Programm

Die Dekarbonisierung der Industrie in Deutschland und Frankreich
Montag, 17. April 2023

Hannover Messe 2023
Messegelände, Hermes Allee
30521 Hannover

Energy 4.0 Bühne - Halle 12, Stand D 35

Das Side Event wird von Sven Rösner (DFBEW) moderiert. Es wird auf Französisch und Deutsch verdolmetscht. Anmeldungen auf www.dfbew.eu

DECARBONIZATION OF THE GLASS INDUSTRY IN GERMANY

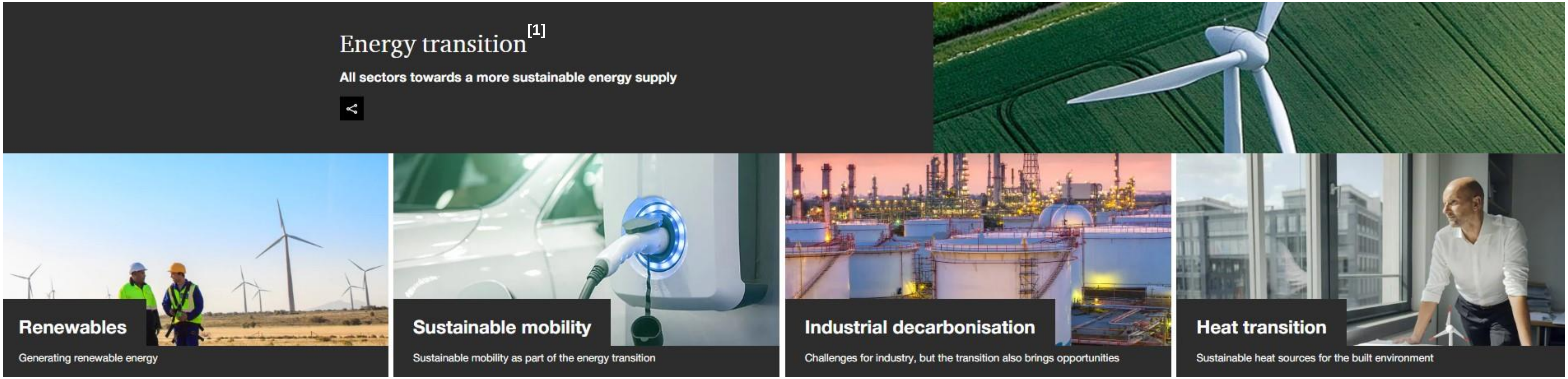
Example for the decarbonization of global basic industry?

Francisco Moser, Yoga Rahmat, Julia Weyand,
Ralph-Uwe Dietrich,
Ferdinand Drünert, Bernhard Fleischmann,

DLR

Energy transition demand – Affecting the entire society

Global emissions 2022[2]: 36.8 Gt_{CO2} (New annual peak!)



[1] https://www.pwc.nl/en/topics/sustainability/energy-transition.html
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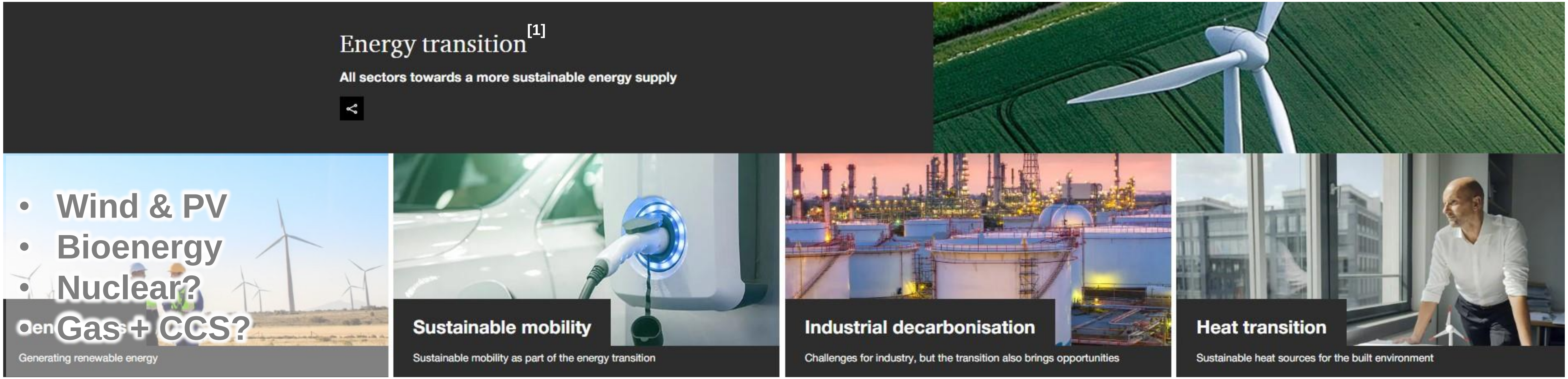

- Wind & PV
- Bioenergy
- Nuclear?
- Gas + CCS?

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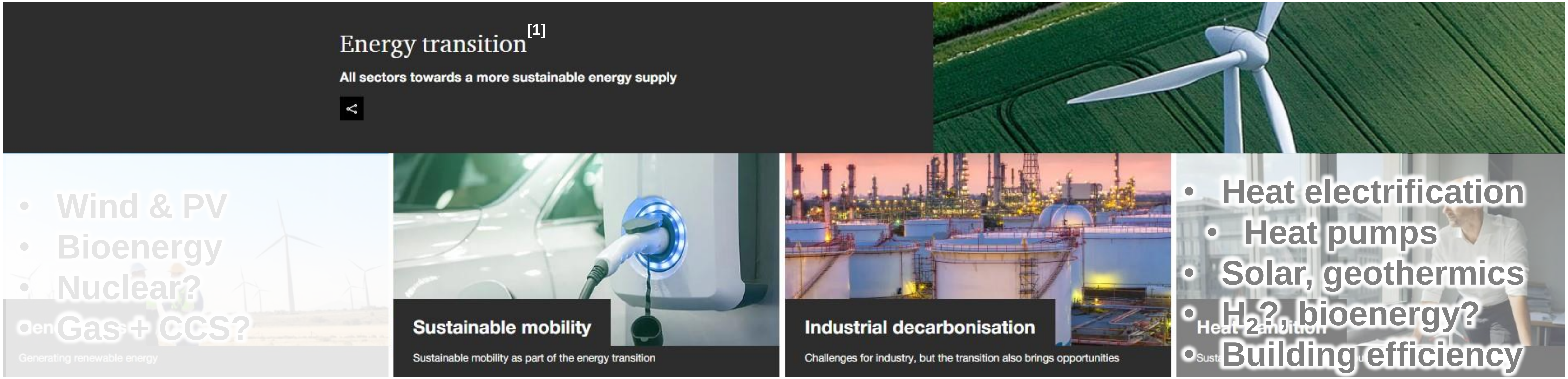

- Wind & PV
- Bioenergy
- Nuclear?
- Gas + CCS?

- Heat electrification
  - Heat pumps
- Solar, geothermics
- H_2?, bioenergy?
- Building efficiency

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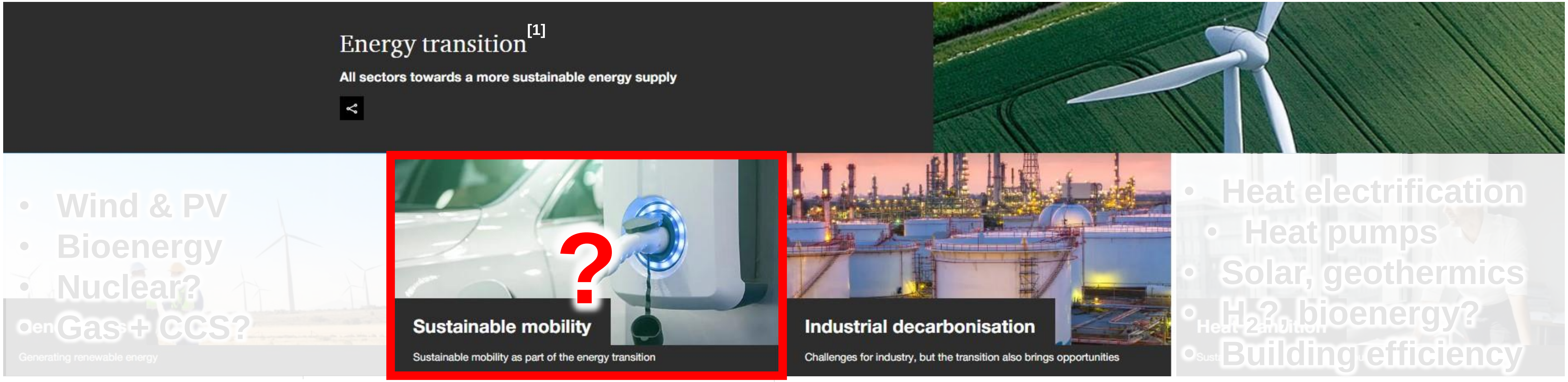
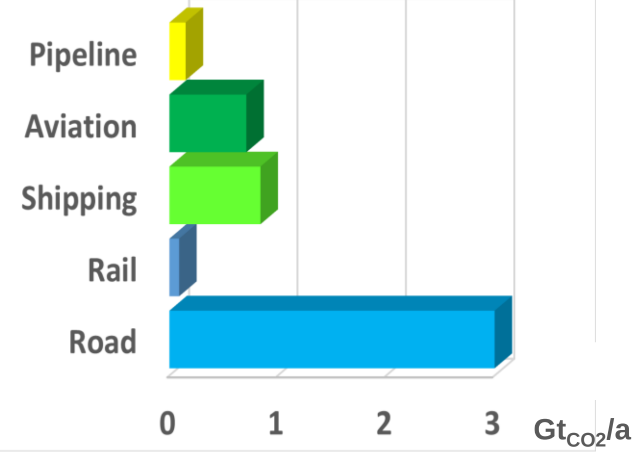


Global transport 2022[2]: 8.0 Gt_{CO2} (ca. 22 %)



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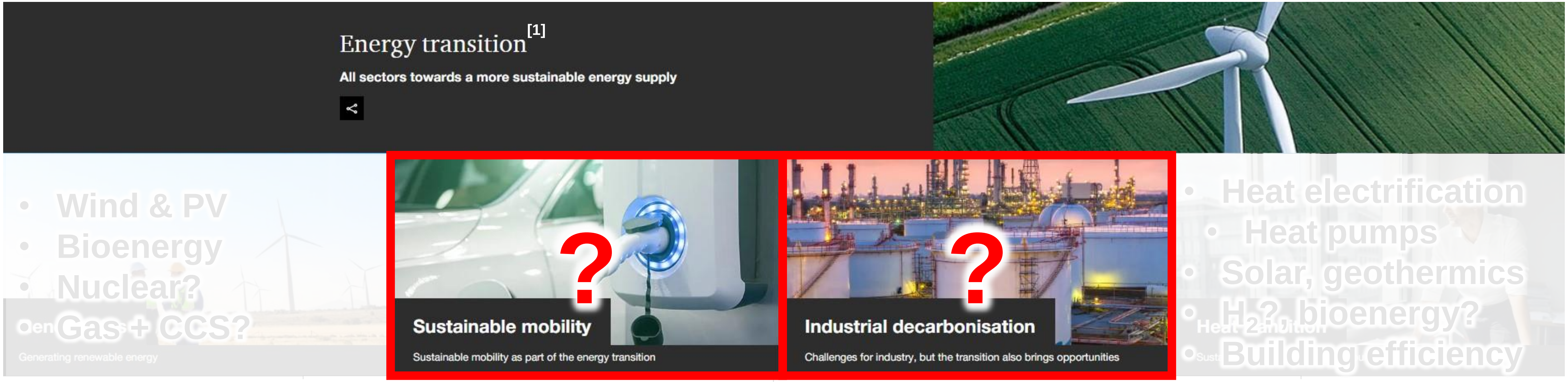

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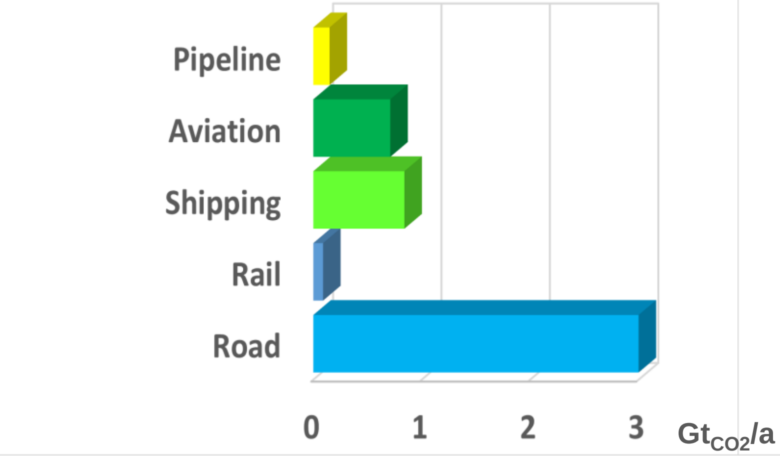
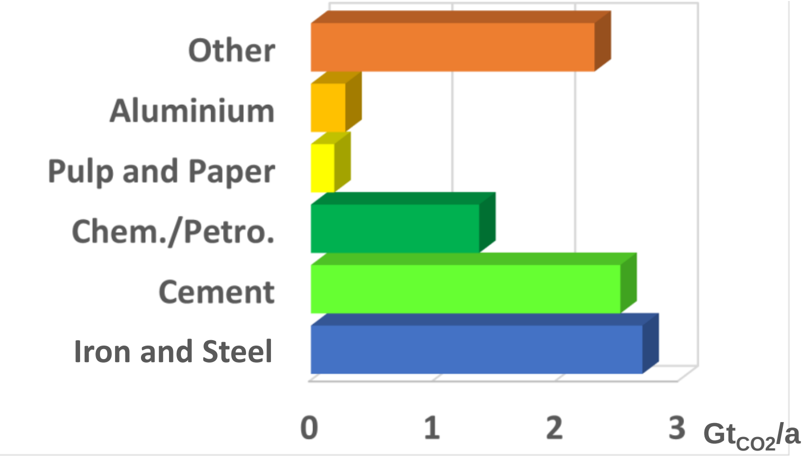


Global industry 2022[2]: 9.2 Gt_{CO2} (ca. 25 %)



