 10 Steel Industry Trends (2023)

A data-driven research explores the top 10 steel industry trends that pave the way for modern steelmaking. The steel industry is seeing advancements in technologies that change the way steel is produced. Smart steel technologies like augmented reality (AR) and virtual reality (VR) offer an immersive training environment and allow the workforce to interact with real-world assets and tools. 3D printing, smart manufacturing, and robotic automation improve the performance and efficiency of steelmaking processes. At the same time, recycled steel manufacturing is becoming one of the major trends in steelmaking, with the aim of enabling a circular economy.

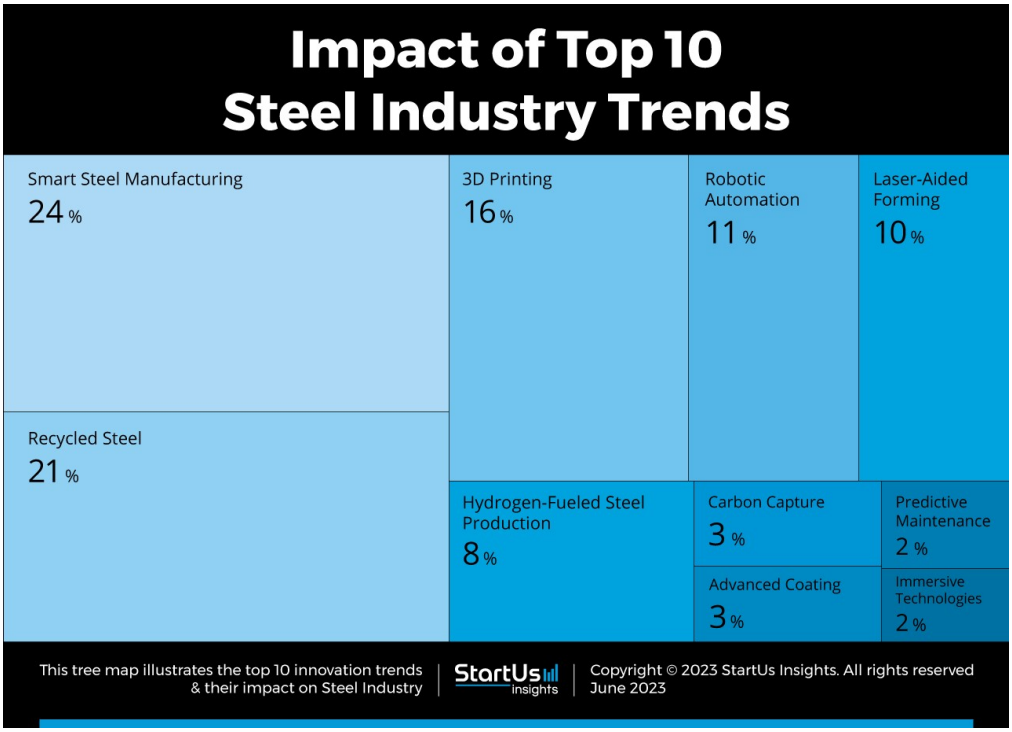
The Steel Manufacturing Innovation Map below, gives a comprehensive overview of the innovation trends and startups.

Top 10 Current Steel Industry Trends in 2023 are:

1. Advanced Coating
2. Smart Steel Manufacturing
3. Recycled Steel
4. 3D Printing
5. Robotic Automation
6. Laser-Aided Forming
7. Hydrogen-Fueled Steel Production
8. Carbon Capture
9. Predictive Maintenance
10. AR & VR in the Steel Industry

Based on the Steelmaking Innovation Map, the *TreeMap* below illustrates the impact of the Top 10 Technology Trends in the Steel Industry. Startups and scaleups are developing solutions to speed up production with the use of smart manufacturing processes, robotic automation, and green steel technology. Immersive technologies also play a major role in safety training and offering visual aids on the shop floor. The use of advanced nano-coatings, carbon capture solutions, and hydrogen-based manufacturing processes enables steelmakers to cut emissions and manufacture clean steel. Other emerging trends focus on laser forming to enhance part-precision and predictive maintenance to extend the life of connected assets.

The *Global Startup Heat Map* below highlights the global distribution of the 670 exemplary startups and scaleups that were analyzed for this research. The *Heat Map* reveals high startup activity in Europe, the US, and India.


