Comprehensive view of sustainable hydrogen production routes for green steelmaking

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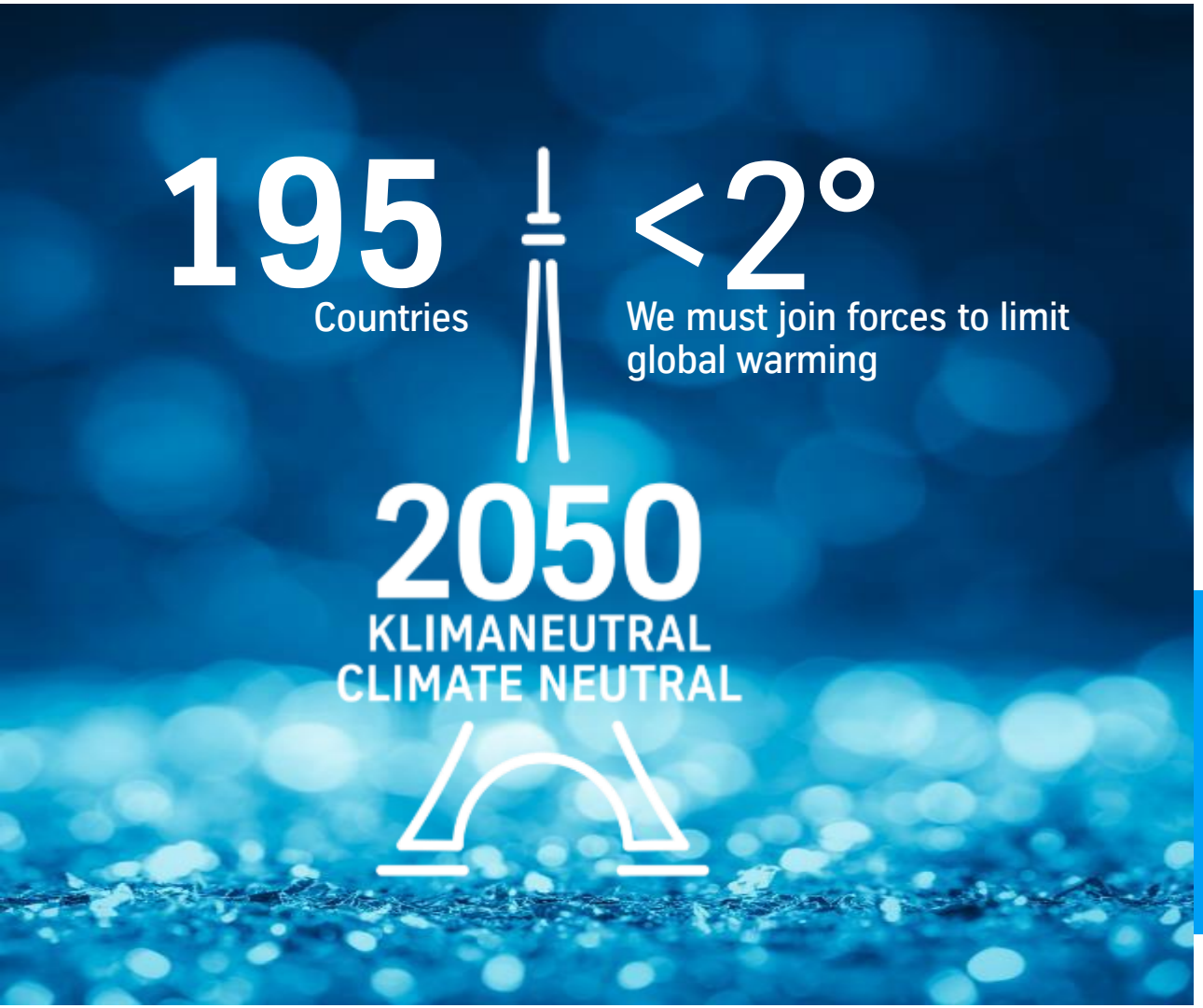
Ambitious targets for climate neutrality in 2050

Only a sustainable transition will be successful



Industry makes its contribution to achieve the targets until 2050

- Switch to natural gas an intermediate solution?
- What hydrogen transformation pathways can be expected?
- What is the related footprint of the final product?

Technological pathways to reduce the CO_2 emissions of the EU steel industry

The building blocks for a sustainable transition

Carbon Direct Avoidance (CDA)

Avoiding CO_2 within the production

Carbon Capture & Utilisation, Storage (CCUS)

Utilisation of CO_2 to produce e.g. chemicals
or the temporary and final storage of CO_2

Circular Economy (CE)

Resource efficiency

Source: Low Carbon Roadmap: Pathways to a CO2-Neutral European Steel Industry, EUROFER, November 2019.

tkSE transformation for carbon neutral steelmaking

Our contribution to climate neutrality

2030

-30% Emissions from our own production and processes[1]

-30% Emissions from the purchase of energy[2]

