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

TFTEI technical secretariat
Simon Glöser-Chahoud (TU BAF)

dfiu
KIT Karlsruher Institut für Technologie
CITEPA

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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
   - Refineries
   - Glass production
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 in 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**
  - Four sectors to be assessed: **cement industries, steel production, glass industries**, 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 2023

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

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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 CO_2 – eq.

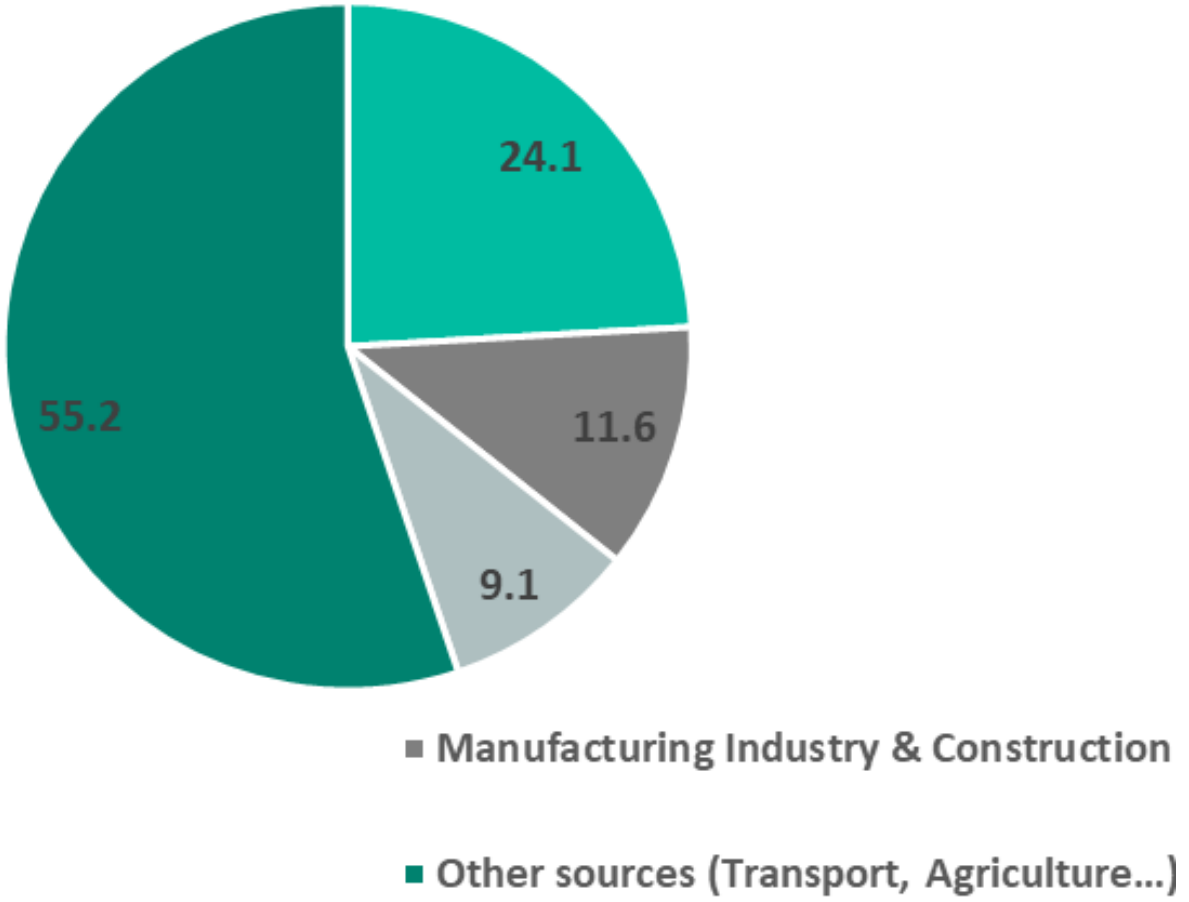
The biggest emitter in the EU is Germany:

- Emissions in 2019:

~0.81 Mt CO_2 – eq.

- Emissions in 2020:

~0.74 Mt CO_2 – 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 CO_2 emissions of the industry sector in Germany (in million t CO_2 – equivalent)

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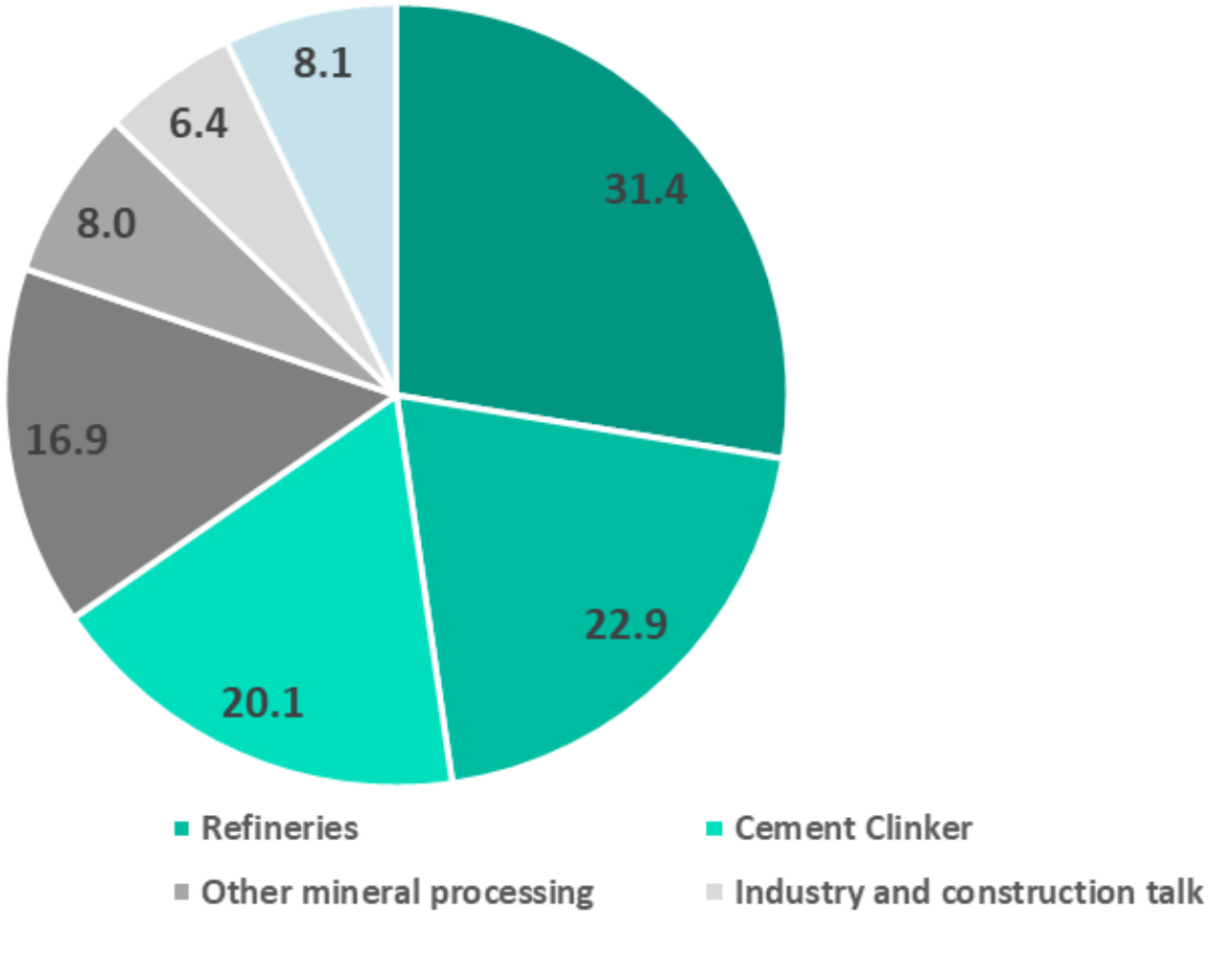

