Tuesday, 14. November 2023

STREAM A:

SAF and Maritime fuels

ERTC

13 - 16 November 2023
LAGO MAGGIORE, ITALY

EUROPEAN REFINERY INTEGRATION OF SUSTAINABLE AVIATION FUELS (SAF)

Technical, economic and ecological assessment of European SAF production

Sandra Adelung, Ralph-Uwe Dietrich, Felix Habermeyer,
Simon Maier, Julia Weyand (DLR e.V., www.DLR.de/tt)

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European Refinery Integration of SAF
Agenda

13 - 16 November 2023
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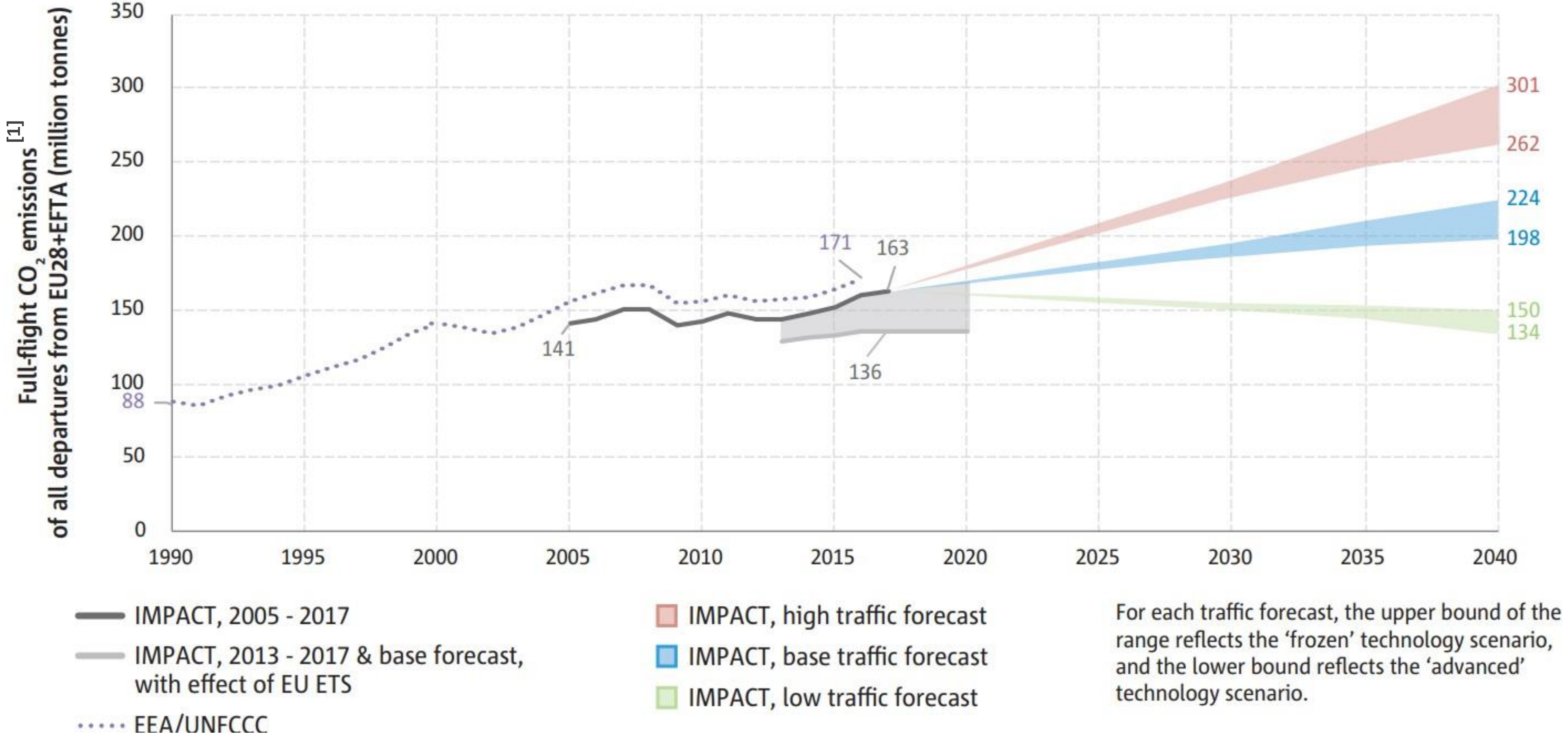
1. SAF options and activities
2. Techno-economic and life cycle analysis
3. Technological readiness
4. Towards a European SAF roadmap
5. SAF deployment plan
6. Conclusion and outlook

