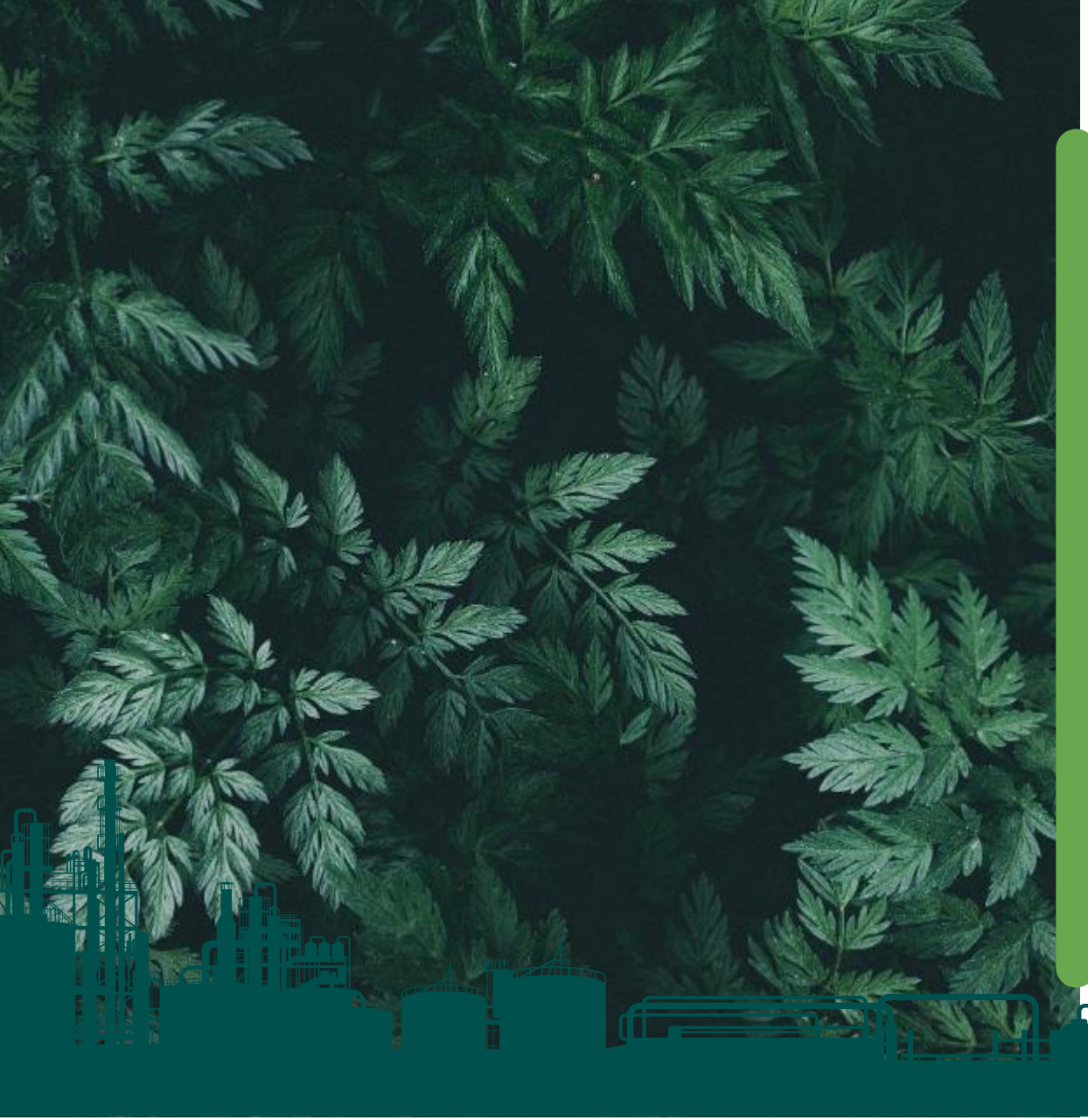


# Leading the change to Green Steel future

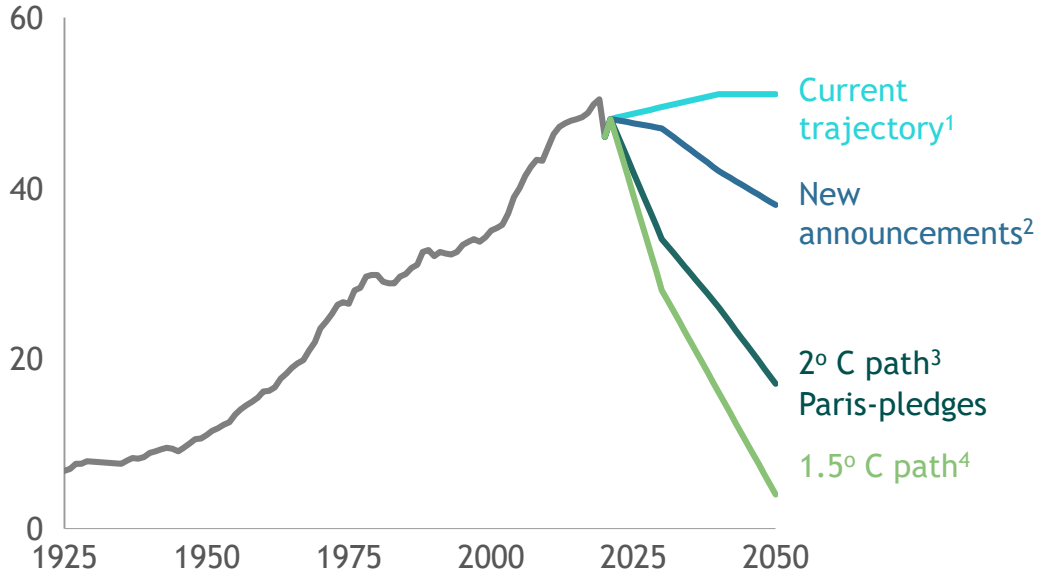
SEPT 2025

## Promoting Article 6 via JCM

# The fight against climate change calls for immediate coordinated action

## Global temperatures have been rising fast and not in track with the Paris pledges…

Global net $CO_2$ emissions & pathways (Gt per year)




