



AIST MENA

Member Chapter Webinar

Steel Industry Transformation:
From Carbon to Green

SUSTAINABLE VERSUS GREEN STEEL

Prepared by:

Prof. Iman Elmahallawi
Eng. Mayar M. Ali, MSc
Eng. Assem Salah, MSc- EZZ Steel
Eng. Dina Atef, MSc

Organized by



Steel industry in Egypt

ANCIENT METAL INDUSTRY

Pig Iron First Production:

China developed the Blast Furnace Technology as early as 500 BC. This allowed full smelting of iron ore into molten Pig Iron for the first time.

Source: Encyclopedia Britannica - Blast Furnace

The Blast Furnace Right around the beginning of the Han Dynasty in the early 200s B.C., Chinese metallurgists built the first blast furnaces, which pumped a blast of air into a heated batch of iron ore to produce cast iron, according to Chinese technology historian Donald B. Wagner.



A study by 'The Minerals, Metals and Materials Society' on its 50th Anniversary notes that the extraction and smelting of iron were first carried out in Egypt around 3500 BC.

Source: Dr. Saad Elraghy (2024), Metal Industries in Egypt Over 7,000 Years

Fe Smelting (Around 3500 B.C., Egyptians)

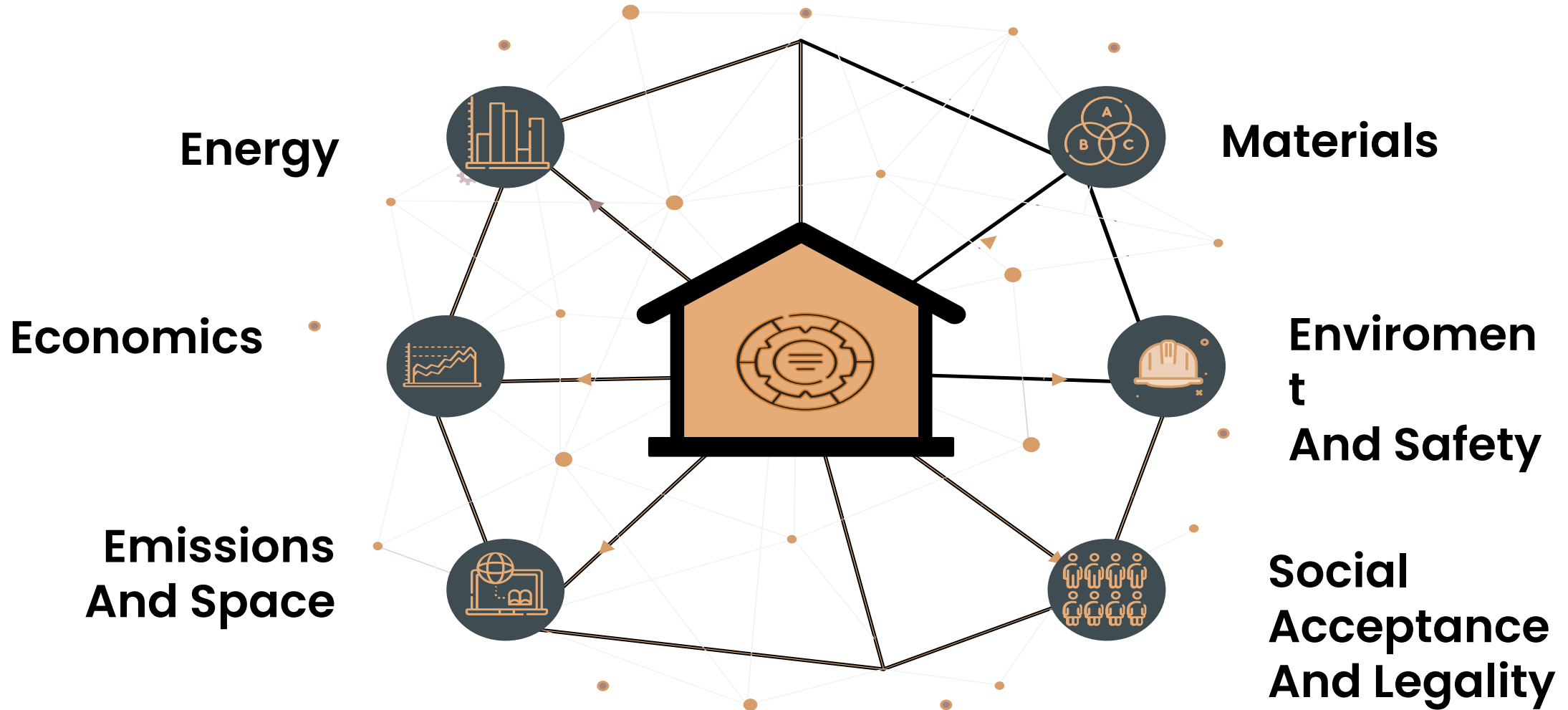
01

Sustainability

Sustainability in steel manufacturing,
Intro to **Green steel** industry

01 Sustainability

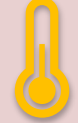
HOW MANY AREAS ARE INCLUDED?



01 Sustainability



**PROTECTING
THE
ENVIRONMENT**



**FIGHTING
CLIMATE
CHANGE**



**ECONOMIC
GROWTH**



SOCIAL EQUITY



01 Sustainability

SDGS RELATED TO IMPROVING INDUSTRY

3 GOOD HEALTH
AND WELL-BEING



8 DECENT WORK AND
ECONOMIC GROWTH



9 INDUSTRY, INNOVATION
AND INFRASTRUCTURE



11 SUSTAINABLE CITIES
AND COMMUNITIES



12 RESPONSIBLE
CONSUMPTION
AND PRODUCTION



13 CLIMATE
ACTION



SDG 3 – Good Health and Well-Being.

SDG 8 – Decent Work and Economic Growth.

SDG 9 – Industry, Innovation and Infrastructure

SDG 11 – Sustainable Cities and Communities.

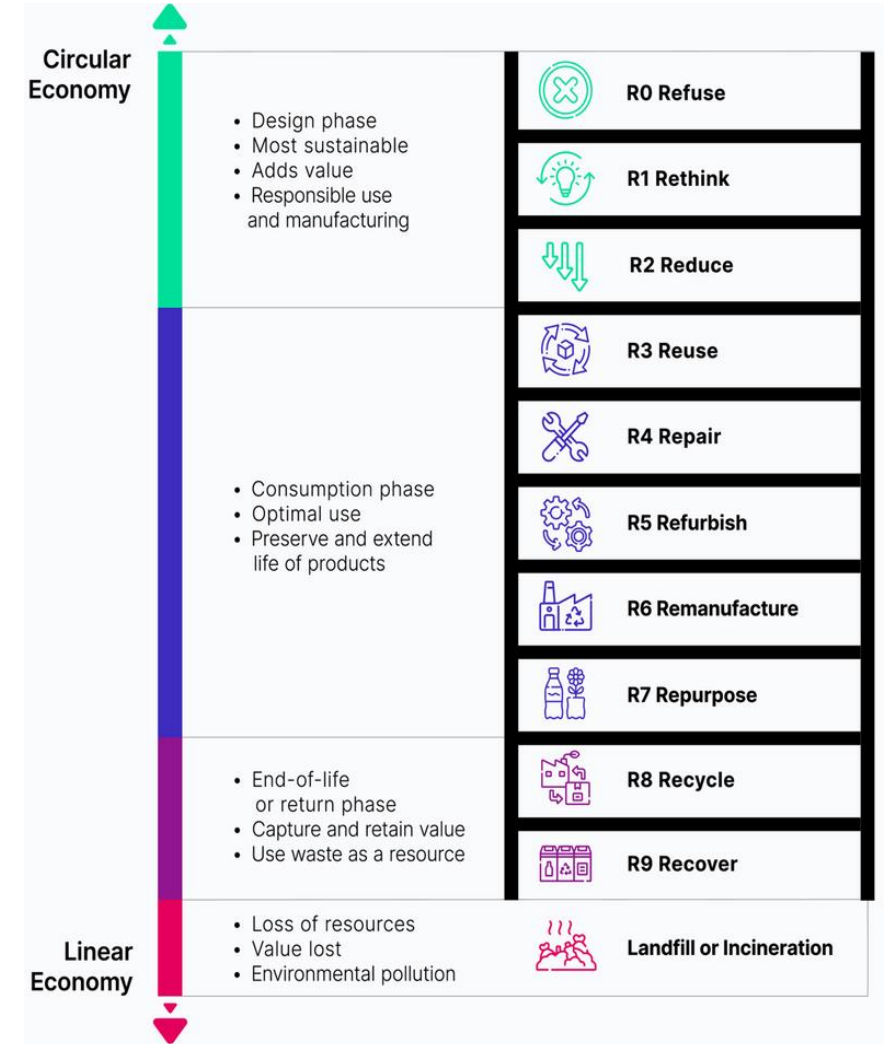
SDG 12 – Responsible Consumption and Production- And this will have an impact.