- [1)]SCOPE 1 emissions, base year 2018; [2)] SCOPE 2 emissions, base year 2018

tkSE transformation for carbon neutral steelmaking

Our contribution to climate neutrality

tkH2Steel

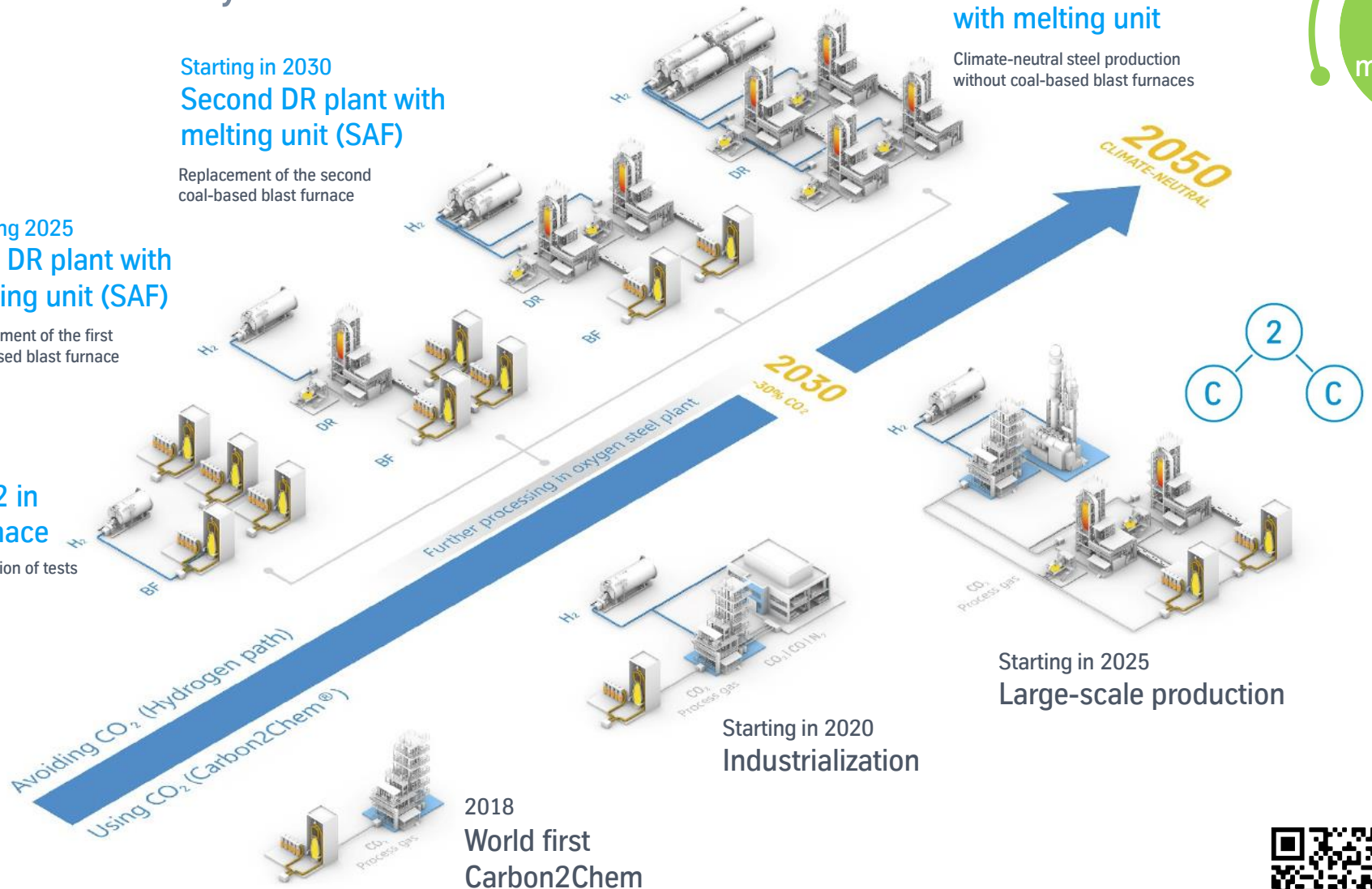
-20 million t CO_2

By 2050
3rd & 4th DR plant with melting unit
Climate-neutral steel production without coal-based blast furnaces

Starting in 2030
Second DR plant with melting unit (SAF)
Replacement of the second coal-based blast furnace

Starting 2025
First DR plant with melting unit (SAF)
Replacement of the first coal-based blast furnace

Since 2019
Use of H2 in blast furnace
Ongoing extension of tests



Starting in 2025
Large-scale production

Starting in 2020
Industrialization

2018
World first Carbon2Chem
The pilot system uses steel mill gases to produce base chemicals

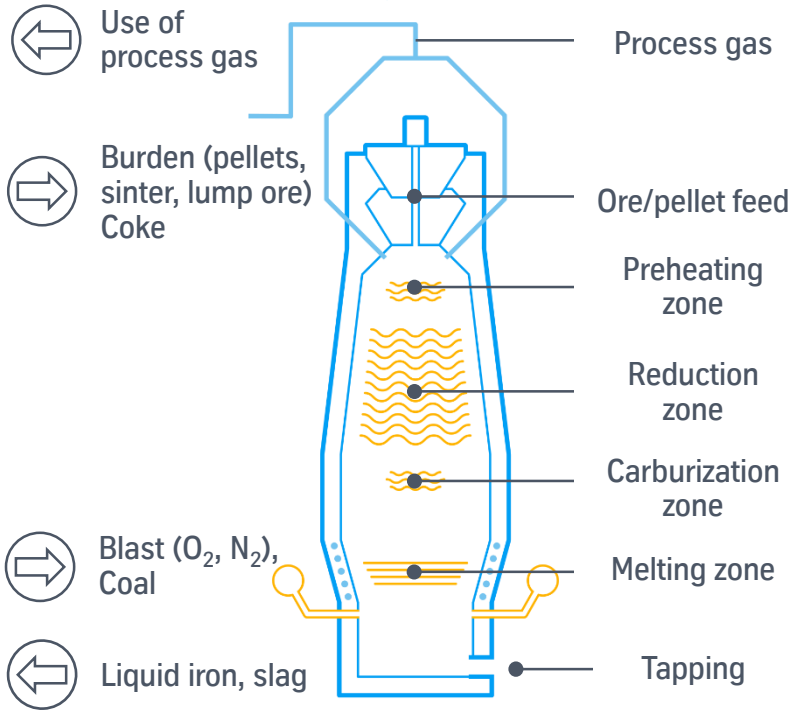
For more information please scan:

