



Under the Convention on Long Range Transboundary Air Pollution

Analysis of the impact of decarbonisation on emissions of air pollutants in selected industrial sectors

TFTEI technical secretariat

Simon Glöser-Chahoud (DFIU/KIT)



8th TFTEI Annual Meeting, October 7th 2022, Rome, Italy

Agenda



1. Technical background document in preparation
2. Decarbonisation of key industries
3. Potential effects on emissions of air pollutants
4. Exemplary industries
 - Steel production
 - Cement industries
5. Conclusions & Discussion

Technical background document




- Background informal technical document “on the analysis of the impact of decarbonisation on emissions of air pollutants in selected industrial sectors” to be developed until January 2023:
 - Decarbonisation leads to both replacement of existing technologies in various industries and to additional treatments such as “carbon capture” in exhaust gases through e.g. absorption processes
 - Both the replacement of existing technologies and additional end-of-pipe treatments will have an impact on air pollutants from the respective industrial sectors
- ➔ **Assessment of the effect on air pollutant emissions**
- Five sectors to be assessed: **cement industries, steel production**, glass industries, aluminium production, selected processes from chemical industries (e.g. refineries) with description of (new) processes and their developments


Background informal technical document on the analysis of the impact of decarbonisation on emissions of air pollutants in selected industrial sectors (first draft)


TFTEI informal background technical document
December 2022

Prepared by KIT DFIU - TFTEI Technical Secretariat
Simon Glöser-Chahoud

-----Seitenumbruch-----

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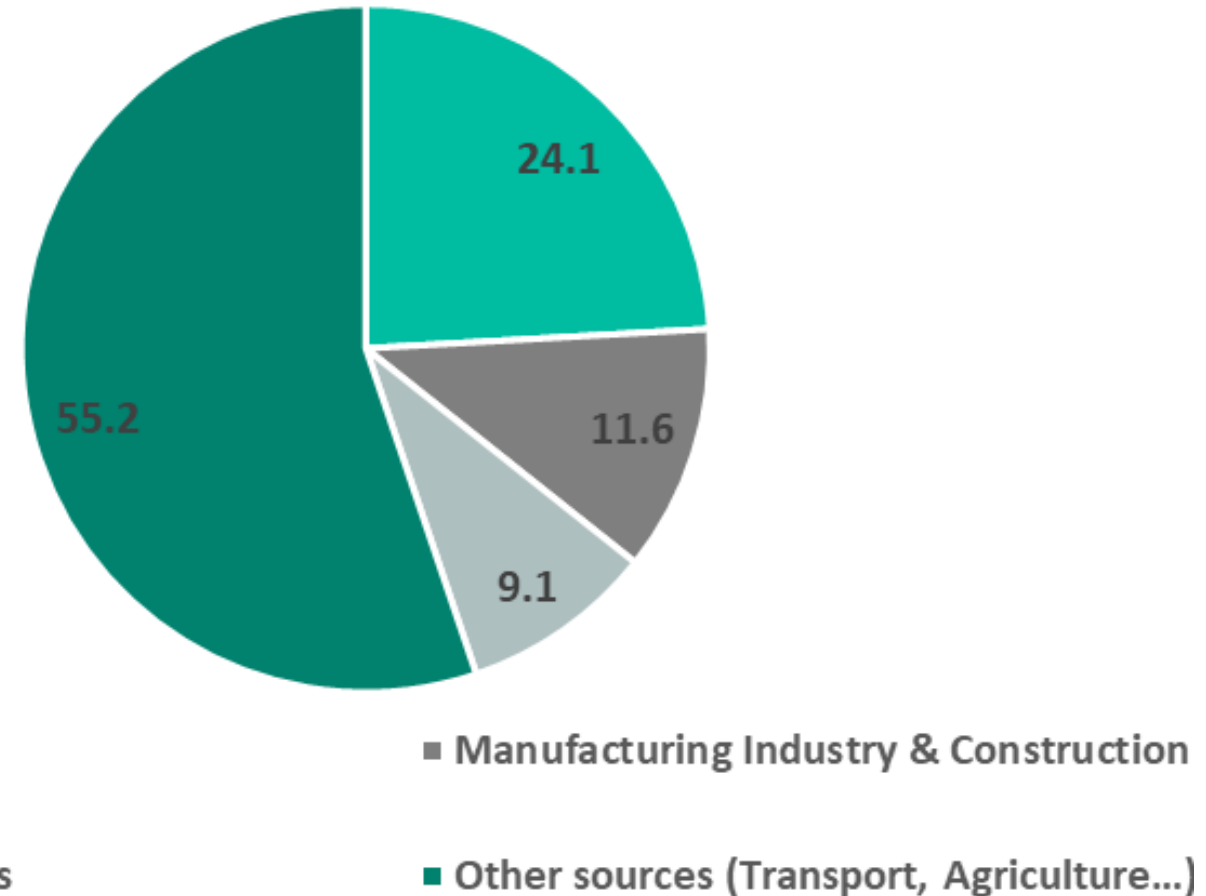
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GHG emissions by IPCC source sector in 2019 in the EU (in percent)

Total emissions of the EU in 2019:
~ 4.067 Mt CO₂ – eq.

The biggest emitter in the EU is Germany:

- Emissions in 2019:
~0.81 Mt CO₂ – eq.
- Emissions in 2020:
~0.74 Mt CO₂ – eq.