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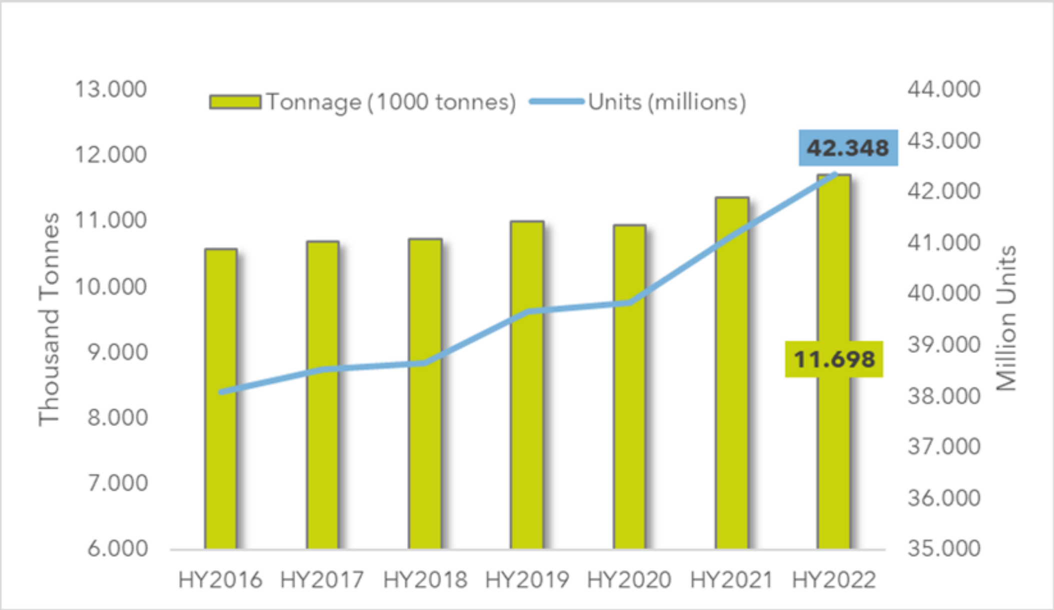
Decarbonization challenge of basic materials industry

- Very diverse & specific processes / requirements
- Optimized for continuous production, little flexibility @ high costs
- Energy intense ☞ intrinsic CO_2

Decarbonization challenge of European glass industry

- Unprecedented market demand growth in all segments
  - Key in some critical sectors of EU economy (food & beverage, medical, pharma supply chains)
  - New record levels for production and total sales (+3 % @ 1st HY 2022) [1]



[1] FEVE (2023). https://feve.org/half-year-2022-glass-packaging-production-at-highest-levels/

Decarbonization challenge of European glass industry

- Unprecedented market demand growth in all segments
  - Key in some critical sectors of EU economy (food & beverage, medical, pharma supply chains)
  - New record levels for production and total sales (+3 % @ 1st HY 2022) [1]
- Energy intense
  - Fuel is ca. ⅓ of glass price
  - Risk of energy shortages (Natural Gas)
  - EU-CO_2 certificate price skyrocketing
- High specific CO_2 emissions
  - up to 370 kg_{CO2}/t_{glass} [2]
  - 95 Mt_{CO2}/a (23% in Europe) [3]

[1] FEVE (2023). https://feve.org/half-year-2022-glass-packaging-production-at-highest-levels/
[2] Typical container glass; 15% cullet. Fraunhofer (2009). https://climate.ec.europa.eu/system/files/2016-11/bm_study-glass_en.pdf
[3] CINEA (2022). "How LIFE is reducing emissions from glass production." from https://cinea.ec.europa.eu/news-events/news/how-life-reducing-emissions-glass-production-2022-03-16_en

Decarbonization of glass industry
Options and limitations

- **Replace / avoid** one of the oldest, unique, trusted materials?
- Glass reuse / recycling

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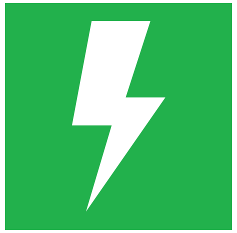

- **Electrification:** Limited to few glass sectors (e.g., brown glass excluded)
- Furnace size limit
- Limited decarbonization (< 85% of the CO_2 abatement)*

* Assuming a 70% cullet percentage.

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- **H_2:** New process design (furnace?, burner?), glass quality?, …
- R&D: what glass sector convertible?
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- **INNOVATIVE ALTERNATIVES?**

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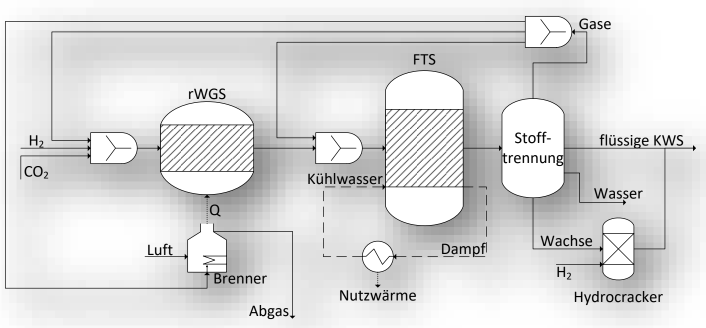
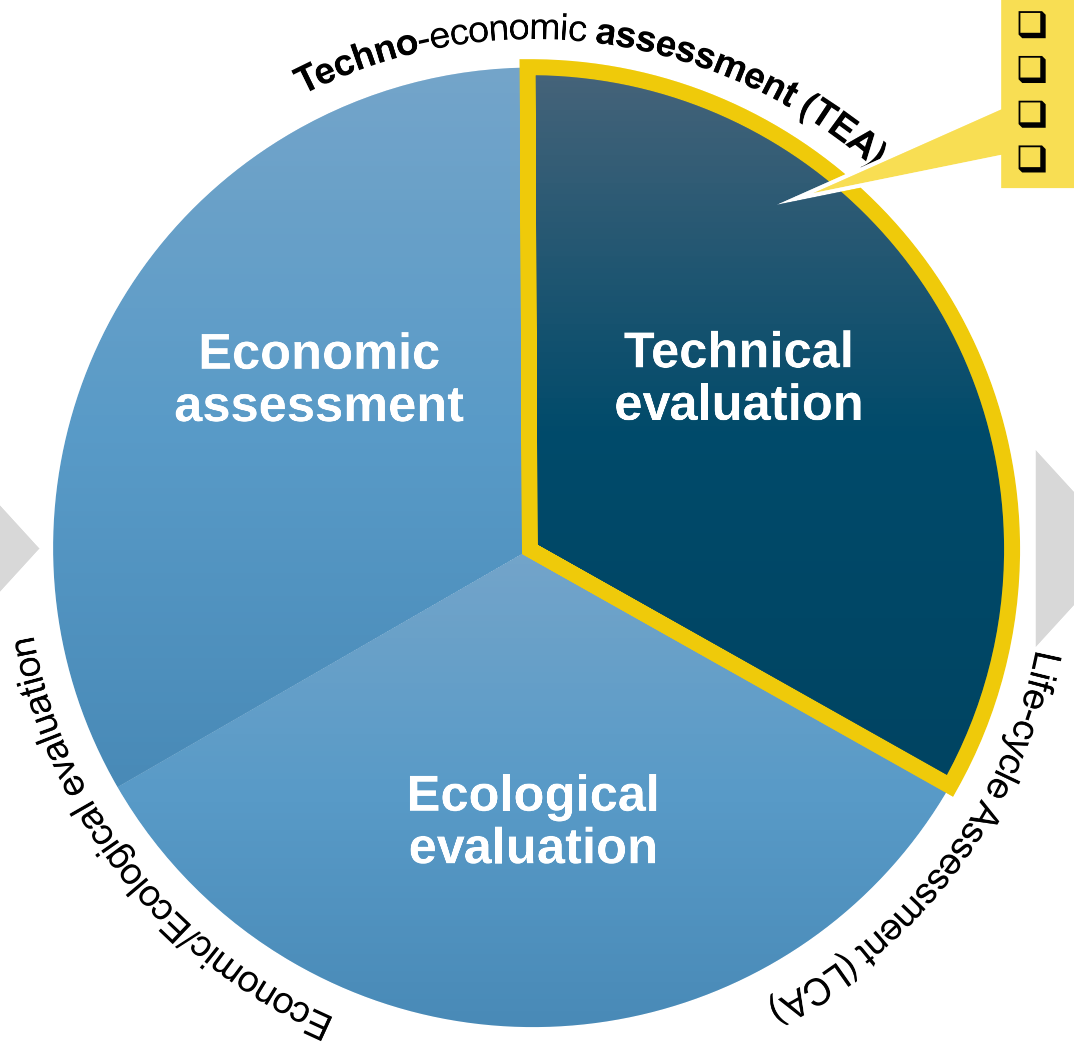
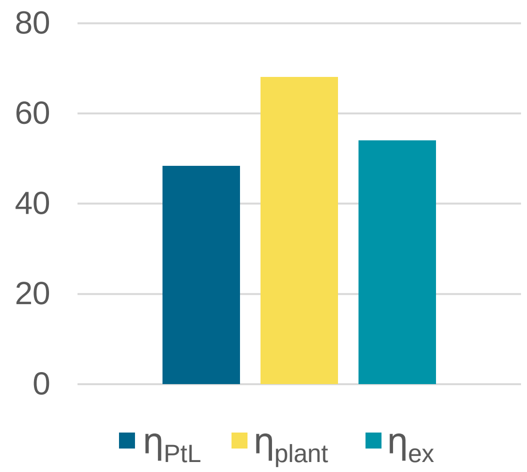
Techno-Economic & Ecological Assessment (TEEA) @ DLR





- ❑ Efficiencies (X-to-Liquid, Overall)
- ❑ Carbon conversion
- ❑ Specific feedstock demand
- ❑ Exergy analysis



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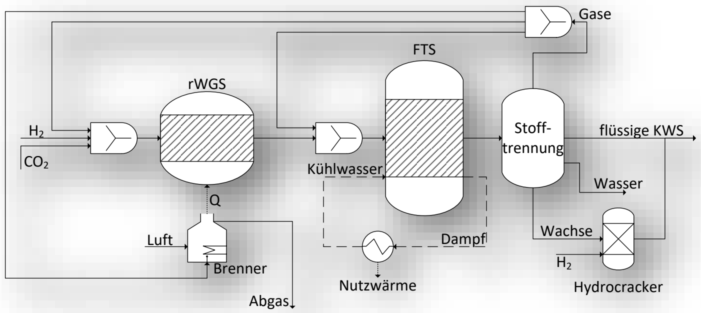

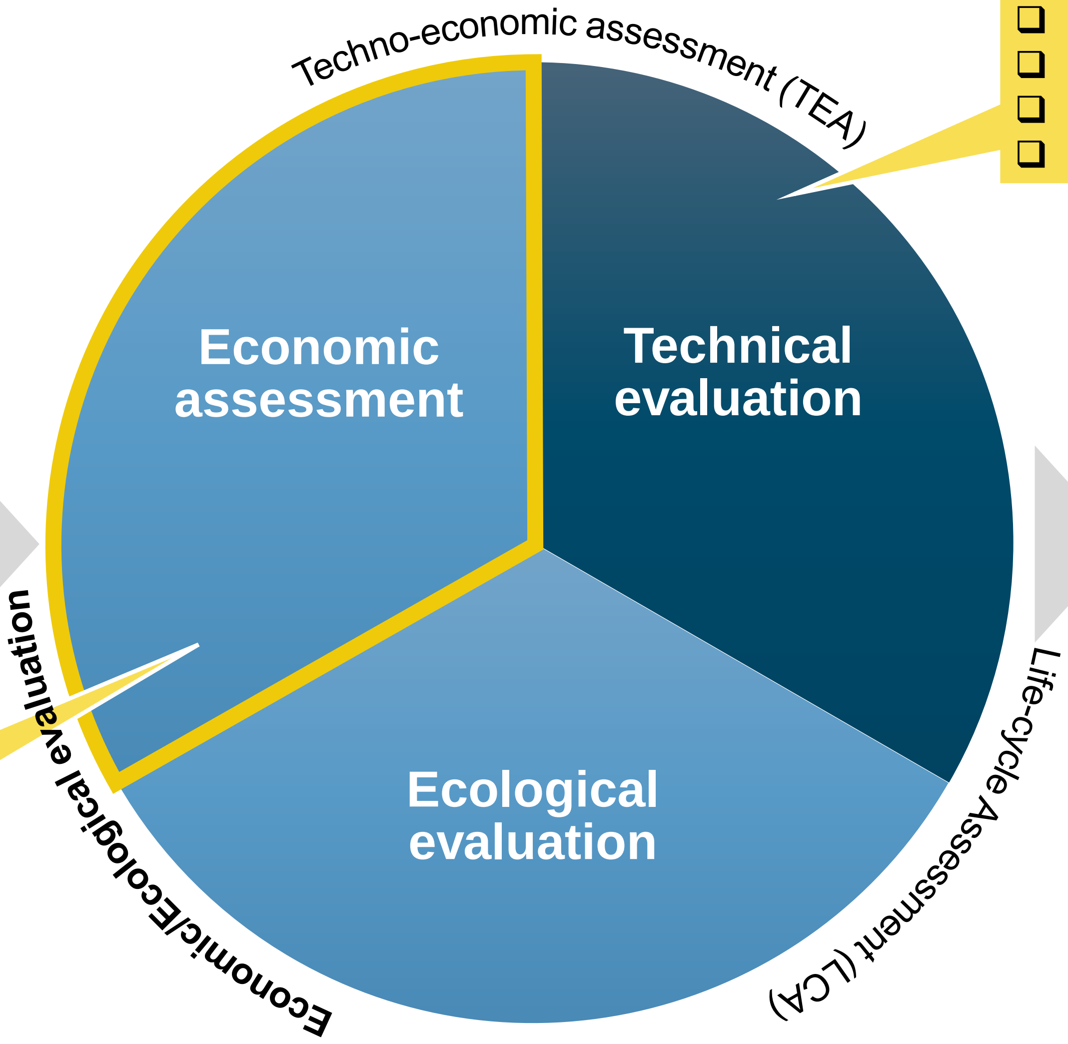

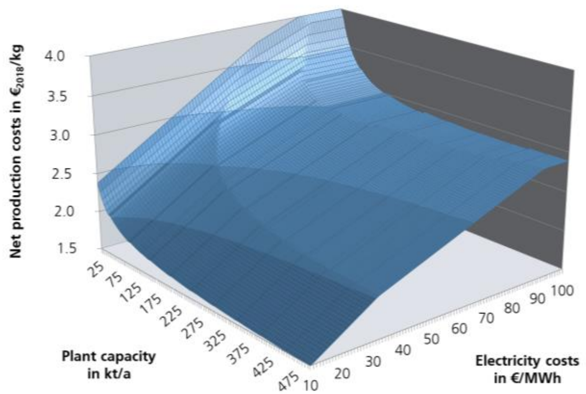

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- ❑ Identification of most economic feasible process design

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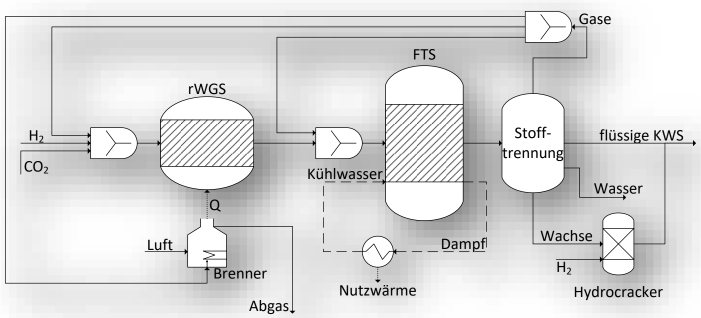