tkSE transformation for carbon neutral steelmaking

Centrepiece of the transformation

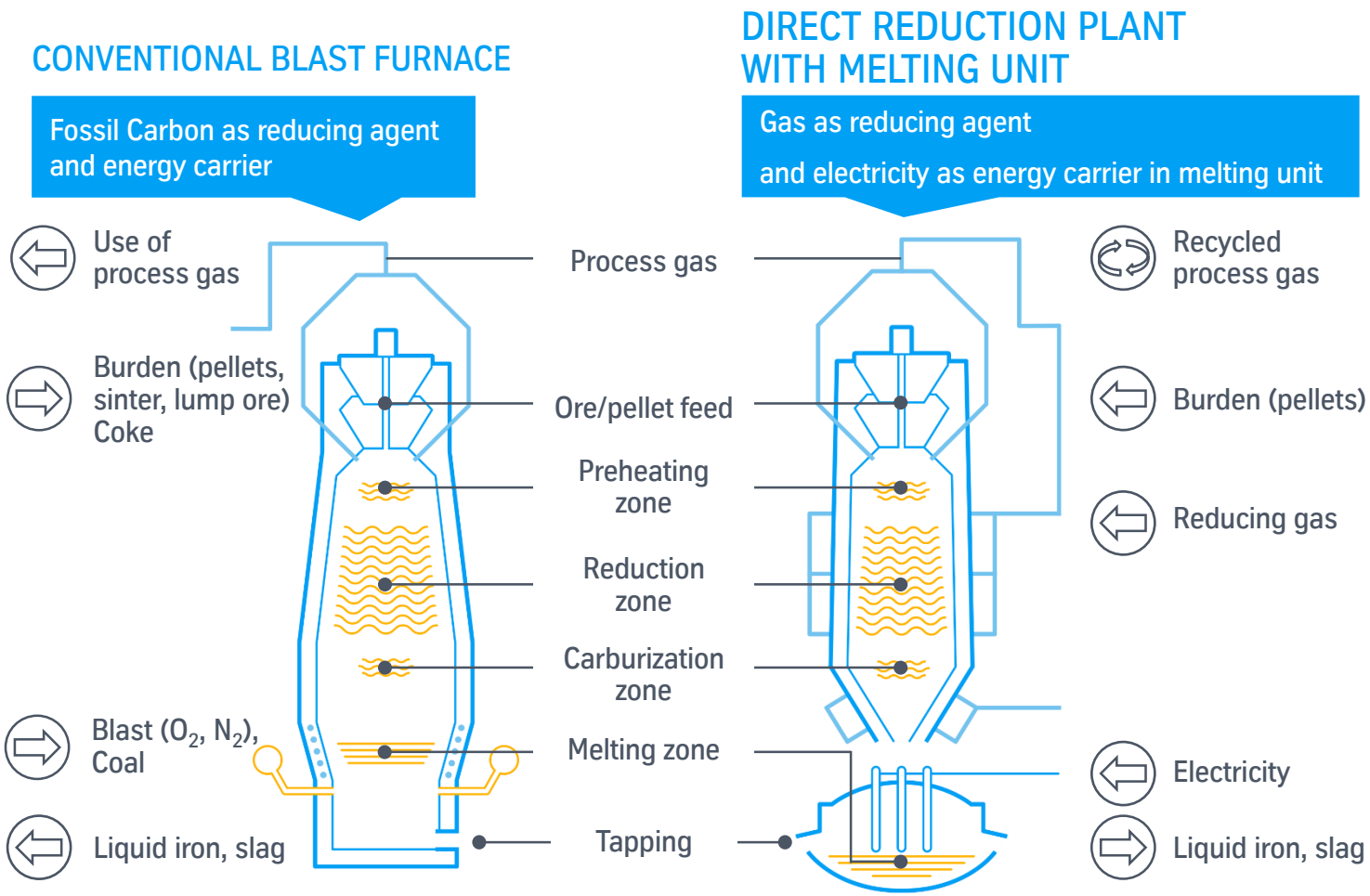
CONVENTIONAL BLAST FURNACE

Fossil Carbon as reducing agent and energy carrier



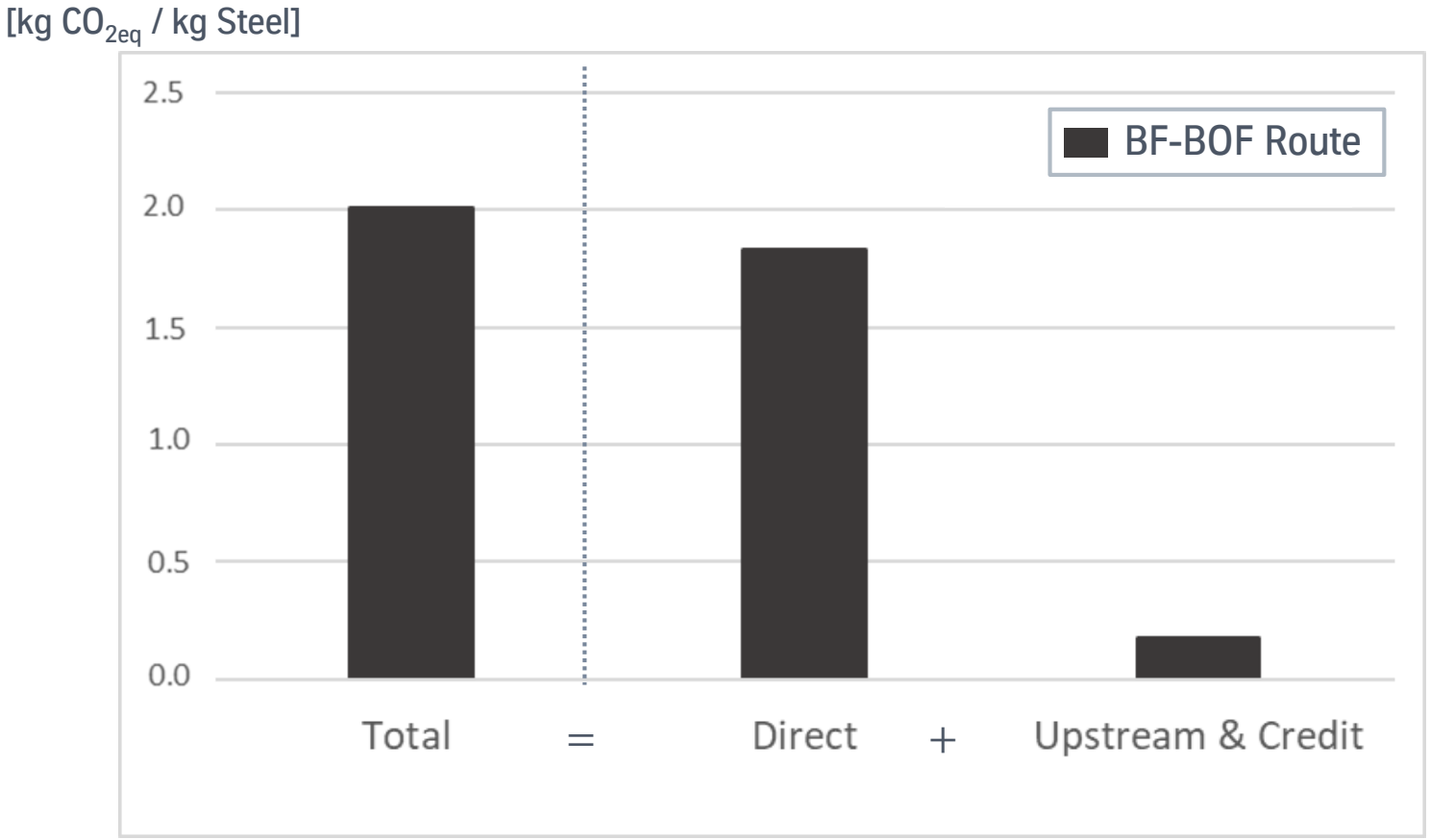
tkSE transformation for carbon neutral steelmaking

Centrepiece of the transformation



Basics of Life Cycle Assessment with focus on Greenhouse Gas (GHG) Emissions

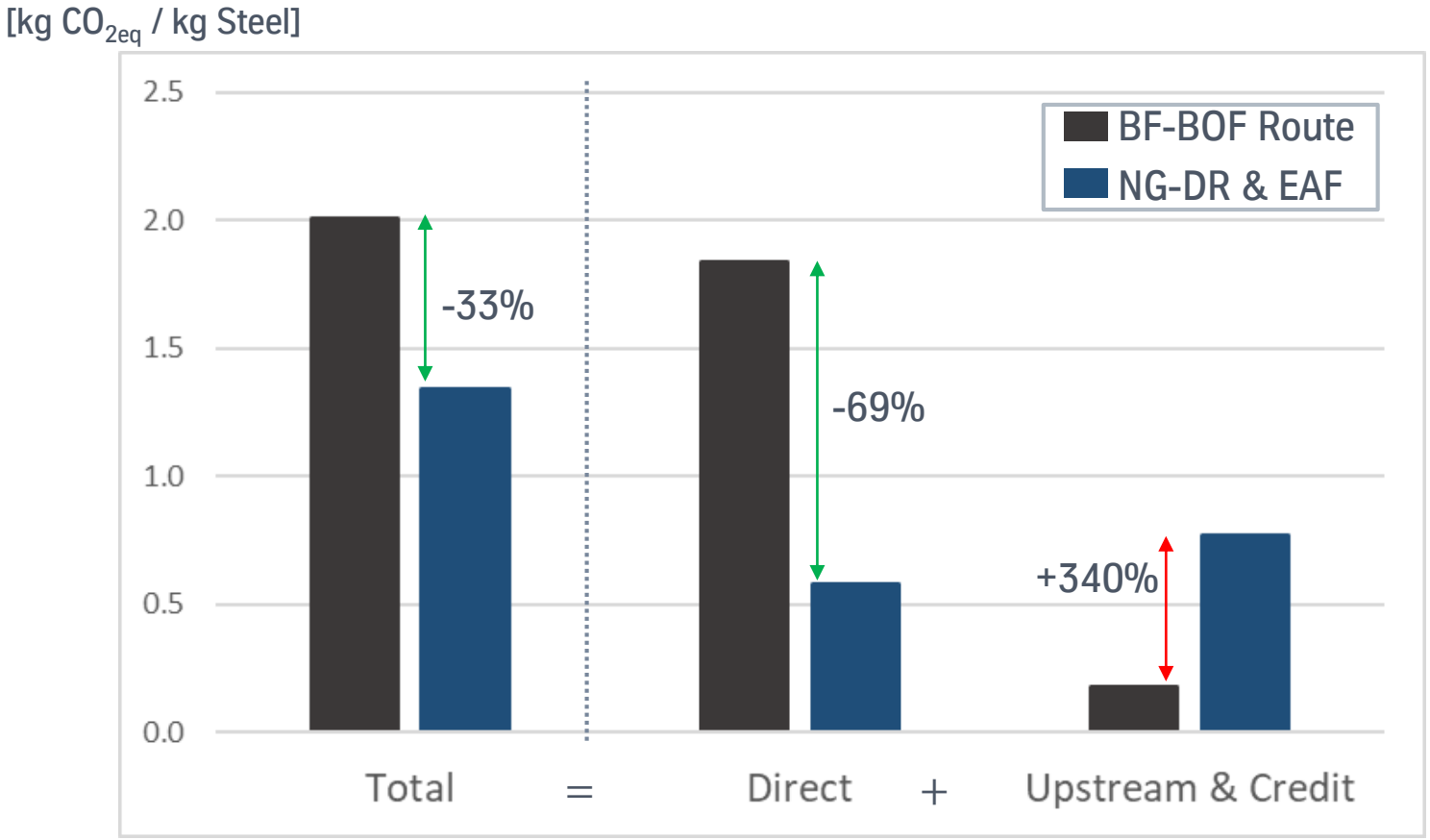
State of the art in primary steel making: Total Emissions BF-BOF