SDG 13 -demands urgent, global action to combat climate change and protect the planet from devastating environmental impacts.

01 Sustainability of Material's Resources

- 7Rs (reduce, reuse, remanufacture, repurpose, retrofit, recycle, recover)
- Current use of steel and AI and why are they used?
- Novel manufacturing process routes
- Using less metal by design
- Reducing yield losses in manufacturing processes by increasing the efficiencies
- Diverting recycling scrap to other uses before melting
- Reusing metal components
- Producing longer life products with delayed replacement
- Options for change in the major products made by steel & AI
- What can we do to use less, recycle more and use plastic for more.
- The actions of individuals

IMPLEMENTATION OF STRATEGIES



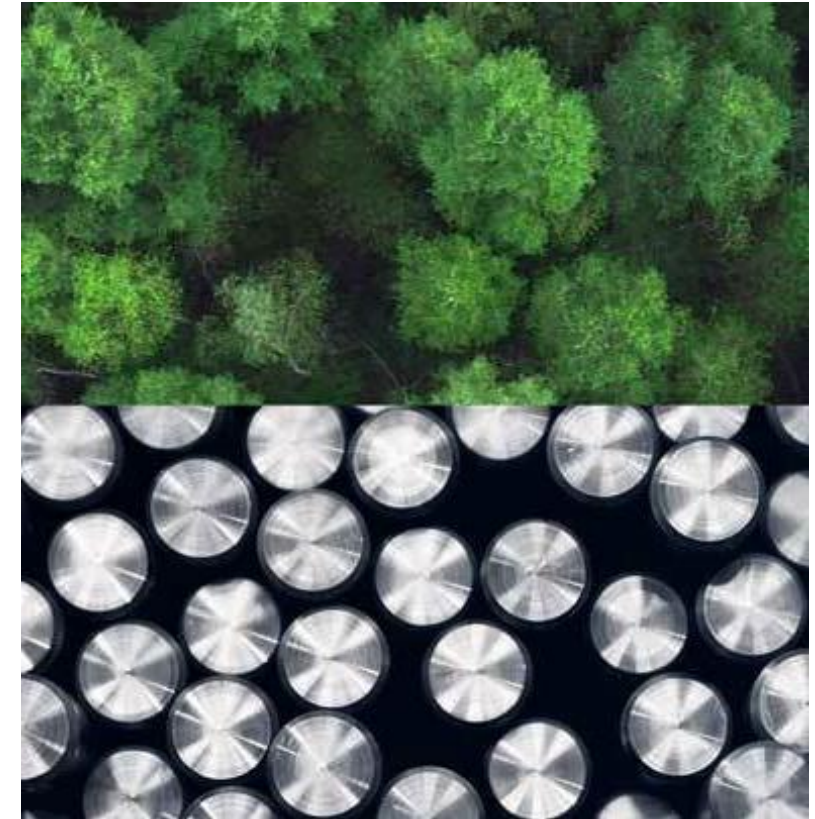
02

Green steel

02 Green steel- Why

WHY GREENING STEEL?

1. Sustainability: consuming resources, minimising waste, reducing energy consumption and reducing carbon emissions of steel production. Sustainable energy includes both increasing energy efficiency and the use of non-renewable energy sources, and.
2. Climate change mitigation: mitigating environmental impact by reducing emissions and increasing energy efficiency.
3. Economic benefits: creating new jobs and stimulate economic growth, as well as improve the competitiveness of the steel industry.
4. Consumer demand: There is growing demand from consumers for environmentally friendly products, and green steel production helps to meet this demand.
5. Legal requirements: Many countries have set targets and standards for reducing greenhouse gas emissions, and green steel production helps to meet these requirements.



02 Green steel – what?

WHAT IS GREENING STEEL INDUSTRY?

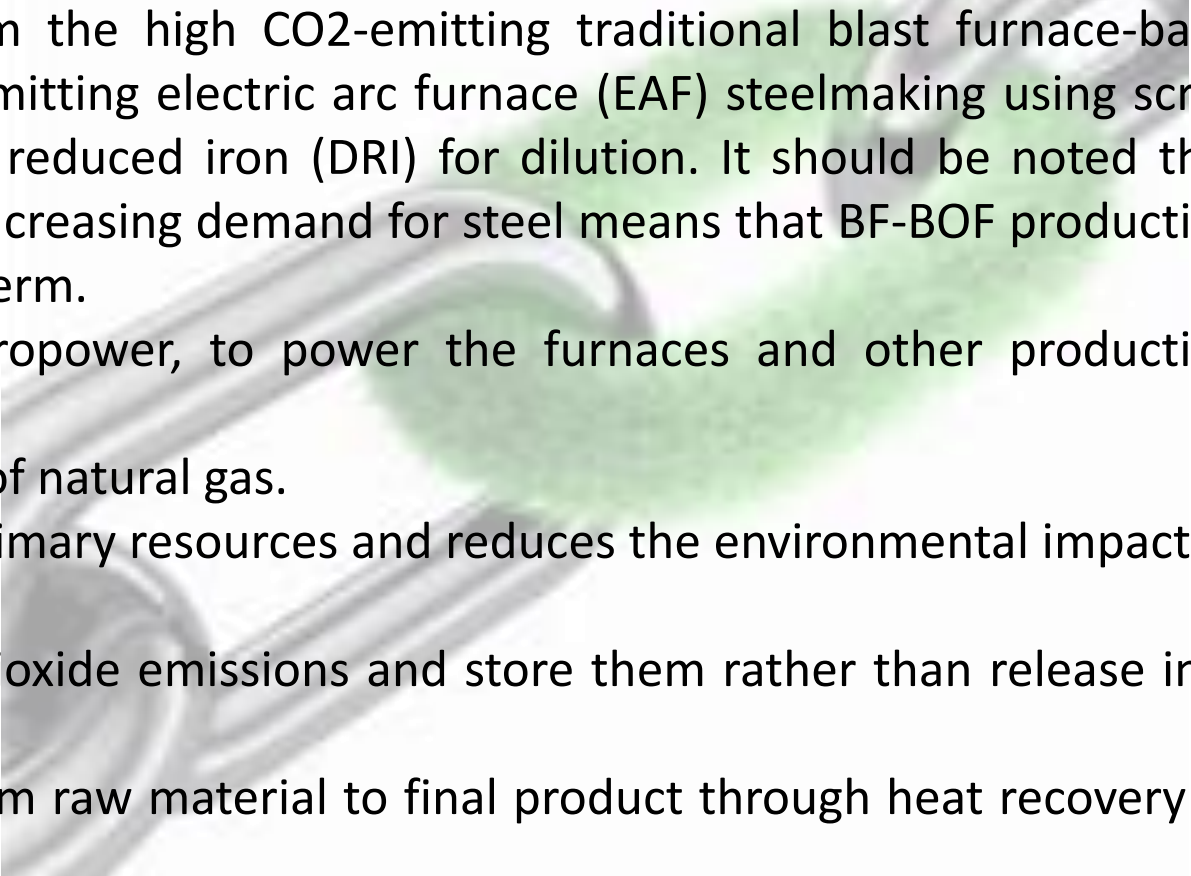
- Reducing or eliminating fossil fuels.
- Lowering Energy.
- Reducing carbon emissions.
- Capturing carbon.
- Consuming resources.
- Maximizing scrap utilization.
- Maximising waste utilization.
- Minimizing rejects and defective production.
- Using renewables.



02 Green steel- how

HOW IS GREEN STEEL MADE?

Green steel is made with a combination of various methods and technologies that aim to reduce the environmental impact of steel production. By using

1. **New steelmaking technologies** moving away from the high CO₂-emitting traditional blast furnace-basic oxygen furnace (BF-BOF) route to the lower CO₂-emitting electric arc furnace (EAF) steelmaking using scrap steel as a feedstock to charge the EAF and direct reduced iron (DRI) for dilution. It should be noted that limited global scrap steel supply and continuously increasing demand for steel means that BF-BOF production will need to continue at least in the short-medium term.
 2. **Renewable energy** such as wind, solar, and hydropower, to power the furnaces and other production equipment.
 3. **Green hydrogen**-based direct reduced iron instead of natural gas.
 4. **Scrap steel recycling** which reduces the need for primary resources and reduces the environmental impact of steel production.
 5. **Carbon capture** and storage by capturing carbon dioxide emissions and store them rather than release into the atmosphere.
 6. **Energy and heat efficiency** through the process from raw material to final product through heat recovery or heating scrap.
- 

02 Green steel

USING GREEN HYDROGEN

Green Steel:

- Decarbonizes heavy industries.
- Reduces dependency on fossil fuels.
- 90% reduction in CO₂ compared to traditional steelmaking
- Supports circular economy through recycling and cleaner production.

Using Green Hydrogen:

- Zero greenhouse gas emissions.
- Storage solution for intermittent renewable energy.
- Water use: 9 liters per kg of hydrogen.