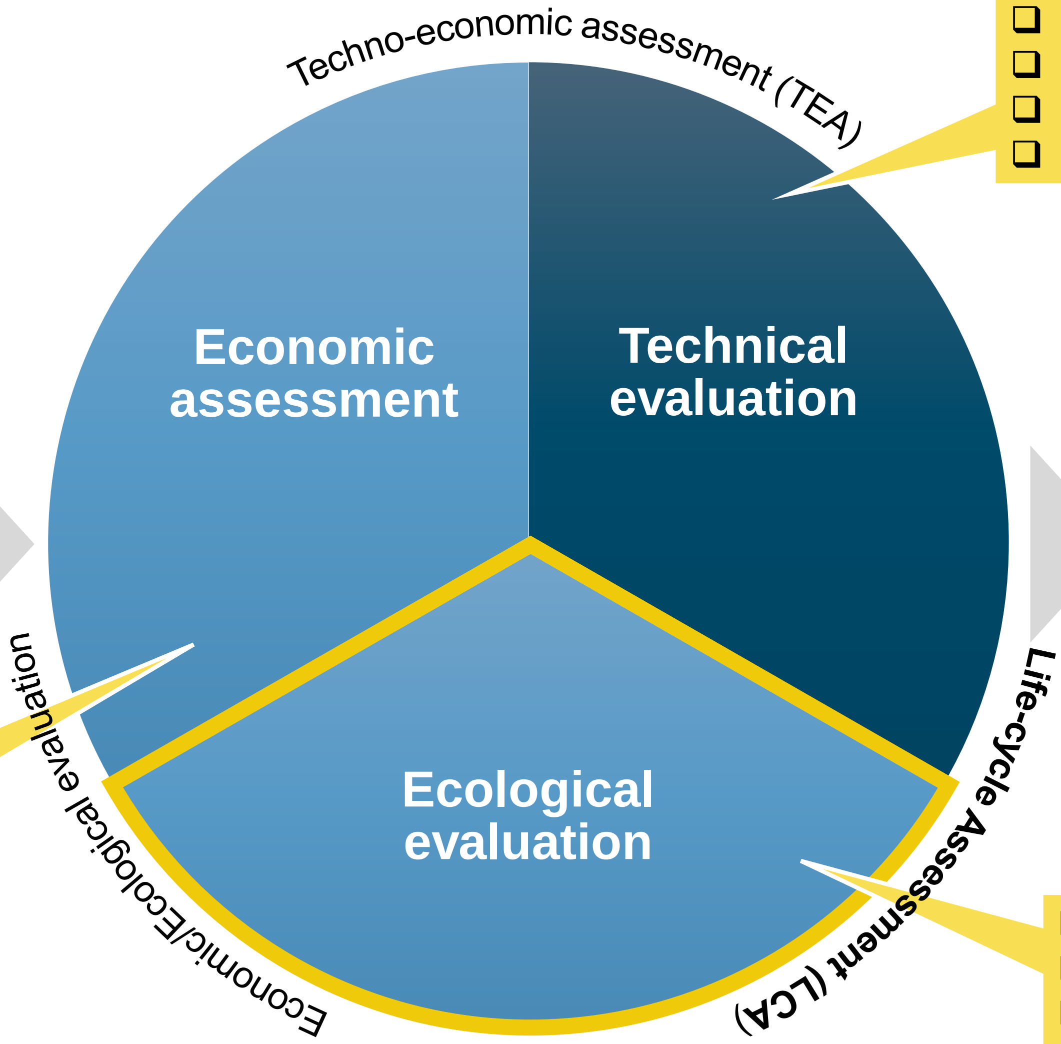

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- ❑ Identification of most economic feasible process design

- ❑ GWP
- ❑ Other impact categories
- ❑ Identification of impact drivers

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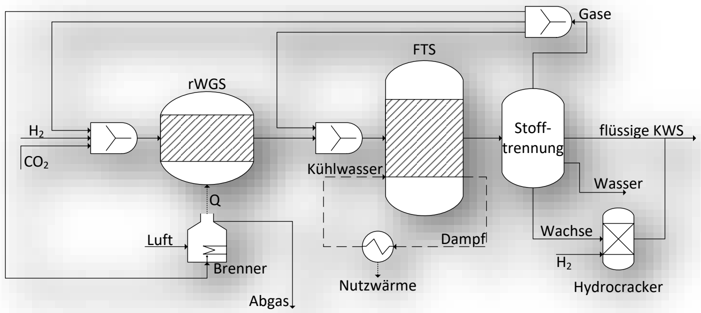

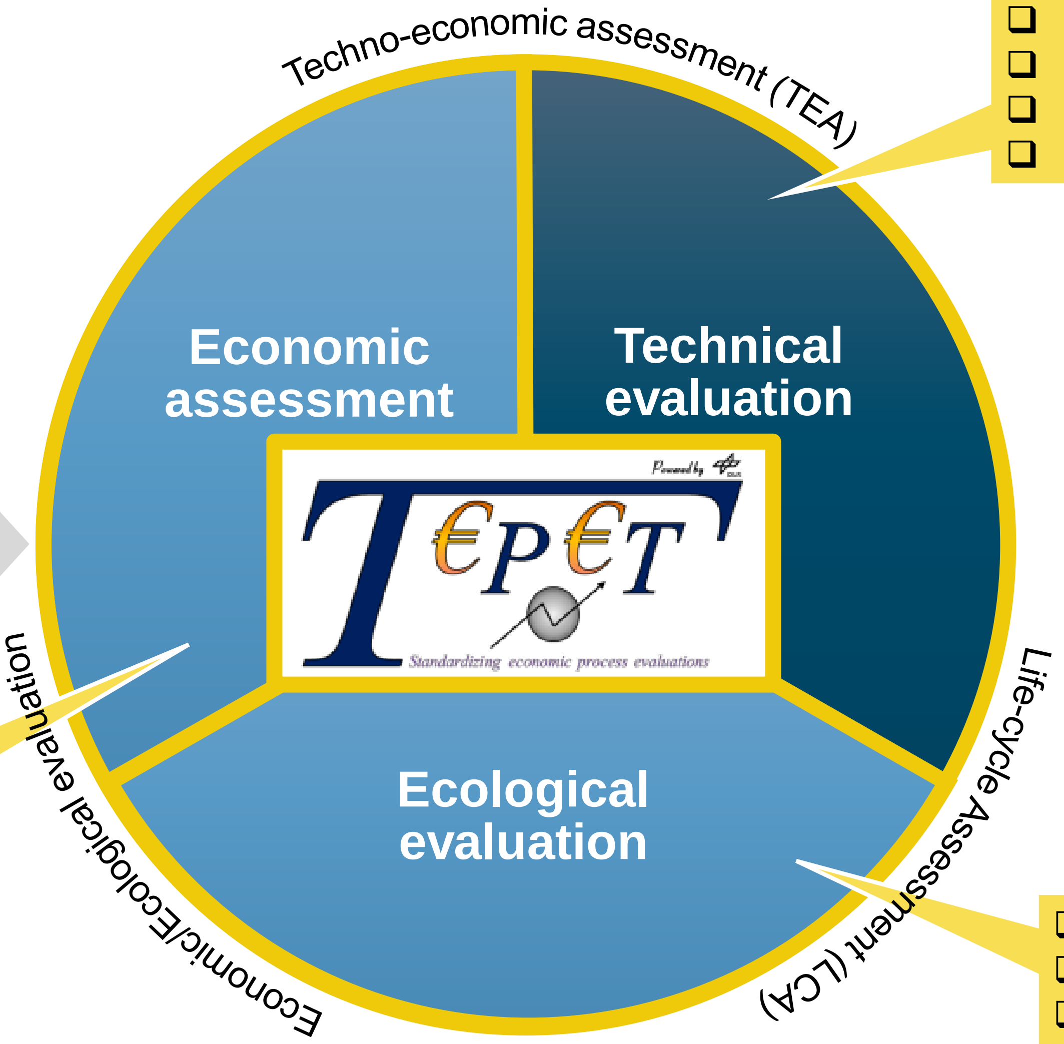

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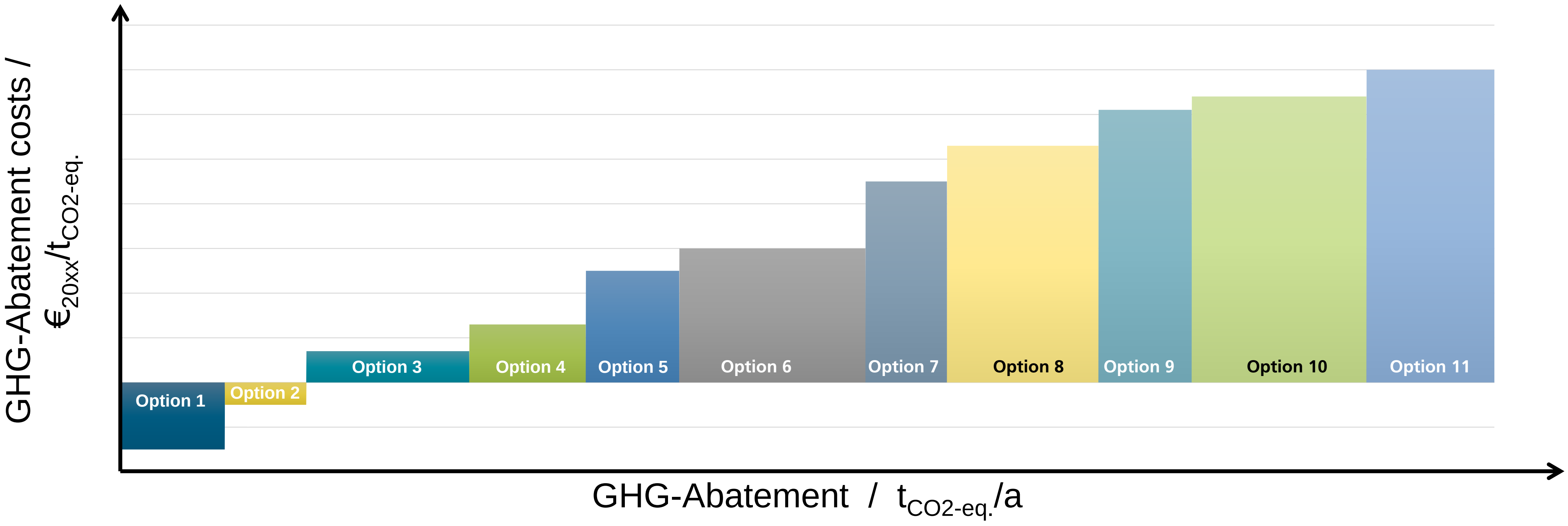
Assessment of renewable energy application concepts …
Merit-Order of GHG reduction technologies



Assessment of renewable energy application concepts …
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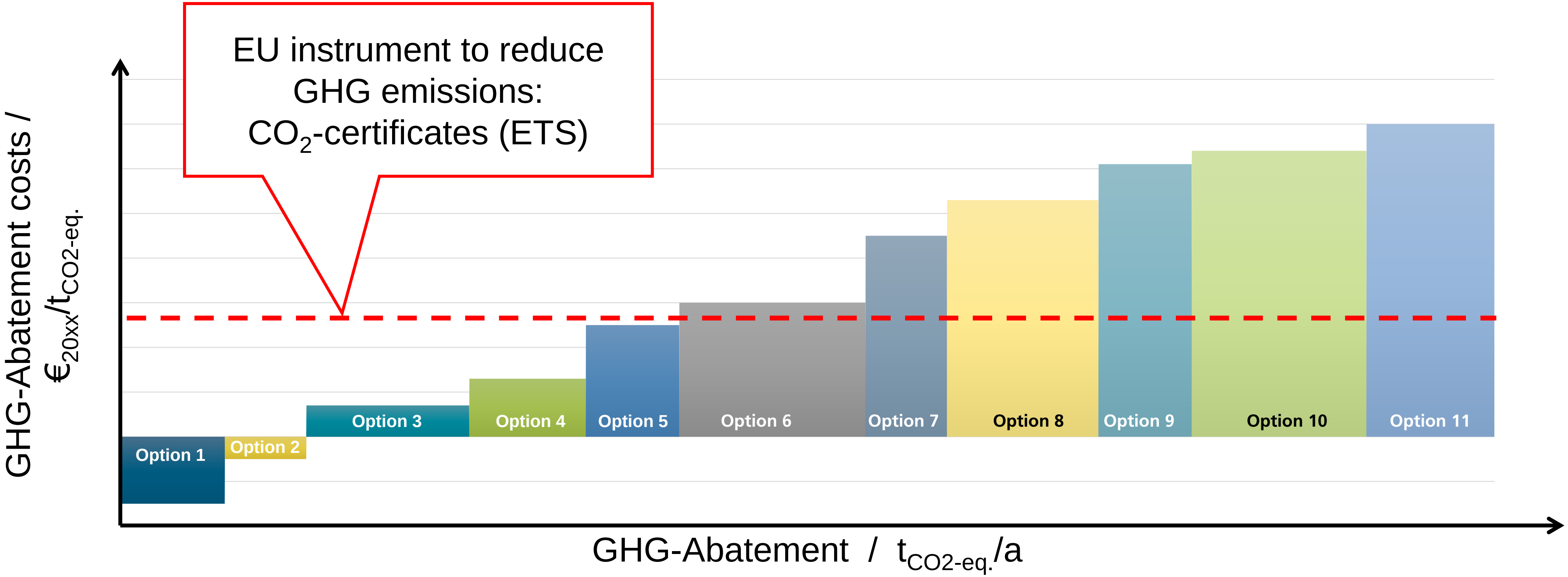
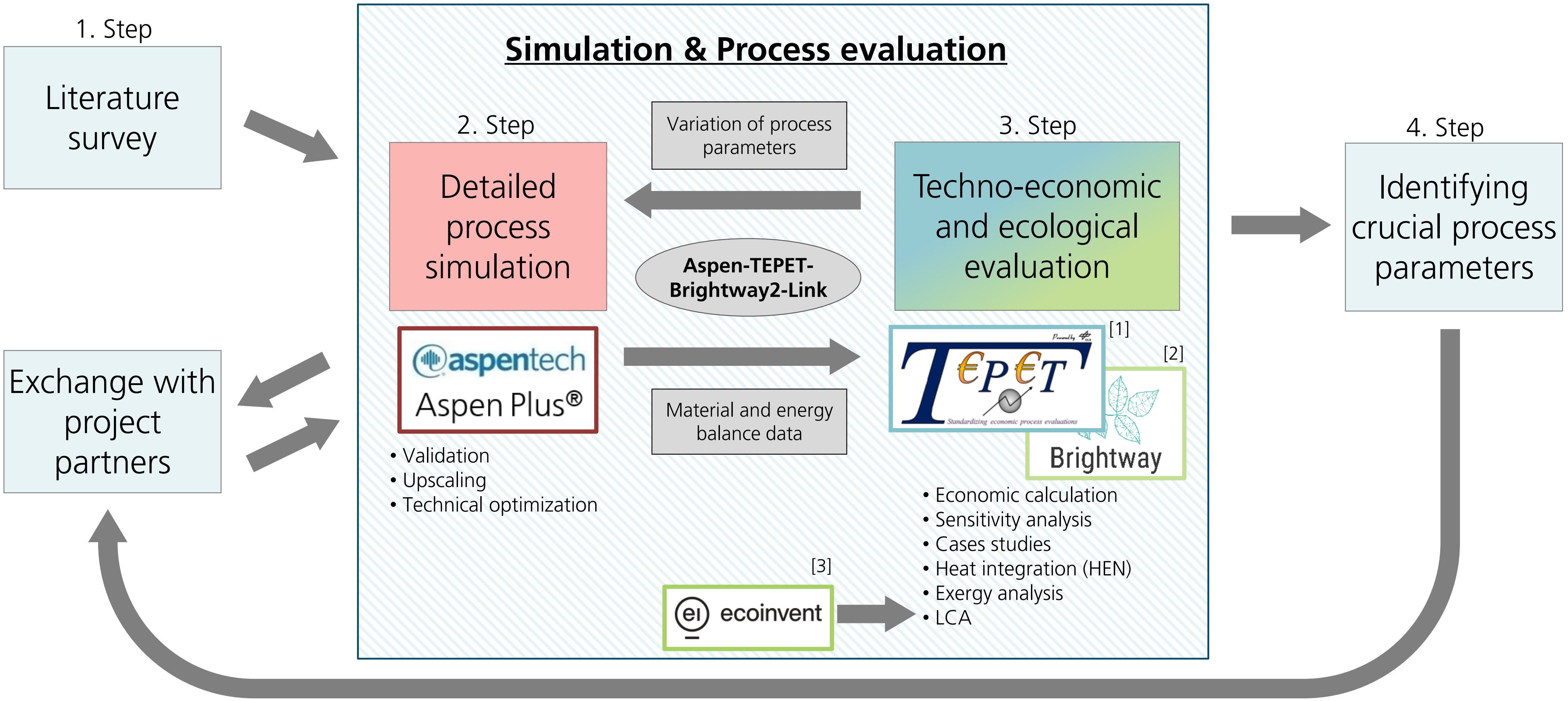