## …The window to limit severe impact due to warming is closing and the time to act is now

Global warming by 2100 → Cost of inaction

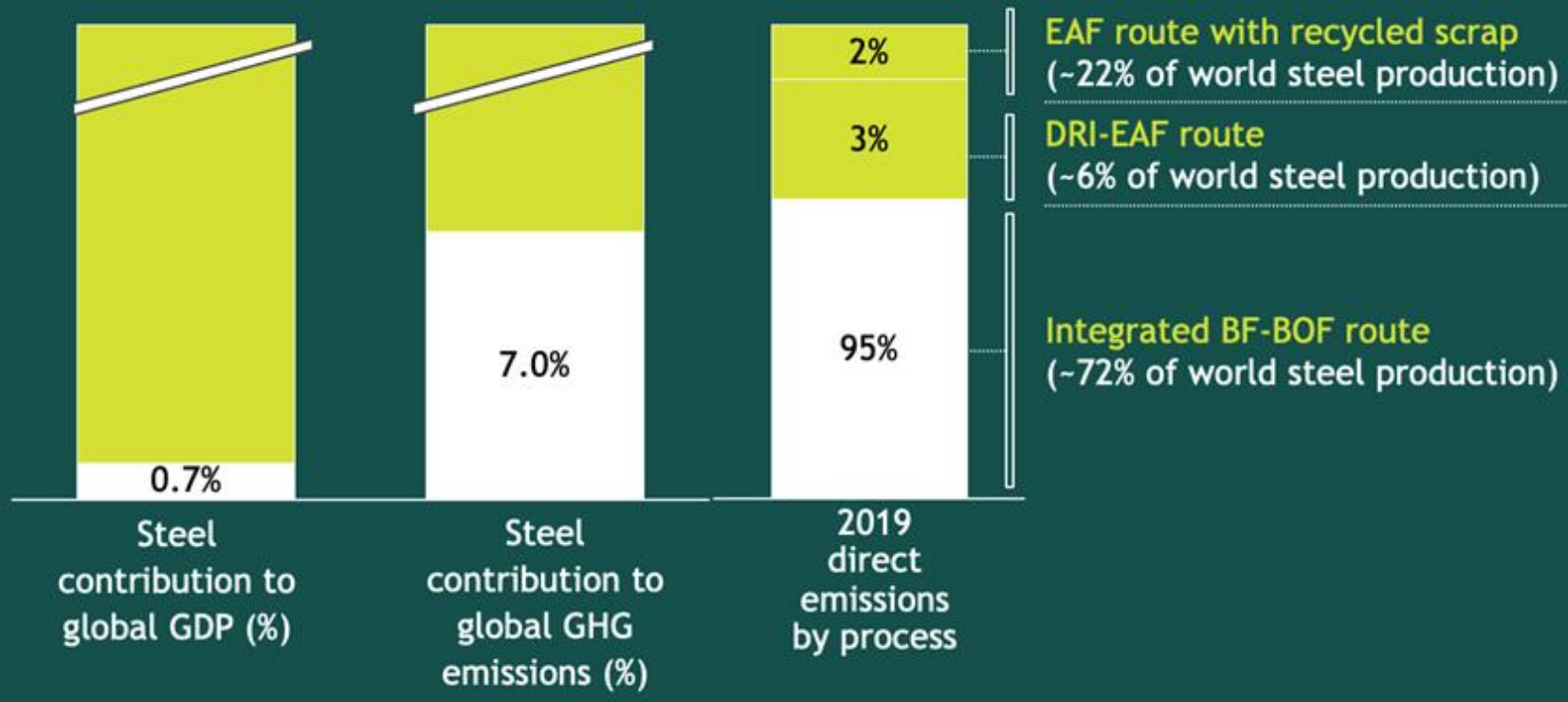
**>+4°C** | *GDP[4] shrinks by >25%*

**+2°C** | *GDP[4] shrinks by ~13%*

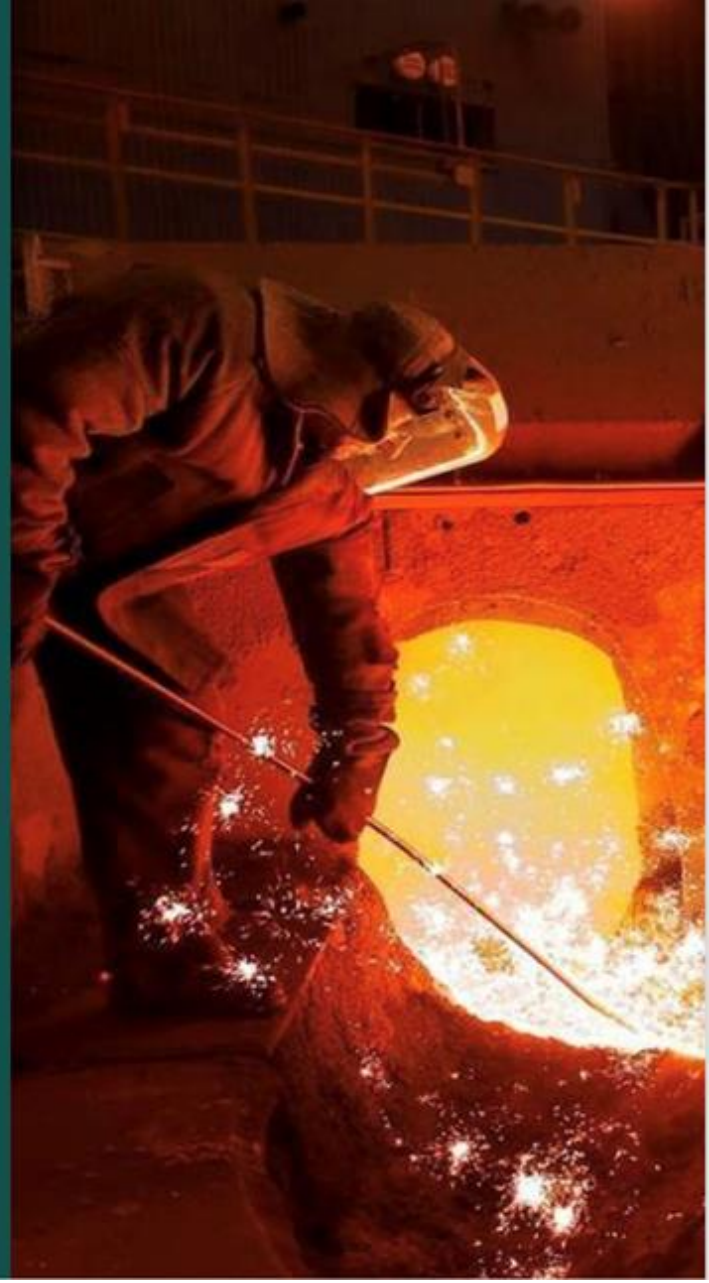
**+1.5°C** | *GDP[4] shrinks by 8%*

1. Current pledges assume countries decarbonize further at same annual rate required to achieve NDCs between 2020 and 2030 2. Newly announced path reflects high-level net-zero ambitions announced by China, EU, Japan, South Korea, Argentina (July 2021) 3. 2º path and 3º path based on emission reductions required by respective 2018 IPCC scenarios
4. Global GDP per capita, relative to no additional warming. According to Burke et al. (2018)
Source: EEA, EDGAR 5.0, EC, IEA, FAO, PRIMAP-hist v2.1, Global Carbon Project, IPCC, UNEP Emissions Gap Report, WRI, Nature (May 2020), BCG analysis

# Steel production contributes 7% of global GHG emissions & has an urgent business need for decarbonization




Source: World Steel Association-worldsteel.org



# Decarbonisation Pillars for Steel Business

## $CO_2$ Minimization

- Syngas based production
- Resource optimisation
- Pellet feed in blast furnaces
- Zero waste approach

## $CO_2$ Avoidance

- Zero power furnace
- Heat recovery from off gases
- Heat recovery from slags
- Use of renewable power
- Maximizing hydrogen usage from existing 55-60%