BF-BOF: Blast Furnace – Basic Oxygen Furnace
Source: World Steel; GaBi; BF; GaBi Database 2021.1 - DE: BF Steel billet/slab/bloom
Peer-reviewed publication already submitted and will be available soon: Optimisation of BF

Essential Milestone: DR & EAF operated with natural gas

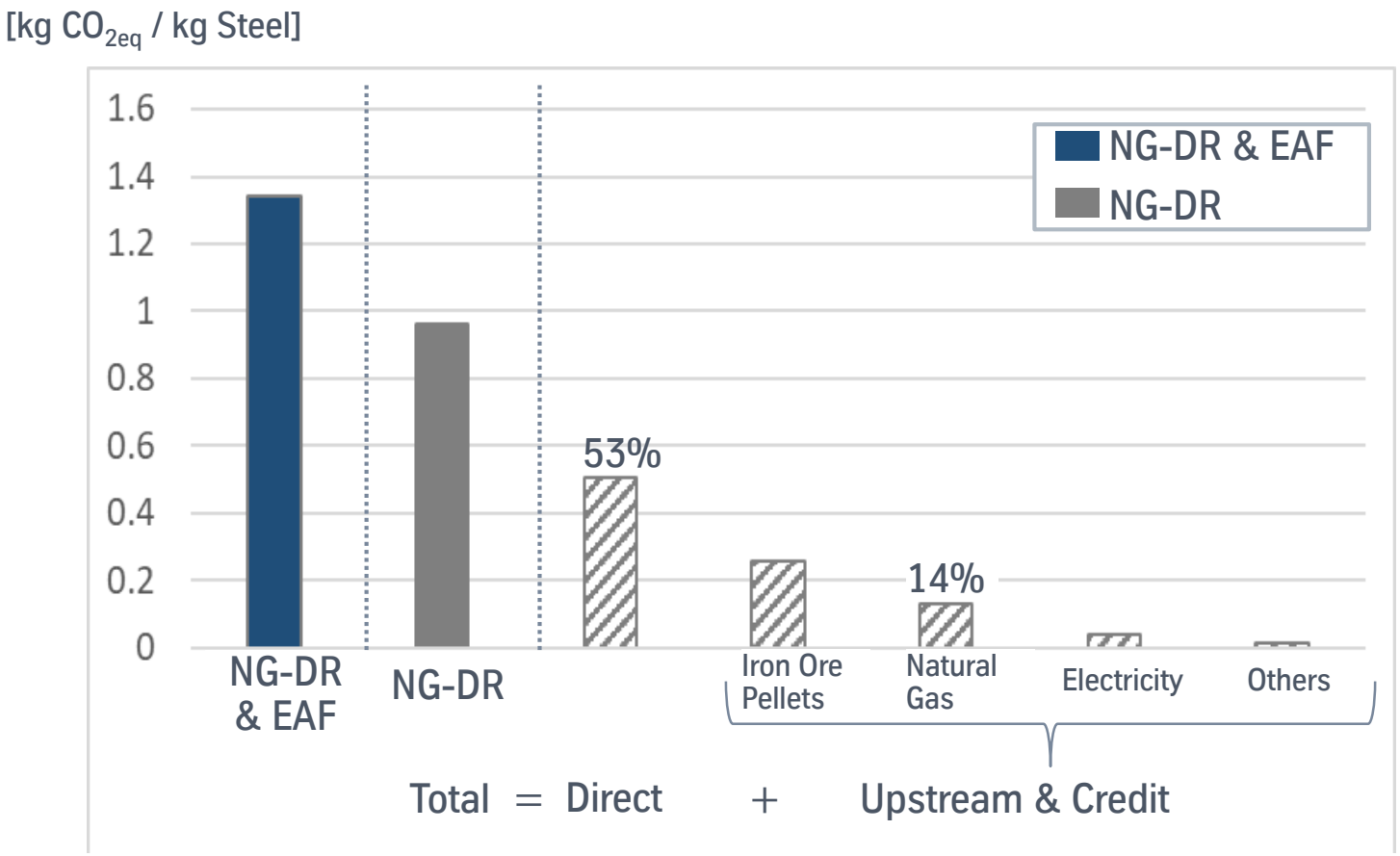
Transition from solid fossil fuels to gaseous fuels



NG = Natural Gas; DR = Direct Reduction Plant

Essential Milestone: DR & EAF operated with natural gas

Basic Scenario: Detailed overview of the footprint of NG-DR route



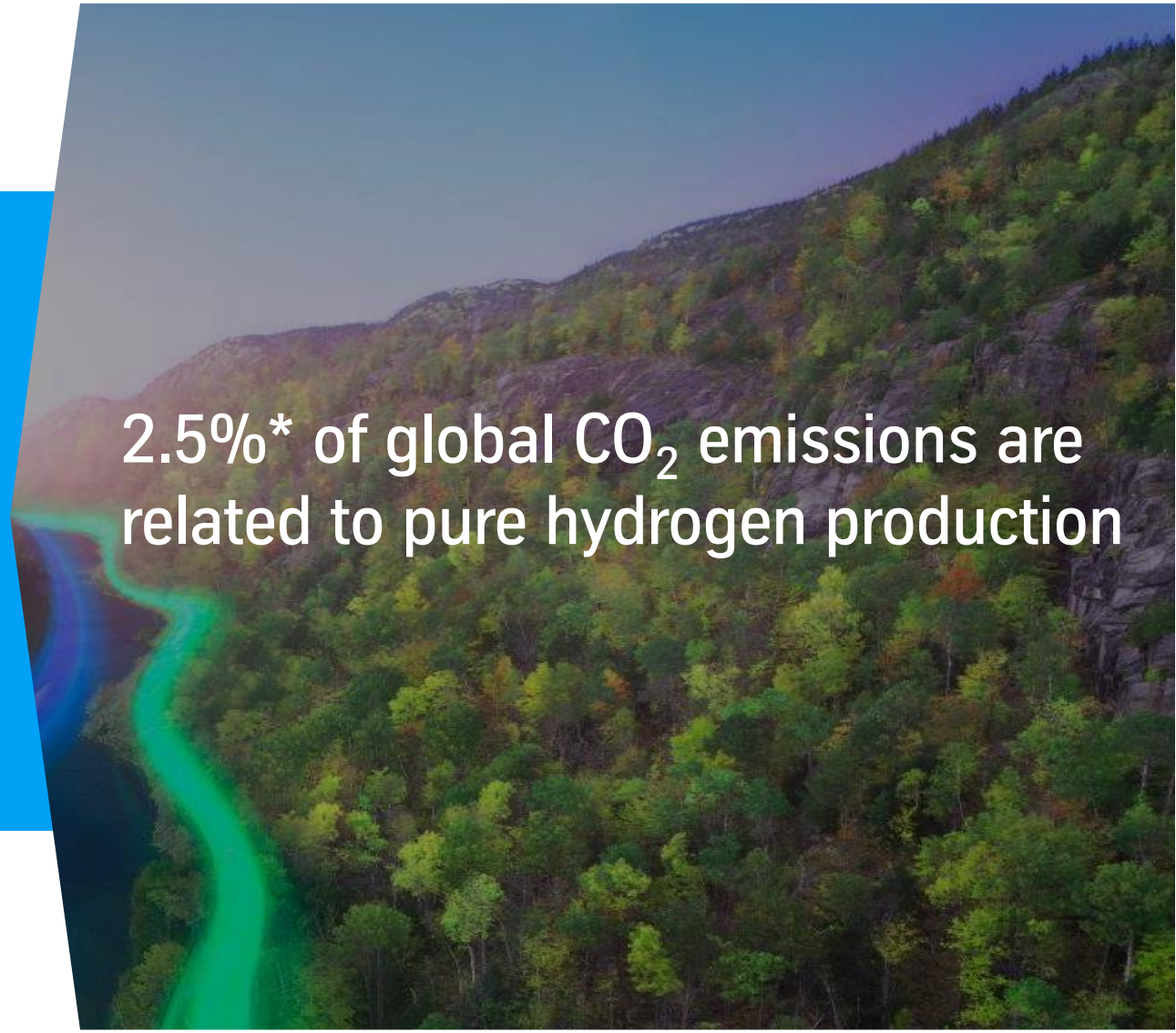
Utilisation of hydrogen to reduce overall emissions of a DR plant