Goal: Maximal CO_2 reduction @ minimized GHG-Abatement cost, either by reducing GHG footprint or costs!

→ Standardized assessment methodology! → @ DLR

Techno-economic and ecological assessment (TEEA) @DLR



[1] Albrecht et al. (2016) - A standardized methodology for the techno-economic evaluation of alternative fuels – A case study, Fuel, 194: 511-526
[2] Mutel (2017) - Brightway: An open source framework for Life Cycle Assessment, Journal of Open Source Software, 2(12): 236
[3] Wernet, G et al. (2016) – The ecoinvent database version 3 (part I): overview and methodology. The International Journal of Life Cycle Assessment, 21(9): 1218–1230.

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THE KLIMPRO BMBF PROJECT GLAS-CO2 (01LJ2005A+B)

Kreislaufführung des Kohlendioxids aus dem Glasschmelzprozess zur Herstellung synthetischer Brennstoffe

Carbon dioxide recycle from glass melting for the production of synthetic fuels

HVG-DGG
Service und Forschung für die Glasherstellung

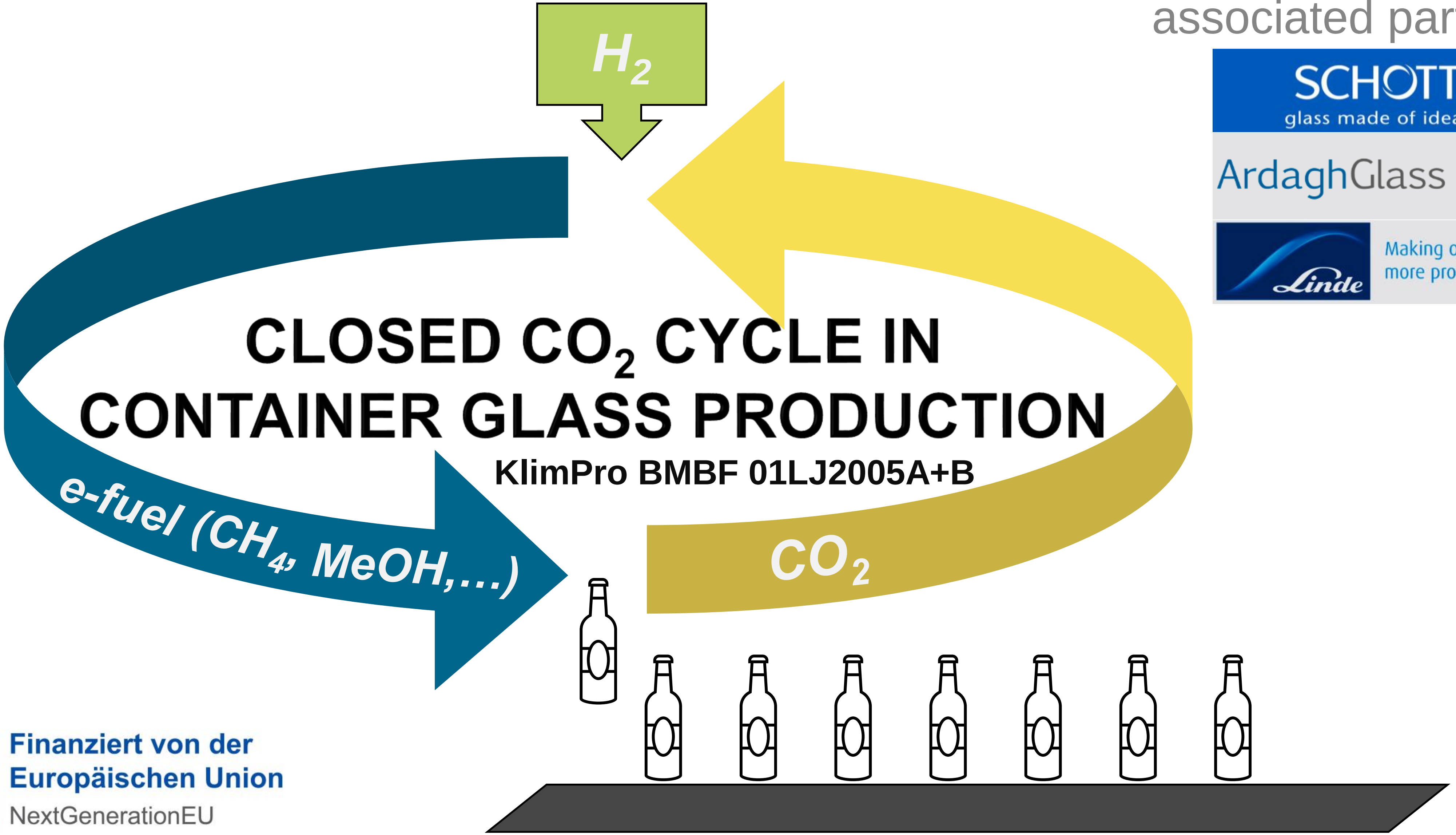
DLR

Glas-CO2 project idea

HVG-DGG
Service und Forschung für die Glasherstellung
DLR

associated partner

SCHOTT
glass made of ideas
ArdaghGlass
Linde
Making our world more productive



Finanziert von der
Europäischen Union
NextGenerationEU

Oxyfuel furnace process details

- Clean combustion (Fuel + O_2)
  - CO_2 concentration ≥ 95% (dry)
- Energy intense
  - 4.2 GJ_{th}/t_{glass}
- Strictly continuous operation (24/7/365)
  - +/- 20% production volume possible
- CO_2 emissions: 370 kg_{CO2}/t_{glass} (15% cullet)

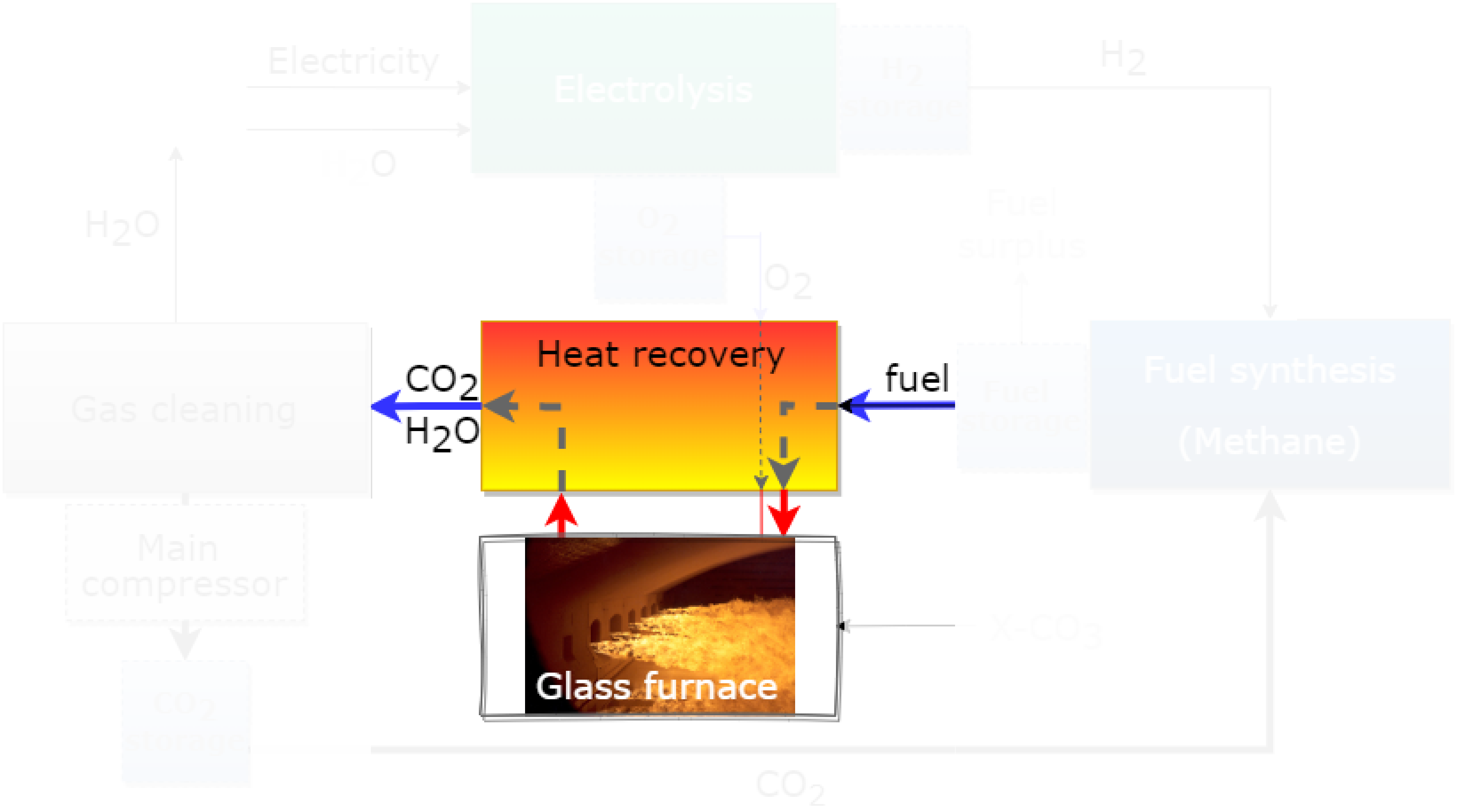
Oxyfuel furnace process details
Project data deduced

- Clean combustion (Fuel + O_2)
  - CO_2 concentration ≥ 95% (dry)
- Energy intense
  - 4.2 GJ_{th}/t_{glass}
- Strictly continuous operation (24/7/365)
  - +/- 20% production volume possible
- CO_2 emissions: 370 kg_{CO2}/t_{glass} (15% cullet)
  GLAS-CO2: 320 kg_{CO2}/t_{glass} (55% cullet)
  - 75% from fuel combustion
  - 25% from batch (carbonates)