SAF deployment still lagging behind

Too little too late



[1] European Aviation Environmental Report 2019, https://www.easa.europa.eu/eaer/system/files/usr_uploaded/219473_EASA_EAER_2019_WEB_LOW-RES.pdf

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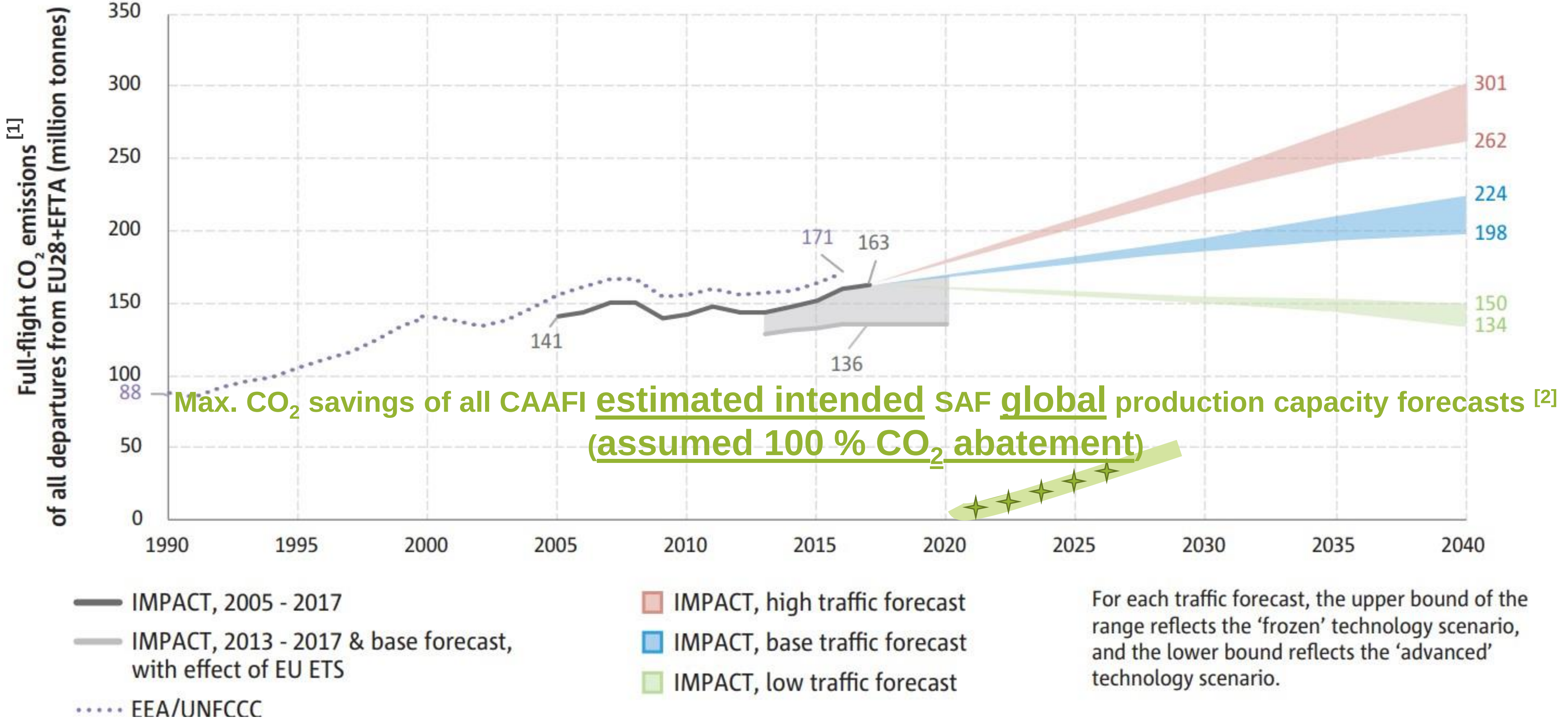