Source: Umweltbundesamt, Treibhausgasemissionen 2021

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

- Climate crisis has gained increasing importance in recent years
- EU member states seek to transform their industry sector to reach near zero emissions until 2050 (some member states have even more ambitious goals)
- 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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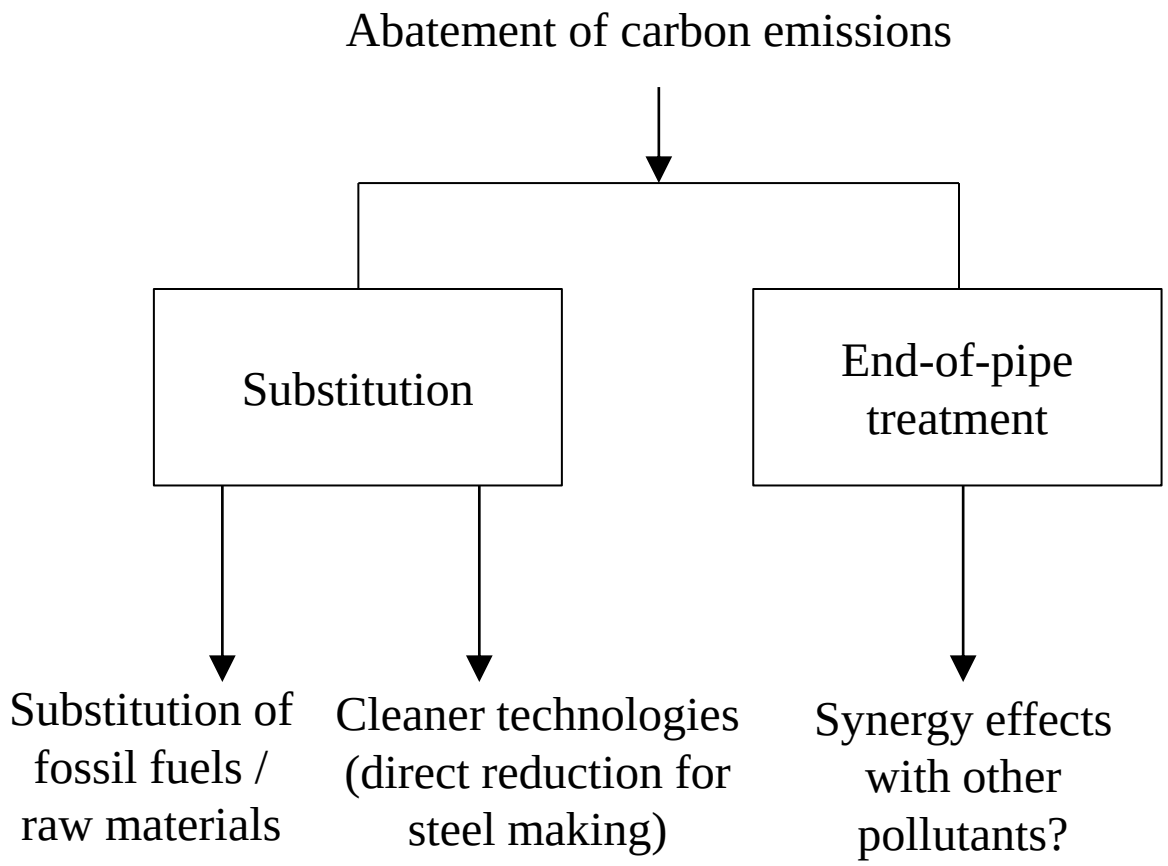
2 basic effects of low carbon technologies on air pollutants from specific industries

1. **Substitution / 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

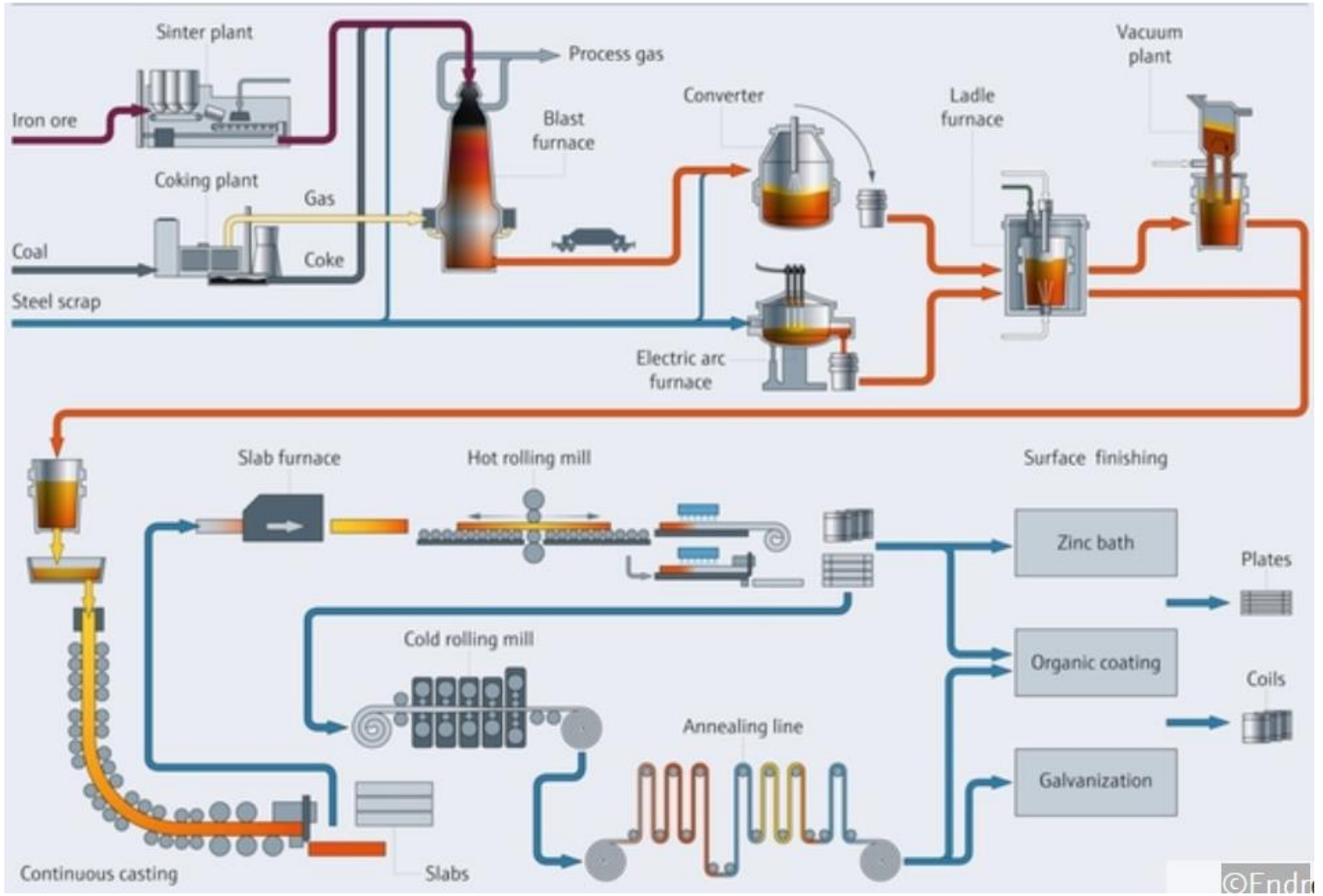
2. **Synergies:** End-of-pipe treatment to remove CO_2 from exhaust gases will also affect other pollutants: e.g. carbon capture and utilization (CCU) through absorption processes