Source: GaBi Database 2021.1 - DE: BF Steel billet/slab/bloom

Comprehensive view of sustainable hydrogen production routes for green steelmaking

Hydrogen is already an important part of today‘s value chains

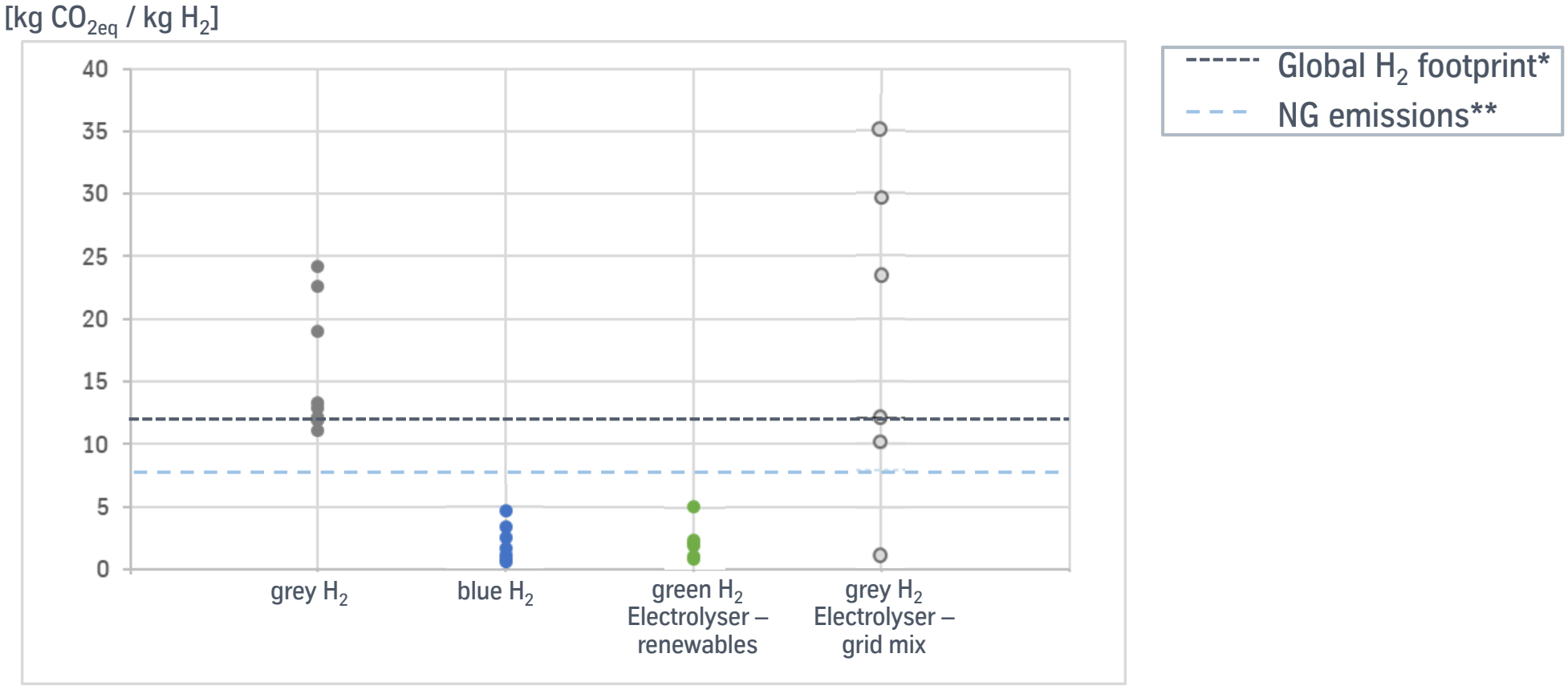
- Approx. 70,000,000 t H_2/year
  - 0.5% is green hydrogen
  - 6% of the global natural gas consumption is used for hydrogen production
  - 2% of the global coal consumption is used for hydrogen production



Source: https://www.iea.org/reports/hydrogen;
* 830.000.000 t CO_2/a

Greenhouse Gas Emissions of hydrogen production pathways

Literature review of footprints of hydrogen



The CO_{2eq} footprint of hydrogen depends on the production pathway and framework conditions

*Average global footprint based on direct emission: ~12 kg CO_{2eq}/kg H_2; **: Direct and Upstream Emissions of NG based on comparison LHV

Source: Peer-Reviewed and official public available studies. For the complete list, please do not hesitate to contact us. Data will be provided within the foreseen publication.

Modeling sustainable hydrogen production

Global Warming Potential (GWP) of hydrogen produced by electrolysis plant

$$0.05^{*} \times \frac{kg\ CO_{2equi}}{kgH_2}$$

$$GWP_{H_2} = Operation\ of\ the\ Plant + Production\ of\ Electrolysis\ Plant$$

$$\boldsymbol{GWP\ Electricity} \times Energy\ Demand$$

$$0.158^{*} \times \frac{kg\ CO_{2equi}}{MJ}$$

$$\frac{1}{\boldsymbol{Efficiency}} \times Energy\ Hydrogen$$

$$\frac{1}{62.5\%^{*}} \times 120 \frac{MJ}{kgH_2}$$

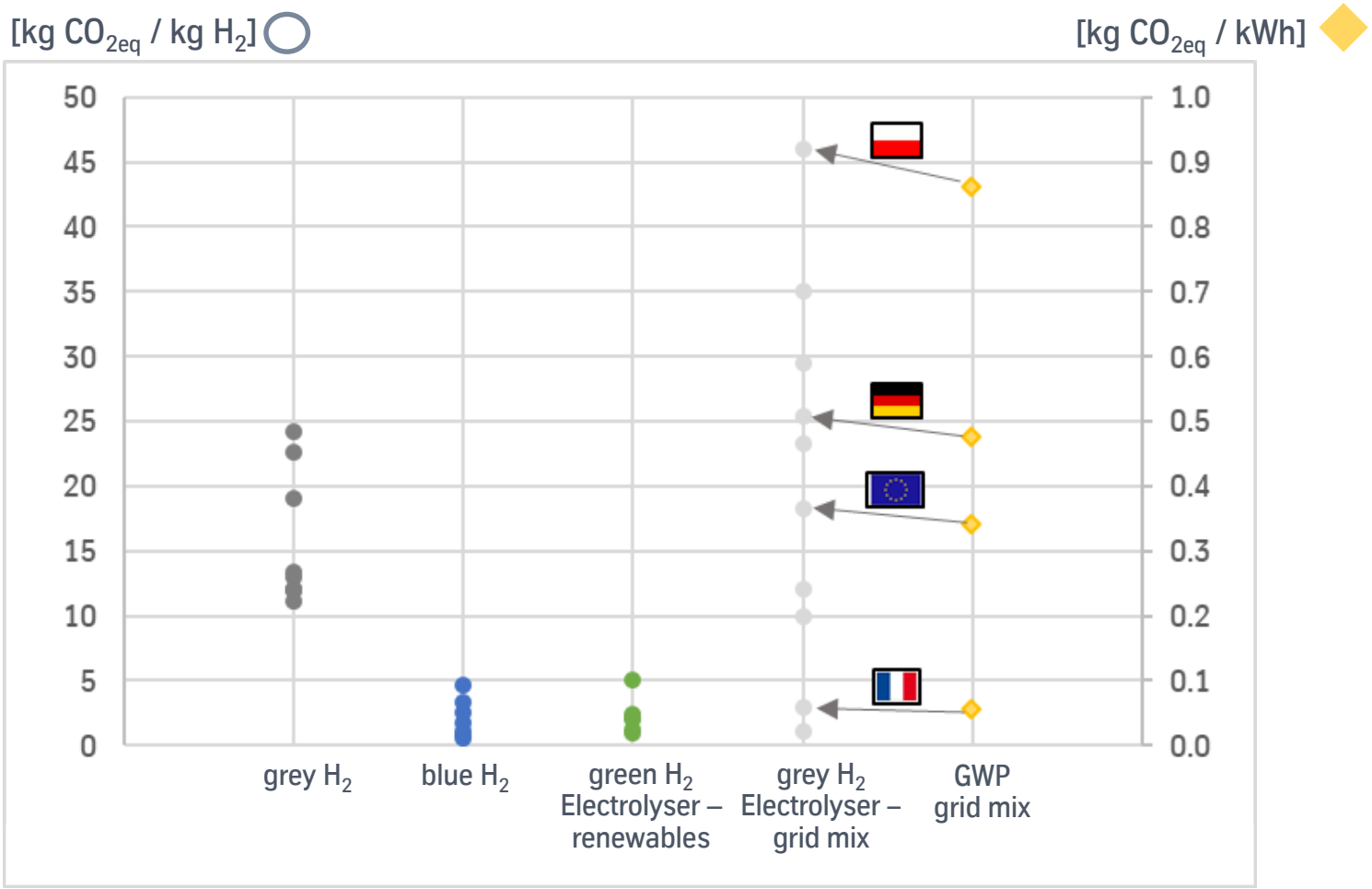
The main parameters are the GWP of the electricity and the efficiency of the plant