Impact of Top 10
Steel Industry Trends
Smart Steel Manufacturing
24 %
3D Printing
16 %
Robotic Automation
11 %
Laser-Aided Forming
10 %
Recycled Steel
21 %
Hydrogen-Fueled Steel Production
8 %
Carbon Capture
3 %
Predictive Maintenance
2 %
Advanced Coating
3 %
Immersive Technologies
2 %
This tree map illustrates the top 10 innovation trends & their impact on Steel Industry
StartUs insights
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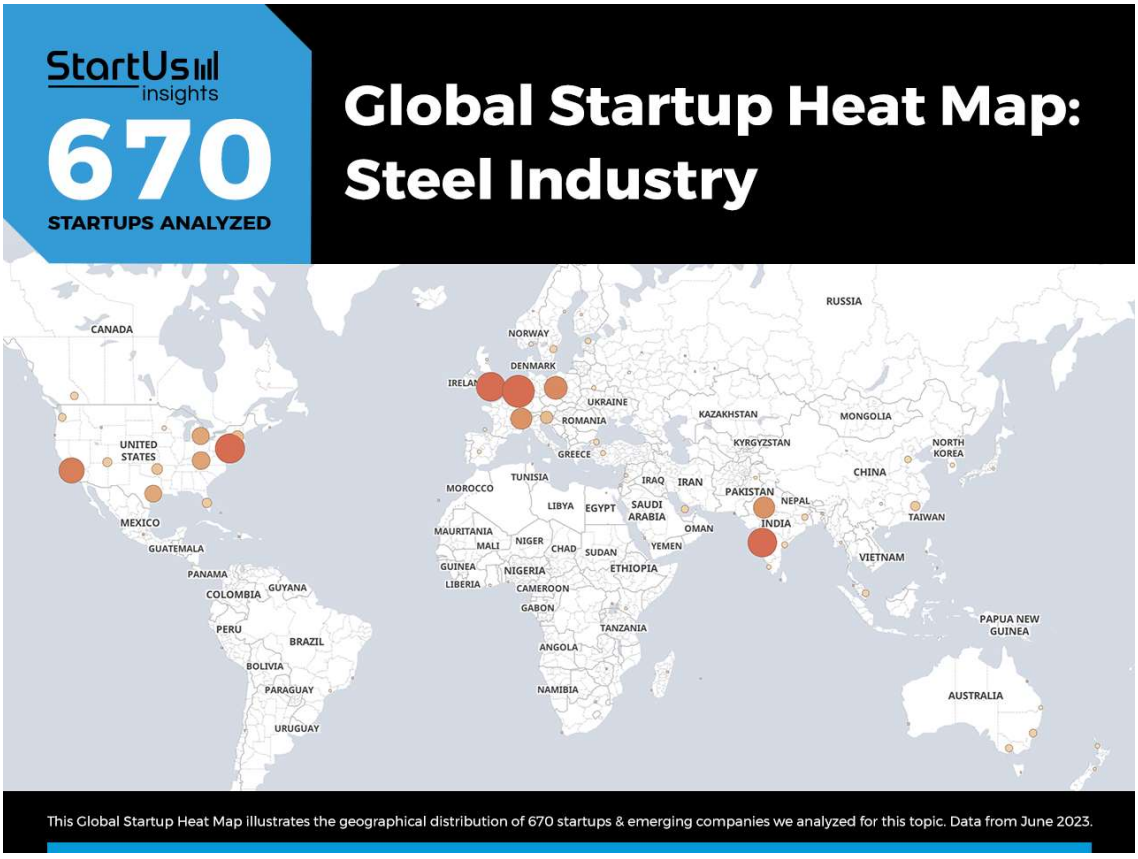
June 2023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670
STARTUPS ANALYZED
Global Startup Heat Map:
Steel Industry
RUSSIA
CANADA
NORWAY
DENMARK
IRELAND
UKRAINE
ROMANIA
KAZAKHSTAN
MONGOLIA
KYRGYZSTAN
NORTH KOREA
GREECE
CHINA
UNITED STATES
TUNISIA
MOROCCO
IRAQ
IRAN
PAKISTAN
NEPAL
LIBYA
EGYPT
SAUDI ARABIA
INDIA
TAIWAN
MEXICO
MAURITANIA
OMAN
MALI
NIGER
CHAD
SUDAN
YEMEN
VIETNAM
GUATEMALA
GUINEA
NIGERIA
ETHIOPIA
PANAMA
LIBERIA
CAMEROON
COLOMBIA
GUYANA
GABON
PAPUA NEW GUINEA
PERU
TANZANIA
BRAZIL
ANGOLA
BOLIVIA
NAMIBIA
AUSTRALIA
PARAGUAY
URUGUAY
This Global Startup Heat Map illustrates the geographical distribution of 670 startups & emerging companies we analyzed for this topic. Data from June 2023.

1. Advanced Coating

Advanced coating plays an important role in the steelmaking industry by enhancing surface performance, durability, and quality of steel products. Galvanizing and polymer coatings provide resistance to corrosion and abrasion by applying thin layers of polymers like epoxy and polyester. Also, coatings like ceramic as well as thermal sprays and passivation contribute to the overall longevity and aesthetic appeal of steel products. This enables a variety of applications in the construction, aerospace, automotive, and manufacturing industries.

Allium Engineering offers Coated Rebar Technology

US-based startup *Allium Engineering* provides coated rebar technology for the steel industry. It increases the steel products' lifetime and reduces carbon emissions. For this, the startup uses a thin stainless steel layer and a protective oxide barrier coating to shield the steel core against corrosion. The coating prevents rust and water buildup on the surface of the steel rebar to ensure better performance. Allium Engineering allows the construction industry to coat steel and concrete structures exposed to the environment to reduce emissions and maintenance costs.

Nanosentrix makes Micro and Nanomaterial Inks

Indian startup *Nanosentrix* manufactures micro- and nano-material inks and screen printing solutions for the steel industry. It offers *Nanosentrix Thermoresist*, a graphite electrode surface coating to prevent the oxidation of electrodes in an electric arc furnace. The startup's coating utilizes an aqueous solution of self-healing nanocomposite suspension to improve oxidation resistance during baking. *Nanosentrix* also increases the diameter of an electrode tip to reduce the linear wear of the overall electrode in an electric arc furnace (EAF). Nanosentrix caters to the steel smelting industry and EAF manufacturers, allowing them to improve the lifecycle of an electrode by preventing oxidation.