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

Scheme of steel production from iron ore

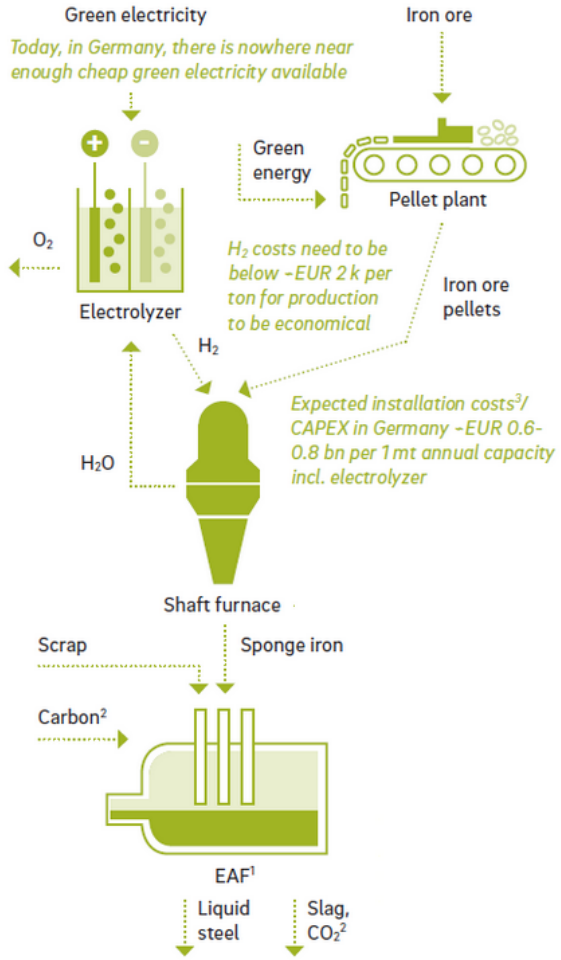
- Sinter plants agglomerate iron ore fines (dust) with other fine materials at high temperature, to create a product that can be used in a blast furnace.
- In the blast furnace, oxidic iron ore is reduced to iron by adding carbon (Coke) because oxygen has a higher affinity for carbon than for iron.→ high CO_2 emissions
- The liquid metal is hardened afterward further melting steps in different furnaces and further processed to get different shapes

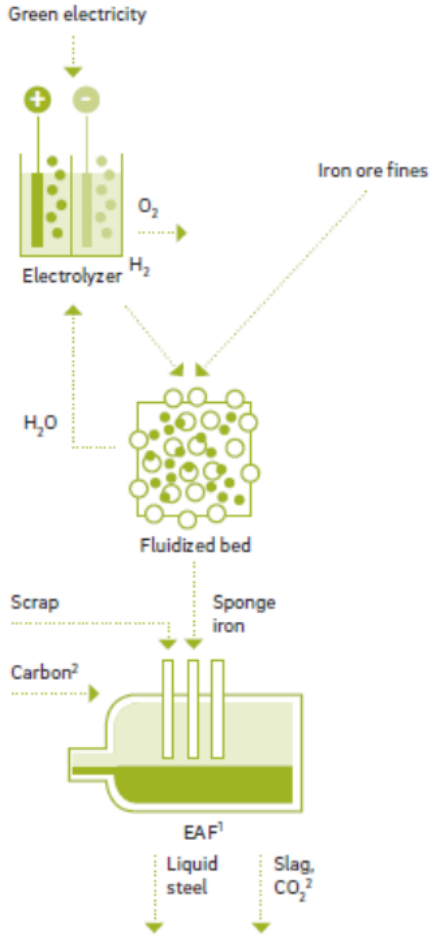


Source: Endress + Hauser, https://www.lasc.endress.com/en/industry-expertise/mining-minerals-metals/Cost-efficient-steel-production

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

- Coke as a reduction agent in a blast furnace is very CO_2 intense
- Electric arc furnaces enable a significant reduction of CO_2 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

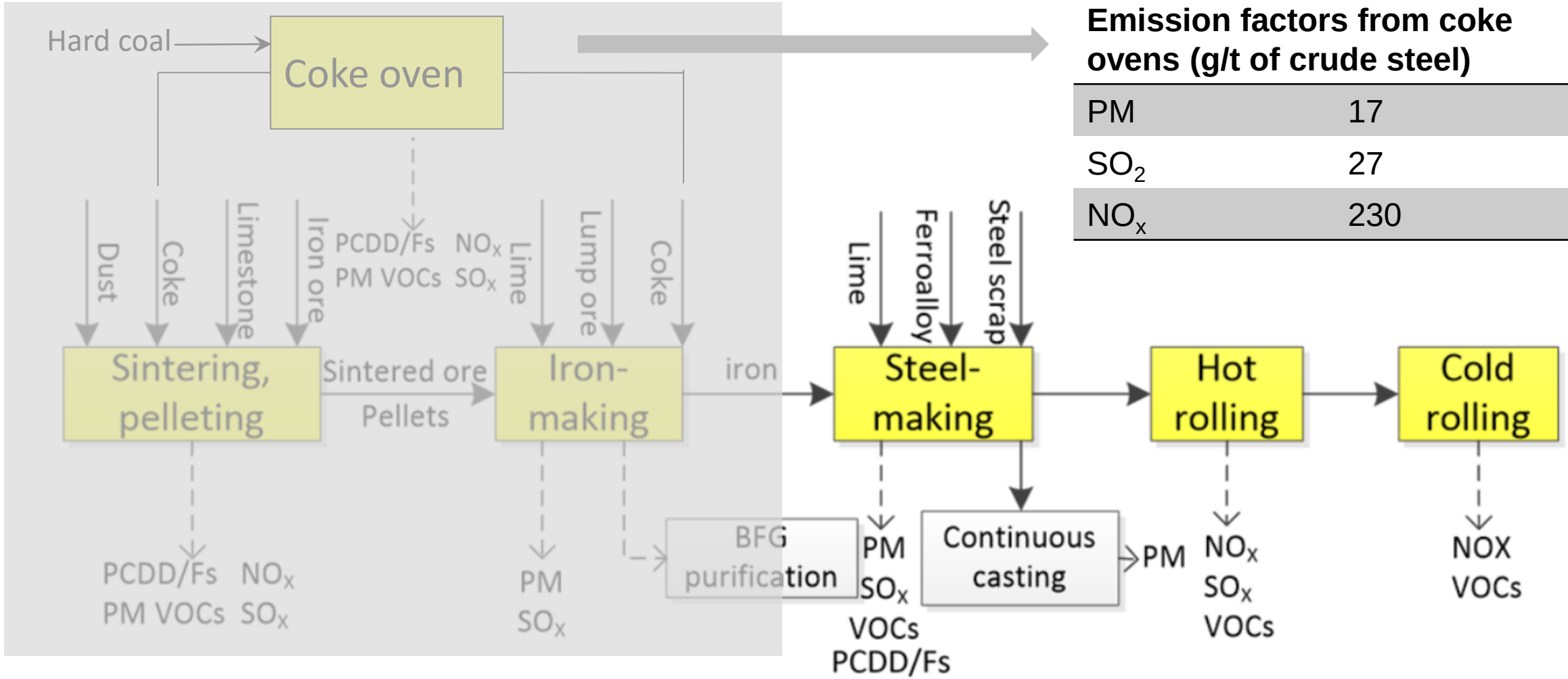




Source: EUROFER: Low Carbon Roadmap, (2019); https://de.ramboll.com/designing-the-new-normal/gruene-stahlindustrie-durch-wasserstoff