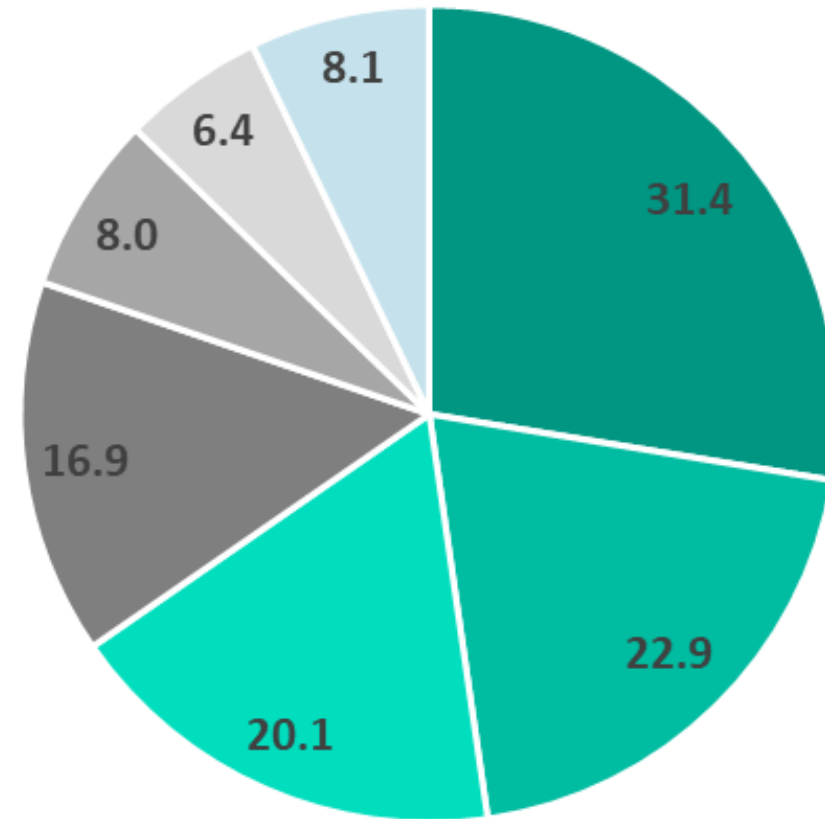
Source: eurostat, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Climate_change_-_driving_forces#GHG_footprint_of_EU_consumption_and_investment
 Umweltbundesamt, <https://www.umweltbundesamt.de/presse/pressemitteilungen/treibhausgasemissionen-sinken-2020-um-87-prozent>
 EEA, Annual European Union greenhouse gas inventory 1990–2019 and inventory report 2021

Share of CO₂ emissions of the industry sector in Germany (in million t CO₂ – equivalent)

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- Iron and Steel
- Refineries
- Cement Clinker
- Chem. Industry
- Other mineral processing
- Industry and construction talk
- Other industry

Source: Umweltbundesamt, Treibhausgasemissionen 2021

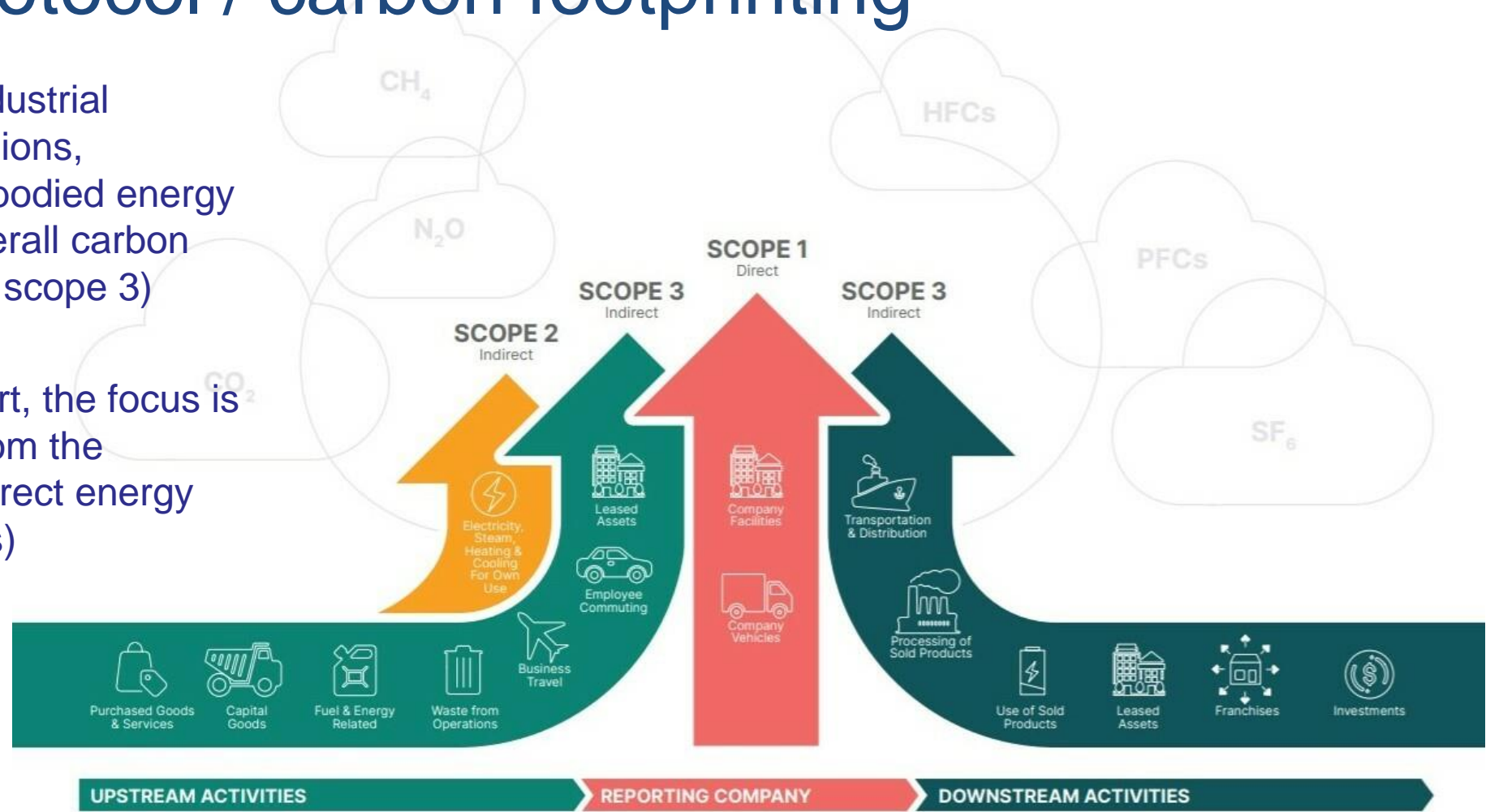
Goals of the EU for the year 2050 (Green Deal)



- Climate crisis has gained increasing importance in the recent years
- EU member states seek to transform their industry sector to reach near zero emissions until 2050
- Small improvements are not enough, radical innovations are necessary to decarbonize the industry
- As possible transformation leaders towards a green industry, specific industries face challenges but also rewarding chances