*: Indicative data based on GaBi database 2018

Source: DE Energy Mix 2018; LHV Efficiency Global decentral Hydrogen Production GaBi Database 2021.1

Global Warming Potential (GWP) of hydrogen produced by electrolysis plant

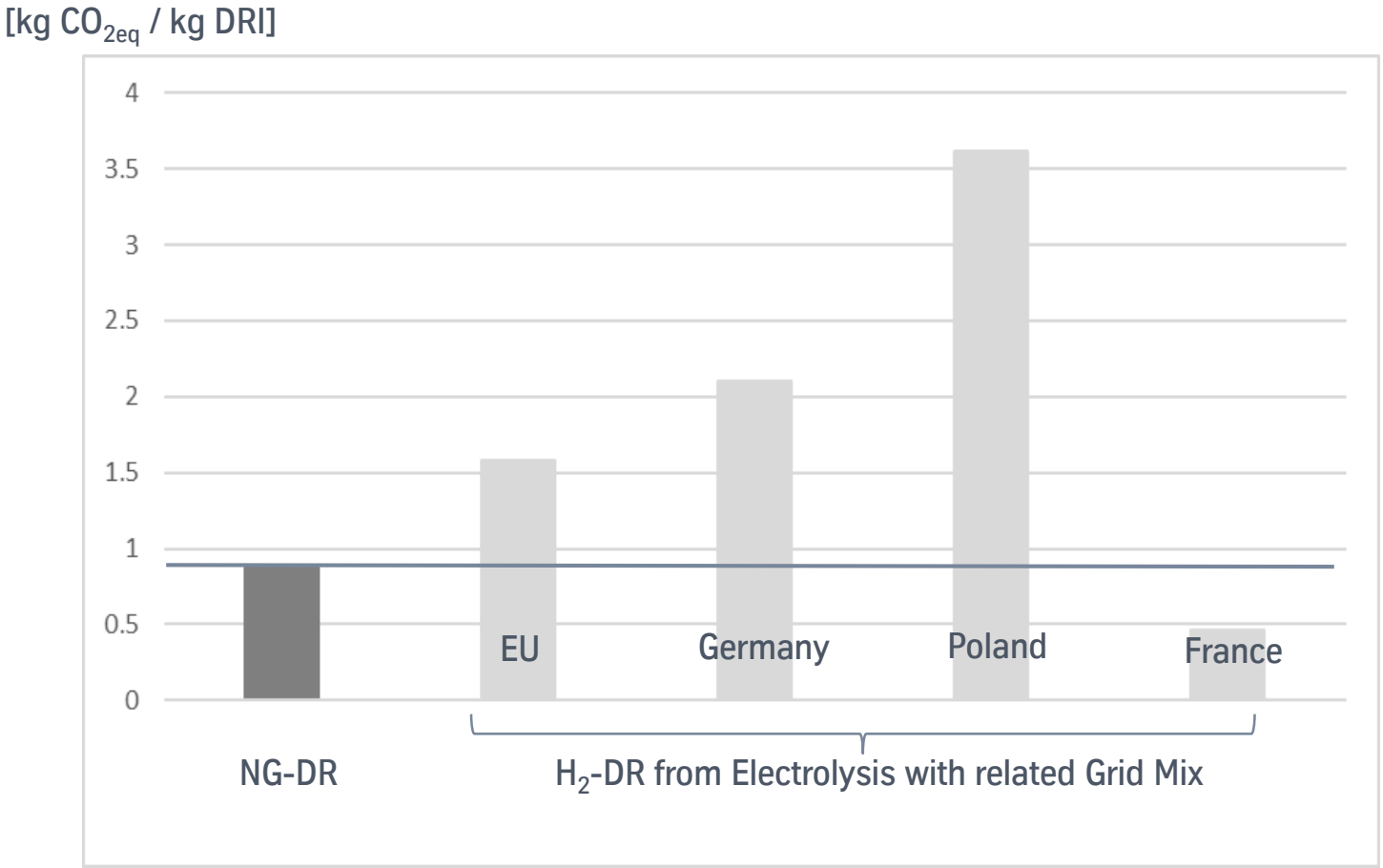
Modeling Power production today: Europe, Germany, France, Poland