2. Smart Steel Manufacturing

Smart manufacturing processes incorporate industry 4.0 solutions and the Industrial Internet of Things (IIoT) to transform steelmaking. Advanced steel technologies and data-driven solutions optimize production processes, increase efficiency, and enhance product quality. For example, data analytics, machine learning, advanced sensors, and

monitoring systems enable early detection of issues and provide precise control of machinery. The technologies also help in the supply chain optimization of raw steel by integrating data from suppliers, inventory systems, and production schedules.

Foresight Data Machines develops Process Control Solutions

Foresight Data Machines is a UK-based startup that builds process control solutions for EAF steelmaking. Its AI-enabled solution understands the relationship between raw material quality and operating procedures to provide meaningful insights. The solution translates the data into actionable process control recommendations to improve energy and raw material efficiency, yield, and quality. Foresight Data Machines thus helps operators, process engineers, plant managers, and purchasing teams in raw material inventory and quality management.

XYMA Analytics creates Measurement Sensors

Indian startup *XYMA Analytics* provides multi-point sensing, temperature, and level management sensors for steel manufacturing businesses. It offers *μTMaps and μSTMaps* – two multi-point high-temperature mapping sensors that use a single waveguide sensor technology. The sensors feature insulation damage and humidity control to detect abnormal temperature drops and possible humidity and insulation damage in the pipelines. XYMA Analytics empowers steel manufacturers by safeguarding their processes and enhancing productivity.

3. Energy Efficient Recycled Steel

One of the recent trends in the steel industry is the use of recycled scrap materials as the primary raw material. The recycling of metals takes place in an electric furnace, driven by renewable energy, which provides an energy-efficient alternative to traditional steelmaking. The process involves collecting and sorting scrap metal, including end-of-life steel products, to melt and refine the alloys and adjust composition. Recycled steelmaking offers many environmental benefits such as lowering carbon emissions and reducing the wastage of valuable natural resources. This allows manufacturers to reduce costs of production and achieve net zero emissions.

PRINZ Blades advances Low-Carbon Steelmaking

German startup *PRINZ Blades* manufactures green steel from EAF and renewable energy. The startup uses recycled steel scraps and alloys, along with a photovoltaic

system with multiple solar modules, to manufacture a range of blades. The blades tamper with a hardening process for an optimal balance of tenacity and hardness to offer increased durability and performance. With resource-efficient and environmentally friendly processes and raw materials, the startup allows steel manufacturers to increase process sustainability. PRINZ Blades offers product lifetime optimization, welding, and maintenance solutions to direct customers and industries.

Envigen offers Closed-Loop Metal Recovery

Envigen is a UK-based startup that offers closed-loop metal recovery and recycling to provide shredded stainless steel and alloys. The solution uses an energy and time-efficient process to reclaim copper, aluminium, steel, and plastic from waste. The startup leverages renewable energy to power furnaces in the recycling plant and also feeds electricity back into the grid, enabling a circular economy. *Envigen* produces sustainable and recycled stainless steel for the shipbuilding, civil engineering, power plant, and medical industries while reducing the cost of raw materials.

4. 3D Printing

3D printing is one of the most reliable processes to manufacture complex metal parts, components, and prototypes. Traditional steelmaking works on subtractive principles like cutting, shaping, milling, and grinding, which increases the scraps from production. Additive manufacturing enables the direct fabrication of steel parts layer by layer to eliminate wastage. It uses powder bed fusion and direct energy deposition technology to melt the metal powder. For melting, a 3D printer utilizes a laser, electron beam, or plasma arc to make parts for precise applications. Such advanced steel technology allows steel product manufacturers to make parts with precision and eliminate raw material wastage.

Aditiv Solutions deploys Metal Additive Manufacturing Solutions

Aditiv Solutions is a startup from South Africa that designs and builds metal additive manufacturing equipment. Its *HYRAX* is a 3D printing system that allows the development of intricate parts directly from metal powder. The solution uses powder bed fusion technology equipped with precision lasers and optical systems to ensure quality. *Aditiv Solutions* deploys machine design, simulation, code development, and product life-cycle management to offer cost-effective manufacturing solutions to steel manufacturers.

Headmade Materials provides Additive Material for Powder Metallurgy

German startup *Headmade Materials* offers materials for the 3D printing and powder metallurgy industries. Its sinter-based *Cold Metal Fusion* technology provides high-strength eco-friendly parts to simplify cleaning and handling. The startup's feedstock fits into existing machines and processes to eliminate new equipment costs and help in producing quality metal parts. *Headmade Materials* embeds metal powders in a plastic matrix that allows better metal particle binding to improve occupational safety in additive manufacturing and automotive industries.

5. Robotic Automation

Robotic automation plays a vital role in modern manufacturing processes. It revolutionizes the steel industry by improving efficiency, productivity, safety, and quality control. By incorporating technologies like AI and continuous monitoring, steel manufacturers automate their plants with greater efficiency. Robots in steelmaking enable autonomous raw material handling, assisted welding and assembly, continuous casting, and automated furnace operations. Robotic automation also allows manufacturing plant owners and managers to streamline repetitive and dangerous tasks by removing the need for direct human involvement.