Carbon emission scopes according to the GHG protocol / carbon footprinting

- In energy intensive industrial sectors, indirect emissions, particularly due to embodied energy play a huge role in overall carbon footprint (scope 2 and scope 3)
- However, for this report, the focus is on direct emissions from the processes including direct energy input (e.g. for smelters)
→ **Scope 1**



<https://radiclebalance.com/resources/articles/reducing-scope-1-2-and-3-emissions>

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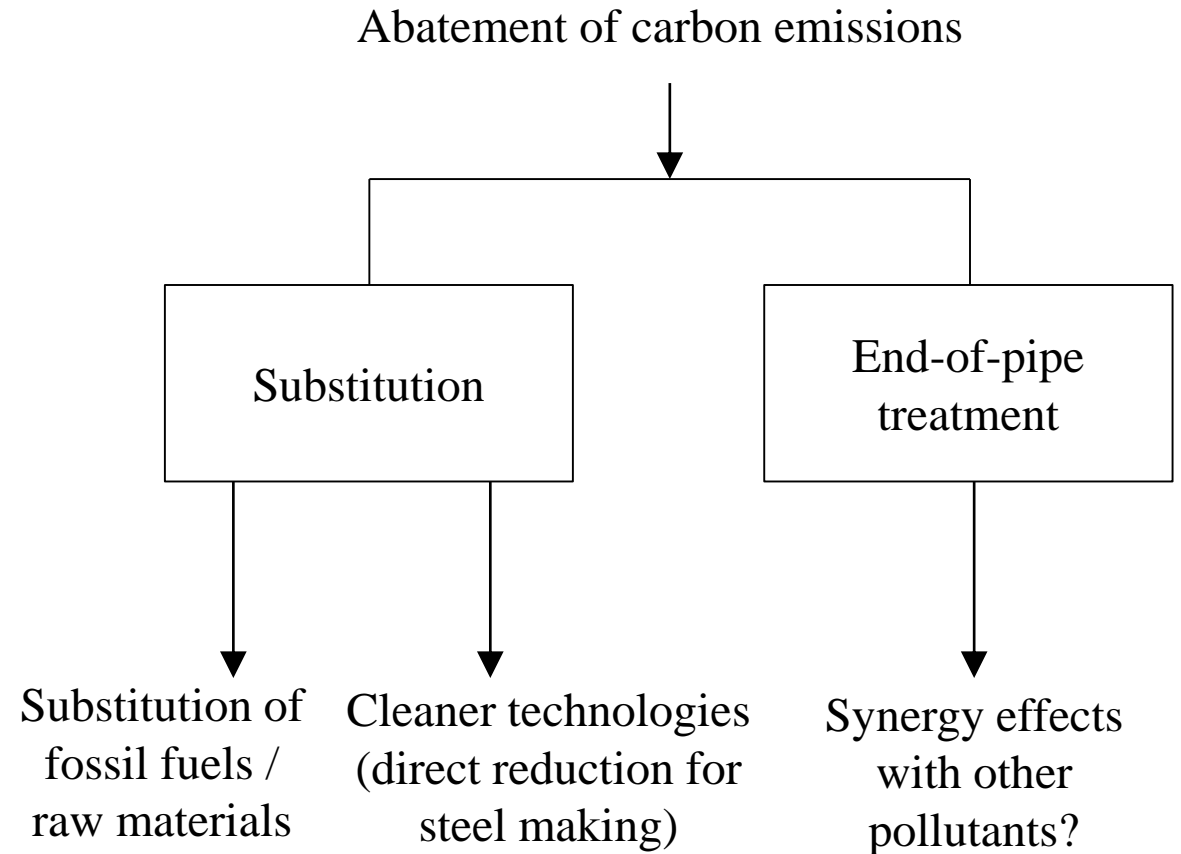
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2 basic effects of low carbon technologies on air pollutants from specific industries

1. Replacement: If parts of the process / processing chain are replaced by alternative technologies with lower carbon emissions, this directly affects the emission of other air pollutants from that sector:

- Replacement of blast furnaces with coke reduction in steel production by direct reduction with (green) hydrogen or natural gas
- Replacement of fossil fuels, e.g. for power generation

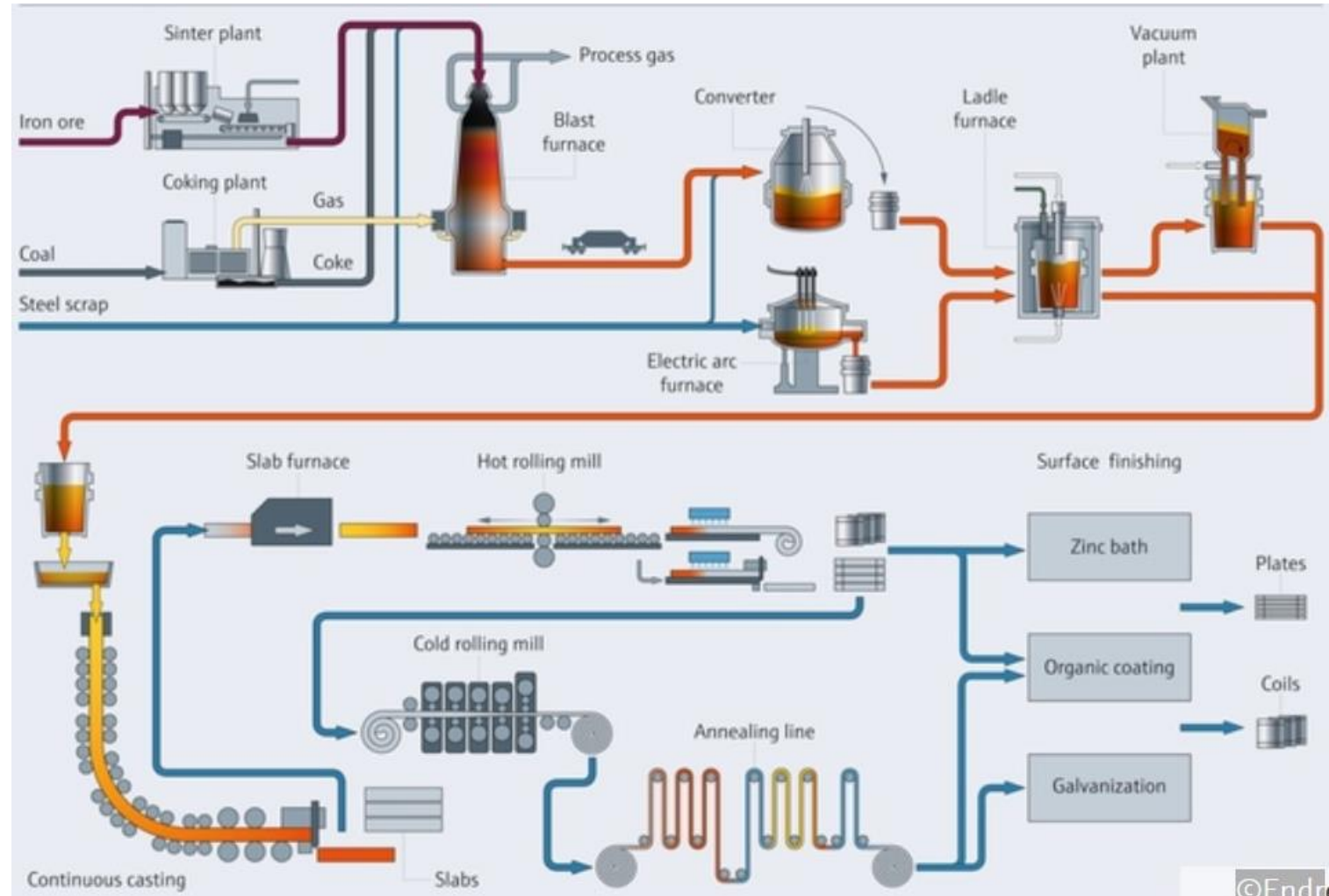
2. Synergies: End-of-pipe treatment to remove CO₂ from exhaust gases will also affect other pollutants: e.g. carbon capture and utilization (CCU) through absorption processes