[1] European Aviation Environmental Report 2019, https://www.easa.europa.eu/eaer/system/files/usr_uploaded/219473_EASA_EAER_2019_WEB_LOW-RES.pdf
[2] calc. from (slide 2) S. Csonka, Aviation's Market Pull for SAF, https://www.caafi.org/focus_areas/docs/CAAFI_SAF_Market_Pull_from_Aviation.pdf.

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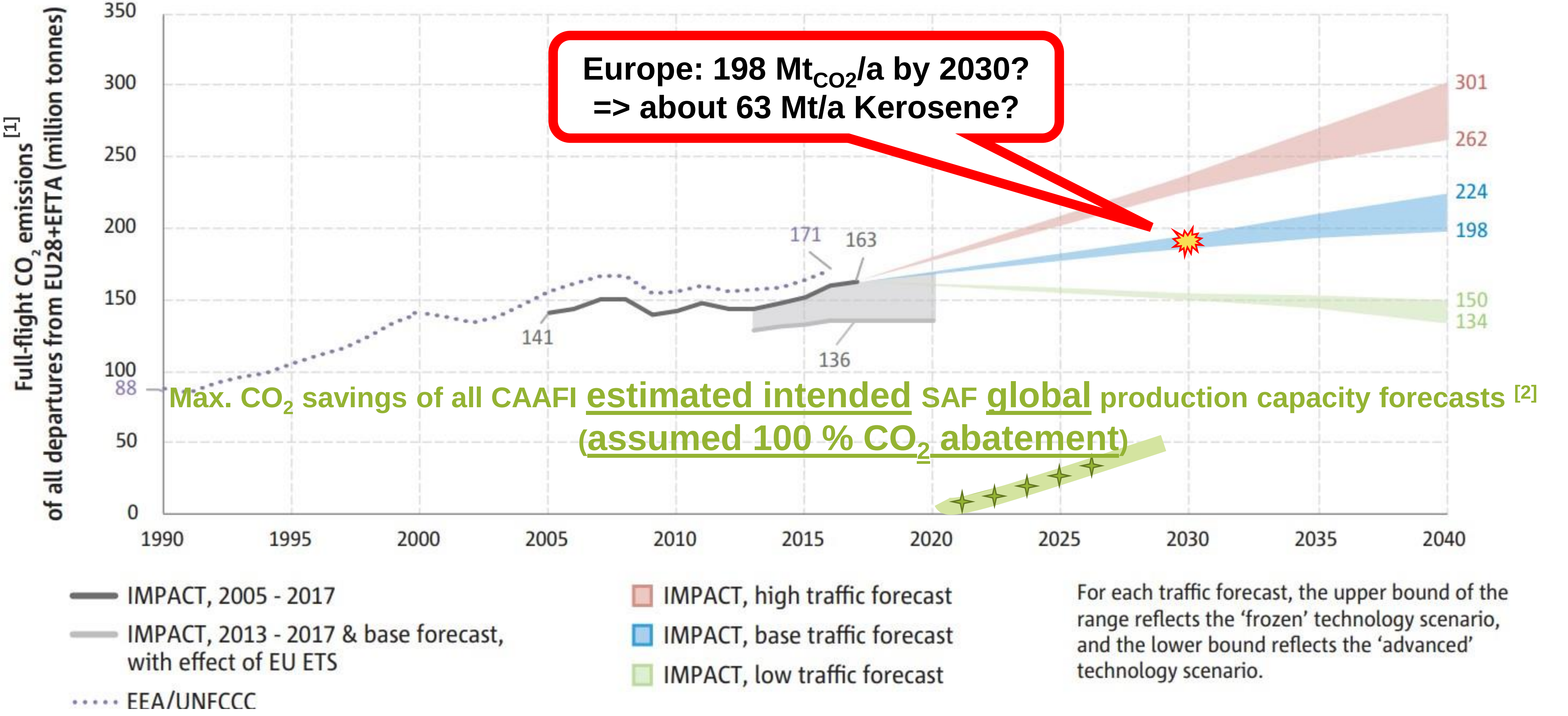