Wattman delivers AI-Powered Robotic Manufacturing

Chinese startup *Wattman* provides industrial intelligence with robots, machine vision, and 3D intelligence perception to steel manufacturers. It offers *WATT iRobot*, a smart robot series for anode carbon block cleaning and target object repairing. The startup's robots feature camera-based arms for performing 3D reconstruction and analysis of objects. It also offers intelligent mucking and palletizing robots to enable the automatic handling of stacking operations for steel. This way, *Wattman* develops a smart lifecycle management system for metallurgical furnaces, improving the operational efficiency of steel plants.

Mech-Mind Robotics enables Intelligent Robot Control

German startup *Mech-Mind Robotics* offers solutions for intelligent robot control using 3D simulations. The startup offers *Mech-Viz*, a robot programming software for path planning, collision detection, and grasp planning. The all-in-one system enables the programming of robots visually and code-free by using AI to calculate the fastest motion sequence. By integrating a robot controller with *Mech-Viz*, *Mech-Mind* helps automotive, logistics, home appliance, and steelmaking industries utilize autonomous

robots for process automation.

6. Laser-Aided Forming

Modern steelmaking utilizes new technologies in terms of manufacturing, bending, and forming. Laser-aided forming uses high-power laser beams for metal deformation, forming, and precision control. It offers unique capabilities for shaping and forming metal components with high precision over traditional technologies. Laser forming also reduces tooling requirements, improves formability, and allows for complex shape geometries. This technology reduces spring back in formed parts by inducing compressive stresses during the forming process. Further, laser beams enable steel manufacturers to achieve bends, complex contours, and sharp angles with higher accuracy in complex productions.

Applied Impulse advances Impulse Manufacturing for Steelmaking

US-based startup *Applied Impulse* uses electrical and optical pulsed power for impulse manufacturing in steel factories. It uses laser ablation technology with parasitic ionization to weld thick aluminium sheets to steel parts for improving corrosion resistance. The solution utilizes a vaporizing conductor and electromagnetic induction to pass a high transient current between the sheet and the workpiece. Applied Impulse's technology offers welding, cutting, shaping, conformal interference joints, and ballistic additive manufacturing to part manufacturers and steel-forming industries.

SG Metals aids Plasma and Laser Melting

SG Metals is a US-based startup that provides thick steel plates, steel shearing, bending, and sawing solutions. It uses an in-house steel precision laser and high-definition plasma cutting technologies for commercial, manufacturing, and industrial applications. With automatic feeds and measuring devices for precision accuracy, the technology enables the manufacturing of structural and coil steel. SG Metals caters to automobile factories, construction sites, and manufacturing plants.

7. Hydrogen-Fueled Steel Production

Traditional steel production relies heavily on fossil fuels, such as coal and natural gas, which emit carbon dioxide (CO_2) and contribute to greenhouse gas emissions and climate change. Startups now use hydrogen as a reducing agent in the direct reduction of iron ore to form sponge iron. Further, hydrogen acts as a clean source of heat in

EAFs that enables steelmakers to produce green steel. For generating hydrogen, companies use methods like steam methane reforming (SMR), electrolysis, methane pyrolysis, and biomass gasification. This ensures a sustainable and cost-effective supply of hydrogen in steelmaking plants.

Hystar develops Proton Exchange Membrane Electrolysers

Hystar is a Norwegian startup that develops proton exchange membrane (PEM) electrolyzers for green hydrogen production from water electrolysis. It offers *Vega*, *Mira*, and *Orion*, modular and scalable electrolyzer systems that utilize its patented technology. The solution features full containerized systems for rapid deployment of autonomous and independent electrolyzers without any additional constructions. It uses thin membranes, anode air feed, and cathode water feed for efficient operations and higher output. This enables Hystar to deploy green steel solutions to reduce carbon emissions and optimize the cost of the steel manufacturing plant and processes.

ELECTRIC HYDROGEN provides an Integrated Electrolysis Technology

US-based startup *ELECTRIC HYDROGEN* creates electrolyzer technologies for clean, abundant, and low-cost hydrogen. It leverages renewable energy sources to generate sustainable hydrogen for heavy industries. The startup designs and provides integrated electrolysis plants to improve performance and reduce capital and operating expenditures. Additionally, *ELECTRIC HYDROGEN* allows plant managers to predict operations and production to reduce project costs and prevent schedule overruns.

8. Carbon Capture

Carbon capture technology enables CO_2 emissions capture during steel production. This technology uses pre- or post-combustion capture to collect carbon. The captured CO_2 is stored underground for enhanced oil recovery (EOR) or the production of chemicals, polymers, and construction materials. Integrating carbon capture into the steelmaking industry enables plant owners to achieve net-zero emissions and fight climate change.

Verde CO2 develops Carbon Capture & Storage (CCS) Solutions

US-based startup *Verde CO2* makes carbon capture and storage solutions for carbon reduction in the steelmaking industry. It manufactures CO_2 capture equipment to

improve carbon capture and storage for a net-zero environment. The startup offers geologic analysis to identify viable sequestration reservoirs for CO_2 separation from fossil or biomass-fuelled power plants and industrial facilities. This enables *Verde CO2* to transport, store, and use collected carbon as input and feedstock for steel production facilities and industries.