<https://radiclebalance.com/resources/articles/reducing-scope-1-2-and-3-emissions>

Scheme of steel production from iron ore

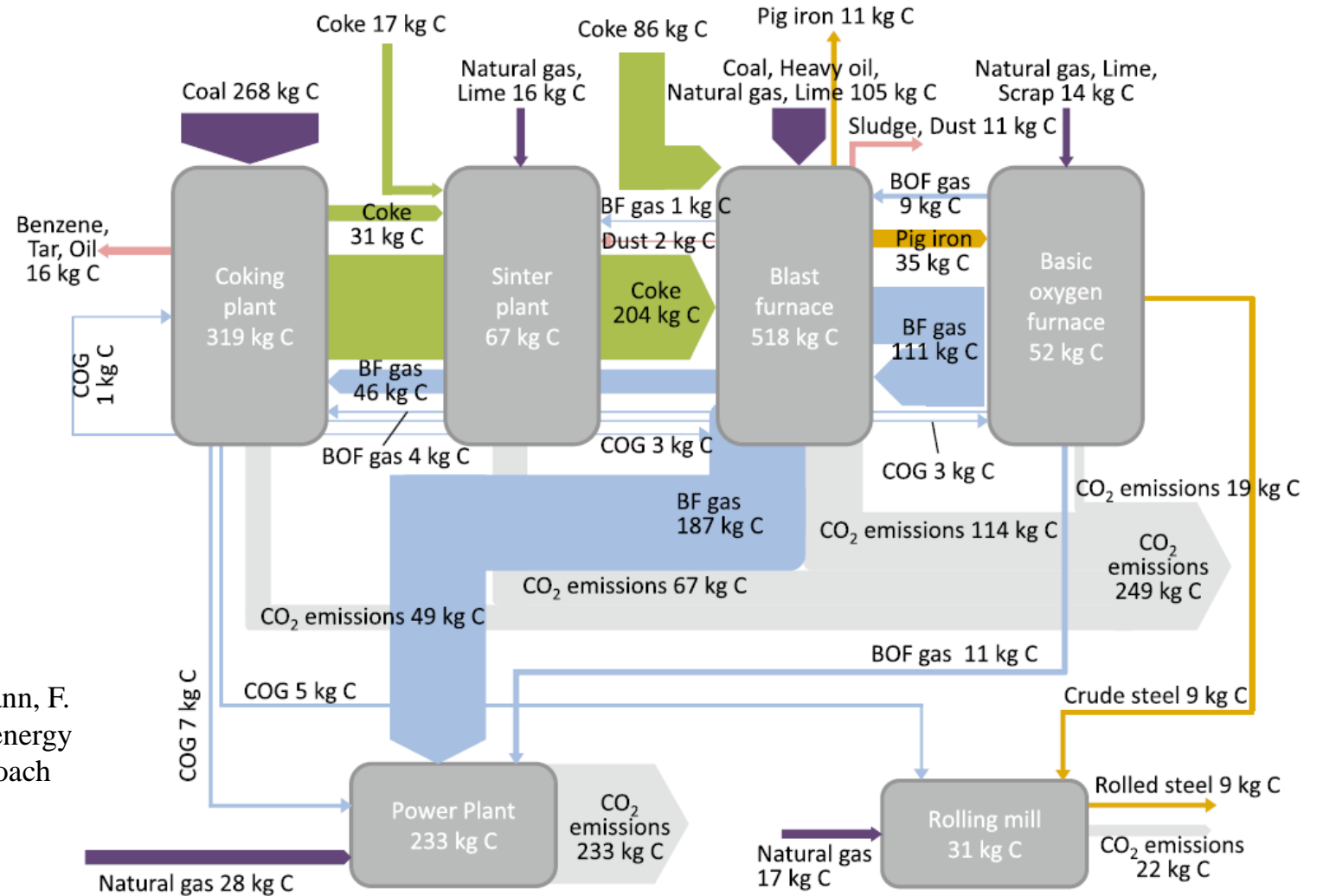
- Sinter plants agglomerate iron ore fines (dust) with other fine materials at high temperature, to create a product that can be used in a blast furnace.
- In the blast furnace, oxidic iron ore is reduced to iron by adding carbon (Coke) because oxygen has a higher affinity for carbon than for iron. → high CO₂ emissions
- The liquid metal is hardened afterward further melting steps in different furnaces and further processed to get different shapes



Source: Endress + Hauser, <https://www.lasc.endress.com/en/industry-expertise/mining-minerals-metals/Cost-efficient-steel-production>

Sankey diagram of carbon flows for an exemplary integrated steelwork (blast furnace)

- Direct CO₂ emissions per ton of steel produced:
 - 249 kg C → 913 kg CO₂
- Indirect emissions for power generation:
 - 233 kg C → 854 kg CO₂



Source: Breun, P., Fröhling, M., Zimmer, K., & Schultmann, F. (2017). Analyzing investment strategies under changing energy and climate policies: an interdisciplinary bottom-up approach regarding German metal industries. *Journal of Business Economics*, 87(1), 5-39.