## Carbon Circularity

- $CO_2$ to CO
- CO electrolysis
- Dry reforming of $CO_2$

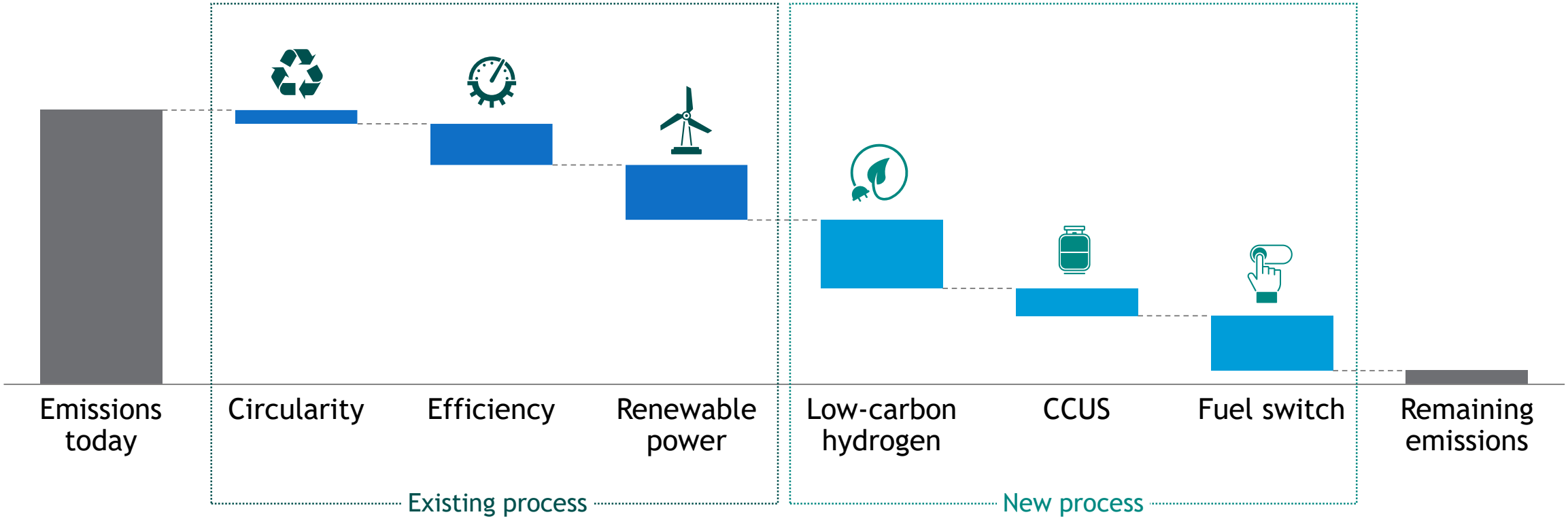
## Carbon Capture & Utilization

- Fuels – bioethanol
- Chemicals – methanol, sodium bicarbonate
- Biological – crude algae oil (biodiesel/ SAF)

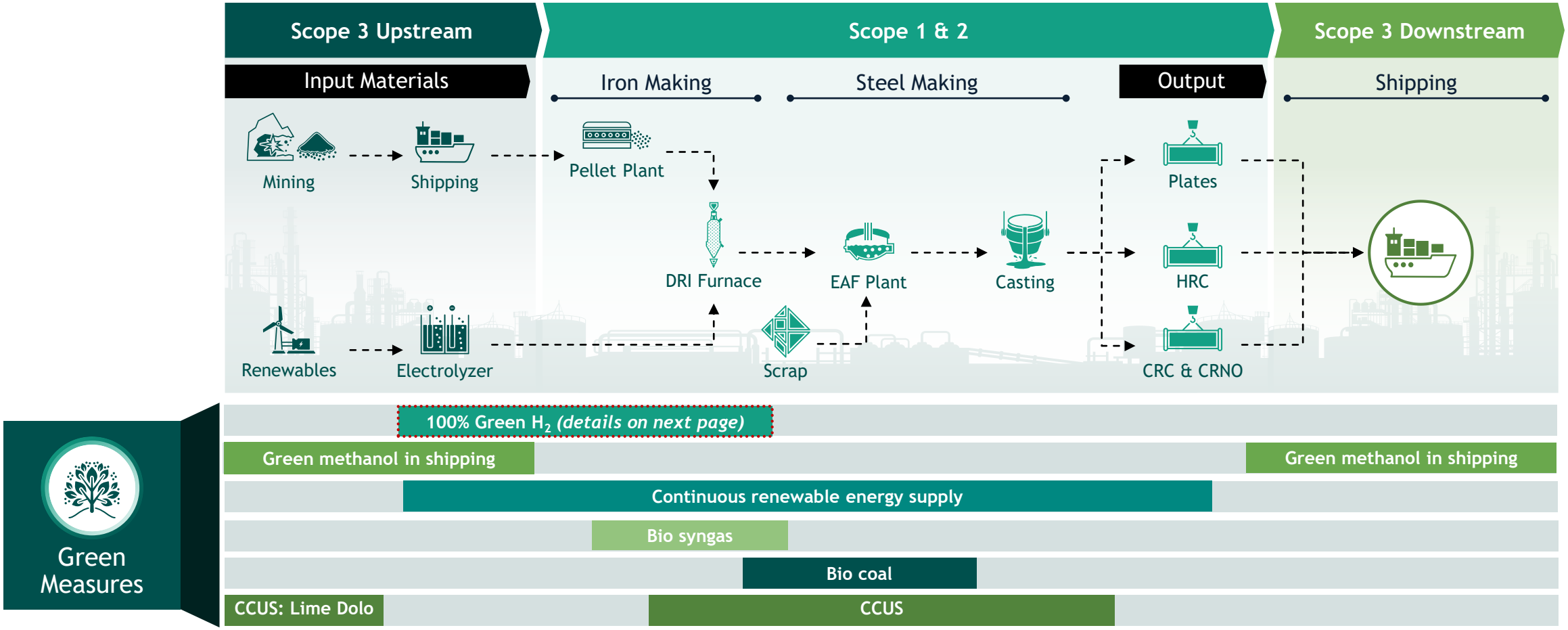
# True steel decarbonization requires implementation of multiple green measures from mines to metal (1/2)