Additional Benefits:

- Reduced air pollutants (e.g., SO_x, NO_x) from traditional steelmaking



02 Green steel

DECARBONIZING STEEL PRODUCTION

Traditional Steelmaking Process:

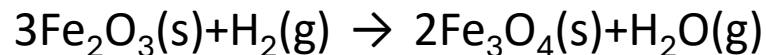
- Uses blast furnaces -basic oxygen furnace (BF-BOF) fueled by coal and coke (a carbon-intensive method).
- Emits ~2 tons of CO₂ per ton of steel.

Electric Arc Furnace (EAF): Uses electricity to melt sponge iron into steel. EAF steel production using scrap reduces CO₂ emissions by around 1.5 tCO₂/t of new steel manufactured.

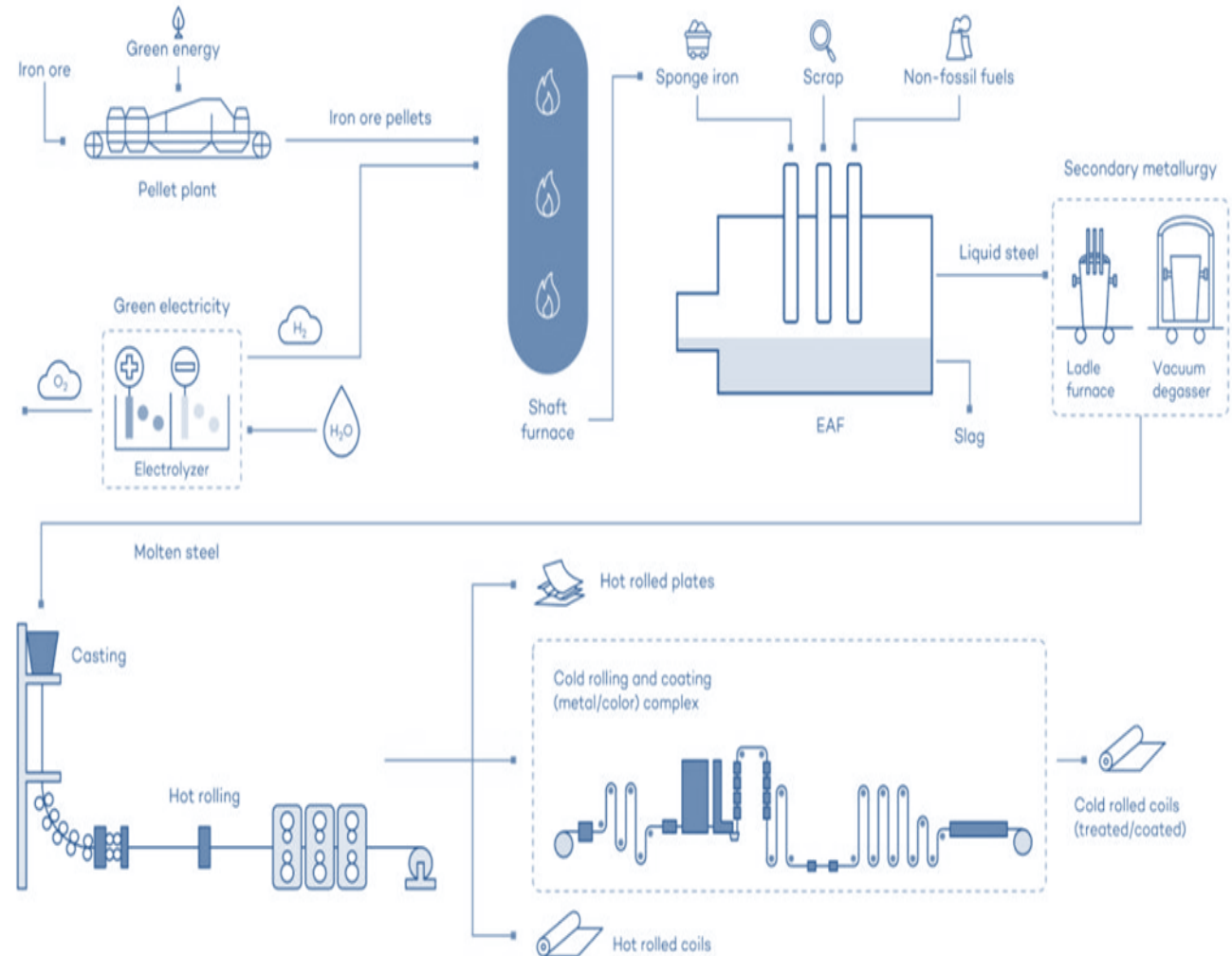
Green Steel Process Using Hydrogen:

Hydrogen replaces coke as the reducing agent.

Reaction



Direct Reduced Iron (DRI): Iron ore is reduced to sponge iron using hydrogen gas.



02 Green steel

GLOBAL INITIATIVES AND ADOPTION

Green Hydrogen Projects:

- Europe: Germany's national hydrogen strategy.
- Middle East: NEOM Green Hydrogen Project in Saudi Arabia.
- Australia: Large-scale hydrogen export plans.

Green Steel Projects:

- Sweden: HYBRIT initiative by SSAB, LKAB, and Vattenfall.
- Germany: Thyssenkrupp's green steel production roadmap.
- India: Tata Steel's green hydrogen pilot projects



02 Green steel

CHALLENGES AND BARRIERS

High Production Costs:

- Green hydrogen: ~\$5-6/kg vs. ~\$1.5/kg for grey hydrogen.
- Green steel: 20-30% more expensive than traditional steel.

Infrastructure Requirements:

- Electrolyzer manufacturing capacity.
- Hydrogen transport (pipelines, storage).
- Retrofitting steel plants for hydrogen use.

Scalability:

- High renewable energy demand.
- Availability of raw materials like rare earths for electrolyzers.

Water Resource Management:

- Sourcing water in arid regions for electrolysis.



02 Green steel

INNOVATIONS AND FUTURE DIRECTIONS

Technological Advancements:

- **Efficient Catalysts:** Lowering energy demand for electrolysis.
- **Advanced Electrolyzers:** Hybrid systems combining PEM and SOE technologies.
- **AI and Digital Tools:** Optimizing plant efficiency and resource management.

Policy and Market Trends:

- Carbon pricing and green subsidies.
- Global hydrogen trade networks.
- Collaboration between energy and industrial sectors.

Global Projections:

- Green hydrogen market to grow to \$250 billion by 2030.
- 10-20% of global steel production expected to shift to green steel by 2050.

Synergies:

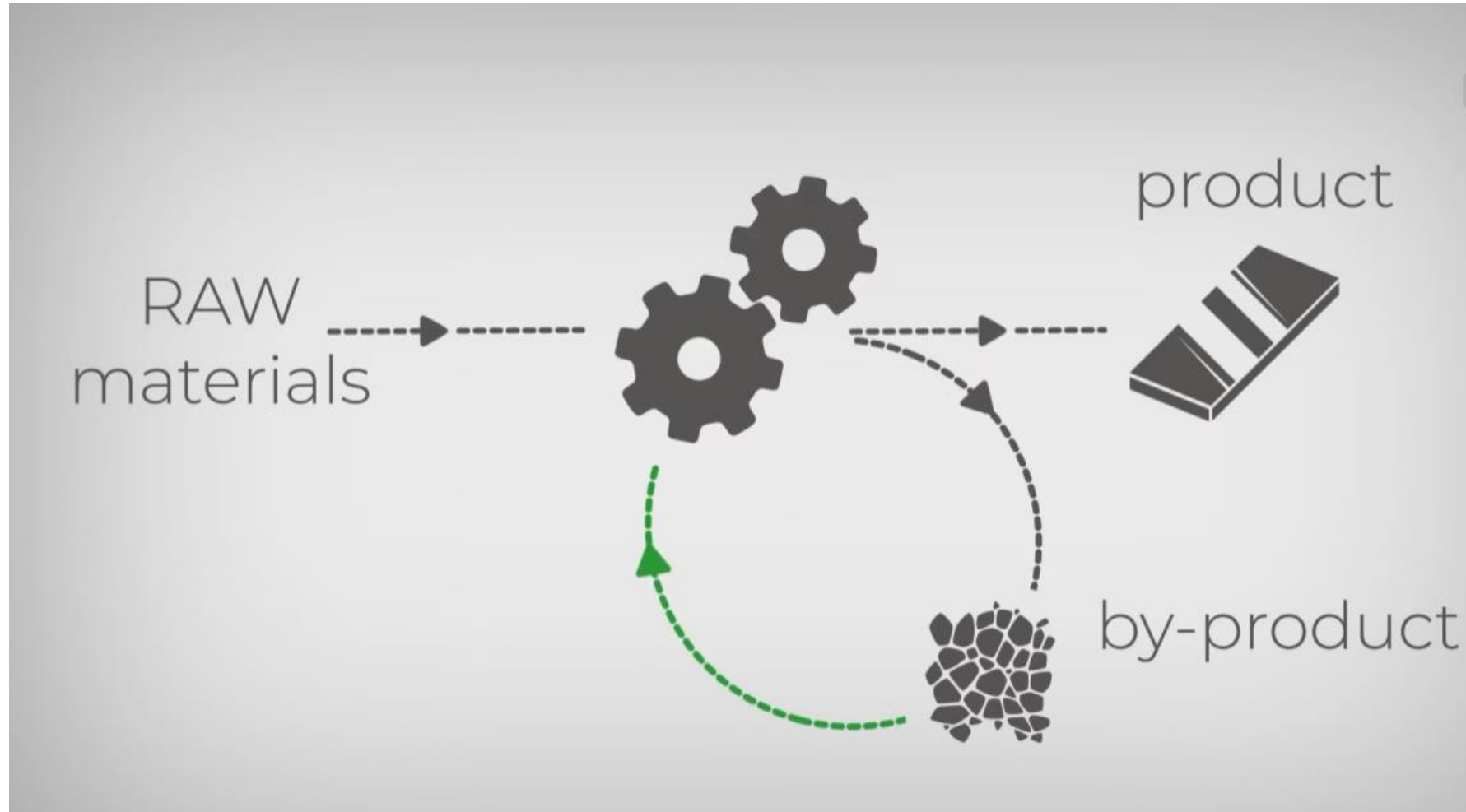
- Pairing green hydrogen with carbon capture and utilization (CCU) for enhanced decarbonization.
- Hydrogen as a key enabler for heavy industry decarbonization beyond steel (cement, chemicals).