Capture6 enables Irreversible Carbon Capture

US-based startup *Capture6* provides permanent and irreversible carbon capture solutions for reducing GHG emissions in the environment. Its solution uses a direct air capture (DAC) approach for carbon removal to increase freshwater supply for agricultural uses. The startup features point source capture for ethanol, fertilizers, steel, and cement manufacturing industries to create longer decarbonization timelines. *Capture6* effectively captures and stores carbon for higher geological timescales with its mineralizing process.

9. Predictive Maintenance and Defect Prediction

By leveraging real-time data and machine learning algorithms, steel manufacturers predict potential failures and schedule maintenance activities proactively. Temperature, vibration, and energy consumption data help systems to monitor deviations and provide actionable insights to plant managers. Real-time monitoring of equipment also detects early signs of deterioration or abnormalities. By continuously analyzing data from sensors, maintenance teams take timely action by identifying deviations from normal operating conditions.

Deep Meta facilitates Metallurgical Defect Prediction

Deep Meta is a UK-based startup that provides a digital twin platform to analyze and predict metallurgical defects in production plants. The startup's software harnesses historical data to create digital versions of potential defects to optimize production output. It offers real-time insights for warning operators about casting cracks and rolling defects to reduce the wastage and costs of raw materials. *Deep Meta* tracks and monitors the steel remotely in the supply chain and predicts material behaviour and lifecycles for better allocation of resources in modern steel plants.

Bayanatai offers a Defect Detection Algorithm

Bayanatai is a startup from Qatar that develops defect detection algorithms to identify surface defects on steel sheets. It implements AI algorithms to predict the location and

type of imperfections in steel manufacturing. The solution leverages machine learning to provide real-time analysis, intelligent solutions, and prediction models to make better strategic decisions in steelmaking plants. *Bayanatai* caters to the construction, retail, and industrial sector by providing object detection, prediction models, and natural language processing (NLP) solutions. This allows industries to make deliver better customer experiences.

10. Immersive Technologies

AR provides a realistic and interactive training environment for steelworkers. Immersive simulations replicate complex steelmaking processes. They allow employees to practice operating machinery, handling equipment, and performing maintenance tasks in a safe and controlled virtual environment. Additionally, it enables manufacturers to visualize steel products, plant layouts, and equipment designs for engineers to create virtual models and identify potential issues before physical construction.

Eterio Realities enables AR-assisted Steel Production

Canadian startup *Eterio Realities* creates integrated AR production software tools for first-line workers to improve production cycles. It offers *FabStation-Steel*, an AR solution that visually places 3D assets into workflows for construction and inspection workers. Its AR-based steel production tools for fabrication floors allow for real-time reporting and data exchange. By doing so, *Eterio Realities* provides status updates as well as time and material tracking to improve production performance in steel plants.

Warp VR provides VR-enabled Workforce Training

Warp VR is a Dutch startup that creates VR workforce training solutions to upskill the workforce and improve performance. It utilizes a story-based immersive learning approach to train the workforce and improve completion rates and retention. The solution works on multiple devices and supports learning management system (LMS) integrations, single sign-on (SSO), and multiple languages. This way, Warp VR empowers instructor-led, on-the-job, and online training remotely, fostering employee skill development and bolstering their confidence.

Conclusions

The future of steelmaking is set for significant transformation with the integration of advanced technologies like AR/VR and advanced coatings. By using cyber-physical systems (CPS), AI, and IoT, the steel industry embraces digitalization to create smart

and connected plants. The industry also seeks to adopt cleaner energy sources like hydrogen, renewable electricity, and advanced carbon capture solutions to reduce GHG emissions. The steel manufacturing trends and startups outlined here only scratch the surface of trends. Identifying new opportunities and emerging technologies to implement into business goes a long way in gaining a competitive advantage.

Source: StartUs Insight

2023 Was World's Hottest Year

Last year was the planet's hottest on record by a substantial margin and likely the world's warmest in the last 1,00,000 years, as per the European Union's Copernicus Climate Change Service (C3S).

Scientists had widely expected the milestone after climate records were repeatedly broken. Since June, every month has been the world's hottest on record compared with the corresponding month in previous years. This has been a very exceptional year, climate-wise... in a league of its own, even when compared to other very warm years.

C3S confirmed 2023 as the hottest year in global temperature records going back to 1850. When checked against paleoclimatic data records from sources such as tree rings and air bubbles in glaciers, it was "very likely" the warmest year in the last 1,00,000 years.

On average, in 2023 the planet was 1.48 degrees Celsius warmer than in the 1850-1900 pre-industrial period, when humans began burning fossil fuels on an industrial scale, pumping carbon dioxide into the atmosphere.

Countries agreed in the 2015 Paris Agreement to try to prevent global warming surpassing 1.5 ^{0}C, to avoid its most severe consequences.

The world has not breached that target, which refers to an average global temperature of 1.5 ^{0}C over decades, but C3S said that temperatures had exceeded the level on nearly half of the days of 2023 set "a dire precedent".

Despite the proliferation of governments' and companies' climate targets, CO_2 emissions remain stubbornly high. The world's CO_2 emissions from burning coal, oil

and gas hit record levels in 2023.

Last year, the concentration of CO_2 in the atmosphere rose to the highest level recorded, of 419 parts per million, C3S said.