## Emission reduction potential

Illustrative



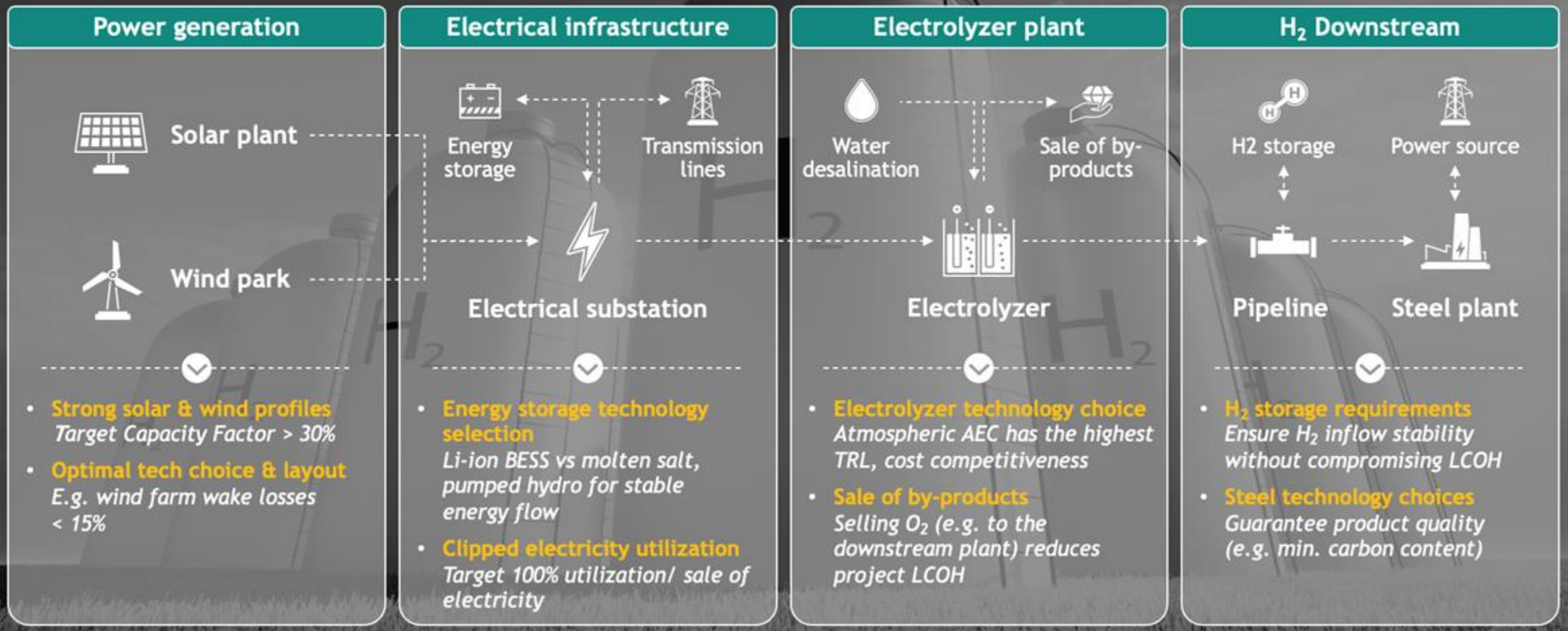
# True steel decarbonization requires implementation of multiple green measures from mines to metal (2/2)




Source: Vulcan Green Steel project experience

# $H_2$ is a key ingredient in green steel production; complexities across $H_2$ value chain need to be addressed

Not exhaustive




Source: Vulcan Green Steel project experience

# Significant progress made in solving for green steel production

Constraint

Enabler

## Green 'low-carbon' **Hydrogen & Power**

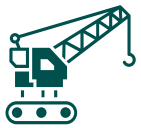
Vast amounts of Green $H_2$ is required to reduce Iron Ore to Iron