03

Industrial Circularity

03 Industrial Circularity



03 Industrial Circularity

FROM GREEN STEEL TECHNOLOGIES TO INDUSTRIAL CIRCULARITY IN PRACTICE



WHY STEEL INDUSTRY MATTERS IN SUSTAINABILITY?

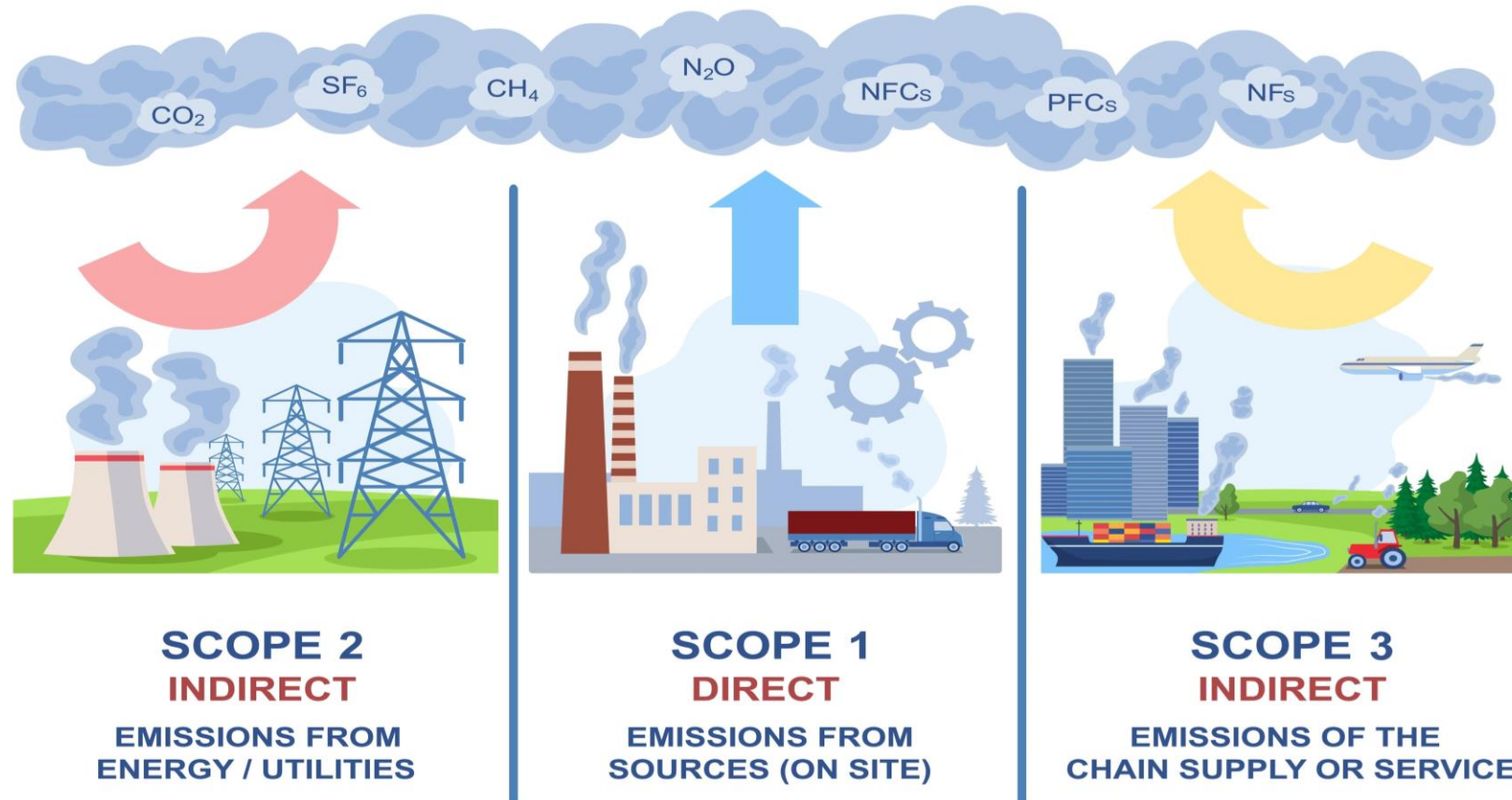
7% of global CO₂ emissions*

8% of global energy use*

* WorldSteel, Sustainability Indicators Report 2023