Source: IEA, World Energy Balances 2020. ; Europe = EU-28

Sustainable Production of Hydrogen

Related Footprint of the Direct Reduced Iron in 2018



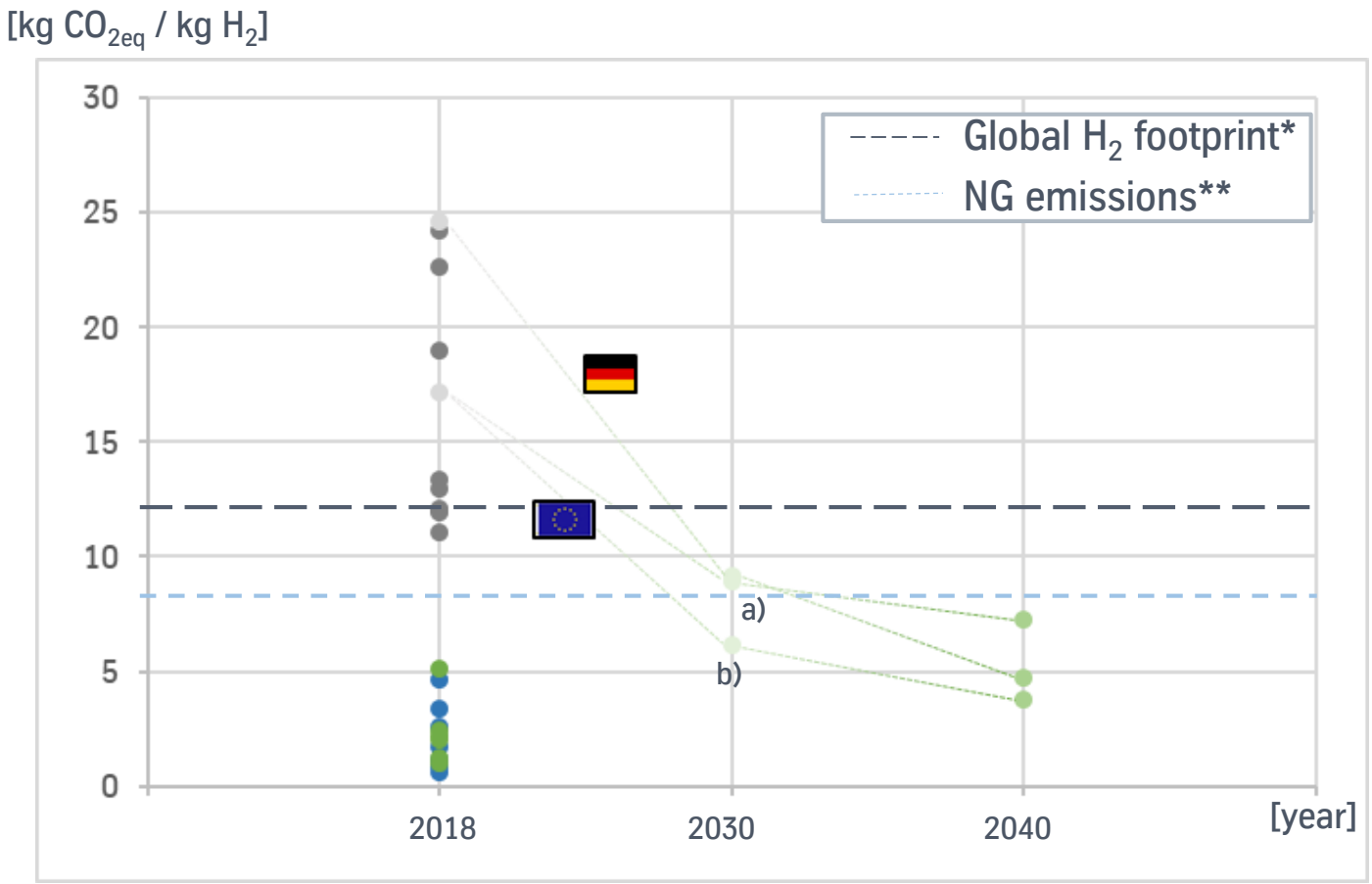
Break-Even-Point: GWP of power from grid mix is 0.16 kg CO_{2eq} / kWh

Global Warming Potential (GWP) of hydrogen produced by electrolysis plant

Modeling Power production Scenarios EU & Germany: Today-2030-2040

Scenarios

- Europe[1] ***
  - a) Stated Policies Scenario
  - b) Sustainable Development Scenario
- Germany[2]
  - Climate-neutral

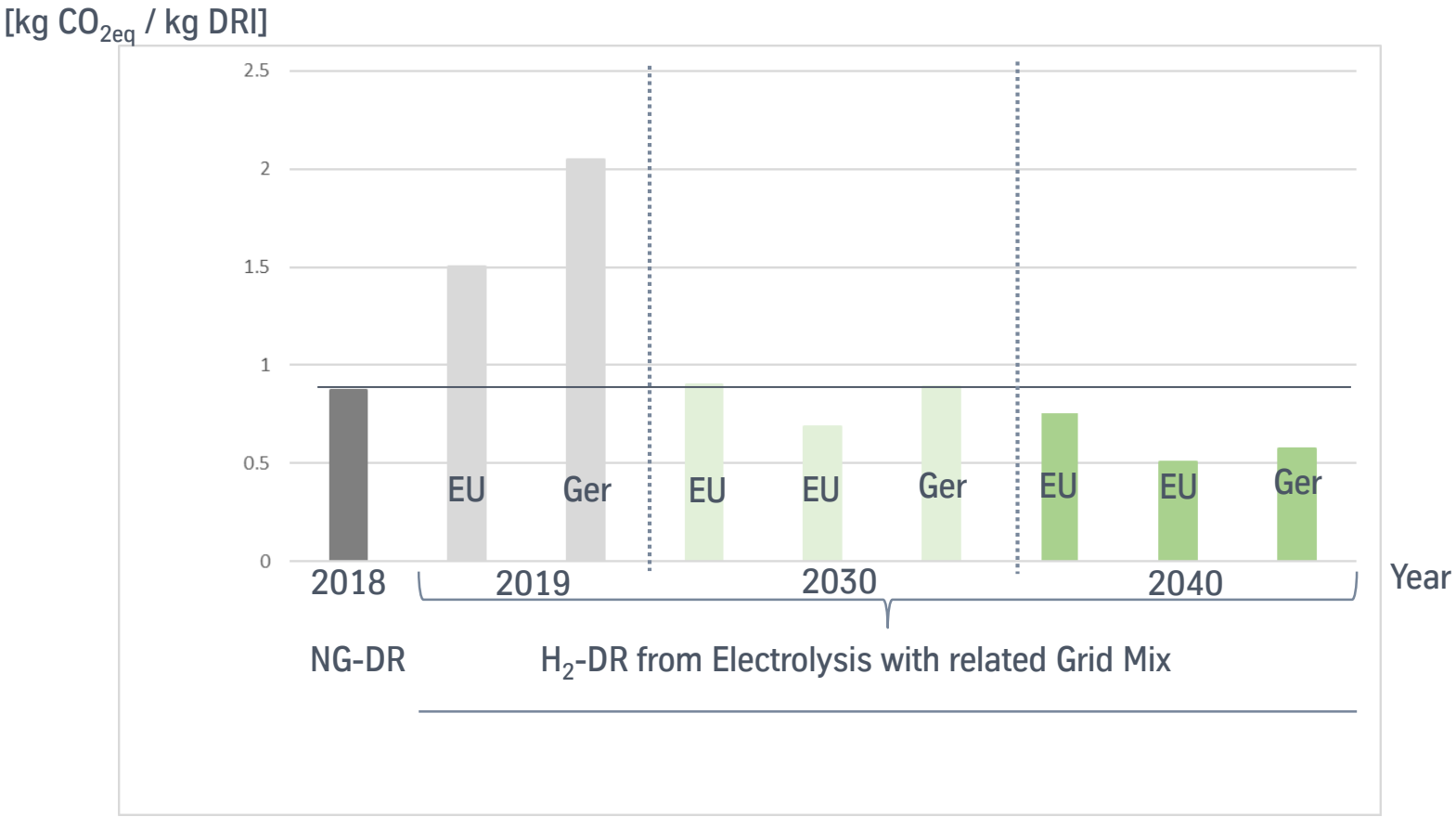


*Average global footprint based on direct emission: ~12 kg CO2eq/kg H2; **: Direct and Upstream Emissions of NG based on comparison LHV; *** EU-27

Source: [1]: IEA (2020), World Energy Outlook 2020, OECD Publishing, Paris, https://doi.org/10.1787/557a761b-en.; [2]:Prognos, Öko-Institut, Wuppertal-Institut (2020): Towards a Climate-Neutral Germany. Agora Energiewende, Agora Verkehrswende and Stiftung Klimaneutralität.