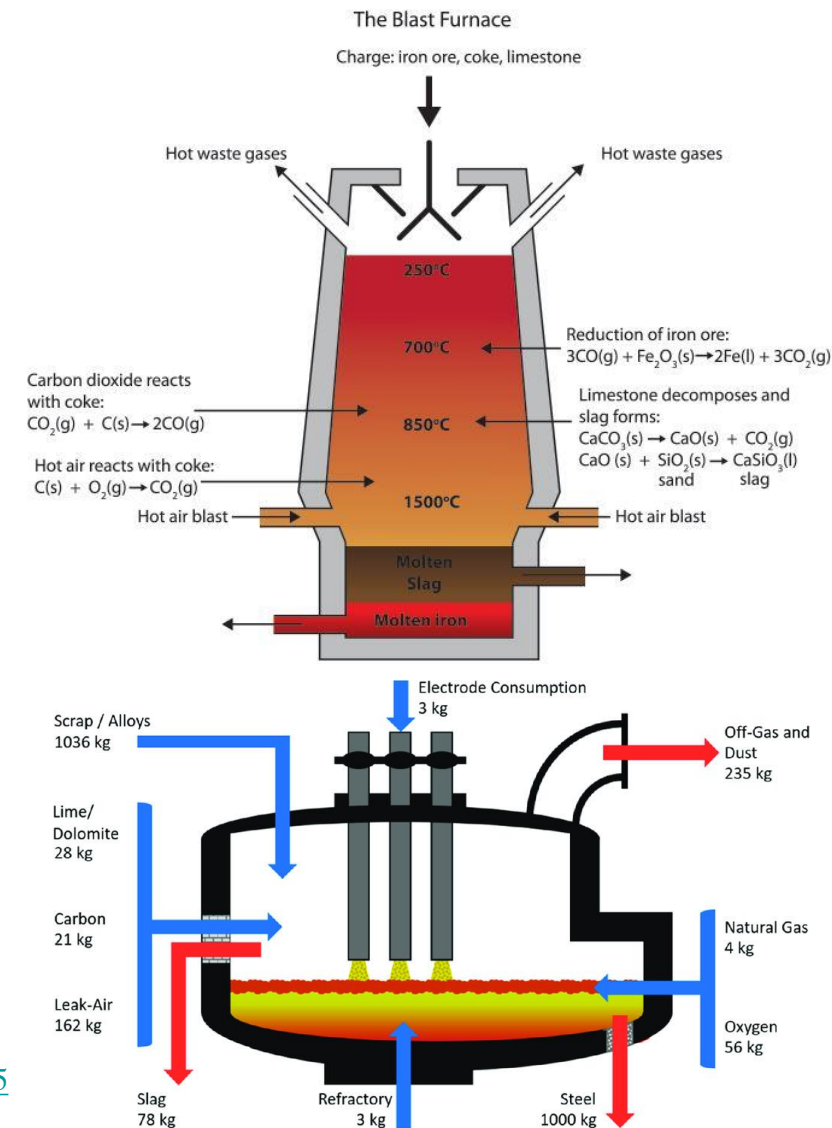
Two types of furnaces for steel production

Blast furnace (see depiction on the right):

- Coal is thermo-treated to produce coke
- Coke has a high concentration of carbon (90-93%) and therefore a high energy value and serves as a reduction agent for steelmaking
- extremely CO₂-intense

Electric arc furnace (commonly used for secondary steel making):

- In the electric arc furnace, steel scrap is melted through high-power electric arcs formed between a cathode and the anodes. The emissions levels are normally mainly related to the indirect emissions due to the high energy consumption of the process.
- Direct reduction of iron ore through natural gas or hydrogen also enables the use of electric arc furnaces for primary steel making



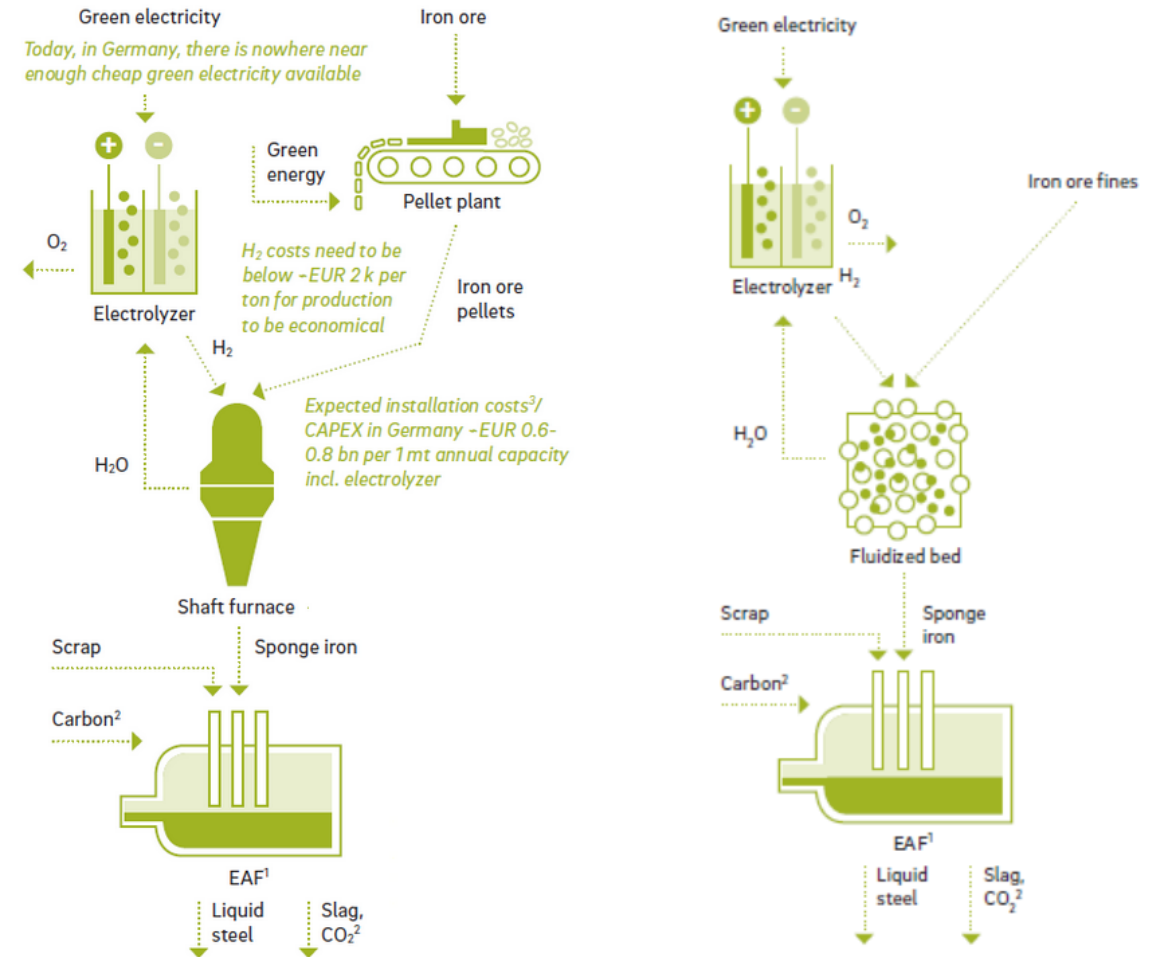
Source: American Iron and Steel Institute, <https://www.steel.org/steel-technology/steel-production/>
 Images: <https://www.metallics.org/pig-iron-bf.html> / <https://onlinelibrary.wiley.com/doi/10.1002/srin.202000395>