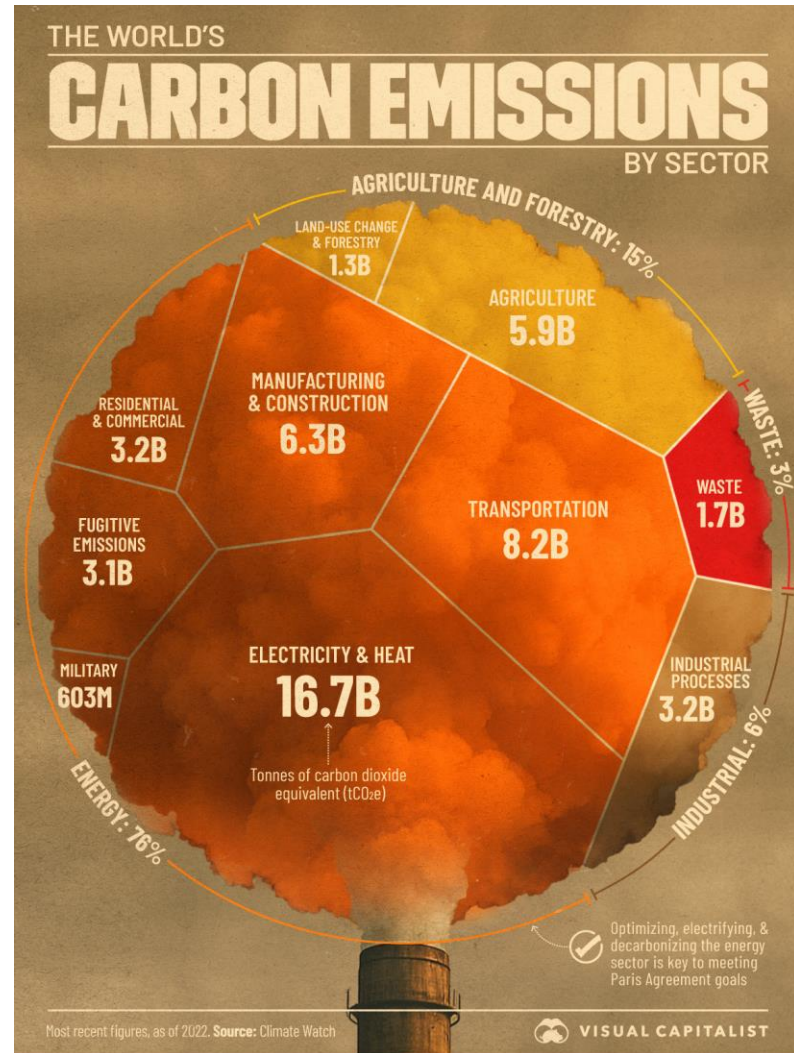
03 Industrial Circularity

SCOPES OF EMISSIONS



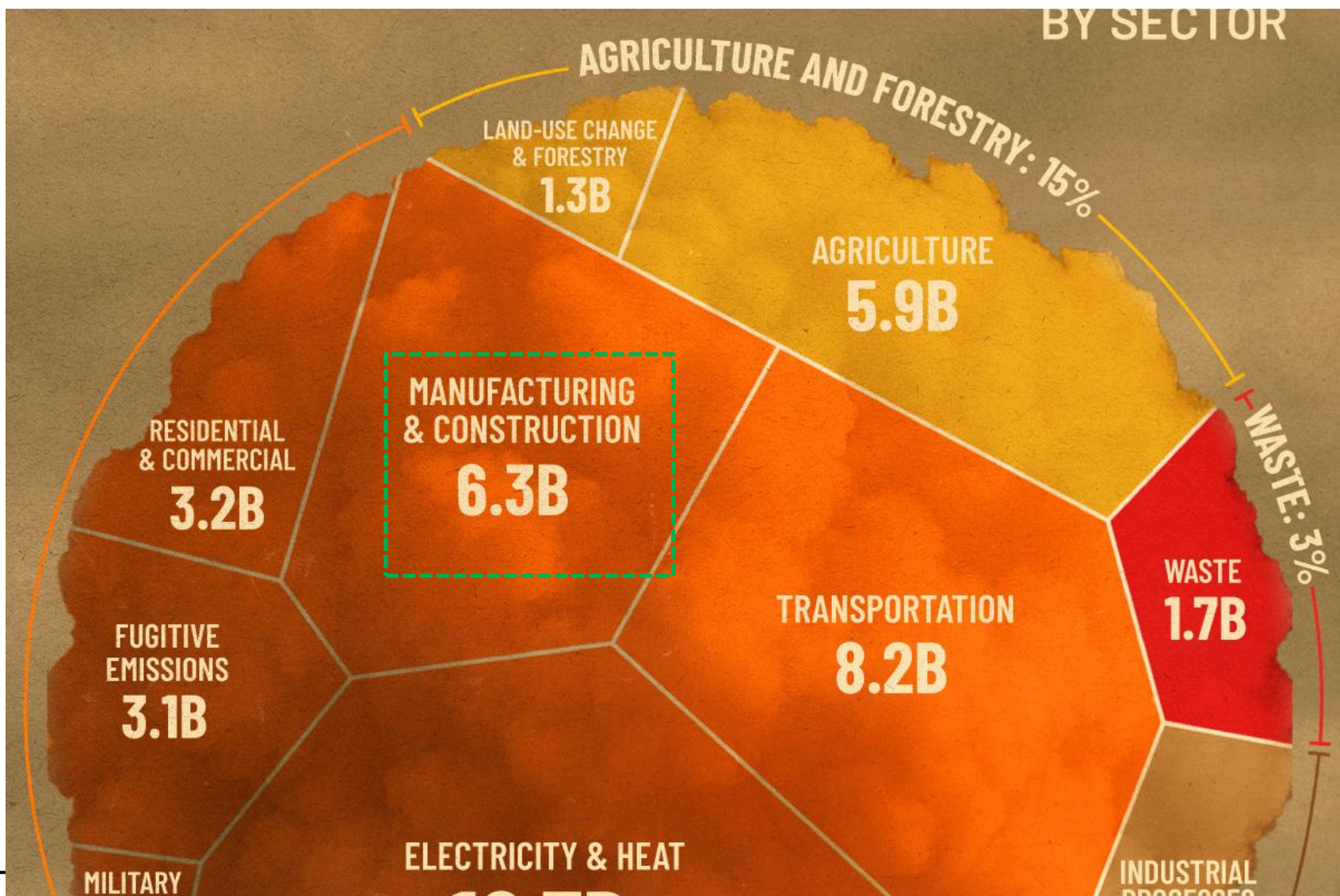
03 Industrial Circularity

SCOPE 3 REDUCTION



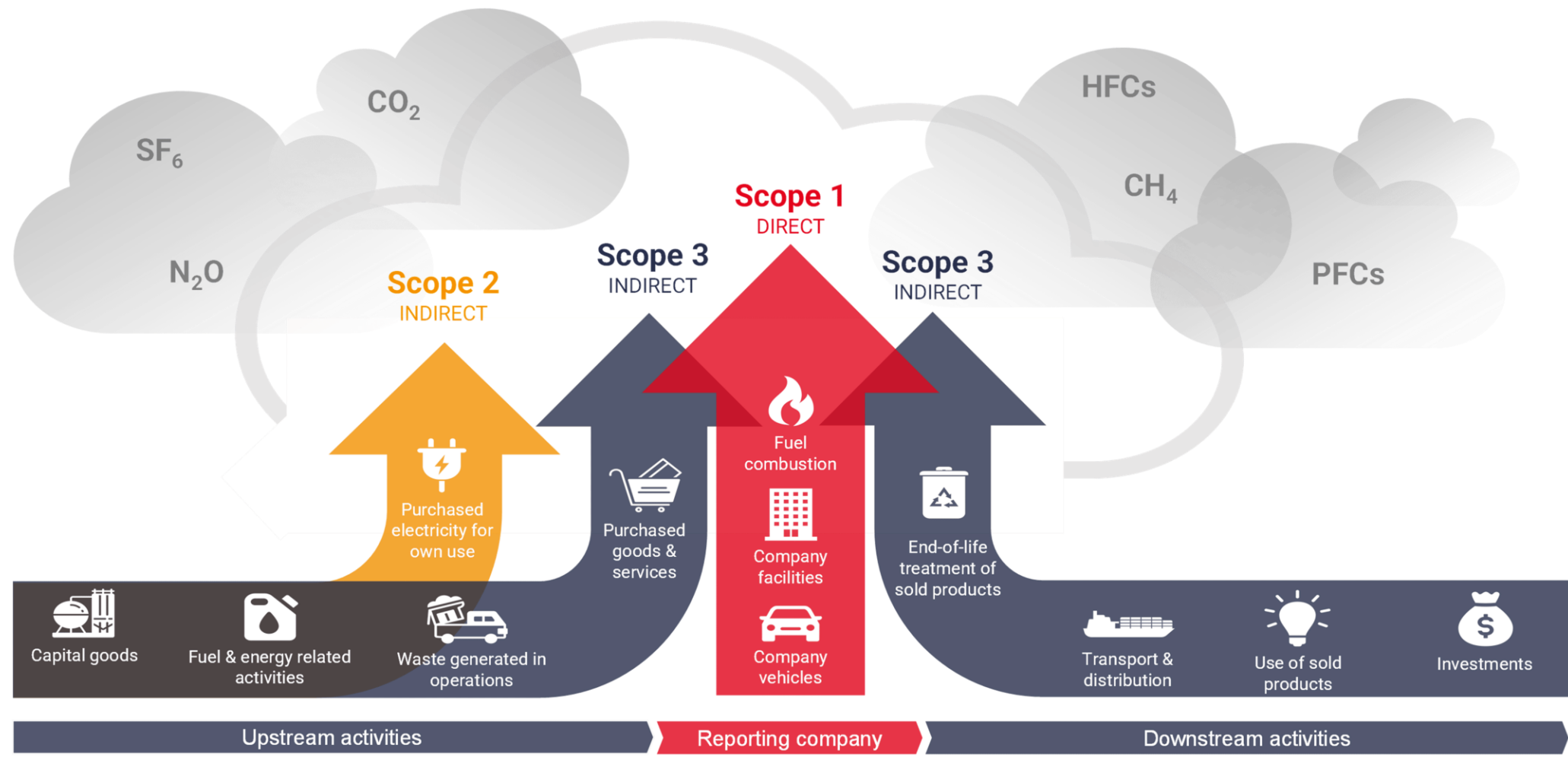
03 Industrial Circularity

SCOPE 3 REDUCTION



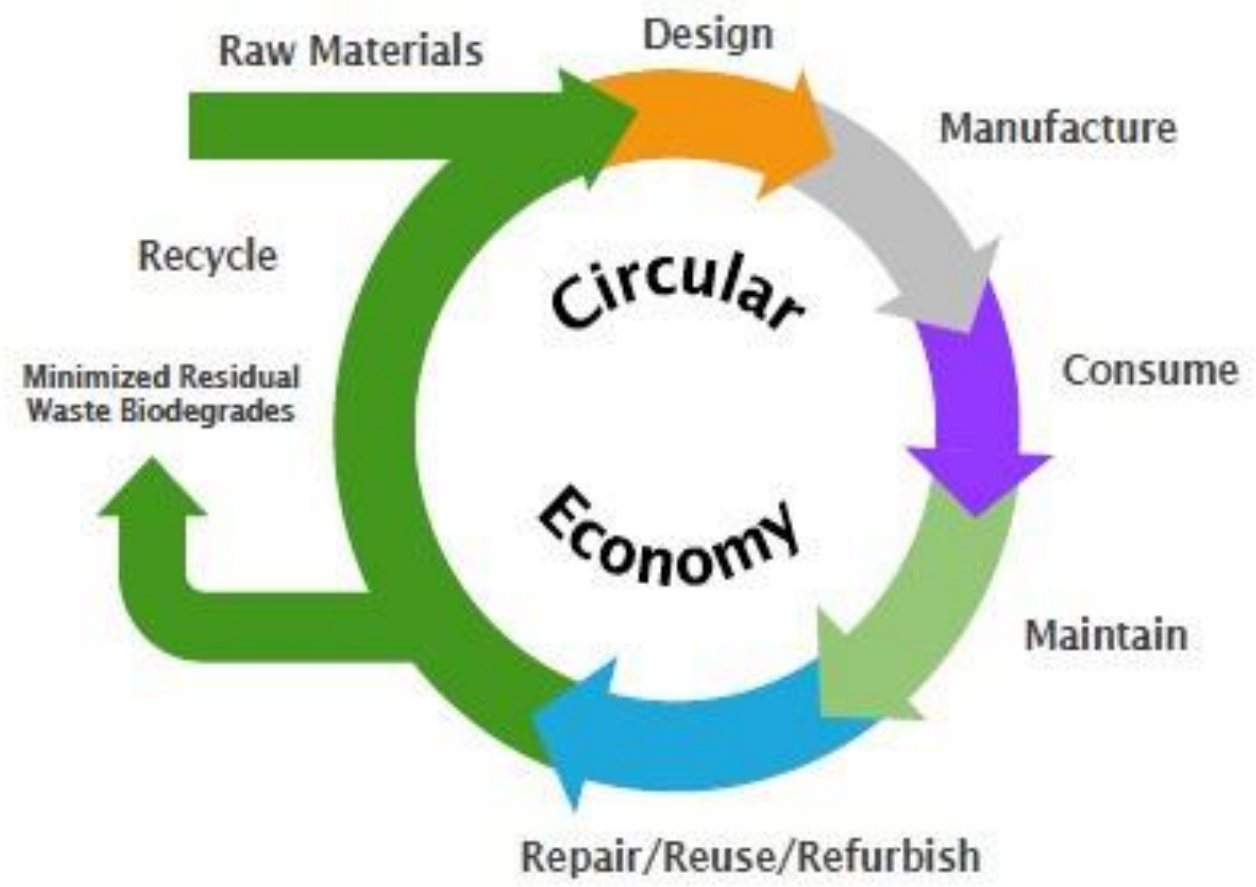
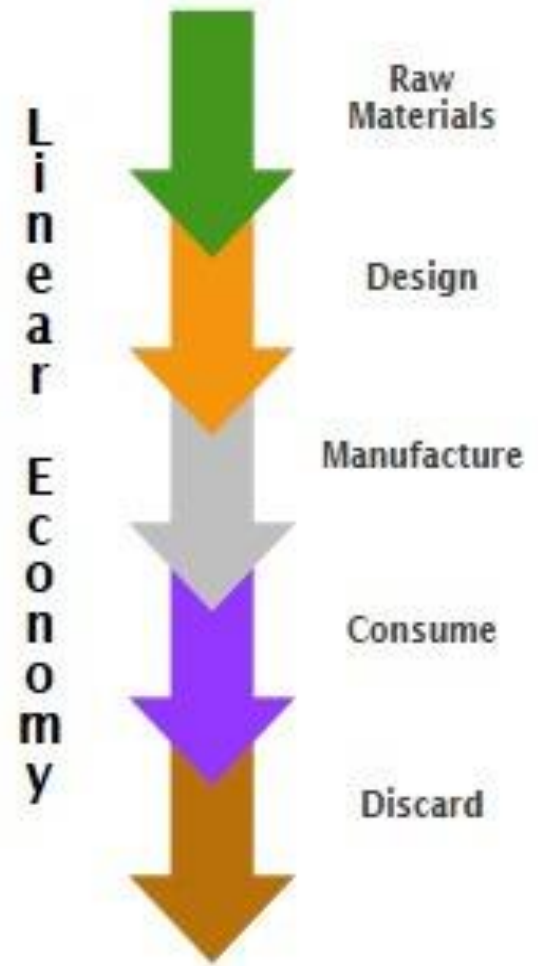