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

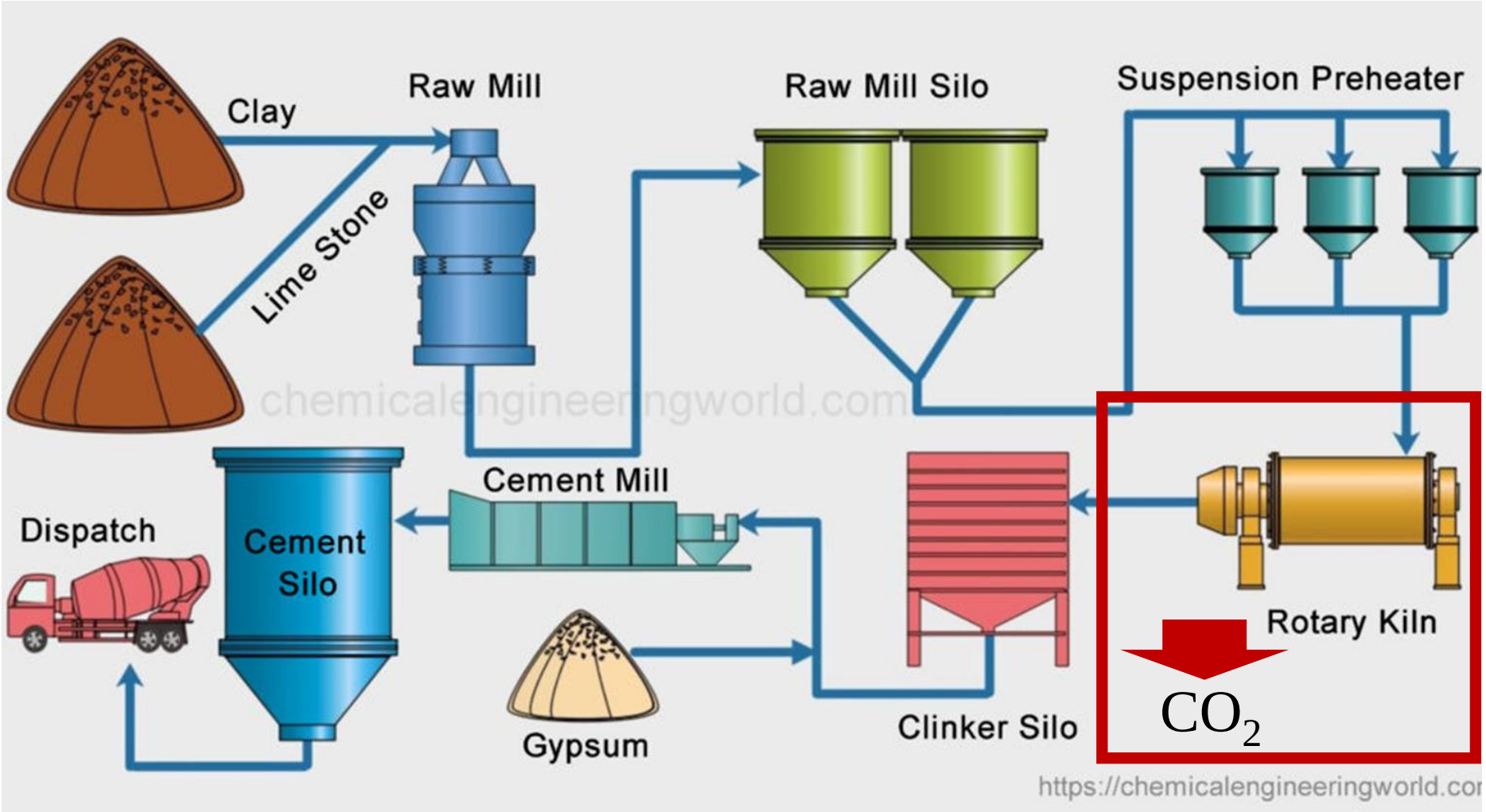


Emission factors from coke ovens (g/t of crude steel)	
PM	17
SO_2	27
NO_x	230

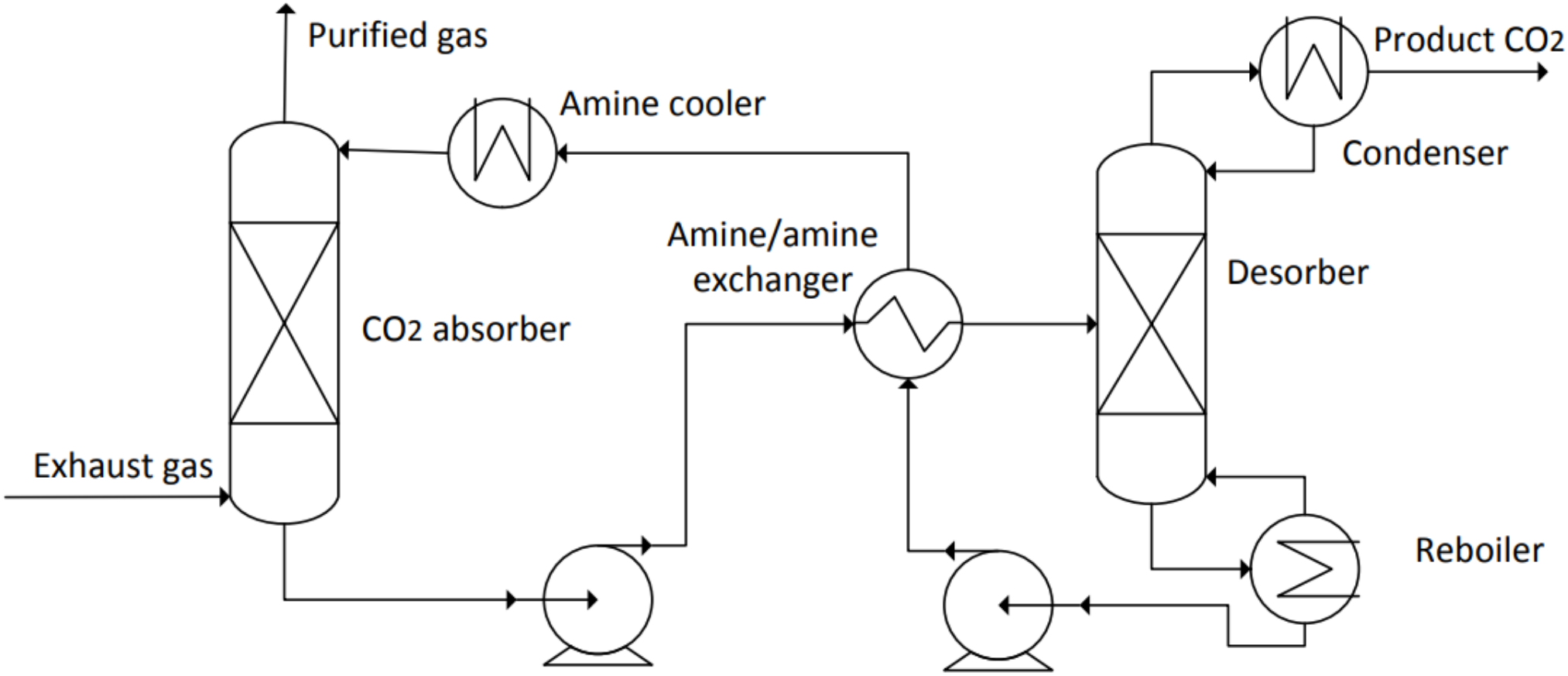
https://aaqr.org/articles/aaqr-15-01-oa-0029.pdf