It was also the first year in which every day was more than 1C hotter than pre-industrial times. For the first time, two days - both of them were in November – were 2^0C warmer than in the pre-industrial period, C3S said.

Last year was 0.17^0C hotter than 2016, the previous hottest year - smashing the record by a "remarkable" margin.

Alongside human-caused climate change, temperatures were boosted by the El Nino weather phenomenon, which warms the surface waters in the eastern Pacific Ocean and contributes to higher global temperatures, in 2023.

The economic consequences of climate change are also escalating. The U.S. suffered at least 25 climate and weather disasters with damages exceeding $1 billion, National Center for Environmental Information data show. Prolonged droughts ravaged soybean crops in Argentina and wheat in Spain.

Source: Evening Wrap, The Hindu, News Alert, Jan. 9, 2024

Advances for Capturing Carbon

A chemical element so visually striking it was named for a goddess shows a "Goldilocks" level of reactivity – neither too much nor too little – that makes it a strong candidate as a carbon scrubbing tool. Oregon State University reports on how Vanadium could be ideal for Direct Air Capture (DAC).

The element is vanadium, and research by Oregon State University scientists has demonstrated the ability of vanadium peroxide molecules to react with and bind carbon dioxide – an important step toward improved technologies for removing carbon dioxide from the atmosphere.

The study is part of a $24 million federal effort to develop new methods for direct air capture, or DAC, of carbon dioxide, a greenhouse gas that's produced by the burning of fossil fuels and is associated with climate change.

Facilities that filter carbon from the air have begun to spring up around the globe but

they're still in their infancy. Technologies for mitigating carbon dioxide at the point of entry into the atmosphere, such as at power plants, are more well developed. Both types of carbon capture will likely be needed if the Earth is to avoid the worst outcomes of climate change, scientists say.

Oregon State's College of Science, Department of Energy team is exploring how some transition metal complexes can react with air to remove carbon dioxide and convert it to a metal carbonate, similar to what is found in many naturally occurring minerals. Transition metals are located near the center of the periodic table and their name arises from the transition of electrons from low energy to high energy states and back again, giving rise to distinctive colours. For this study, the scientists landed on vanadium, named for Vanadis, the old name for the Scandinavian goddess of love, said to be so beautiful that her tears turned to gold.

Carbon dioxide exists in the atmosphere at a density of 400 parts per million. That means for every 1 million air molecules, 400 of them are carbon dioxide, or 0.04%. A challenge with direct air capture is finding molecules or materials that are selective enough, or other reactions with more abundant air molecules, such as reactions with water, will outcompete the reaction with CO_2. A series of molecules were synthesized, that contain three parts that are important in removing carbon dioxide from the atmosphere, and they work together.

One part was vanadium, so named because of the range of beautiful colours it can exhibit, and another part was peroxide, which bonded to the vanadium. Because a vanadium peroxide molecule is negatively charged, it needed alkali cations for charge balance, and the researchers used potassium, rubidium and cesium alkali cations for this study.

Collaborators also tried substituting other metals from the same neighbourhoods on the periodic table for vanadium. Tungsten, niobium and tantalum were not found to be as effective in this chemical form. On the other hand, molybdenum was so reactive that it exploded sometimes.

In addition, the scientists substituted ammonium and tetramethyl ammonium, the former of which is mildly acidic, for the alkalis. Those compounds didn't react at all, a puzzler the researchers are still trying to understand.

When peroxide was removed there was not so much reactivity. In this sense, vanadium peroxide is a beautiful, purple Goldilocks that becomes golden when exposed to air and binds a carbon dioxide molecule.

Another valuable characteristic of vanadium is that it allows for the comparatively low release temperature of about 200 degrees Celsius for the captured carbon dioxide. That's compared to almost 700 degrees Celsius when it is bonded to potassium, lithium or sodium, other metals used for carbon capture. Being able to rerelease the captured CO_2 enables reuse of the carbon capture materials, and the lower the temperature required for doing that, the less energy that's needed and the smaller the cost. There are some very clever ideas about reuse of captured carbon already being implemented – for example, piping the captured CO_2 into a greenhouse to grow plants.

Source: https://today.oregonstate.edu/news/oregon-state-university-research-makes-key-advance-capturing-carbon-air

ArcelorMittal's XCarb® India Accelerator Programme

ArcelorMittal's XCarb® India Accelerator programme, established in collaboration with the Indian Institute of Technology Madras (IIT Madras), which aims to identify and support start-ups focused on the most promising industrial decarbonisation technologies in India, has selected three finalists.

Finalists were selected from eight start-ups that received mentorship and guidance on the commercial development of their disruptive technologies during a workshop at IIT Madras in October 2023 and the 8-week mentorship programme that followed. The mentorship was provided by GDC – a Centre of Innovation & Entrepreneurship at IIT Madras.

ArcelorMittal, recognising India's ambition and potential to support the global climate transition, launched a dedicated XCarb® India Accelerator programme in collaboration with IIT Madras in July 2023. The programme is also supported by ArcelorMittal's joint venture in India, ArcelorMittal Nippon Steel India (AM/NS India), which is actively developing its own decarbonisation strategy and initiatives for lower emissions in domestic steel manufacturing.