Avoiding emissions beforehand via Carbon Direct Avoidance (CDA) in the steel

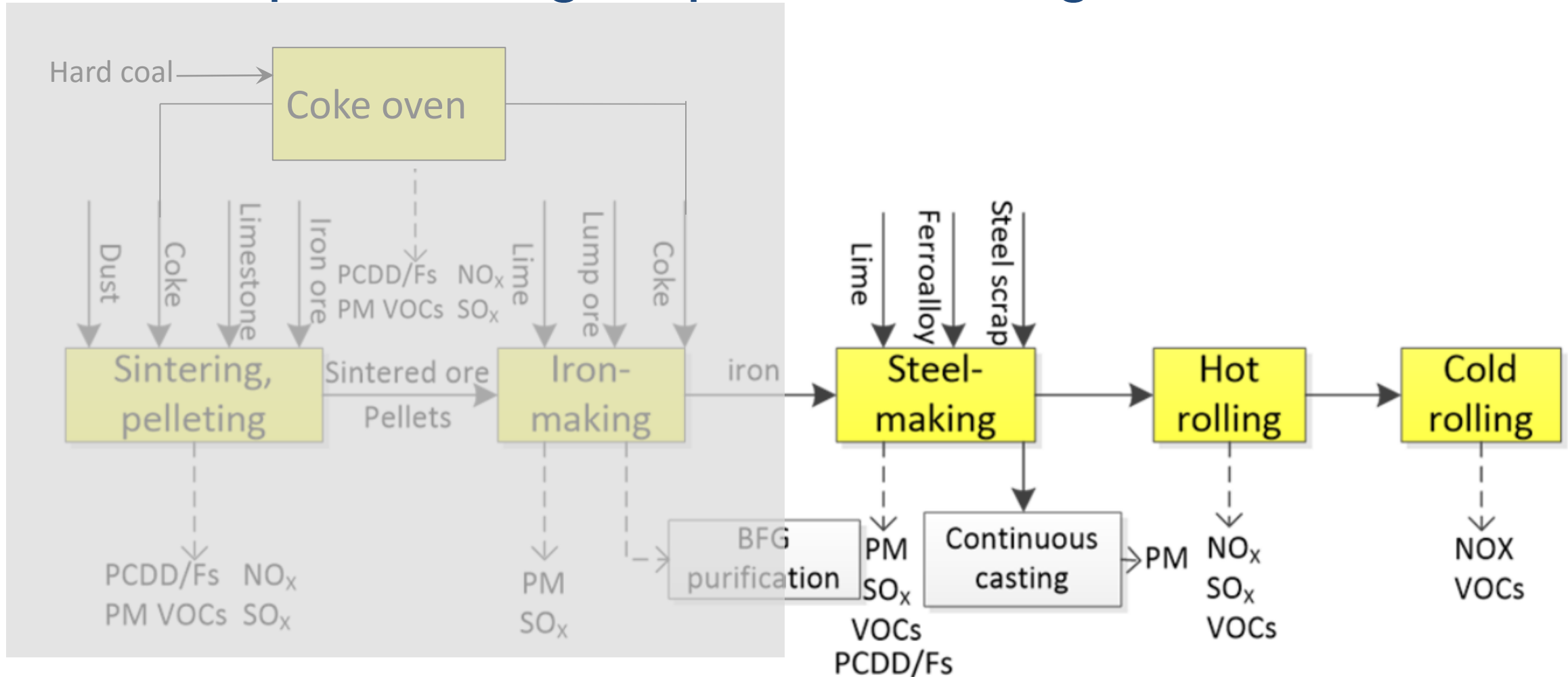
- Coke as a reduction agent in a blast furnace is very CO₂ intense
- Electric arc furnaces enable a significant reduction of CO₂ emissions for steel production **when using mainly renewable electricity**
 - The use of arc furnaces for primary steel production requires a direct reduction of iron ore through methane (natural gas) or hydrogen
 - To avoid fossil fuels and fossil carbon emissions, green hydrogen produced through electrolysis from renewable energy is necessary
 - However, producing green hydrogen as well as building an adequate infrastructure is **very costly**

Source: EUROFER: Low Carbon Roadmap, (2019); <https://de.ramboll.com/designing-the-new-normal/gruene-stahlindustrie-durch-wasserstoff>