Glas-CO2 process concept

HVG-DGG
Service und Forschung für die Glasherstellung
DLR

- Oxyfuel furnace
- Heat recovery

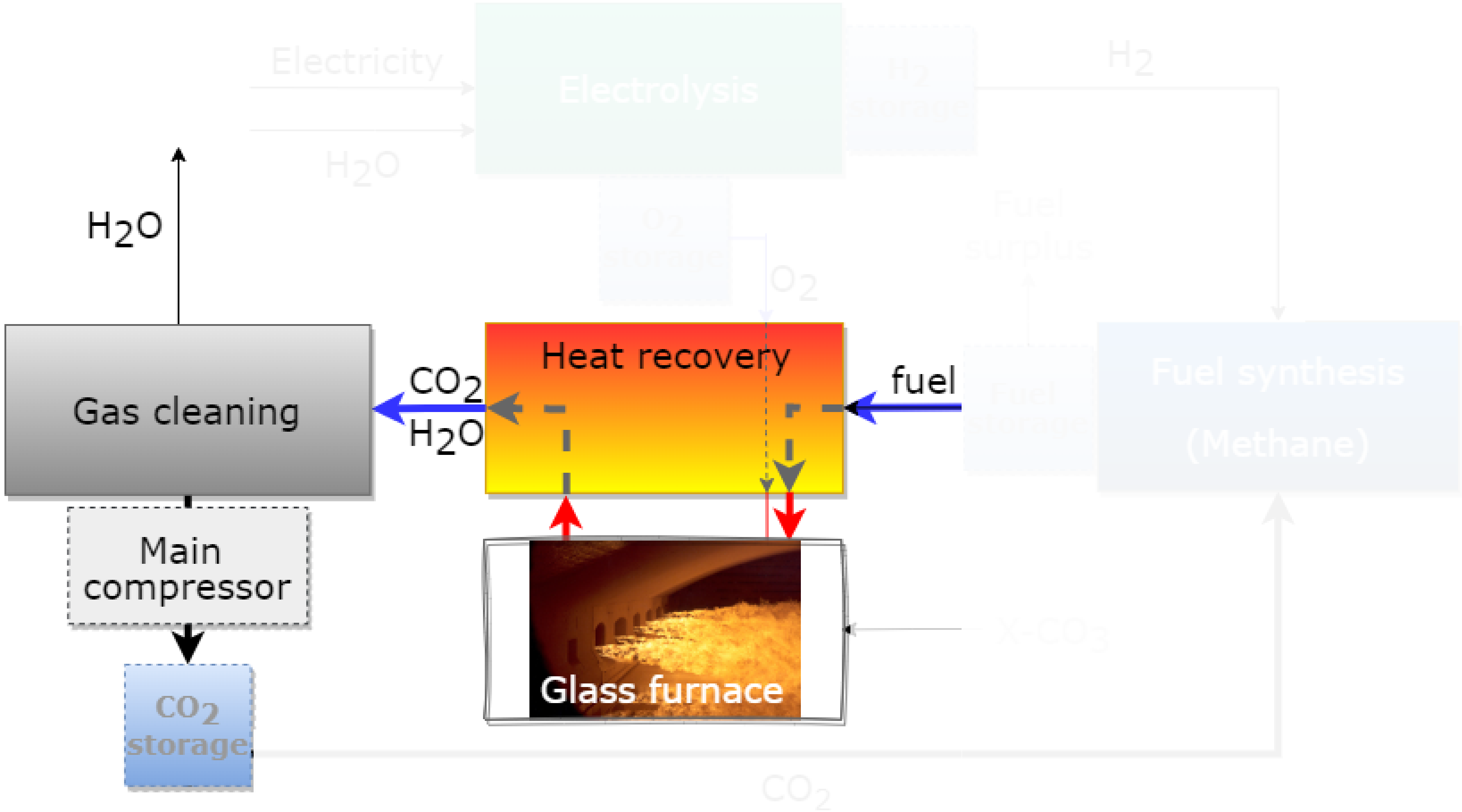


Glas-CO2 process concept
Project related units

- Oxyfuel furnace
- Heat recovery

Glas-CO2 addition

- Gas cleaning:
  - Wet scrubber
  - Hydrogenation
  - Guard beds



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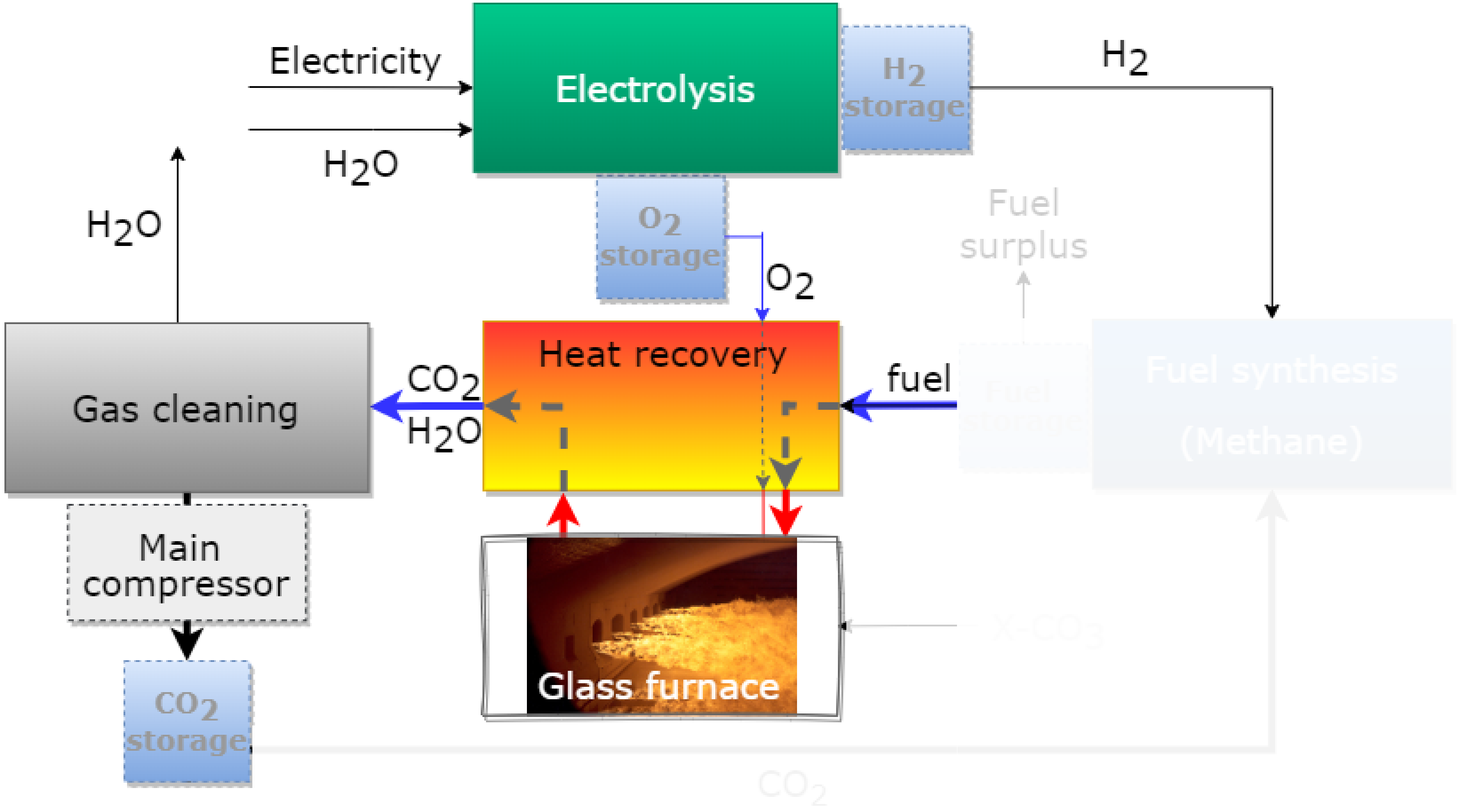

Glas-CO2 process concept
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HVG-DGG Service und Forschung für die Glasherstellung
DLR

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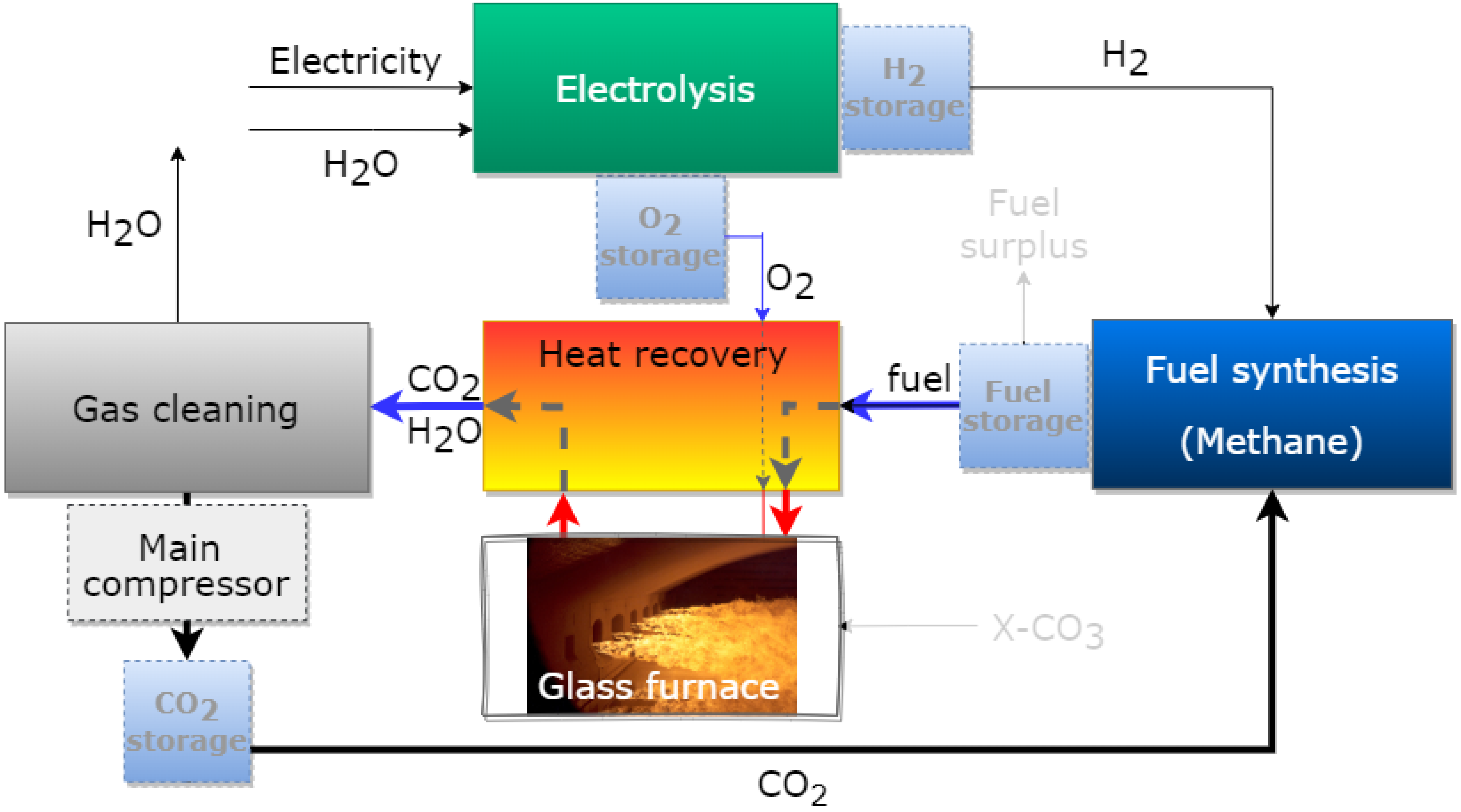
  - TREMP™-process



Glas-CO2 process concept
Project related units

HVG-DGG Service und Forschung für die Glasherstellung DLR

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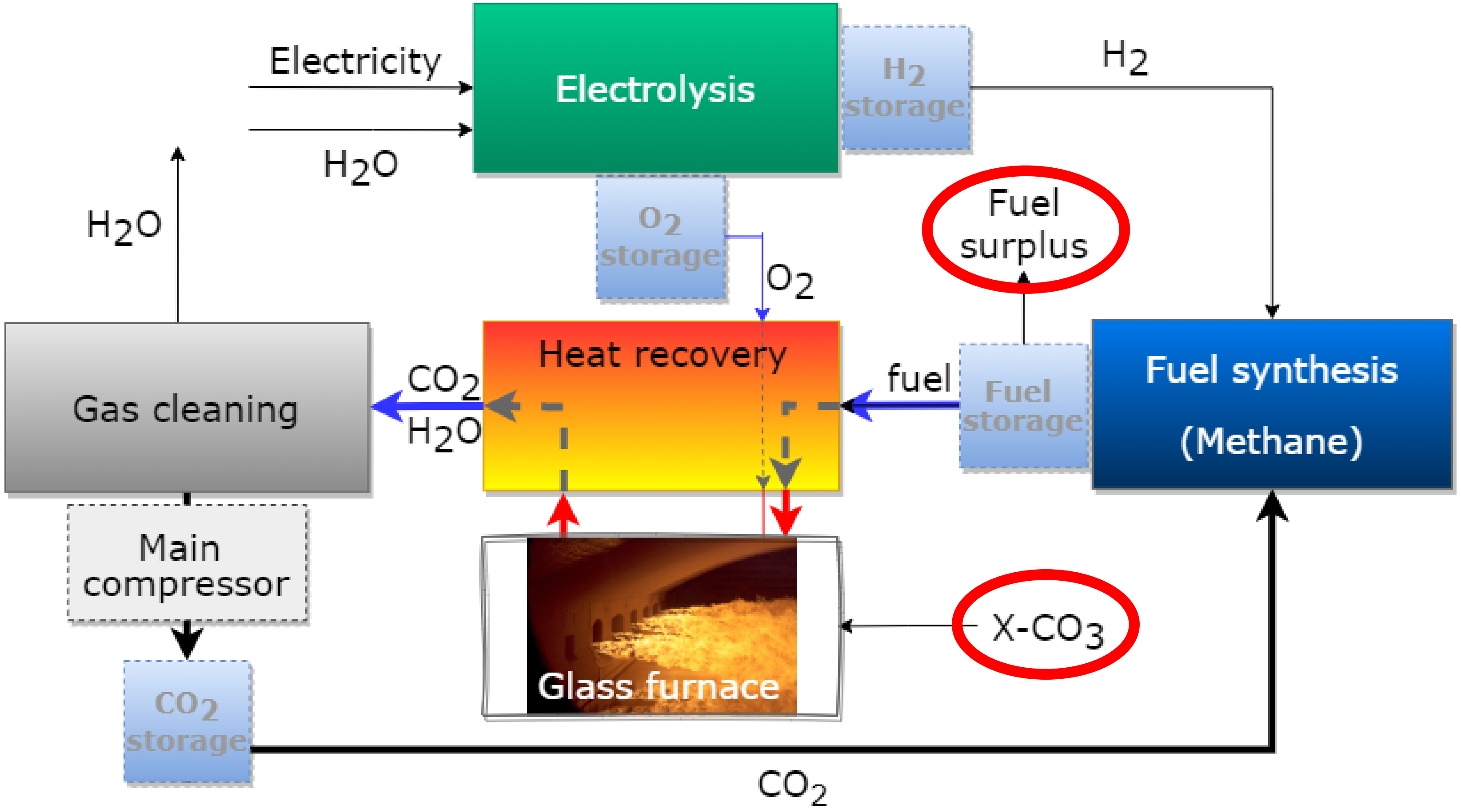
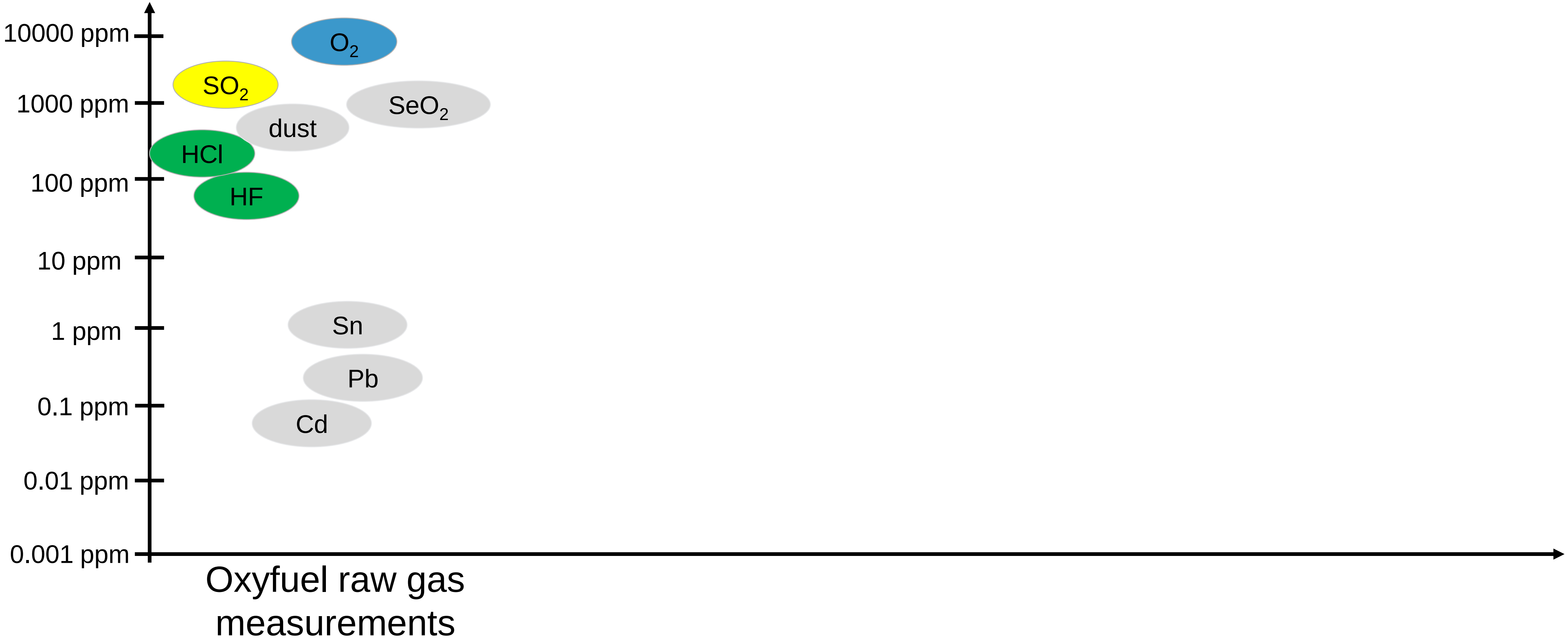