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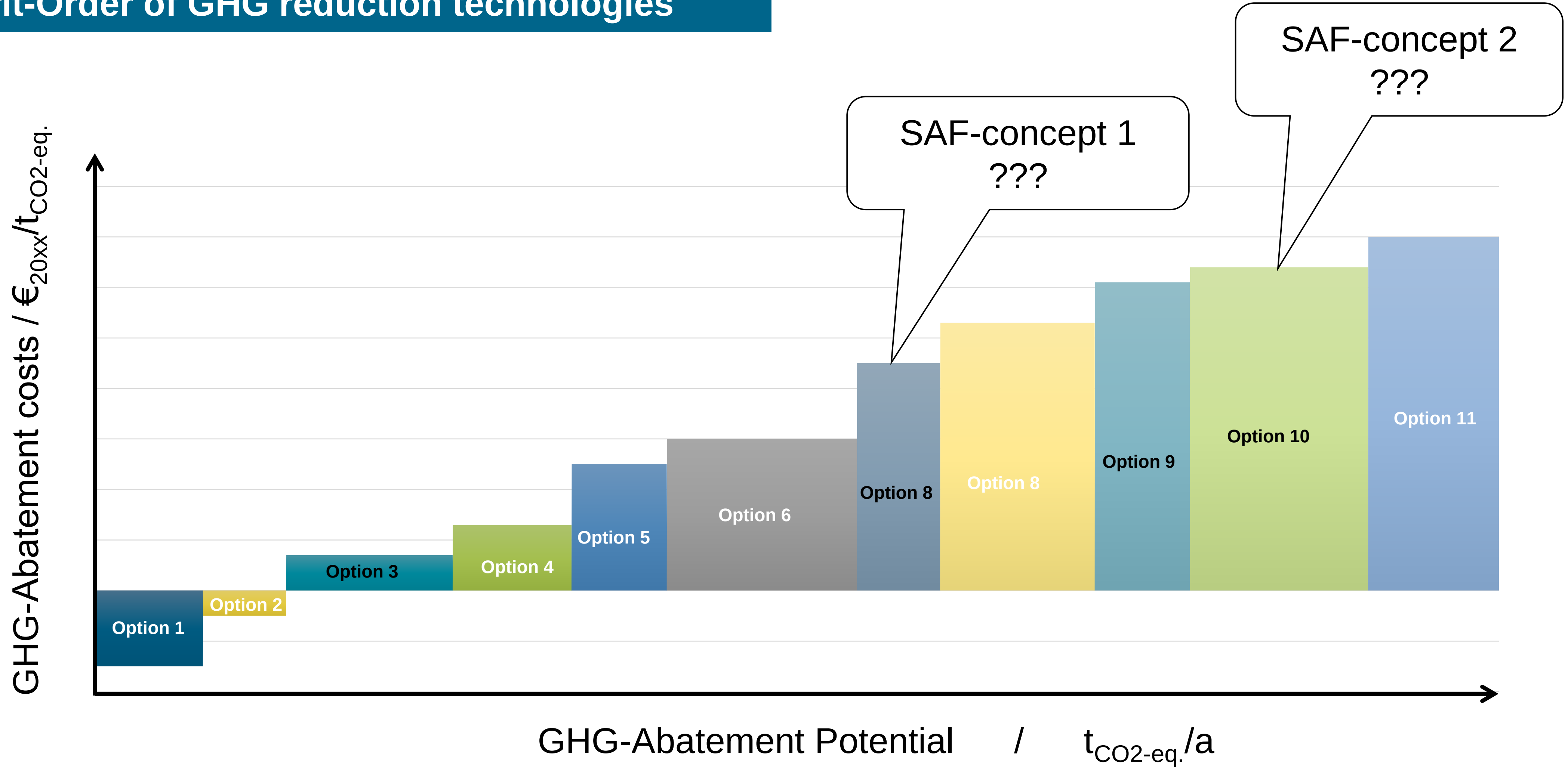
Assessment of SAF concepts / options / configurations / locations / …