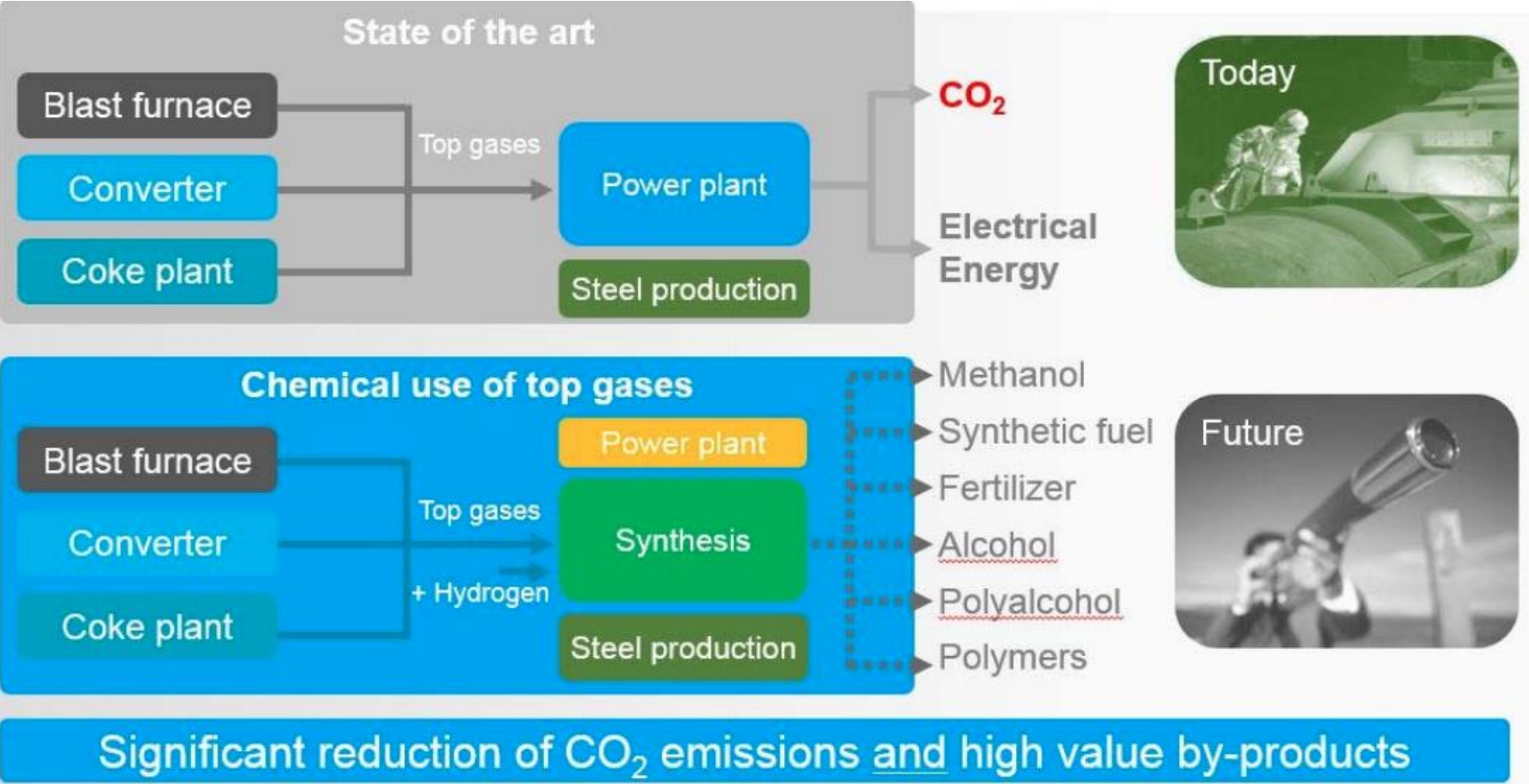
Image: <https://bellona.org/news/climate-change/2021-03-hydrogen-in-steel-production-what-is-happening-in-europe-part-one>



Reduction of emissions by modifying the processing steps / technologies



Carbon Capture and Utilization (CCU) on the example the Thyssenkrupp project Carbon2Chem



Carbon Capture Technologies

CO₂ Separation Technology

Absorption

- Monoethanolamine
- Teritiary Alkanolamine (e.g. Selexol, Rectisol)
- Enhanced chemical and physical absorption