Partnership for $H_2$ procurement & 24-7 access to low-cost renewables

## High-grade **iron ore pellets**

Scarce Ion Ore with >67% Fe-content is required for the DRI-EAF process

Access to iron ore & palletization capacity via MoUs & own mines

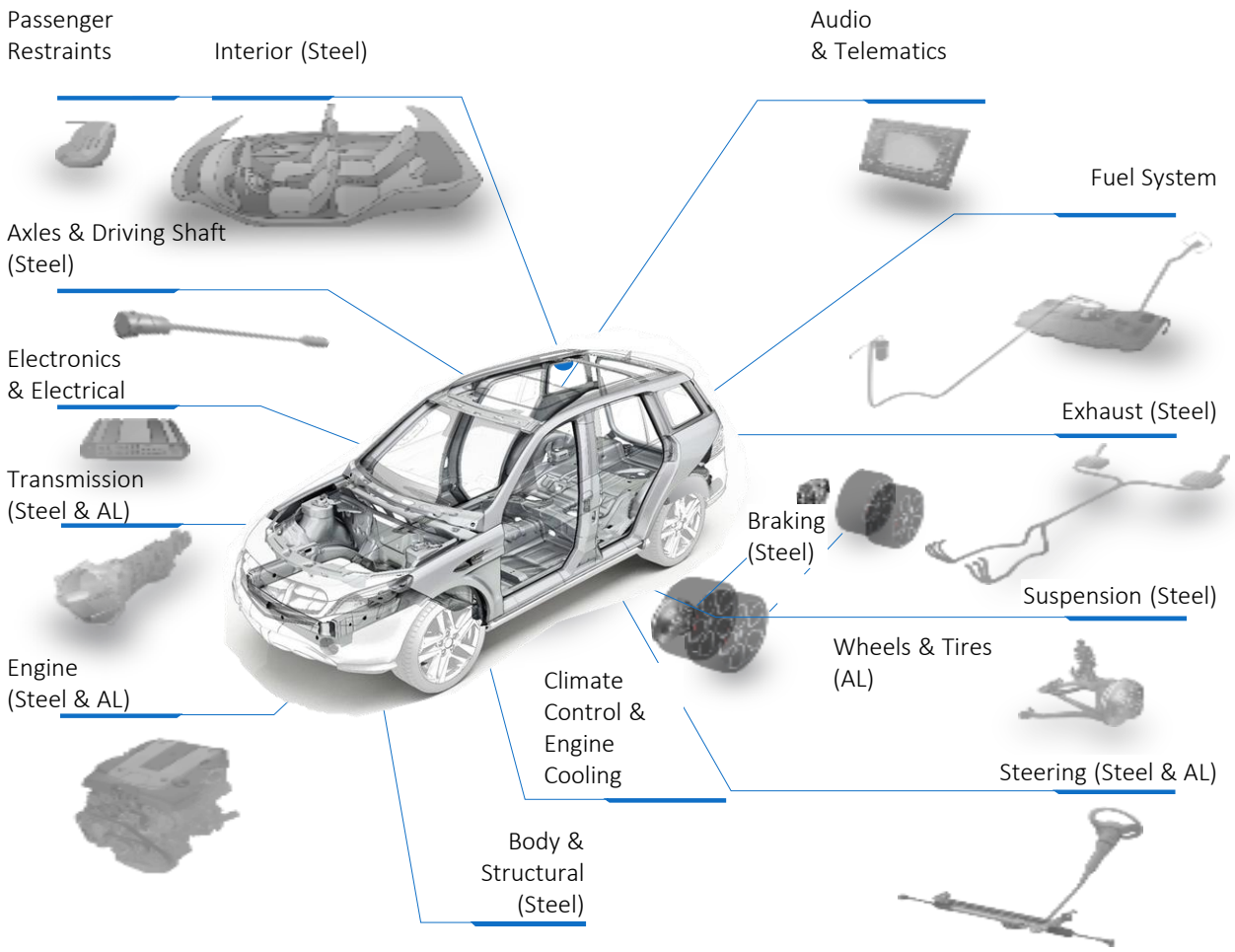


## **DRI-EAF plant** construction

Number & capacity of DRI-EAF plant construction companies is limited

Partnership with plant construction companies

# Steel & AL comprise ~70% of the weight of a car…




# …which can bring down Scope 1, 2 & 3U emissions by >50%

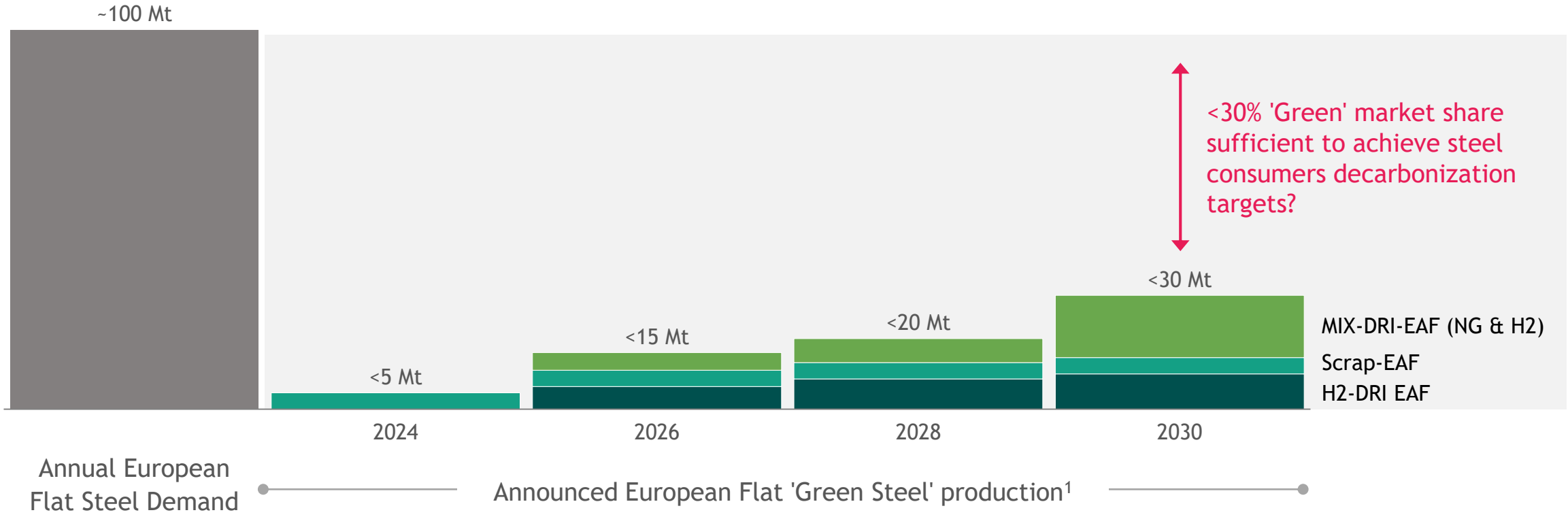
Break-down of Scope 1, 2 & 3U $CO_2$ emissions from a car

| 3.9 tons | + | 2.2 tons | + | 5.4 tons | = | 11.5 tons |
|---|---|---|---|---|---|---|
| $CO_2$ emissions from Aluminium | | $CO_2$ emissions from Steel | | $CO_2$ emissions from other materials like Battery, plastics, transport, etc | | Total emissions from a car |