Glas-CO2 technology selection:
Gas cleaning requirement

- Catalyst´s poisons



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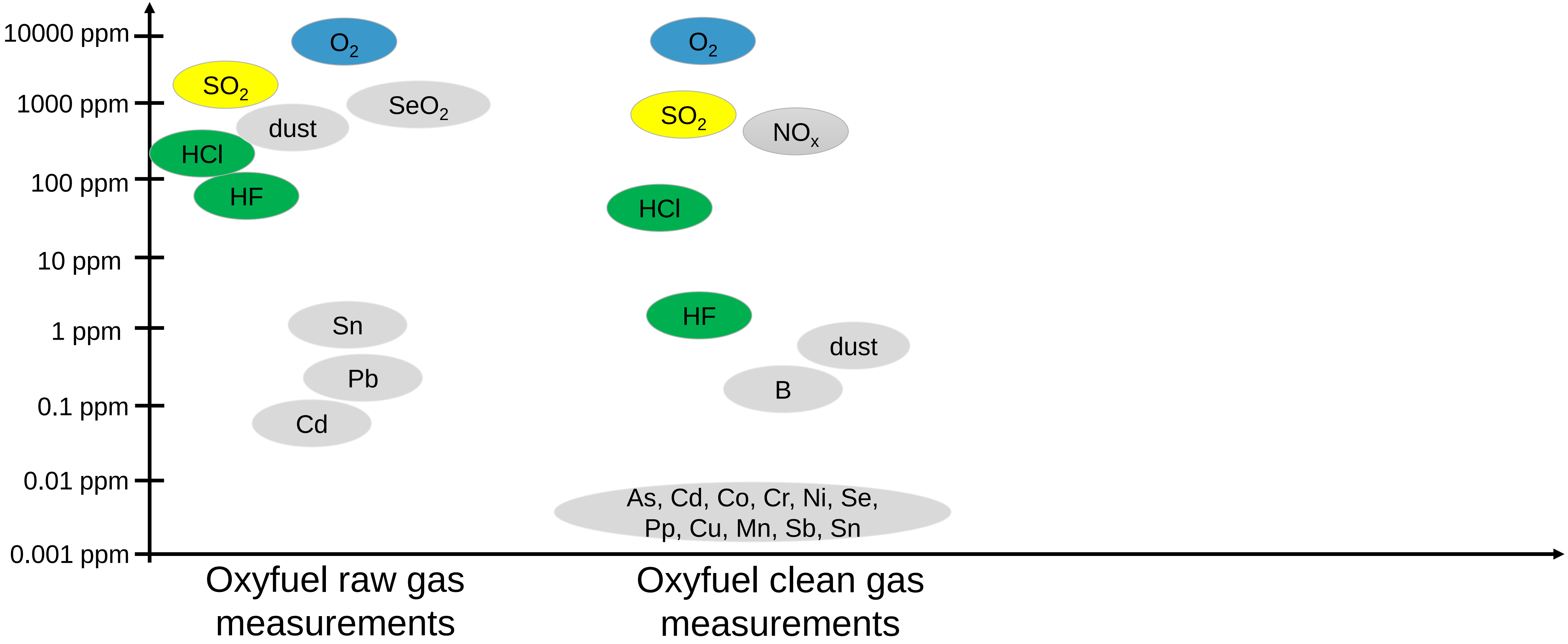

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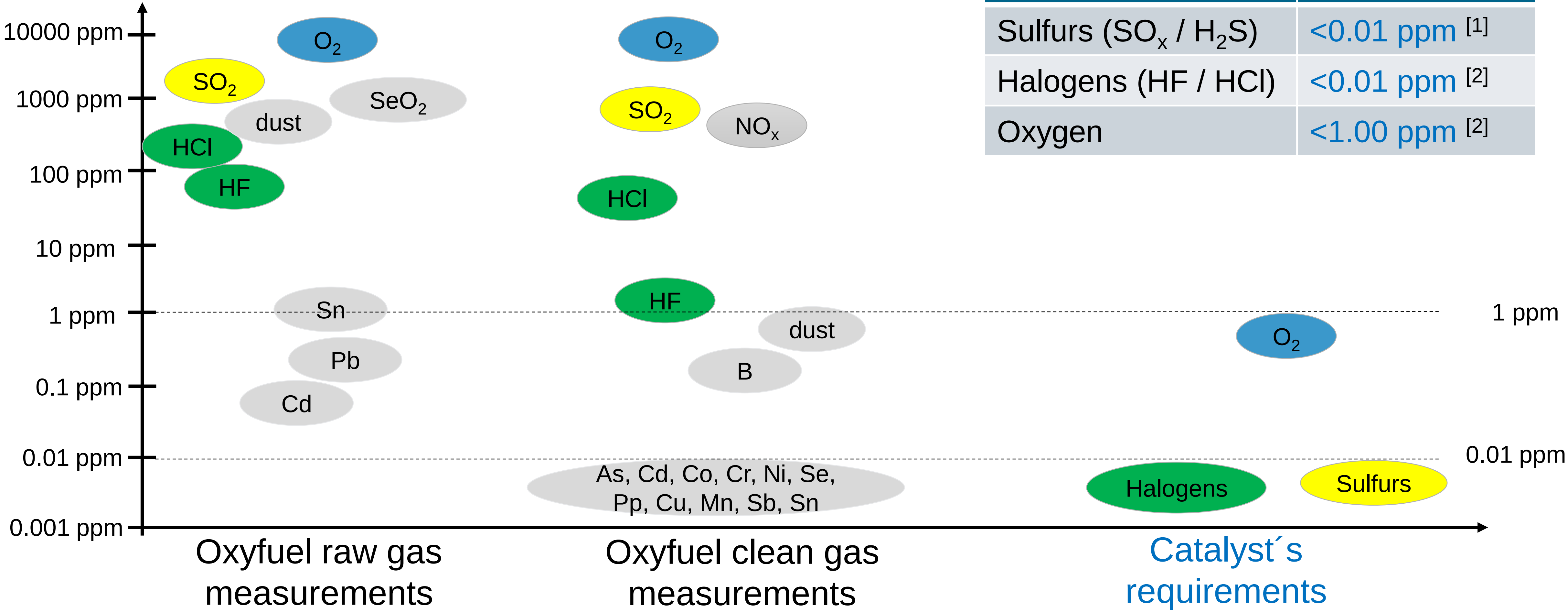

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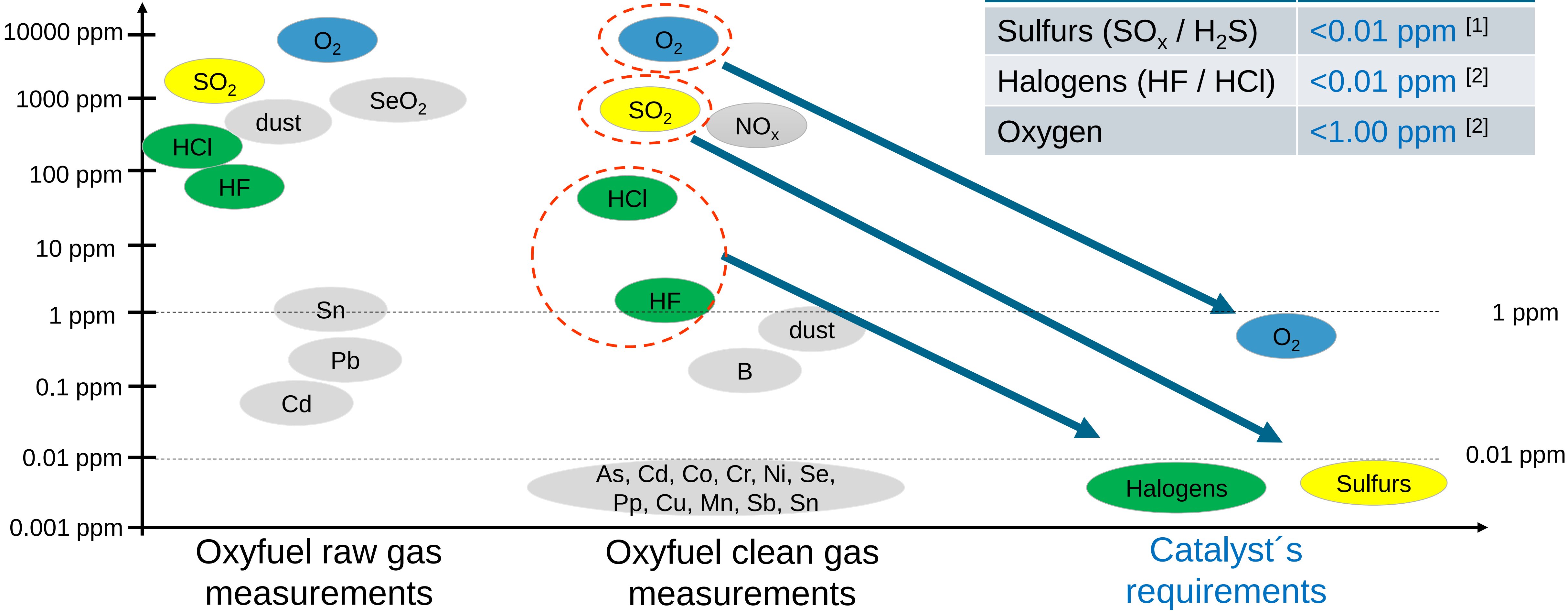

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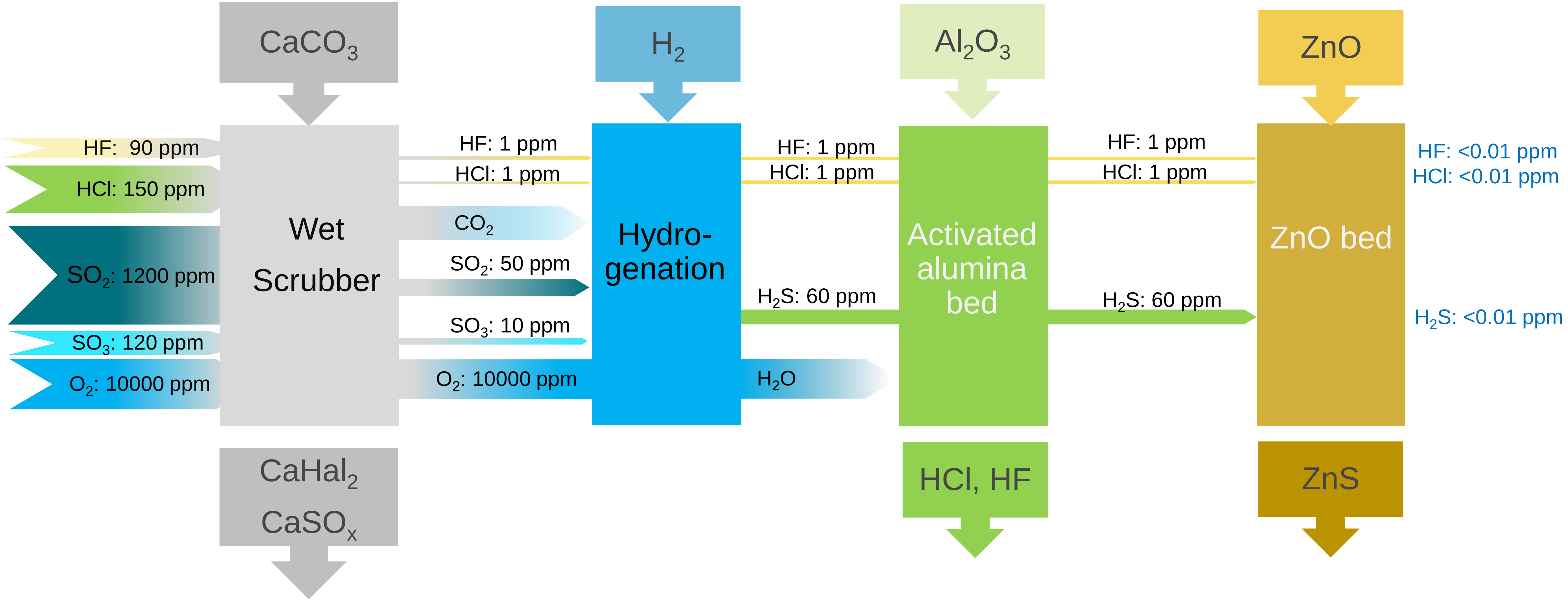
Glas-CO2 technology selection:
Gas cleaning process concept



Glas-CO2 technology selection: Methanization process concept

TREMP™ process *Topsøe's Recycle Energy-Efficient Methanation Process*[1]

- Commercially available
- SNG composition: 95.6% CH_4
  - 3.1% H_2
- Catalyst: Ni/Al_2O_3 (22% Ni)
- Operating conditions:
  - 30 bar
  - 250 - 700 °C
- Kinetic model: Klose et. al [2]
- High temp. waste heat
  - Generation of electricity is possible