Applications were invited across four distinct technology domains and the programme aimed to identify the most promising concepts for commercially scalable technologies that hold strong potential to decarbonise steelmaking. From the almost 50 applications received, eight promising start-ups were shortlisted for intensive mentorship facilitated by GDC of IIT Madras.

The finalists were also invited for a two-day site visit to AM/NS India's steelmaking

facility in Hazira, following which they presented their respective technologies to management from both ArcelorMittal and AM/NS India.

The three finalists are:

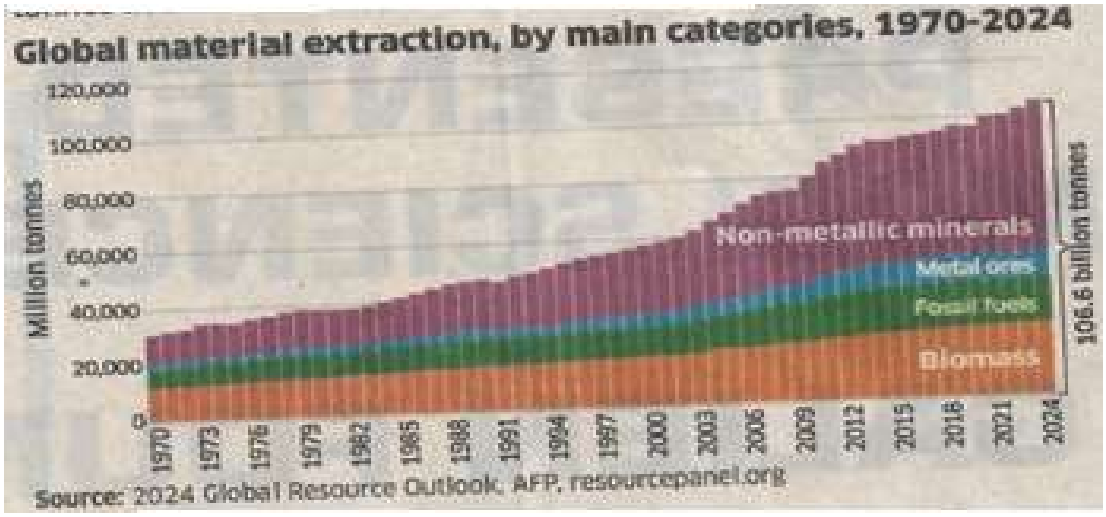
1. AgroMorph Technosolutions Private Limited - developed an algae-based CCUS solution.
2. Susstains Engineering Solutions LLP - invented a novel biochar production technology.
3. UrjanovaC Private Limited - pioneered an innovative CCUS technology.

The technology and business models of these finalists are being reviewed by the XCarb™ Innovation Fund Investment Committee, chaired by Aditya Mittal, CEO of ArcelorMittal. The finalists can potentially be awarded an equity investment or a research collaboration.

Source: ArcelorMittal News 22 Feb. 24

Resource Extraction

Without urgent and concerted action, by 2060 resource extraction could rise by 60% from 2020 levels – driving increasing damage and risks, according to a UNEP report. The global demand for material use has seen prolonged growth over the past five decades – rising in line with GDP but significantly faster than population. The annual global extraction of materials has grown from 30.9 billion tonnes in 1970 to 95.1 billion tonnes in 2020, and is expected to reach 106.6 billion tonnes in 2024 following annual average growth rate to 2.3%..



Comparison of Research Productivity and Innovation Metrics in Selected Countries (2021-22)

Country	Researchers per million inhabitants (2021) (FTE)	PhDs produced annually (2021) (Rank)	Publication output (2022) (Rank)	Top 1% most cited articles (% share)	Patents granted (2022) (Rank)
India	262	40,813 (3)	3,06,800 (3)	0.7	30,490 (6)
The U.S.	4,452	69,525 (1)	15,06,000 (1)	1.88	3,23,410 (2)
The U.K.	4,491	27,366 (5)	2,87,200 (4)	2.35	10,578 (15)
China	1,687	53,778 (2)	9,78,100 (2)	1.12	7,98,347 (1)
S. Korea	9,082	13,882 (11)	1,09,200 (16)	1.02	1,35,180 (4)
Japan	5,638	15,804 (10)	1,71,000 (9)	0.88	2,01,420 (3)
Source: Publications data has been extracted from OpenAlex on February 7, 2024					

Centre Annuls Auction of 13 Critical Mineral Blocks

Out of 13 mines, two got no bids & 11 attracted less than 3 bids each.

The Centre has cancelled auction for 13 of 20 blocks on offer in the first round of critical mineral bids following tepid response. Out of the 13 mines, two got no bids and 11 attracted less than three bids each.

"It has been decided to return the bid security to bidders for 11 mineral blocks that got less than three bids each," on official aware of the development said. These blocks which received poor response hold glauconite, nickel, chromium and platinum group elements (PGE), potash, nickel and copper, molybdenum ore, graphite, and lithium, titanium and bauxite (aluminous laterite).

They are spread across Bihar, Jharkhand, Odisha, Tamil Nadu, Uttar Pradesh and Jammu and Kashmir (J&K).

Seven of these mines will be offered for rebidding under a fresh round of auctions launched earlier this month.

Two blocks which got no bids hold molybdenum and are in Tamil Nadu.

A second round of auctions with 18 other critical mineral blocks is also presently underway.