Replacing Grey AL & Grey Steel in car with Green AL & Green Steel would bring down $CO_2$ emissions of a car by >50%

# Supply gap expected | <30 Mt 'Green steel' announced for 2030

## European Flat Steel Demand & announced 'Green Steel' Production




1. Publicly announced production volumes by Arcelor Mittal, Thyssenkrupp, TATA Steel, Salzgitter, SSAB, H2GreenSteel, Arvedi, Dillinger
Source: BCG analysis

# Transitioning to green steel is also cost-effective across industries

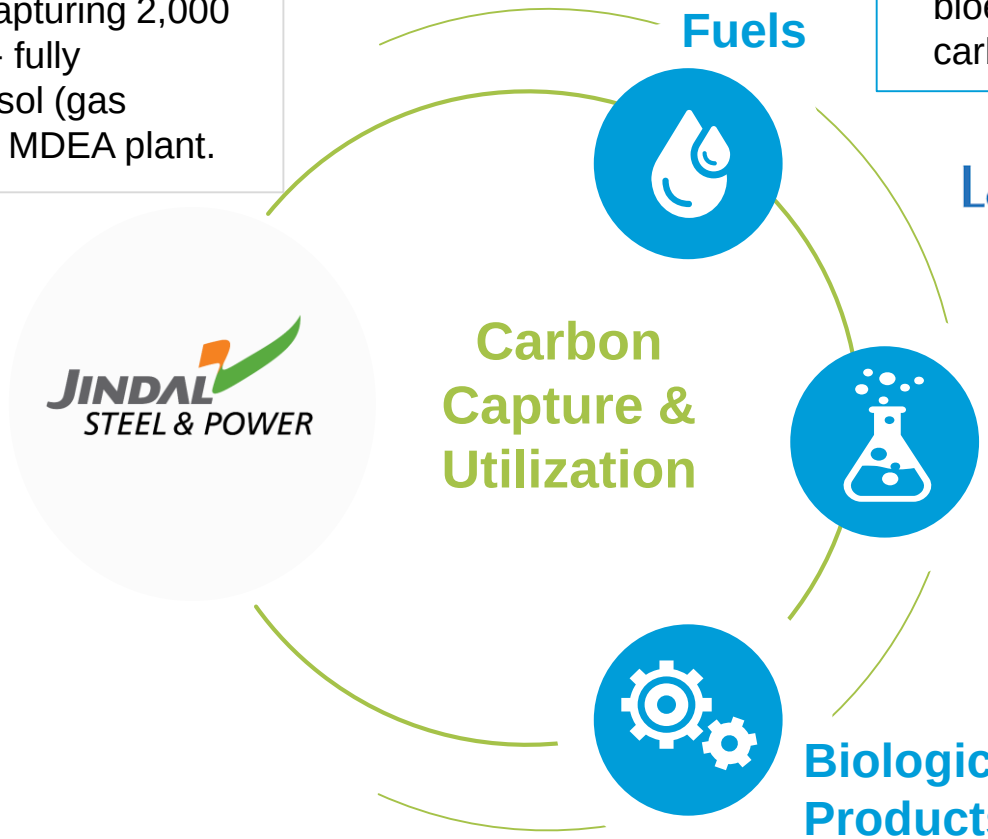
| Details | Wind[1] | Auto | Appliances |
|---|---|---|---|
| Share of steel cost[2] (%) (Steel cost / Others) | 90 – 95% / 5-10% (€2,600k/MW) | 97% / 3% (€30k /car) | 85% / 15% (€330/ washing machine) |
| Steel consumption per unit (t) | 210-230 | ~1 | ~0.05 |
| Premium for Green Steel[3] (€/t) | 250-300 | 250-300 | 250-300 |
| Additional cost (€) | 53k-69k | 250-300 | 12-15 |
| Incremental cost due to green steel(€) (Add. green cost / Base cost) | +1%; €40-50/MWH[4] → €40-50/MWH[4] €0.4-0.8 (Grey steel / Green steel) | +1%; 30k → ~30.3k 250-300 (Grey steel / Green steel) | +4%; 330 → 342-345 12-15 (Grey steel / Green steel) |

1. Cost of setting up offshore wind farm basis discussions with multiple wind suppliers; 2. Average grey steel price: €1,000/t; 3. Premium for green steel in range of € 250-300/t; 4. Levelized cost of electricity
Source: 2025 estimate for large scale projects, Wood Mackenzie, Europa, Bank of America Merill Lynch "Who Makes The Car" 2020 Report, World steel association "Eco-Efficiency Analysis of Washing machines" Öko-Institute, Secondary research, Vulcan Green Steel project experience, BCG analysis

# $CO_2$ capture and utilization pathways



- JSP is already capturing 2,000 tons per of $CO_2$ - fully automated Rectisol (gas sweetening) and MDEA plant.