03 Industrial Circularity

FROM GREEN STEEL TECHNOLOGIES TO INDUSTRIAL CIRCULARITY IN PRACTICE



03 Industrial Circularity

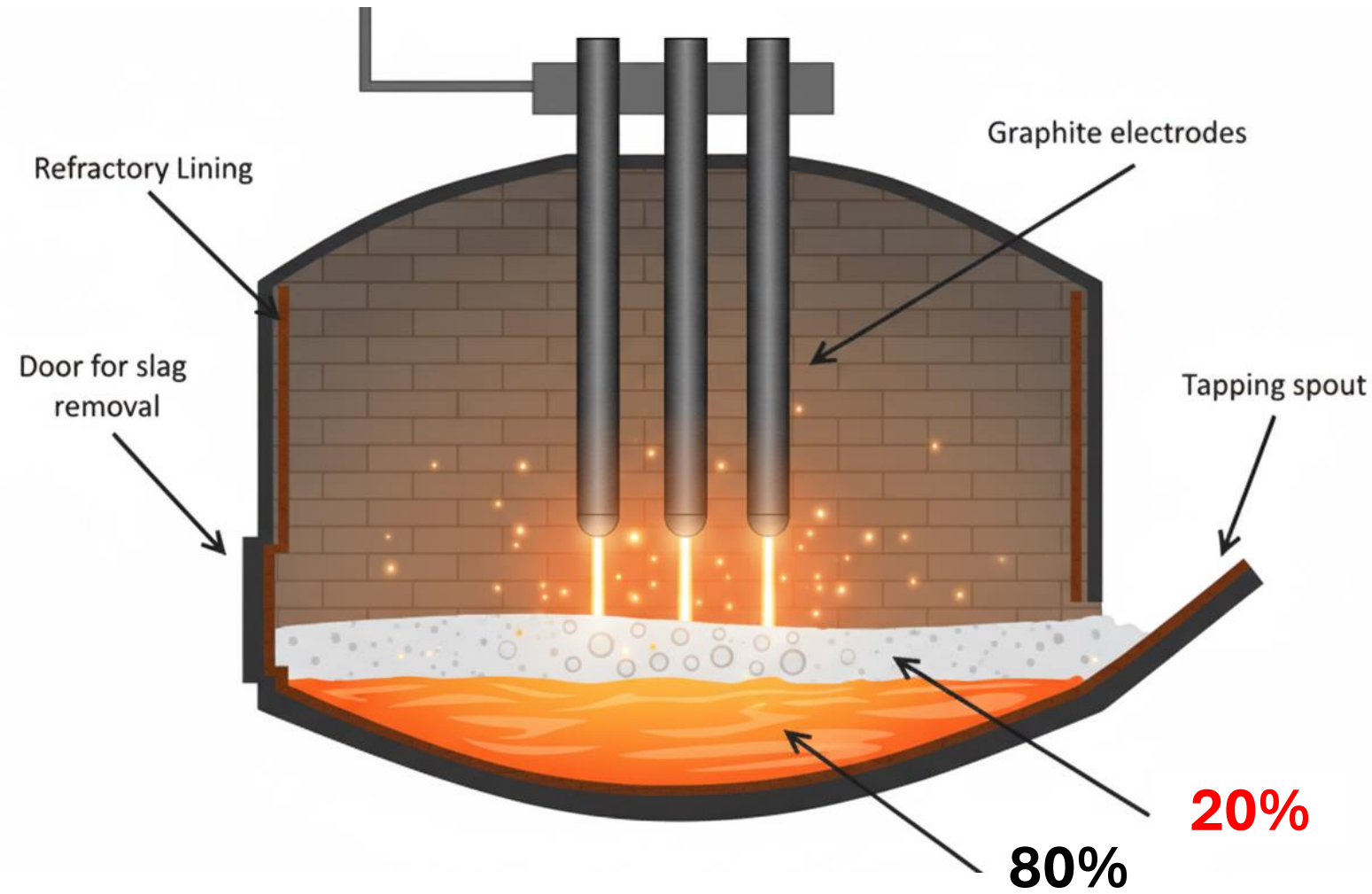
WASTE VALORIZATION



04

Practical solutions

04 Practical solutions



04 Practical solutions

800,000 tons of EAF slag annually
(18–20% of molten steel output)