Sustainable Production of Hydrogen

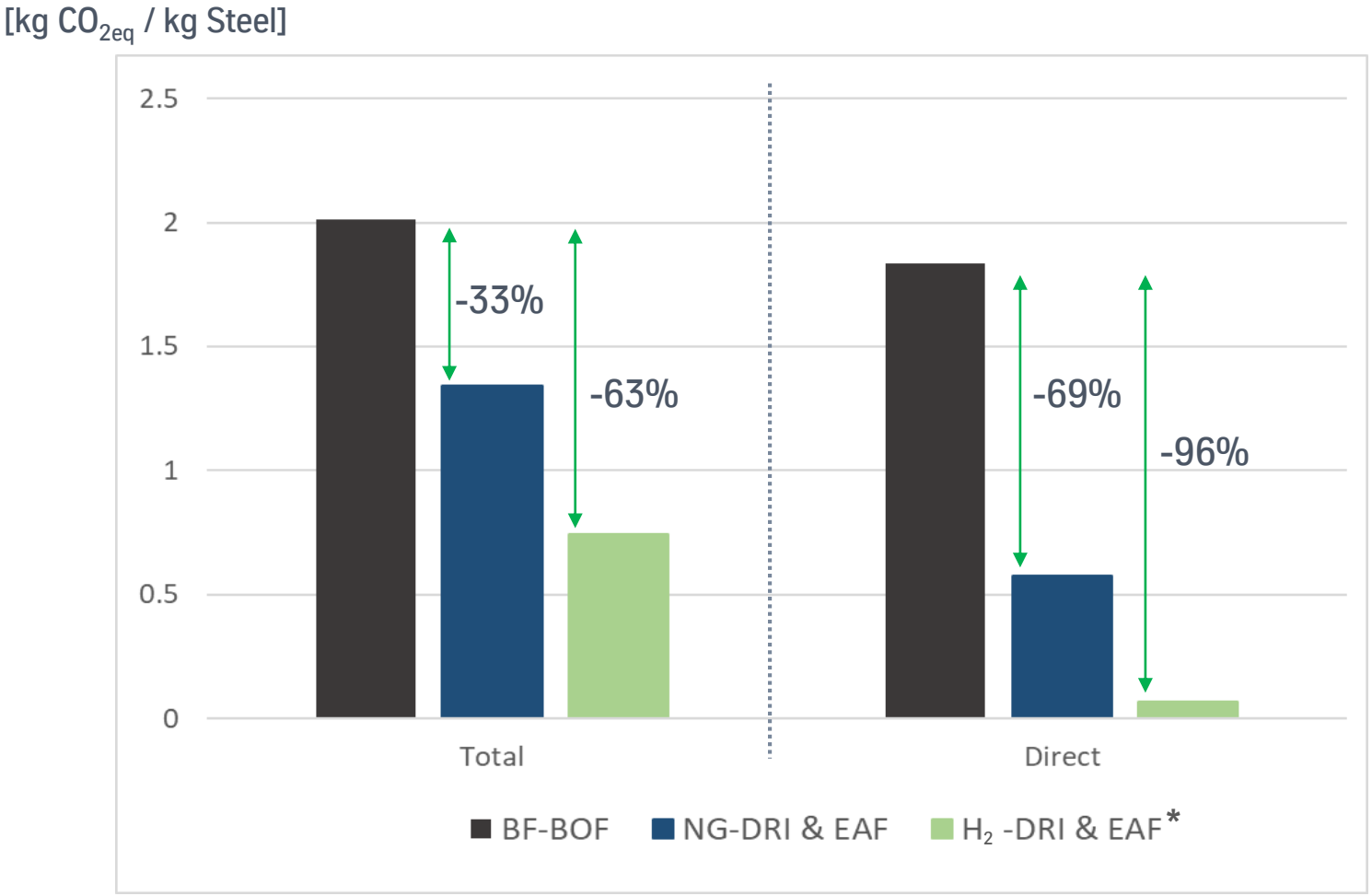
Related Footprint of the Direct Reduced Iron in Scenarios EU & Germany: Today-2030-2040



Break-Even-Point: Within the year 2030 for the considered scenarios

Ambitious targets for climate neutrality in 2050

Total and Direct Emissions of the different production routes



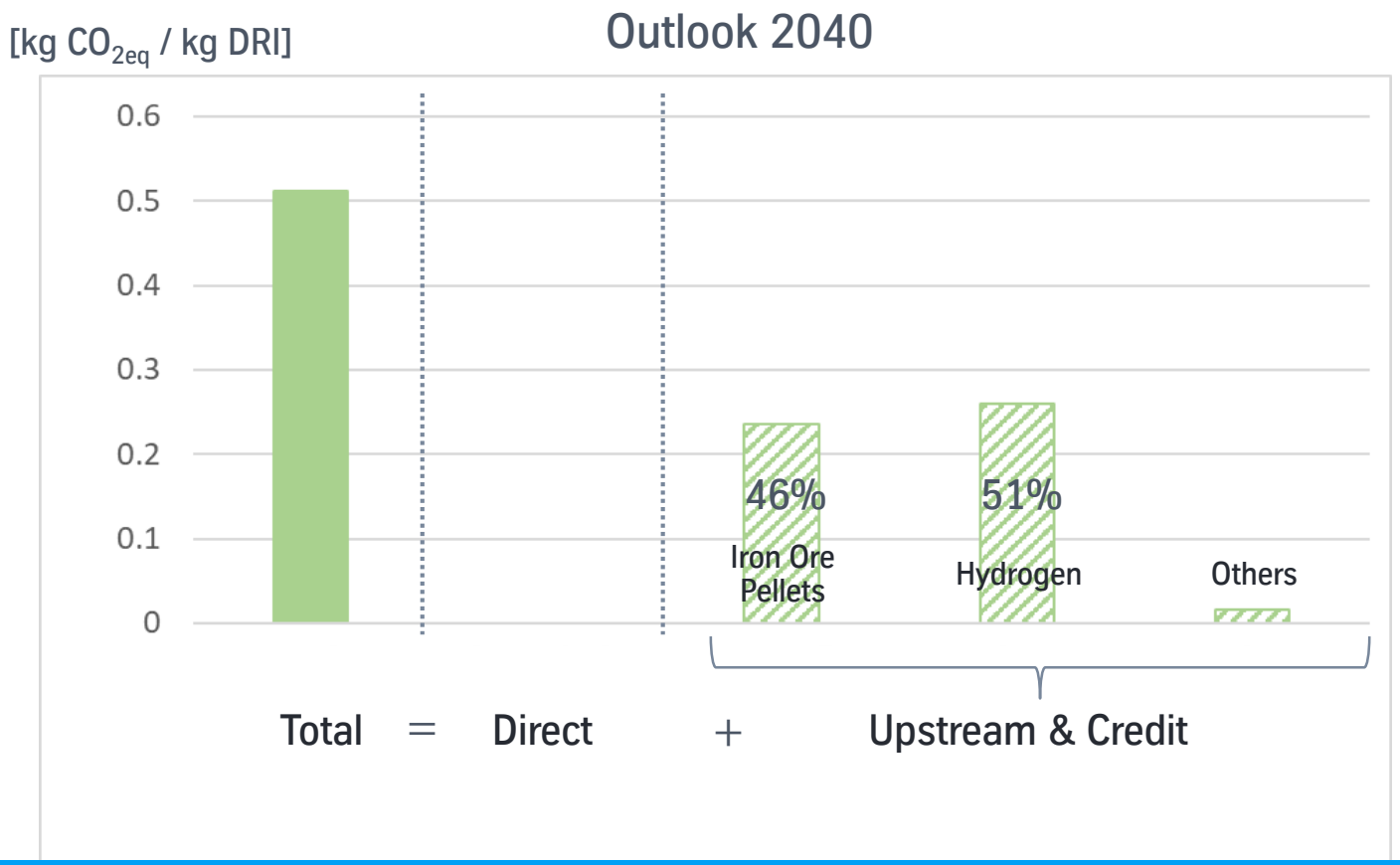
Significant direct emission reductions until year 2040

*: European Grid Mix 2040 (Sustainable Development Scenario) for hydrogen production and consumption of the DR &EAF plant

Ambitious targets for climate neutrality in 2050

Outlook DRI production To-Do's beyond 2040

Peer-Reviewed Publication under preparation!



To achieve the 2050 target for the DR plant, upstream hydrogen and pellet footprint needs to be reduced

Ambitious targets for climate neutrality in 2050

The transformation will be successful if the appropriate framework is created

Other sectors like power production and raw materials sector need to achieve their targets

Political and regulatory framework for climate-neutral technologies

Market model: Incentives for the purchase of green products

Thank you for your attention!

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