- JSP is planning to put up 1,80,000 liters per day of bioethanol project using off gases from BF/BOF resulting in carbon mitigation of around 0.15 million tons

LanzaTech

- Planning to set up 100 tons per day blue methanol plant
- Commercialization of the plant for producing Co molecule from Co2 with support of IIT-Bombay & **SEKISUI Chemical Co. Ltd.**
- Co Electrolysis of captured Co2 into Blue Synthesis Gas

CARBON RECYCLING INTERNATIONAL

HALDOR TOPSOE

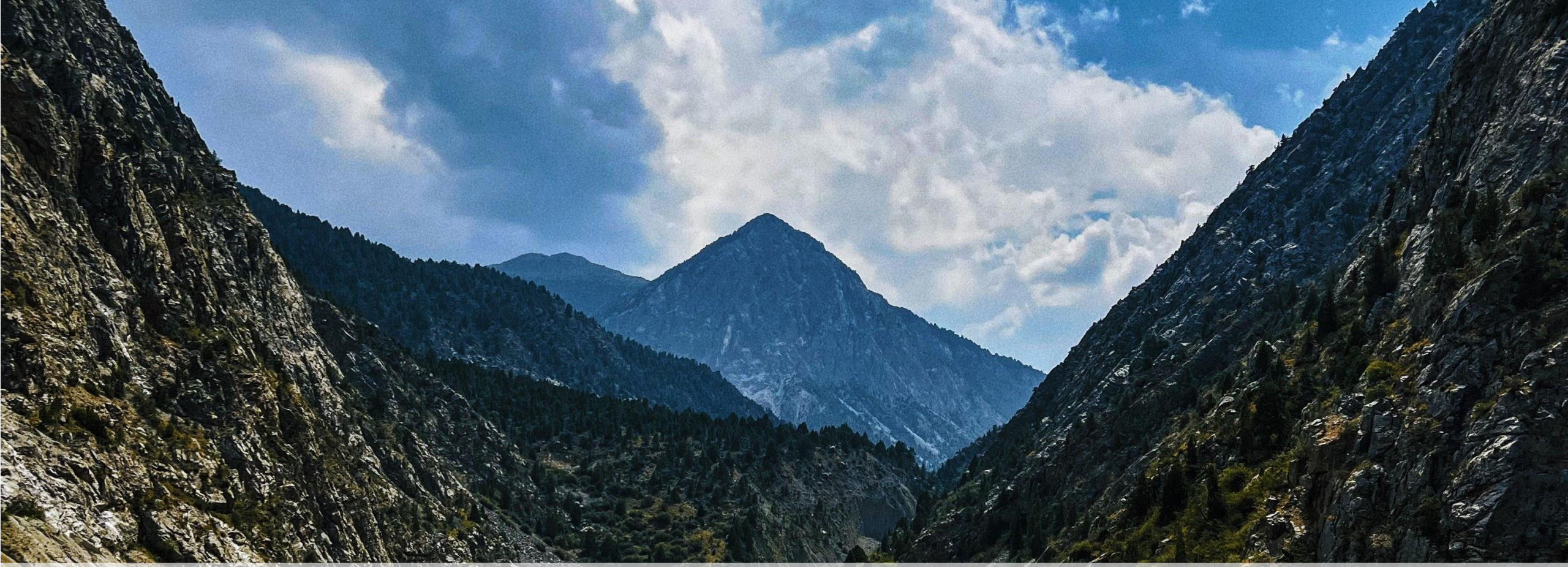
- Planning to utilize CO2 for producing crude algae oil (CAO)

christof global impact

# Steel making technologies that can be deployed to reduce emission intensity of steel

| Category | Technology | Examples | Iron source | Heat/energy | Reductant | Output | Avg T $CO_2$/tcs |
|---|---|---|---|---|---|---|---|
| **Base Technology** | Scrap-EAF | Nucor, Steel Dynamics | 100% scrap | **External** energy source (i.e., NG, grid, renewable) | n/a | Hot metal | 0.46 |
| **Coal-coke based options** | Shaft furnace w/ biomass | Tecnored | Iron oxide briquettes | Combustion of **biomass, syngas, hydrogen** | **Carbon** derived from coal or biochar | Hot metal | 1.43 |
| | Smelting reduction | HIsmelt, COREX, FINEX, Circofer | Iron ore fines, lumps, pellets | Coal-derived **syngas**, non-coking **coal,** NG | **Scraps**, waste, **non-coking coal** | Liquid iron, DRI, syngas | 1.47 |
| **Gas-based options for integration with hydrogen** | 100% NG shaft furnace | MIDREX, HYL/Energiron | High quality pellets/lumps | **Coal-coke** or **liquid fuel** | Hydrocarbon-based reductants (**NG** or **coal-derived syngas**) | DRI, HBI | 1.00 |
| | 100% H2 shaft furnace | MIDREX, HYL/ Energiron (& HYBRIT) | High quality pellets/lumps | **Pure hydrogen** (electrolysis), renewable energy, waste heat, **NG** | **Pure H2** and **CO** | DRI, HBI | 0.30 |
| | Fluidized bed technologies | Circored, FINMET | Iron ore fines | **NG**, Hydrogen-rich **syngas** | **Pure H2** or **syngas** from methane reforming | DRI, HBI | 1.26 |
| **Electrolysis based** | Electrolysis | AIE, MOE | Iron ore fines, virgin ore | **External energy** source (i.e., renewable energy or hydrogen) | **Electrolyzer** | Iron pellets, liquid iron | 0.12 |

***We are exploring Japanese collaboration for low carbon emission steel technologies***



It is not going to be a walk in the park!
However, we are prepared and have started the climb.


Thank you