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

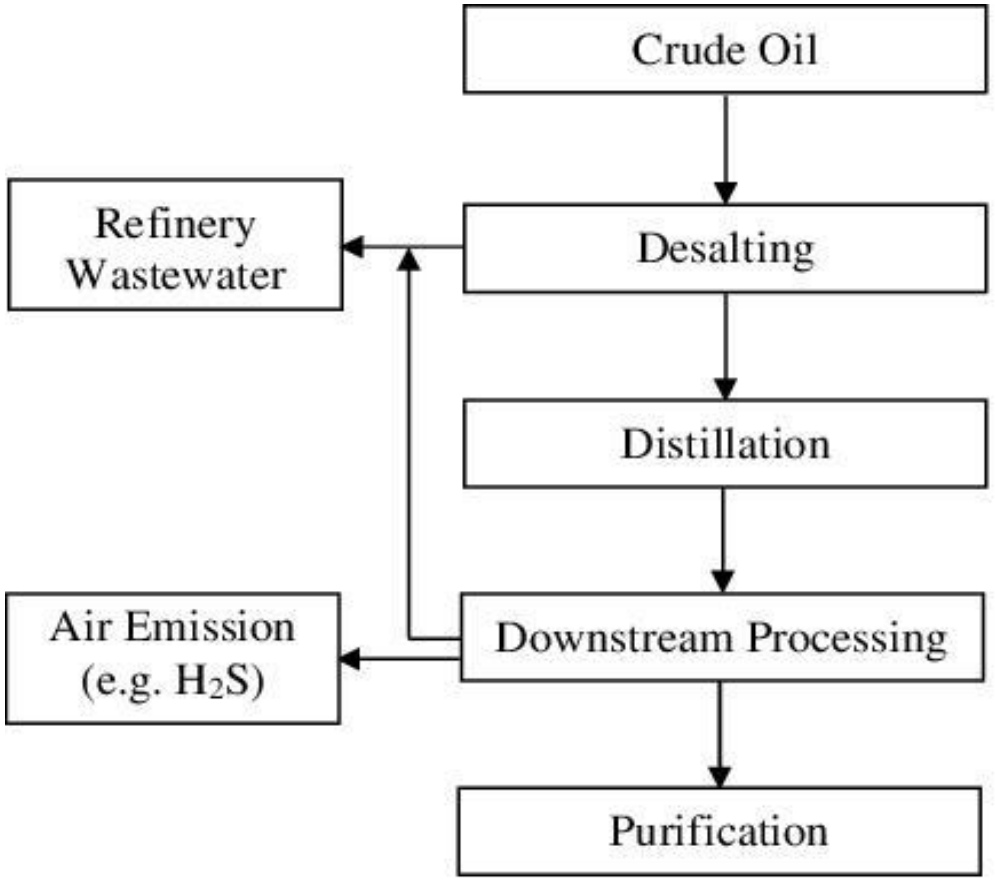
- CCU and CCS are particularly or relevance for those processes where fossil CO_2 emissions are challenging to avoid
- Process related emissions vs. energetic CO_2 emissions
- Cement industries will have high challenges to avoid CO_2
- CCU/CCS of specific relevance

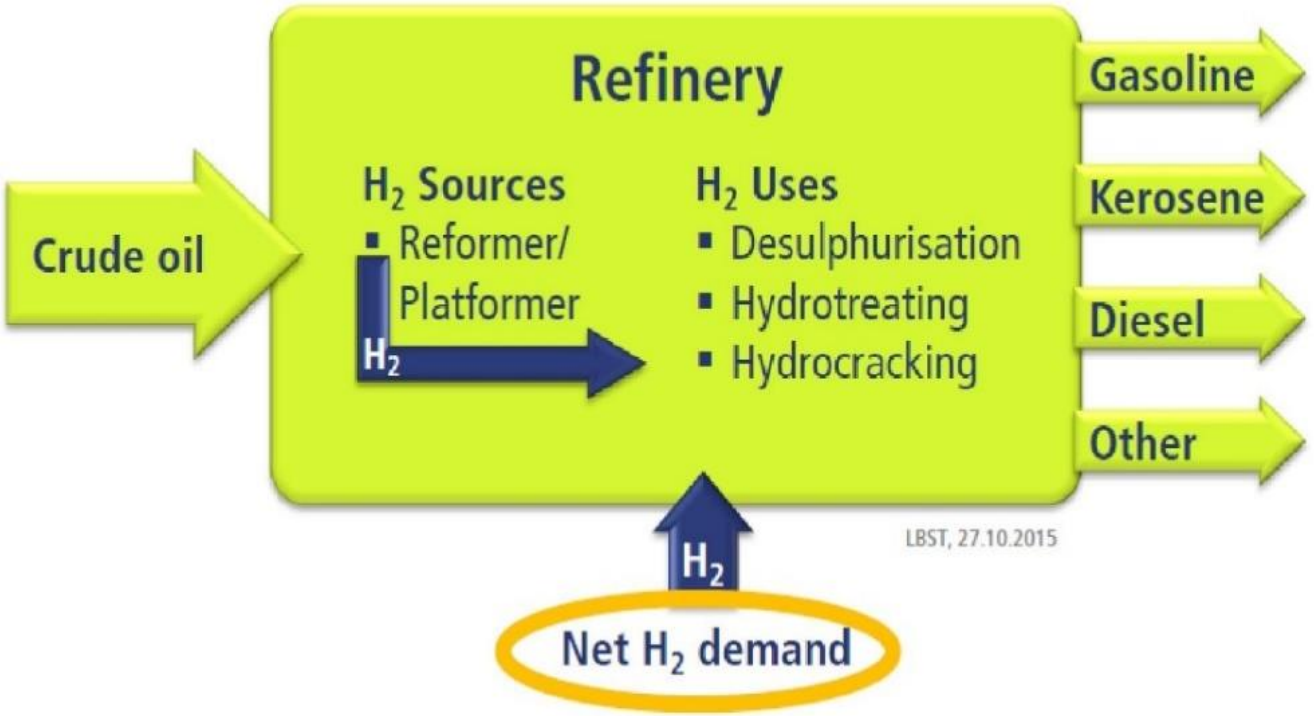


CO_2 removal based on absorption and desorption in amine solution

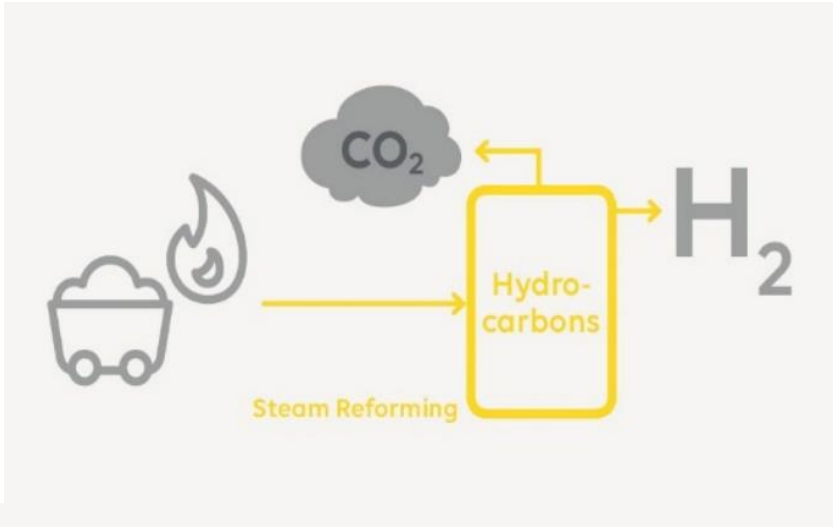


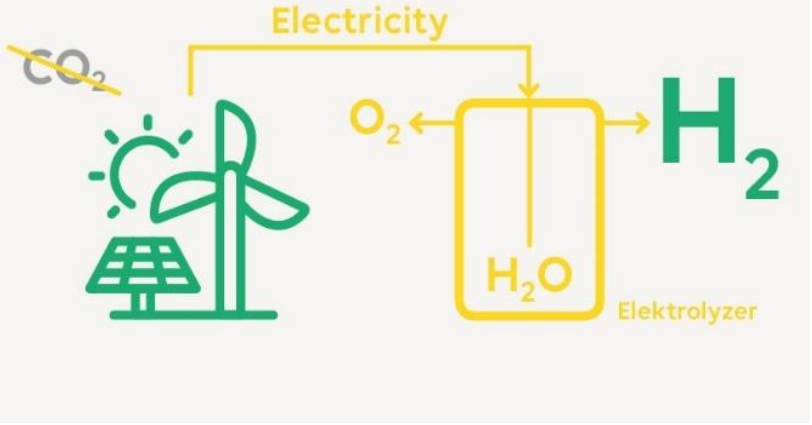
GHG emission reduction in oil refineries I