Cooled by natural air and
water spraying



Slag Aggregate

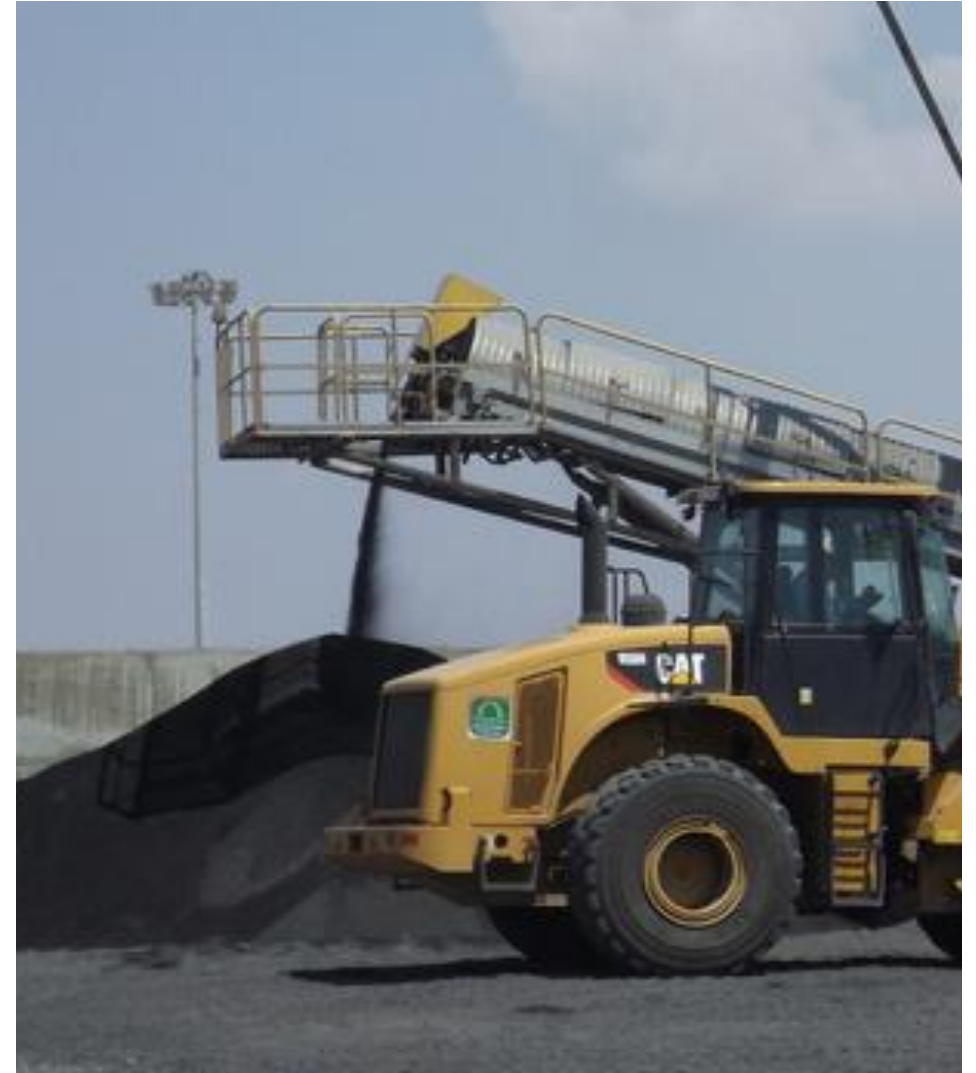


Separated Metal



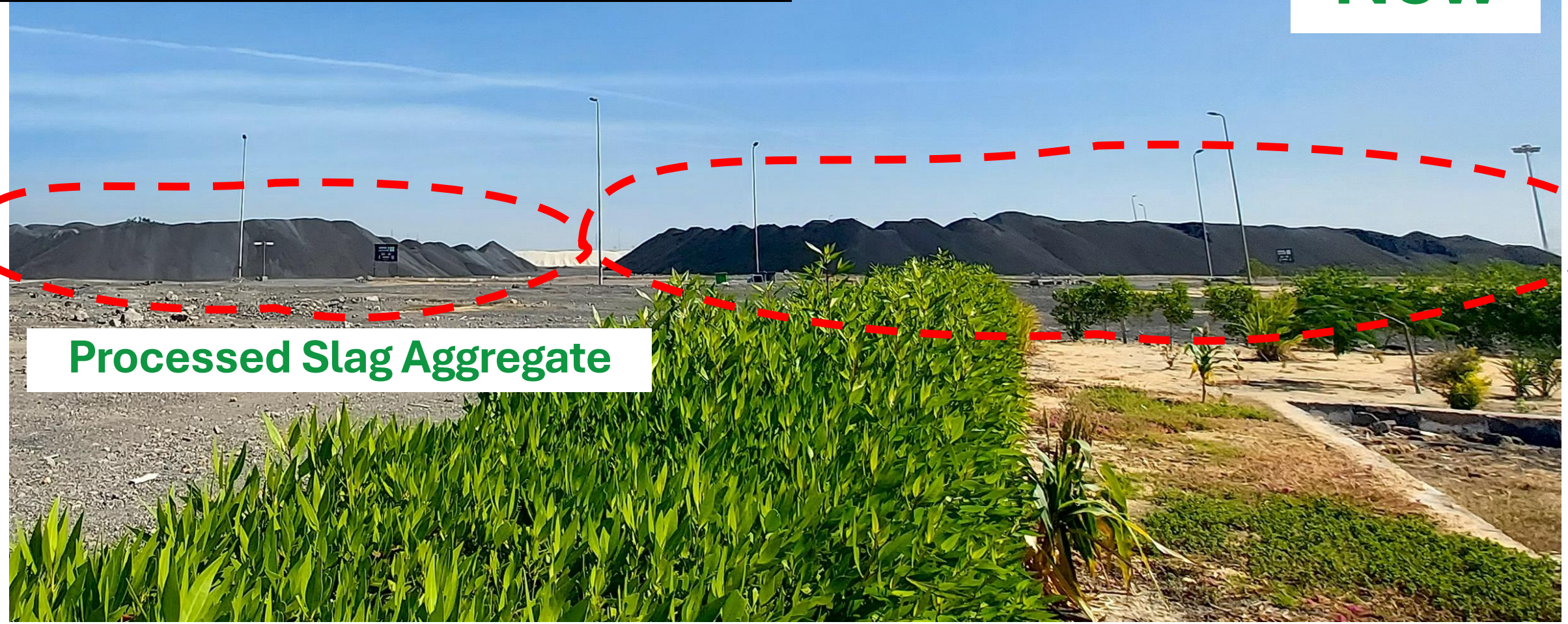
04 Practical solutions

- **6,200,000 tons**
Raw slag have been recycled
- **450,000 tons**
Extracted metal
- **5,700,000 tons**
Slag aggregate have been produced
- **5,200,000 tons**
Slag aggregate have been sold



04 Practical solutions

Now



Processed Slag Aggregate

04 Practical Solutions

SLAG IN ASPHALT

Property	Natural limestone	Steel slag
Abrasion loss (Los Angeles test)	22%	15%



04 Practical Solutions

SLAG IN CONCRETE

Property	Natural limestone	Steel slag
Compressive strength comparison (MPa, 28 days)	35 MPa	47 MPa



04 Practical solutions **SLAG IN CEMENT PRODUCTION**

Property	Ordinary Cement	Cement + Slag
Compressive strength (28 days)	100%	105–110%
Heat of hydration	100%	75–80%
CO ₂ footprint	100%	70%



04 Practical solutions **SLAG IN CEMENT PRODUCTION**

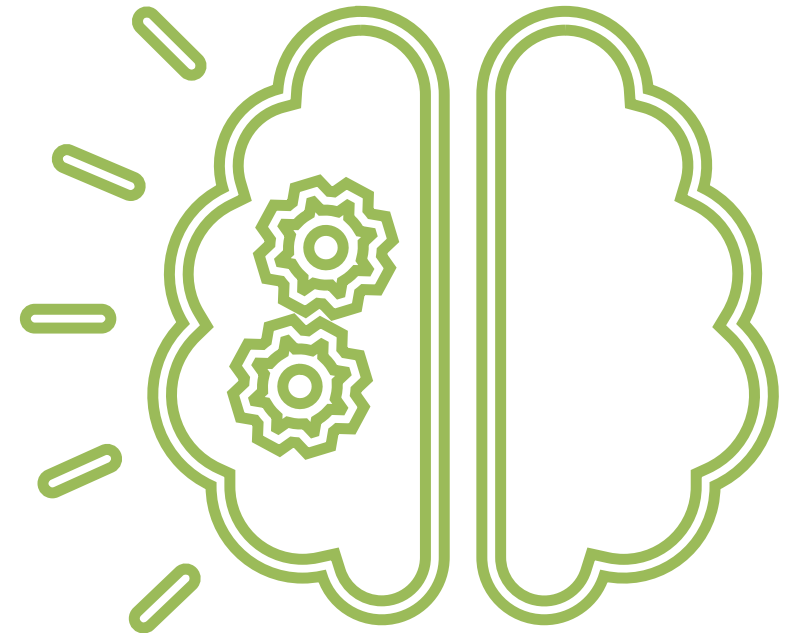


04 Practical Solutions

RECENT INNOVATIONS

In Steel making

1. Production of Seismic-Resistant Steel from Scrap with up to 0.6% Copper
2. Reducing CO₂ emissions using a new BF-IF-BOF steelmaking process



04 Practical Solutions

SEISMIC-RESISTANT STEEL PRODUCTION FROM SCRAP

Deep Desulfurization

Silicon/ or Ni Addition (0.30–0.35%)