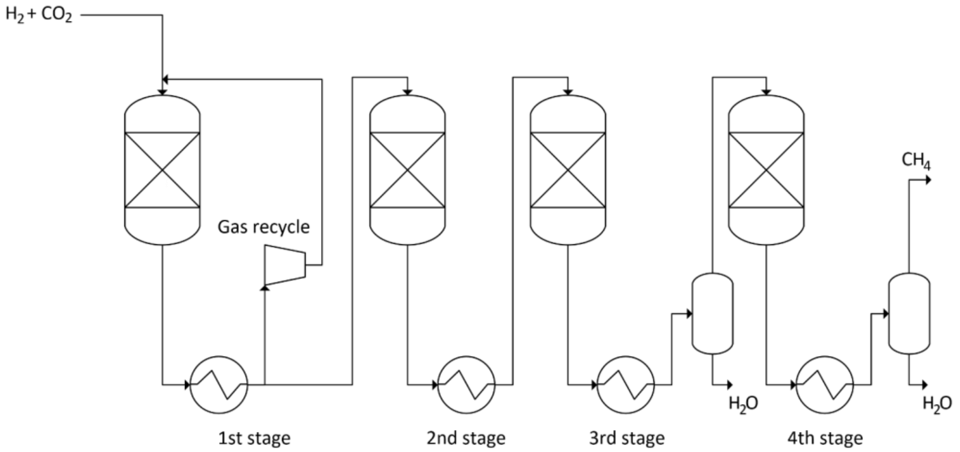
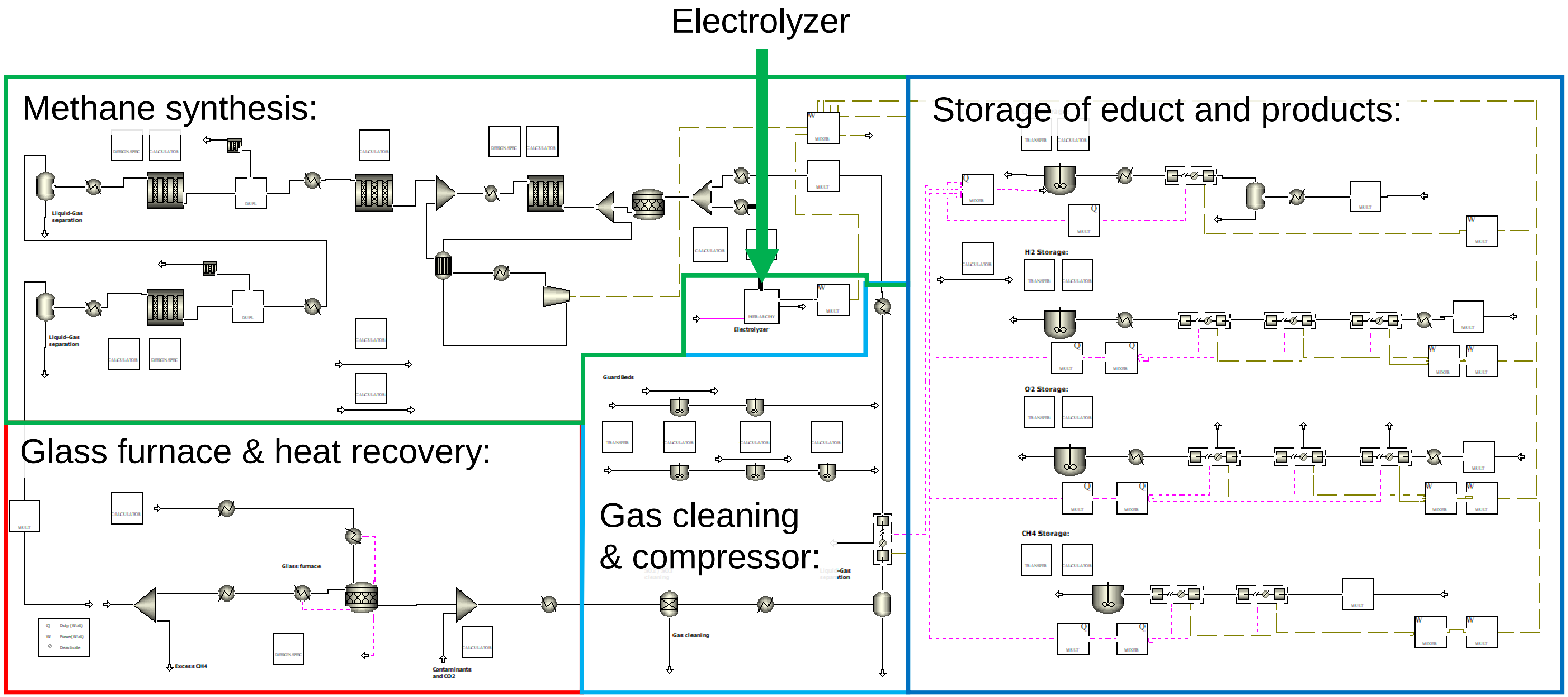


Figure - Topsøe's Recycle Energy-Efficient Methanation Process

[1] © Topsøe, H. (2011). From coal to clean energy.
[2] J. Klose, Kinetics of the methanation of carbon monoxide on an alumina-supported nickel catalyst, Journal of Catalysis, 85 (1984) 105-116.

Glas-CO2 process model

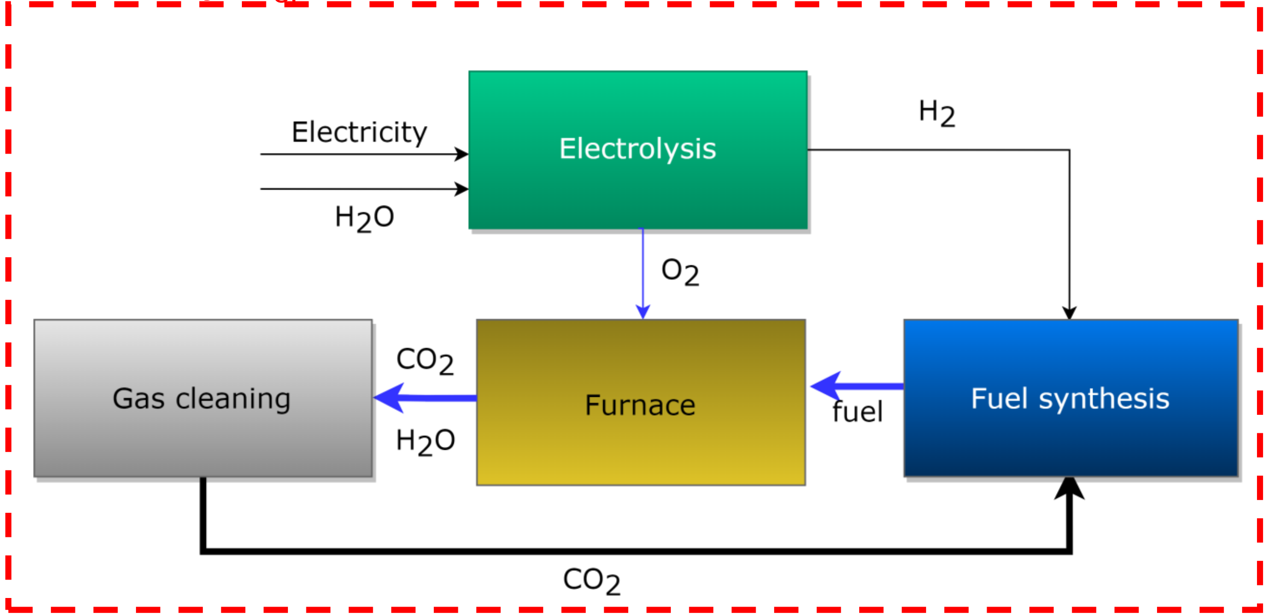


Glas-CO2 process assessment

Technical assessment: efficiencies

- $\eta_{PtF} = \frac{\dot{m}_{Fuel,Total} \cdot LHV}{\dot{P}_{el,PEMEL} + \dot{P}_{el.,others} - \dot{P}_{el.,SC}} = 45\ \%$

Boundary P_{el}-to-Fuel:



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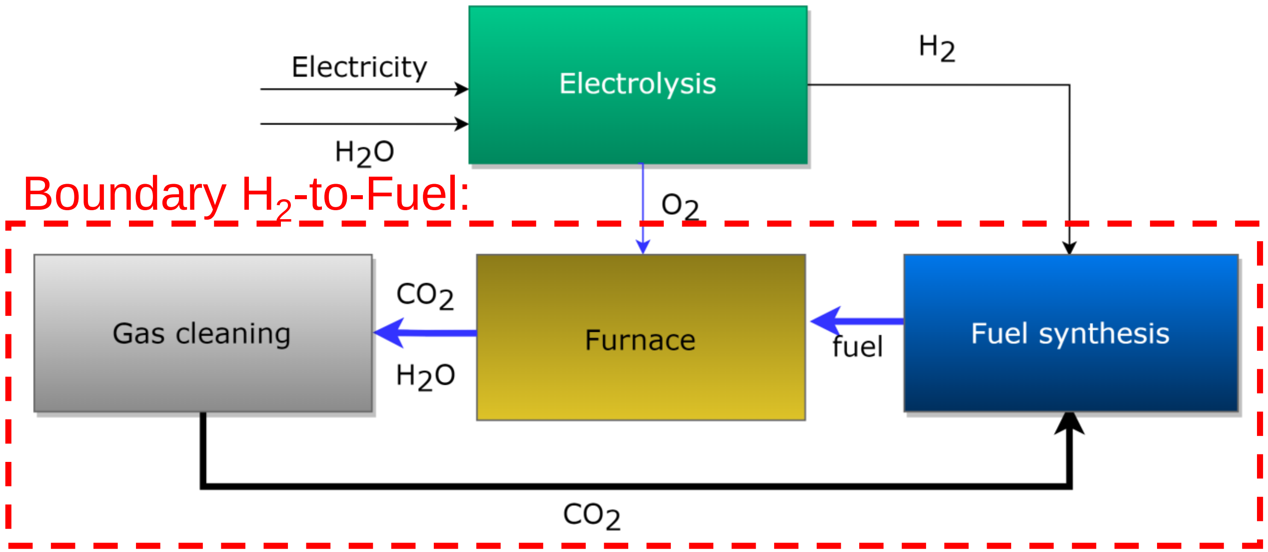
Technical assessment: efficiencies

- $$\eta_{PtF} = \frac{\dot{m}_{Fuel,Total} \cdot LHV}{\dot{P}_{el,PEMEL} + \dot{P}_{el.,others} - \dot{P}_{el.,SC}} = 45\ \%$$

- $$\eta_{H_2tF} = \frac{\dot{m}_{Fuel} \cdot LHV_{Fuel}}{\dot{m}_{H_2} \cdot LHV_{H_2}} = 83\ \%$$



Glas-CO2 process assessment

DLR

Economic assessment: base case definition

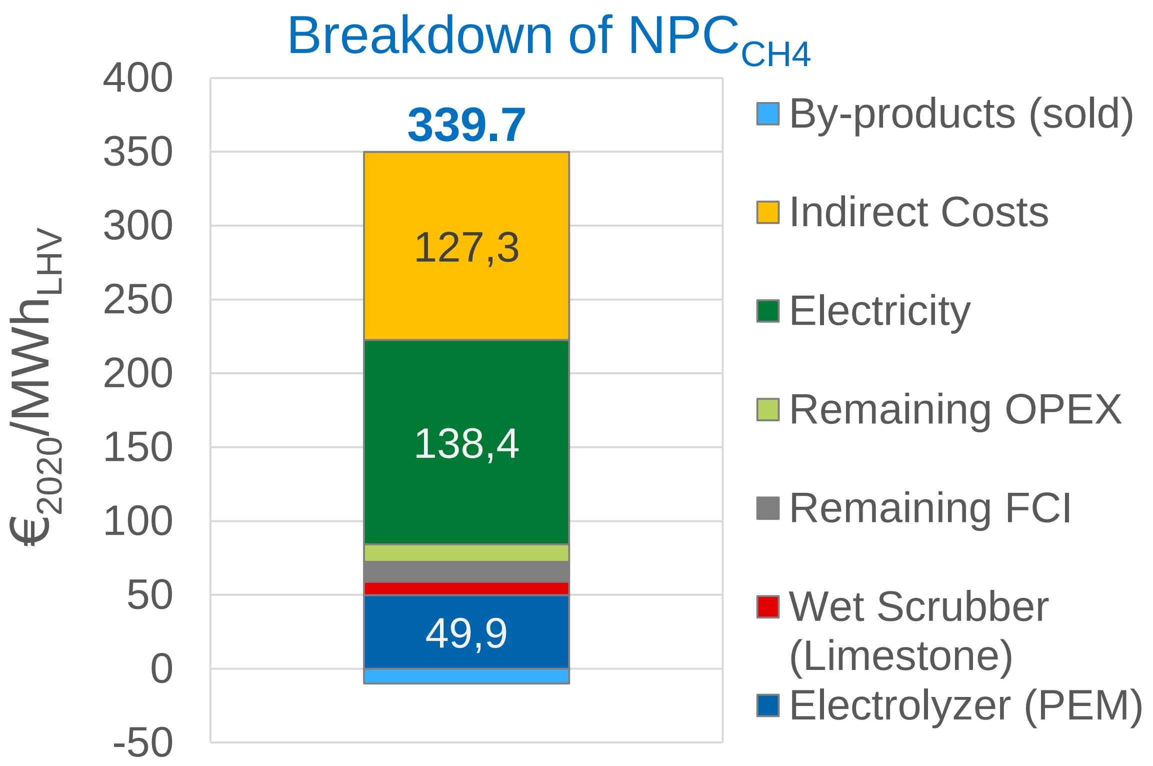
Evaluation input		Ref.
Plant capacity	300 t_{glass}/day	
Plant lifetime	30 a	
Base year	2020	
Interest rate	7%	
Glass furnace operation	24/7/365	
Methanation plant full load hours	8000 h/a	
Green electricity price	42.31 €/MWh	[1,2,3]
Electrolyzer price	957 €/kW	[4]

✓Backup supply through gas grid
✓Costs of glass furnace are excluded

[1] Day-ahead-market of Germany from: https://www.smard.de/home
[2] Kalis, Michael; Wilms, Susan: KEROSyN100 – Regulatorische Hemmnisse und Anreizmechanismen für den Einsatz synthetischer Kraftstoffe in der Luftfahrt. 2020.
[3] Bundesministerium der Justiz, from: https://www.gesetze-im-internet.de
[4] Noack, C., et al., G. S. (2015). Studie über die Planung einer Demonstrationsanlage zur Wasserstoff-Kraftstoffgewinnung durch Elektrolyse mit Zwischenspeicherung in Salzkavernen unter Druck.

Glas-CO2 process assessment
Furnace fuel input 15.5 MW_{LHV}

Economic assessment: methane Net Production Cost (NPC)



[1] M. Peters, K. Timmerhaus and R. West, Plant design and economics for chemical engineers, New York, United States: McGraw-Hill, 2004, ISBN 007-124044-6.