Responding to a query on the seven blocks that did get a good response in the first bid round, a senior government official said. “Blocks holding phosphorite and fertilizer minerals have got 5-6 bids per mine. The lithium block in Chhattisgarh has got more than 10 bids while graphite mines have 4-5 bidders per block.”

In June 2023, the government released a list of 30 minerals considered critical for the country. These include antimony, beryllium, bismuth, cobalt, copper, gallium, germanium, graphite, hafnium, indium, lithium molybdenum, niobium, nickel, platinum group elements (PGE), phosphorous, and potash.

Rare Earth Elements (REE), rhenium, silicon, strontium, tantalum, tellurium, tin, titanium, tungsten, vanadium, zirconium, selenium and cadmium also figure in this list.

Source: The Economic Times, 29th March, 2024

IIM-ATM 2024

As members are aware, Annual Technical Meeting (ATM) is a flagship event of The Indian Institute of Metals. This event is held every year. The IIM-ATM 2024 will be held from 20th to 22nd November 2024 at Bangalore. Along with ATM, International Symposium on "**Transformational Technologies in Materials and Manufacturing**" will also be held.

The event is being organized by IIM Chapters of Vijayanagar, Bangalore and Salem in association with JSW Steel Ltd. The details of the ATM are being mailed to members separately. The members may like to avail of the opportunity of participation in the ATM and Symposium.


IIM-ATM 2024
BENGALURU
IIM
Metallurgy
Materials Engineering
Announcing...
International Symposium on
" Transformational Technologies in
Materials and Manufacturing "
&
78th Annual Technical Meeting of The Indian Institute of Metals
(IIM-ATM 2024)
20 - 22 November 2024
Dr. Babu Rajendra Prasad International Convention Centre,
Gandhi Krishi Vigyan Kendra(GKVK)
University of Agricultural Sciences, Bengaluru
H_2
HYDROGEN
Organising IIM Chapters:
Vijayanagar, Bengaluru, Salem, and Dolvi in Association with JSW Steel Ltd.

Nominations for IIM Honors & Awards

As the esteemed members are aware, the IIM invites nominations every year for IIM Honors and IIM Awards. The details of IIM Honors & IIM Awards are available at IIM Portal (nmd-iimawards.com)

The members may like to send in their nominations for the IIM Honors and IIM Awards.

The nomination process may kindly be referred to by visiting the above mentioned portal.

The last date for IIM Honors and IIM Awards is 10th June 2024 and 15th September 2024 respectively.

In case of any clarification in the matter, members may kindly contact Ms Atashi Saha, Addl. GM, IIM (email id: atashi.sahaiiom@gmail.com, general-admin@iim-india.net and Mob. No. 9051648575)

Participation in the Programmes of IIM Chapters

IIM Human Resources Development Centre (HRDC), Kalpakkam-Chennai in association with IIM Kalpakkam and IIM Chennai Chapter is conducting a Course/Workshop on Artificial Intelligence in Materials Engineering (AIME - 2024) between 26th and 27th April 2024.

iim-india.net//storage/updates/AIME-2024 Flyer and Registration Form.pdf

IIM Thiruvananthapuram Chapter is organizing an International Conference on Science, Technology and Applications on Rare Earth between 21st and 23rd August 2024 at Uday Samudra, Kovalam, Thiruvananthapuram.

iim-india.net//storage/updates/ICSTAR_2024-Brochure.pdf

The details for participation in the above Programmes have been mailed to the members vide our mail dated 26.3.2024. The above mentioned links also find place in the mail dated 26.3.2024 sent to the esteemed members.

May like to participate in the above Programmes.

Mob: 09810203544

E-mail:klmehrotra48@gmail.com

Shri K L Mehrotra is a Chemical Engineer from BHU Banaras (1970 Batch). He enjoys more than four decades of experience in various positions in Private, State and Public Sectors in the field of Project Management, Power, Mineral Exploration, Mining (both underground and Opencast), Machine-tools, Sugar Chemicals and Export Marketing.

Shri K L Mehrotra worked with Engineering Projects (India) Limited, New Delhi, under Ministry of Heavy Industries for over 15 years. Thereafter, he was a Managing Director, Praga Tools Ltd., under Ministry of Heavy Industries for 5 years.

Shri Mehrotra joined Manganese Ore India Ltd (MOIL) under the Ministry of Steel, as CMD. He also held additional charge as CMD (I/c) of Bird Group of Companies under the Ministry of Steel.

Subsequent to superannuation as CMD, MOIL Ltd. in October 2008, Shri Mehrotra served as Independent Director on the Board of Directors of NBCC, Bharat Dynamics Ltd. and MSTC for 3 years. He also served as Independent Director of FACOR for about 14 years

Other Allied Information:

- Life Fellow Member – Institution of Engineers (FIE) & Chartered Engineer
- Life Member – Indian Institute of Chemical Engineers
- Honorary Member – The Indian Institute of Metals. Served as Chairman IIM Delhi Chapter for 3 years
- Chairman, Indian Institute of Production Engineers – Vidharbha and M. P. Chapter
- Was a member of Task Force on Agriculture, Fertilizer, Chemicals & Pharmaceuticals, Trade & Commerce constituted by the Dept. of Public Enterprises, Govt. of India.
- Member of High Level Committee on formulating Code of Ethics for PSU's employees constituted by Dept. of Public Enterprises, Govt. of India