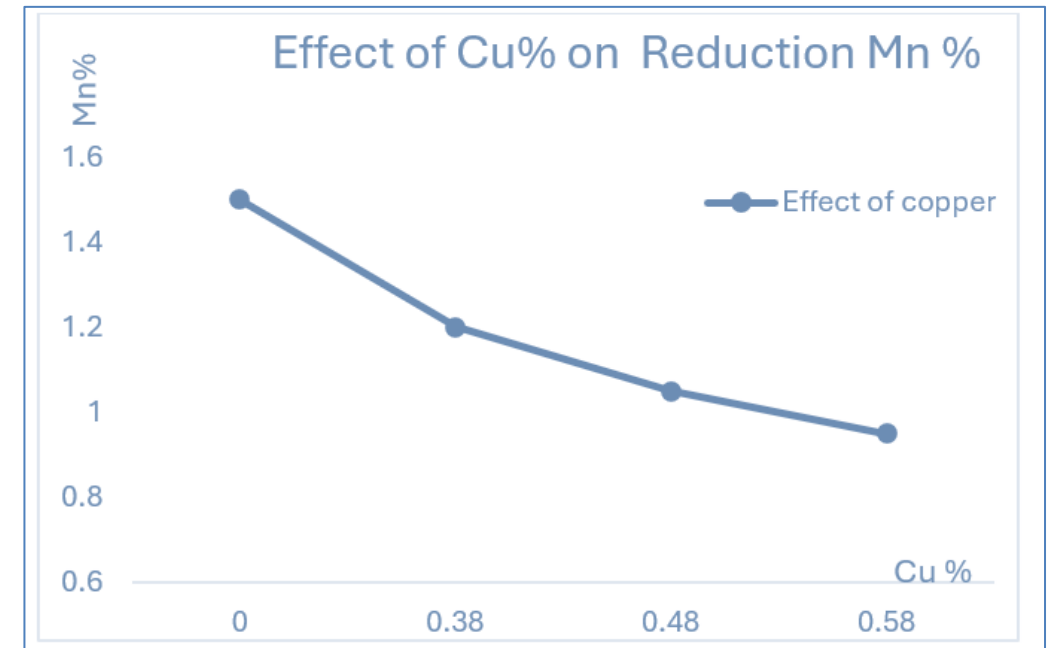
Controlled Manganese Content

Optimized Process Parameters

Outcome:

Earthquake-resistant steel produced with up to 0.6% Cu without compromising mechanical properties.

Reduced Mn addition from ~1.5% to ~0.95%, saving ~\$8/t in alloys and ~\$11/t total with energy savings.



*Ahmed Ramadan Seada and Iman ElMahallawi; Production of Seismic-Resistant Steel from Scrap with up to 0.6% Copper; steel research international, in production.

04 Practical solutions

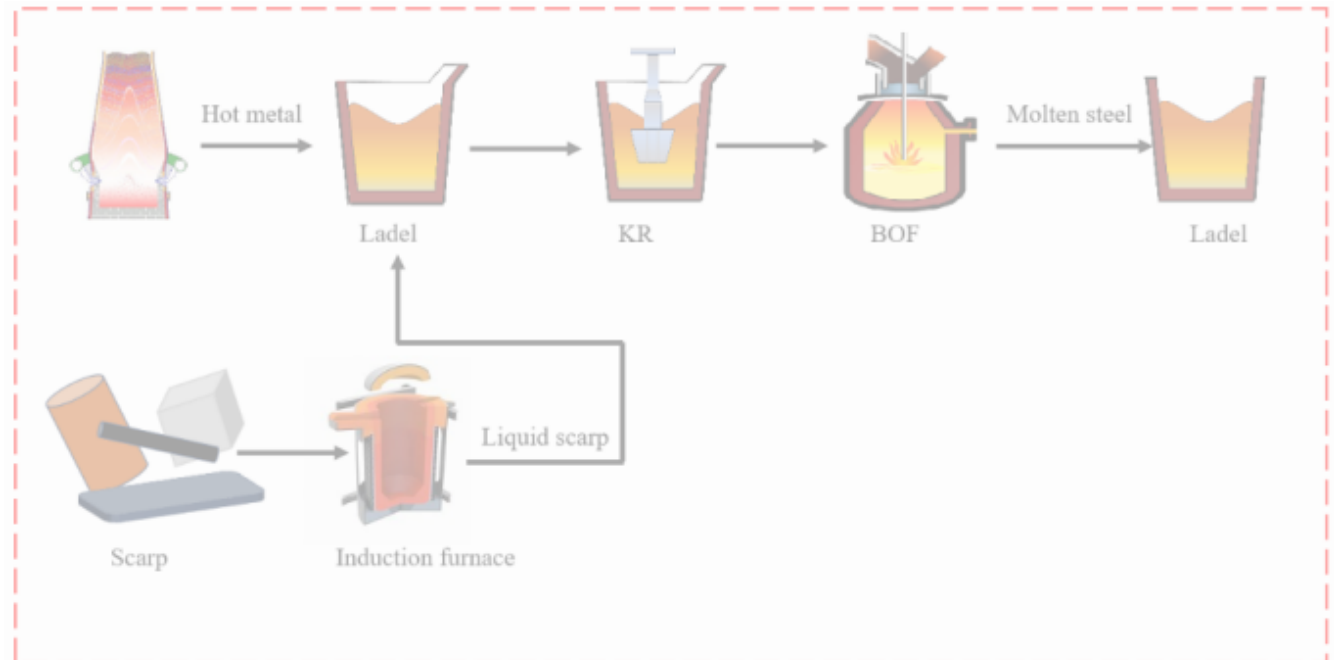
REDUCTION OF CO₂ EMISSIONS IN BF-IF-BOF

The process significantly increases the scrap ratio from the typical 19% up to 90%, enabling substantial CO₂ reductions.

Carbon reduction impact:

CO₂ decreases by 0.309 → 1.685 t CO₂/t steel as scrap increases from 30% to 90%.

Minimum possible emissions range from 0.673 → 0.108 t CO₂/t steel.



04 Practical solutions

REDUCTION OF CO₂ EMISSIONS IN BF-IF-BOF

Why BF-IF-BOF Route is Industrially Feasible??

- Provides a practical decarbonization pathway without relying on immature hydrogen-DRI technologies.
- Avoids quality challenges of EAF routes
- Allows high scrap utilization while maintaining low residuals and stable chemistry.
- **Integrating molten scrap with hot metal enhances:**
- Dephosphorization – Denitrification - Temperature stability
- Enables internal CO₂ utilization inside BOF, reducing credit emissions.
- Improves energy efficiency, steel yield, and operational control.
- Suitable for existing BF-BOF plants → low modification cost and high scalability

04 Practical solutions

REDUCTION OF CO2 EMISSIONS IN BF-IF-BOF

Why BF-IF-BOF Route is Industrially Feasible??

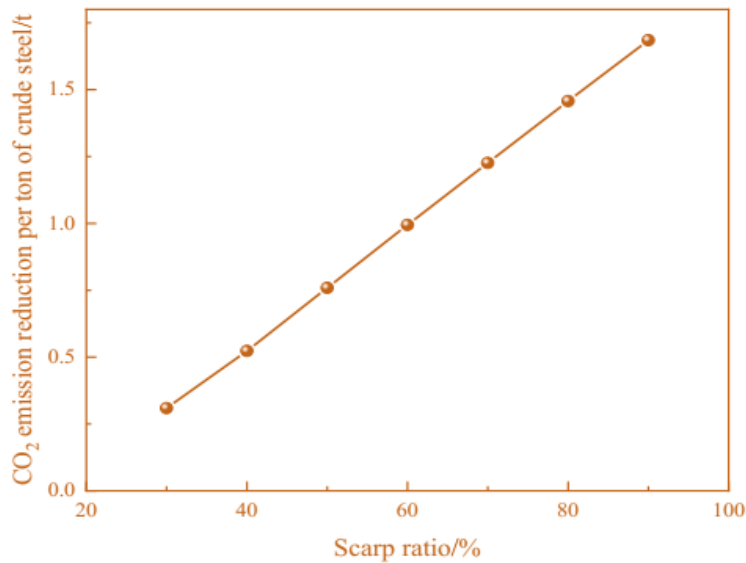


Fig.5. CO₂ emissions reduction at different scrap ratios in BF-IF-BOF process

Table 10 CO₂ emissions reduction in BOF with different scrap ratios

Scrap/t	30	40	50	60	70	80	90
Hot metal/t	70	60	50	40	30	20	10
CO ₂ emissions reduction/t	0.309	0.523	0.759	0.994	1.226	1.457	1.685

Table 12 minimum CO₂ emissions of per ton of crude steel at different scrap ratio

scrap/t	30	40	50	60	70	80	90
Hot metal/t	70	60	50	40	30	20	10
minimum CO ₂ emissions/t	0.673	0.577	0.482	0.387	0.294	0.200	0.108

2026 MENA

Steel Industry Transformation:
From Carbon to Green

THANKS!

Do you have any questions?

ielmahallawi@bue.edu.eg