Glas-CO2 process assessment
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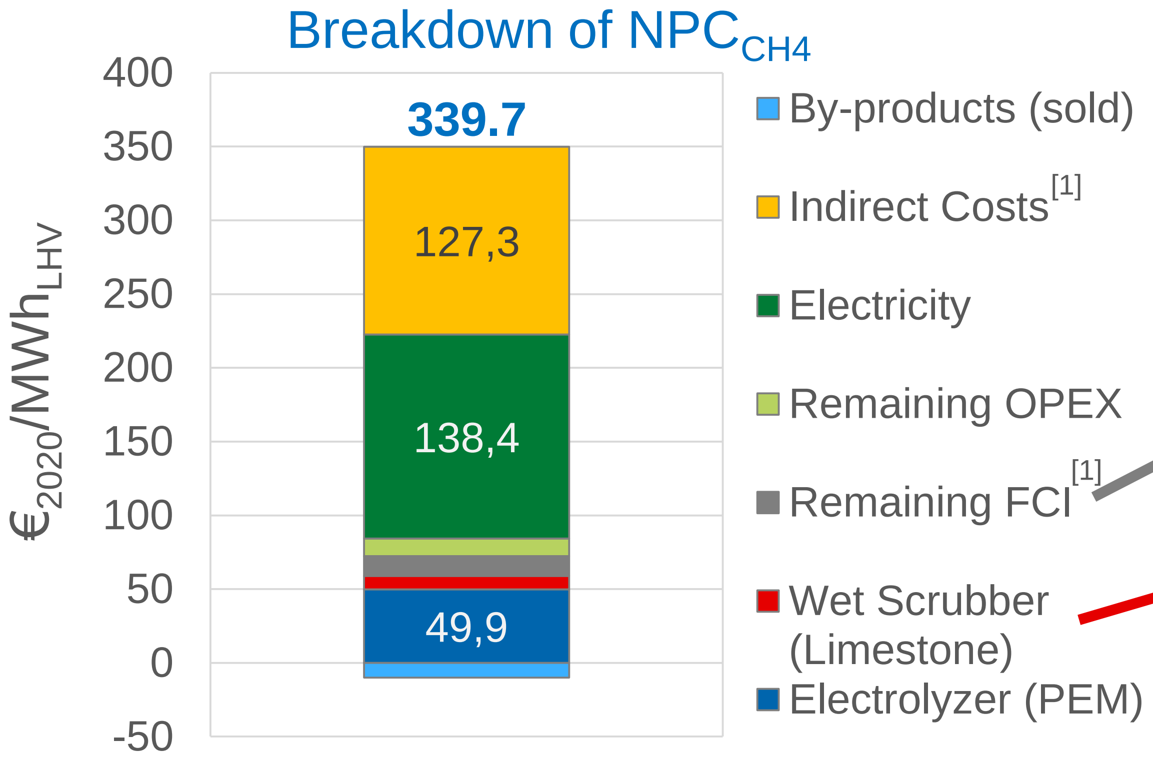
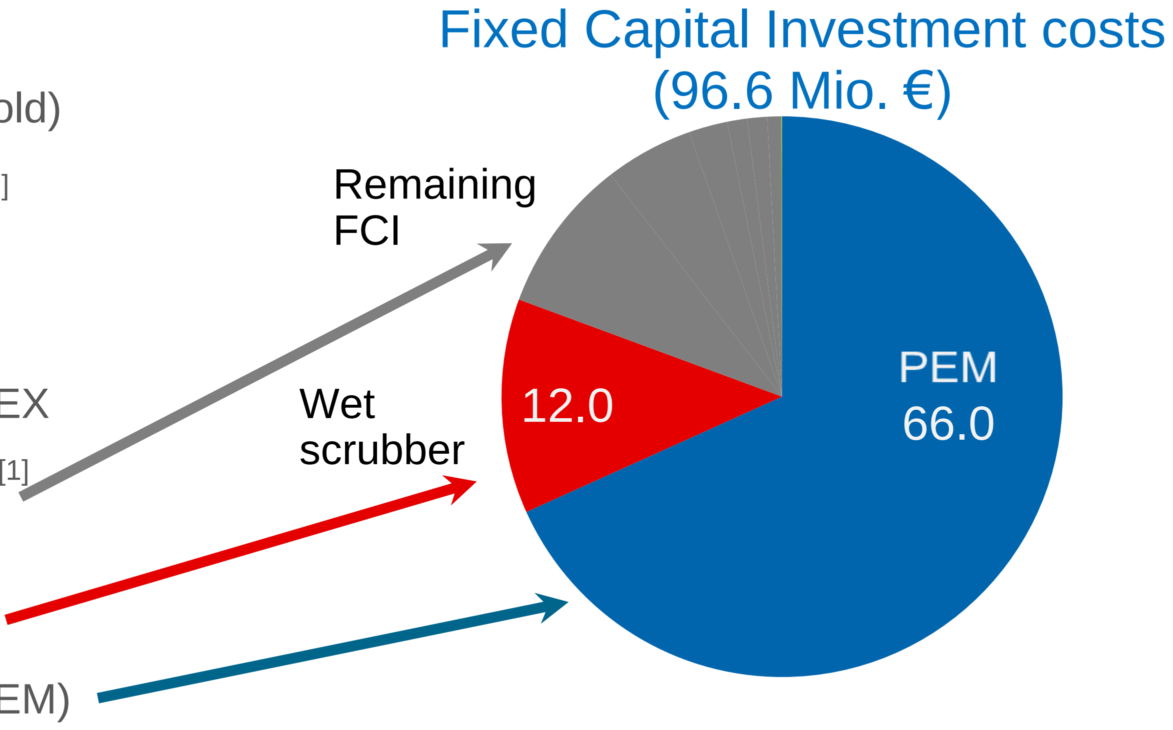


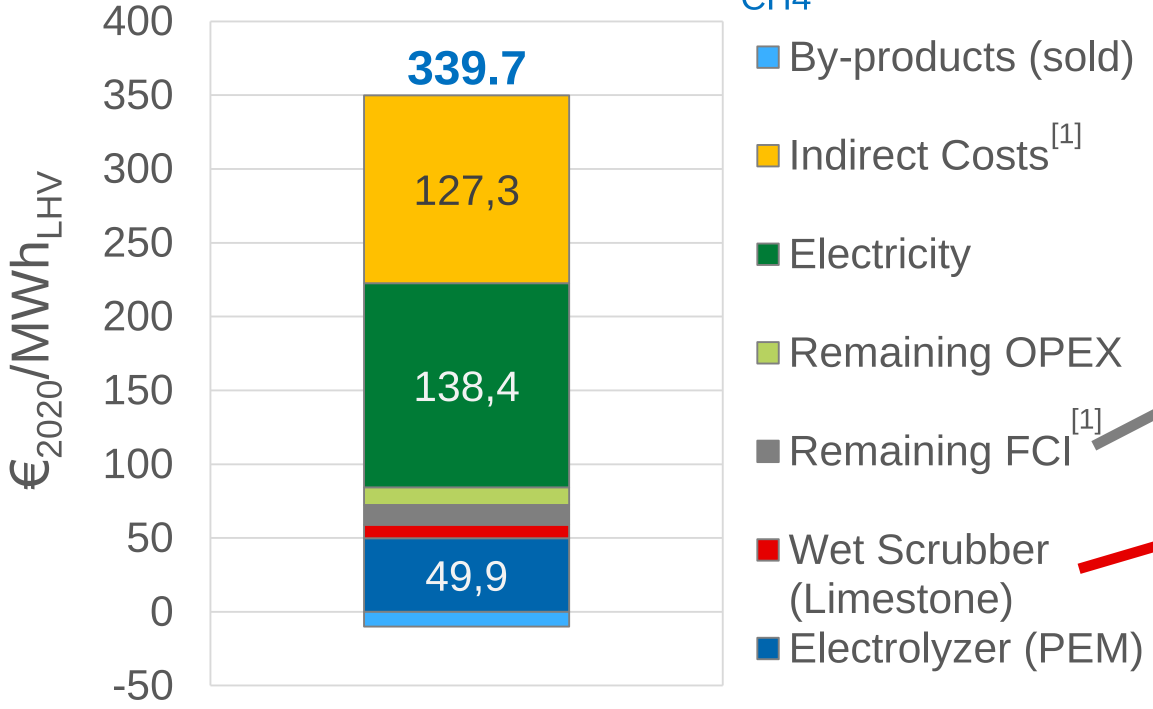


[1] M. Peters, K. Timmerhaus and R. West, Plant design and economics for chemical engineers, New York, United States: McGraw-Hill, 2004, ISBN 007-124044-6.

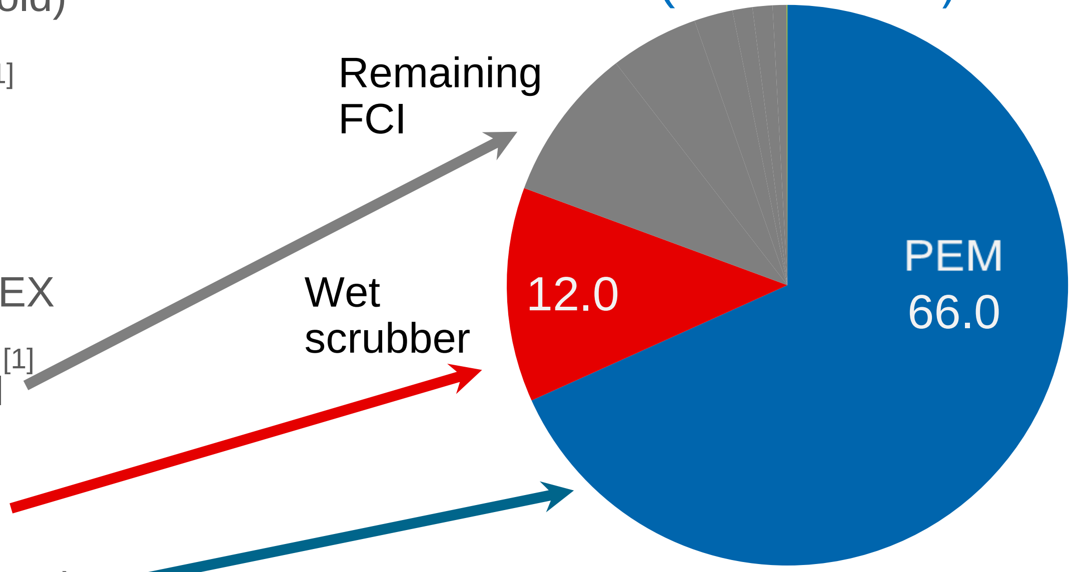
Glas-CO2 process assessment
Furnace fuel input 15.5 MW_{LHV}

Economic assessment: methane Net Production Cost (NPC)

Breakdown of NPC_{CH4}



Fixed Capital Investment costs (96.6 Mio. €)



NPC_{CH4}: 339.7 $\left[\frac{€_{2020}}{MWh_{LHV}}\right] \triangleq 0.40 \left[\frac{€_{2020}}{kg_{glass}}\right]$ Wine bottle: ~ 0.20[3] $\left[\frac{€_{2020}}{kg_{glass,\,fossil}}\right] \rightarrow$ ~ 0.53 $\left[\frac{€_{2020}}{kg_{glass,\,sustainable}}\right]$

CO_2 abatement cost: ~ 900 $\left[\frac{€_{2020}}{t_{CO2}}\right]$

[1] M. Peters, K. Timmerhaus and R. West, Plant design and economics for chemical engineers, New York, United States: McGraw-Hill, 2004, ISBN 007-124044-6.
[2] Tradingeconomics (2022). "EU Natural Gas." from https://tradingeconomics.com/commodity/eu-natural-gas.
[3] Alibaba (2023). https://german.alibaba.com/p-detail/Best-62074144923.html?spm=a2700.details.0.0.35cc7214BQetGB

Decarbonization of glass industry – Example for the decarbonization of global basic industry?

Summary

- Decarbonization of global basic industry is a necessary, huge effort. Currently no silver bullet.
- Glass industry in Germany (and Europe) faces increasing decarbonization pressure from both costumers and regulation
  - Highly concentrated CO_2 offgas of oxyfuel furnaces allows its capture and utilization
  - Demo projects should validate the feasibility of Glas-CO2 approach
- Standardized technical, economic and environmental assessment provides security of investment and minimization of risks
  - DLR methodology is widely accepted for different questions regarding energy transition
- Decarbonization of global basic industry: **look for low hanging fruits now!**

Programm

Die Dekarbonisierung der Industrie in Deutschland und Frankreich
Montag, 17. April 2023

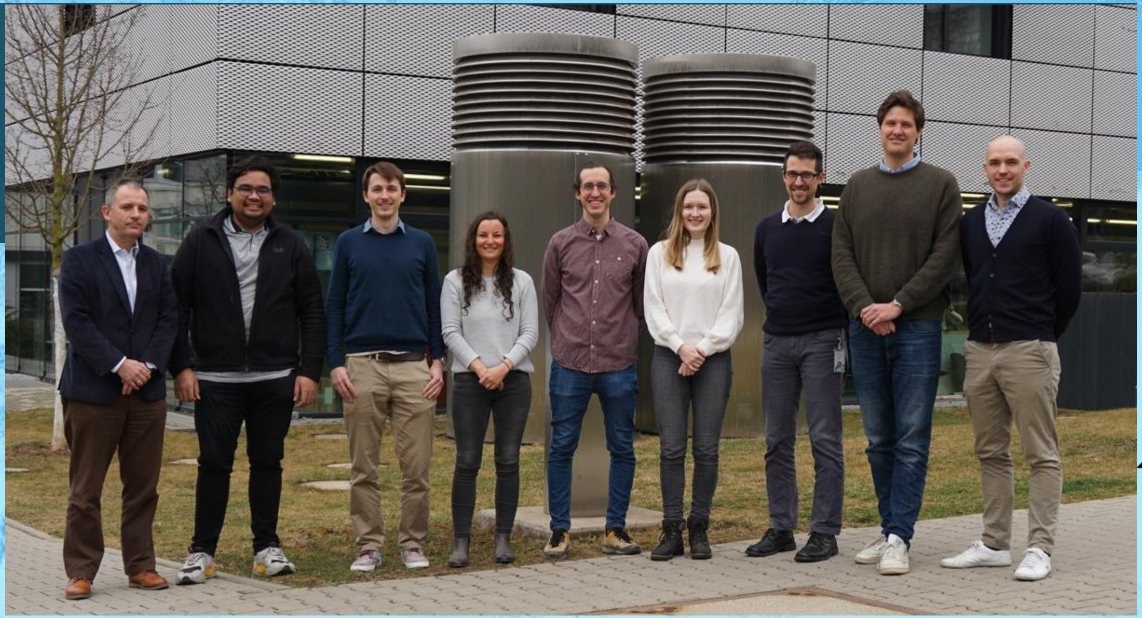
Hannover Messe 2023
Messegelände, Hermes Allee
30521 Hannover

Energy 4.0 Bühne - Halle 12, Stand D 35

Das Side Event wird von Sven Rösner (DFBEW) moderiert. Es wird auf Französisch und Deutsch verdolmetscht. Anmeldungen auf www.dfbew.eu

DECARBONIZATION OF THE GLASS INDUSTRY IN GERMANY

Thanks to the team.
Thank you for your attention.
Questions?



Moritz Raab, Felix Habermeyer, Nathanael Heimann, Julia Weyand, Simon Maier, Sandra Adelung, Francisco Moser, Yoga Rahmat, Ralph-Uwe Dietrich (r. to l.)

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