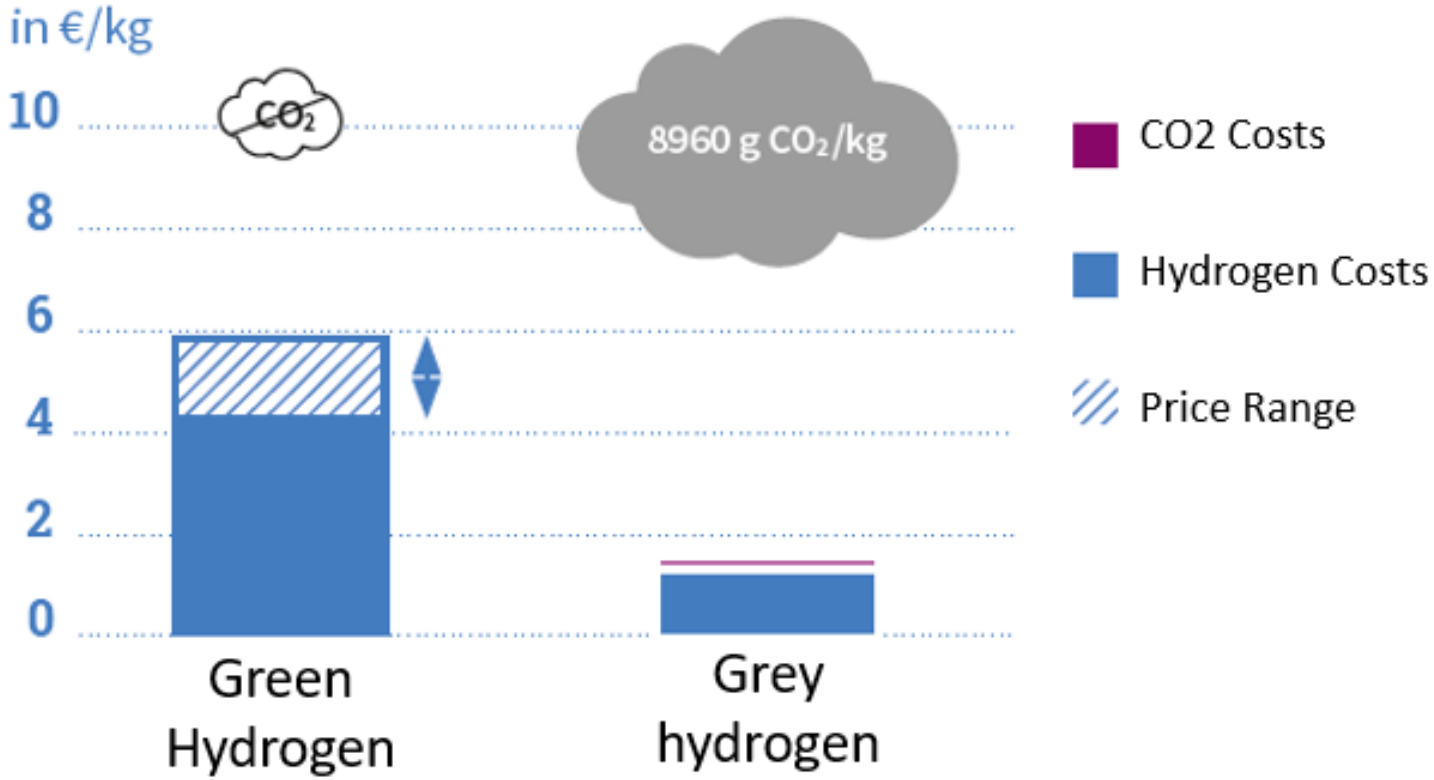




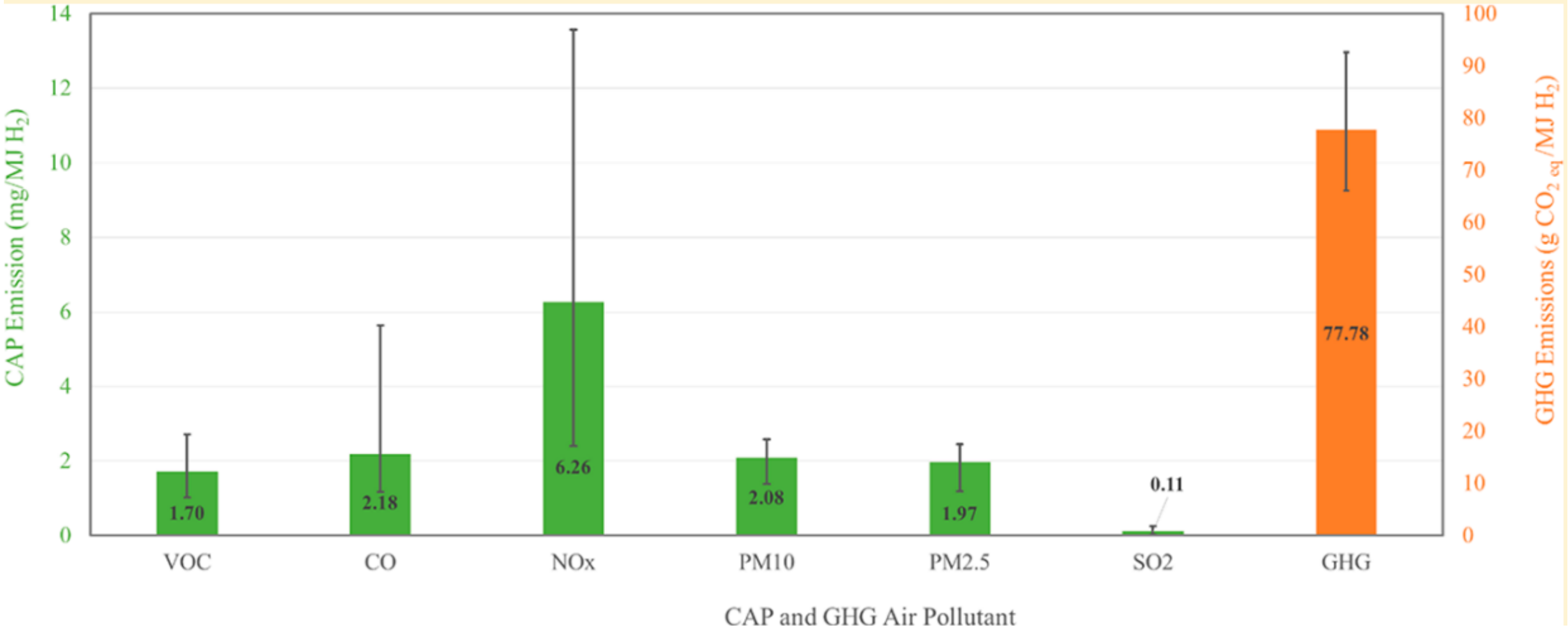
GHG emission reduction in oil refineries II