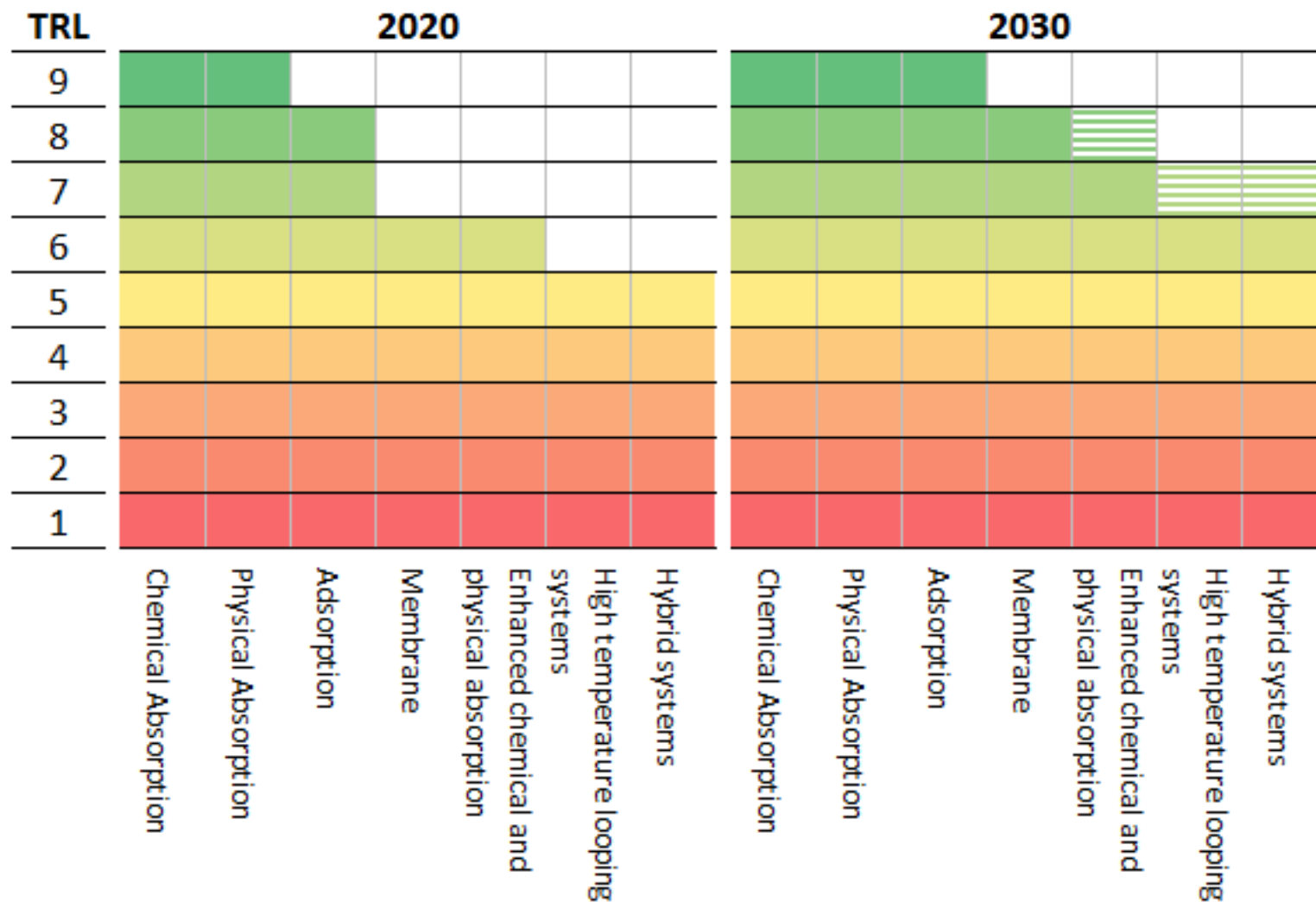
Adsorption

- Zeolite
- Carbon based materials
- Meta-organic frameworks

Membrane

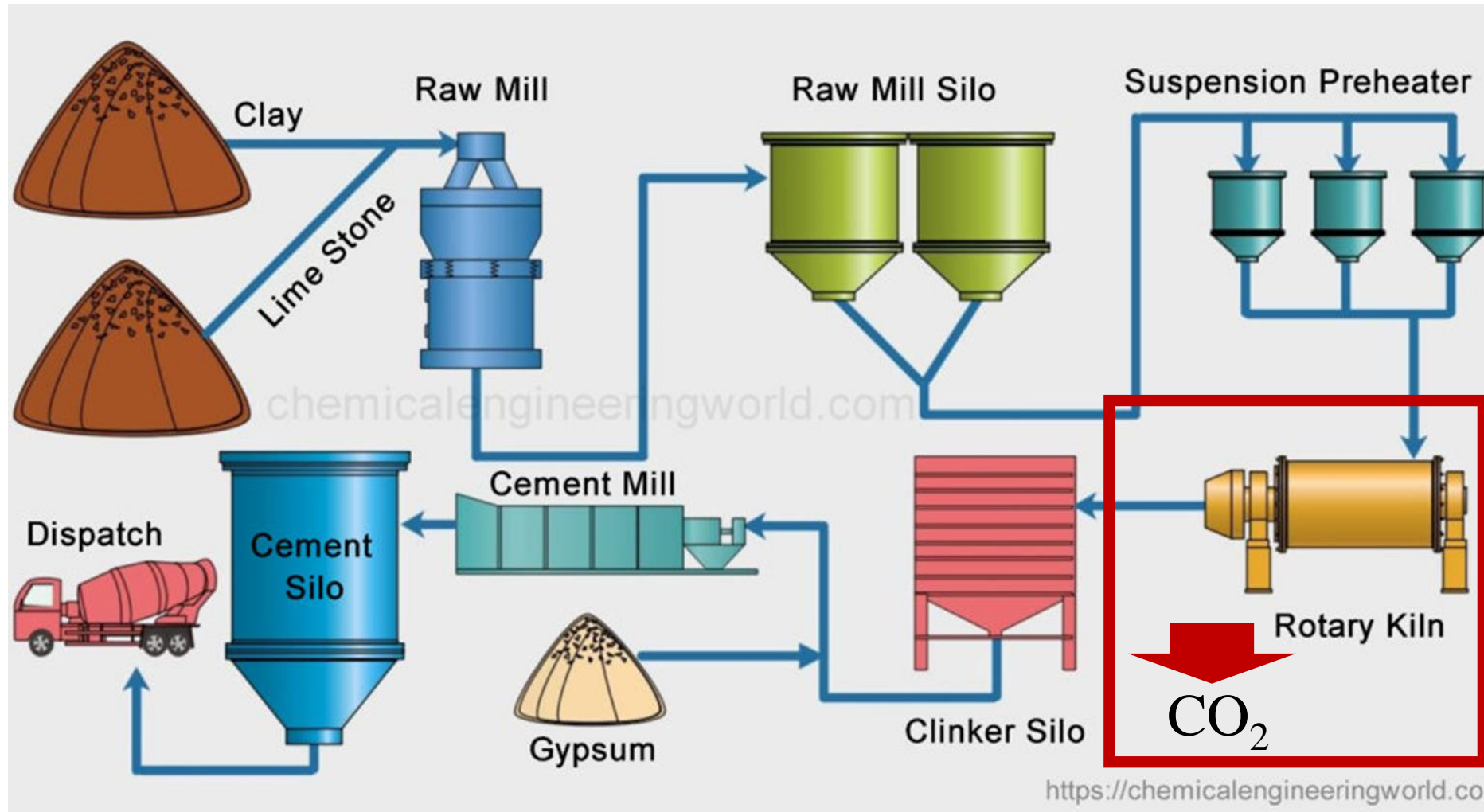
- Polymeric membrane (e.g. Polaris, PolyActive)
- Ceramic / Hybrid membrane

Chemical looping combustion system



Carbon Capture and Utilisation (CCU) and Carbon Capture and Storage (CCS)

- CCU and CCS are particularly or relevance for those processes where fossil CO₂ emissions are challenging to avoid
- Process related emissions vs. energetic CO₂ emissions
- Cement industries will have high challenges to avoid CO₂
- ➔ CCU/CCS of specific relevance



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- Five sectors to be assessed: cement industries, steel production, glass industries, aluminium production, selected processes from chemical industries (e.g. refineries) with description of (new) processes and their developments
 - Direct reduction of steel
 - CCU / CCS
 - Substitution of fossil fuels
 - (Green) hydrogen in chemical industries / glass industries...
- Document will be spread among TFTEI experts early 2023


➔ Feedback is very welcome!


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Thank you very much
for your attention!
Questions?

TFTEI Technical Secretariat