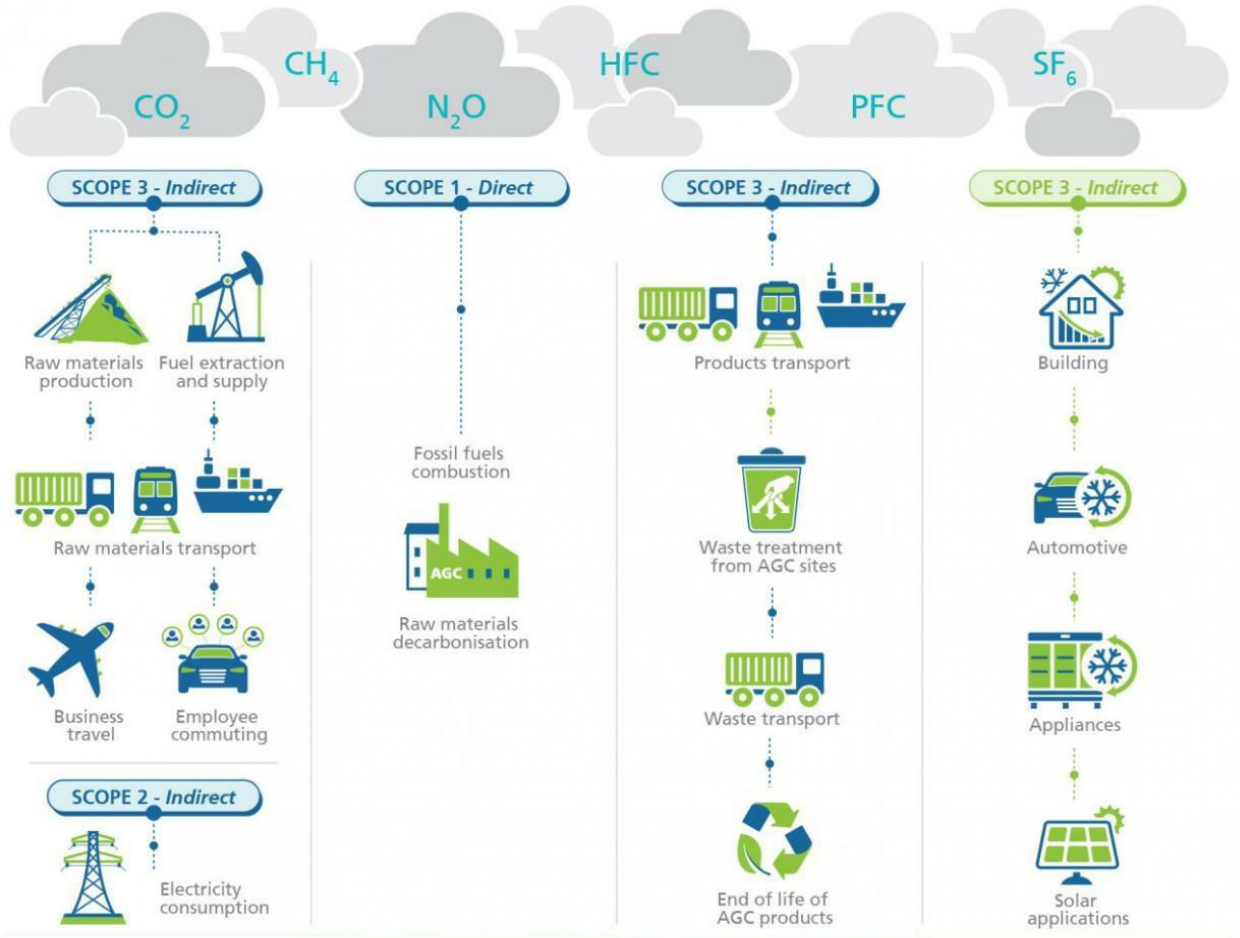




Emissions from Steam Reforming



Glass production and related emissions



- Direct process related emissions from glass production mainly come from fossil fuel combustion (NO_x, SO_x, PM)
- Carbon neutral glass production will very likely use green hydrogen as a fuel
- Reduction of emissions from fossil fuel combustion:
  - NO_x: 1000-2000 mg / Nm^3
  - SO_2: 700-1800 mg / Nm^3

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Technical background document

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- Four sectors to be assessed: cement industries, steel production, glass industries, selected processes from chemical industries (e.g. refineries) with description of (new) processes and their developments
  - Direct reduction of steel
  - CCU / CCS after scrubbing of CO_2
  - Substitution of fossil fuels
  - (Green) hydrogen in chemical industries / glass industries…
- Document will be spread among TFTEI experts in 2023

➡ **Feedback is very welcome!**


Background informal technical document on
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Thank you very much for your attention! Questions?

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Carbon Capture Technologies

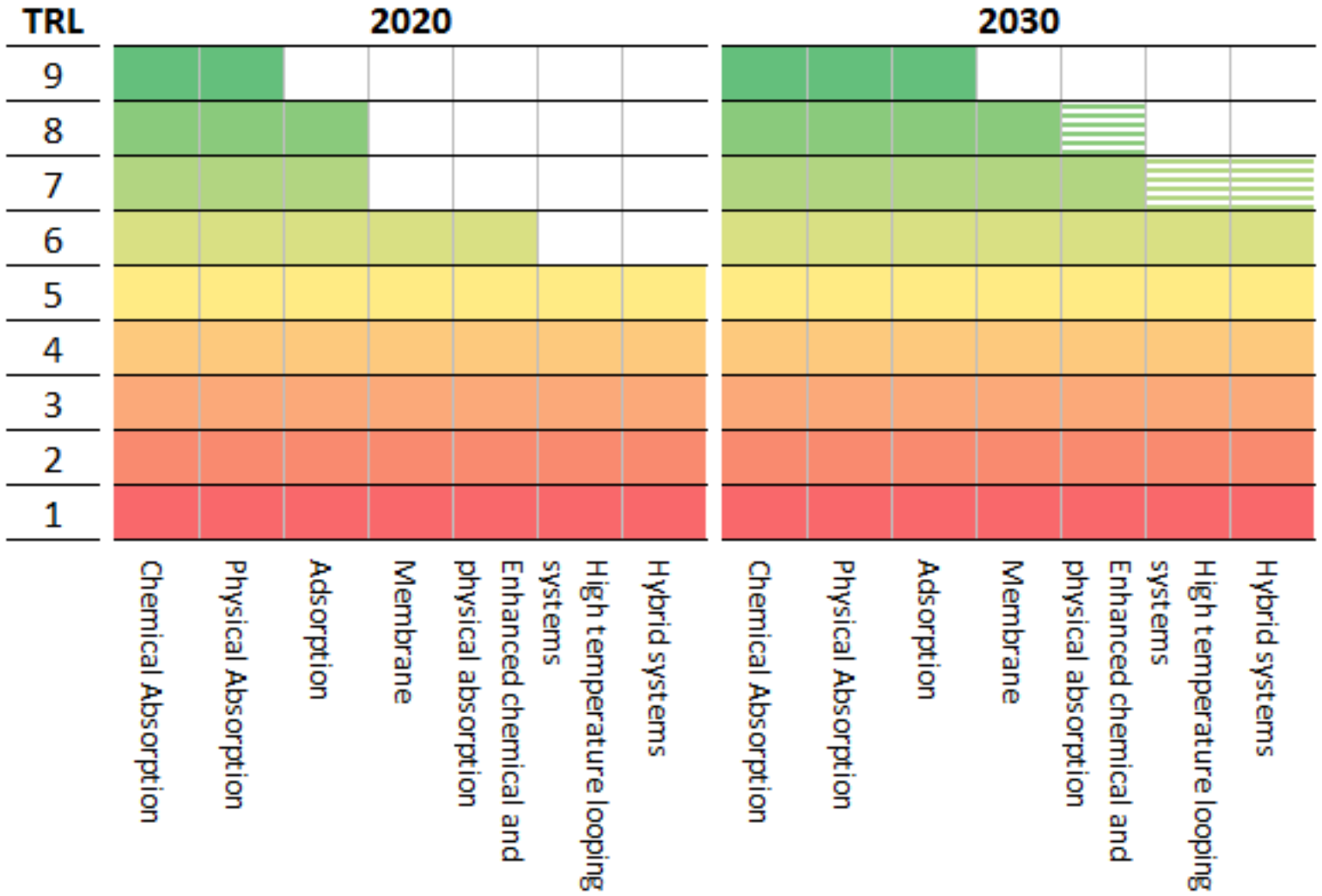
CO_2 Separation Technology

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

Adsorption
- Zeolite
- Carbon based materials
- Meta-organic frameworks

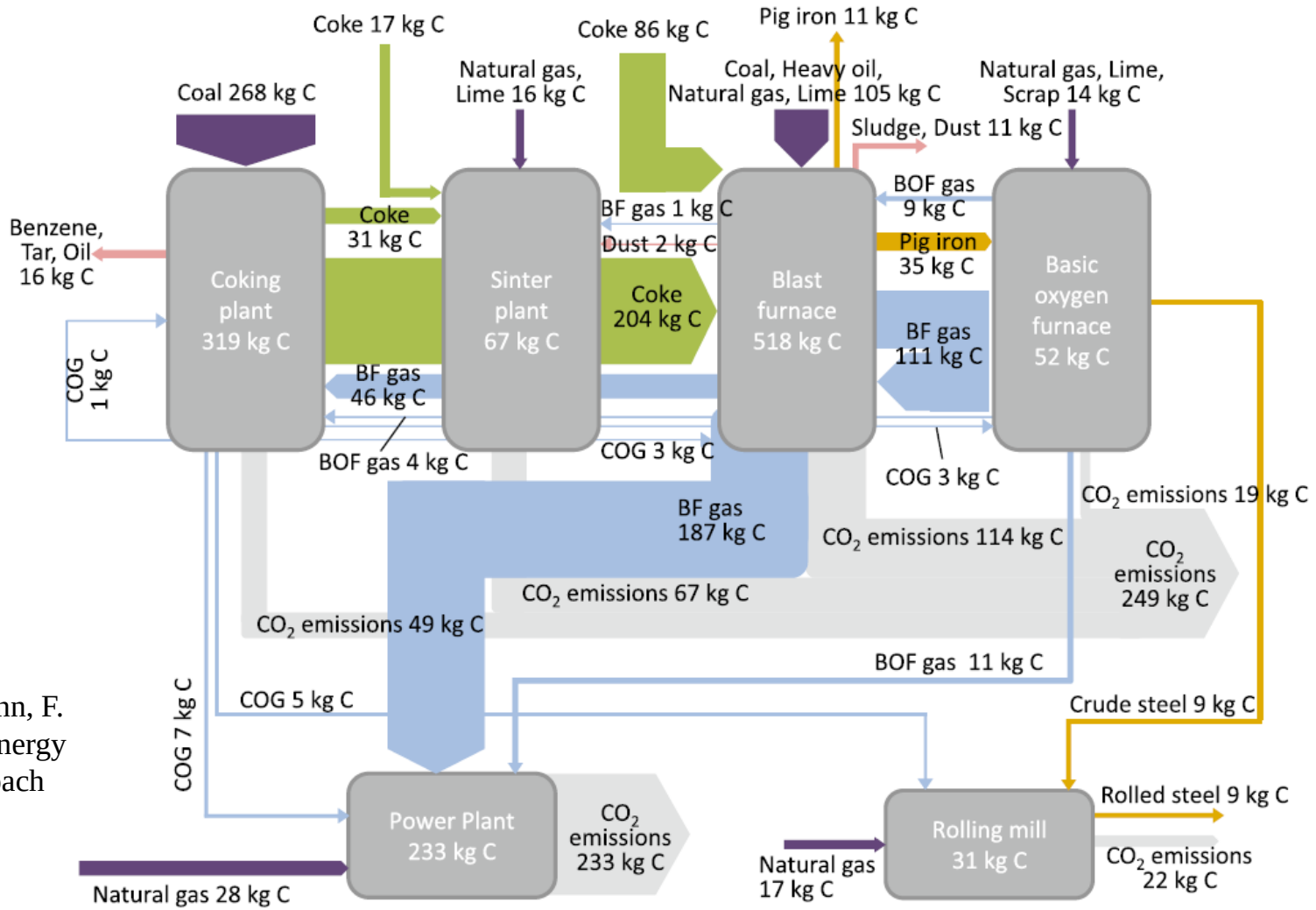
Membrane
- Polymeric membrane (e.g. Polaris, PolyActive)
- Ceramic / Hybrid membrane

Chemical looping combustion system



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

- Direct CO_2 emissions per ton of steel produced:
  - 249 kg C → 913 kg CO_2
- Indirect emissions for power generation:
  - 233 kg C → 854 kg CO_2



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.

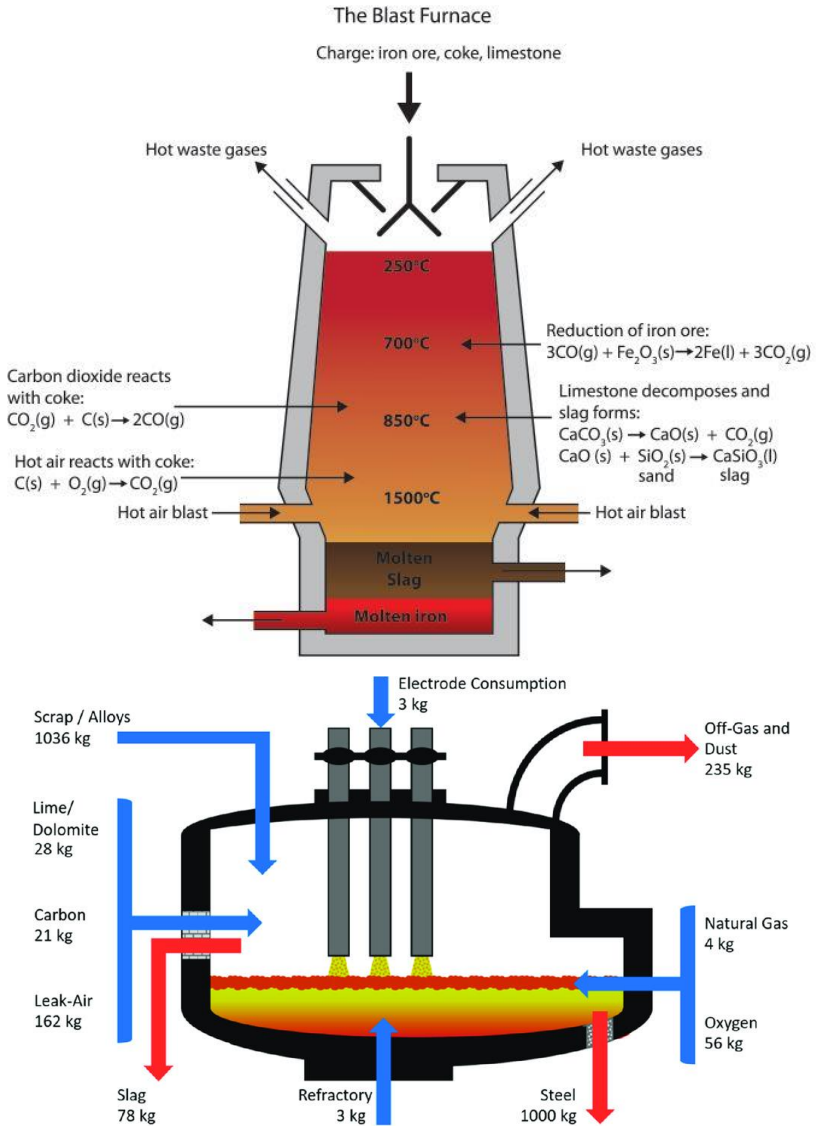
Two types of furnaces for steel production

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 CO_2-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