Merit-Order of GHG reduction technologies



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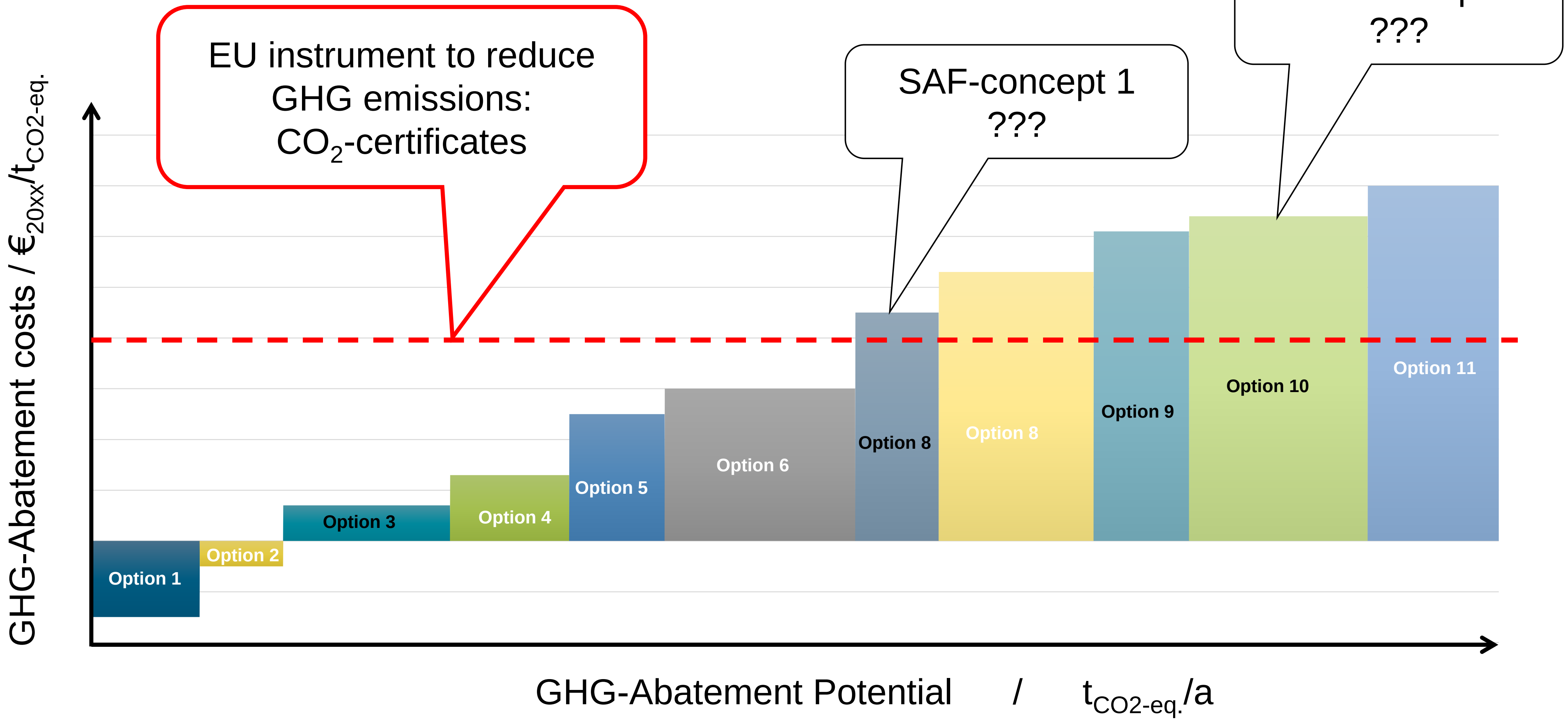

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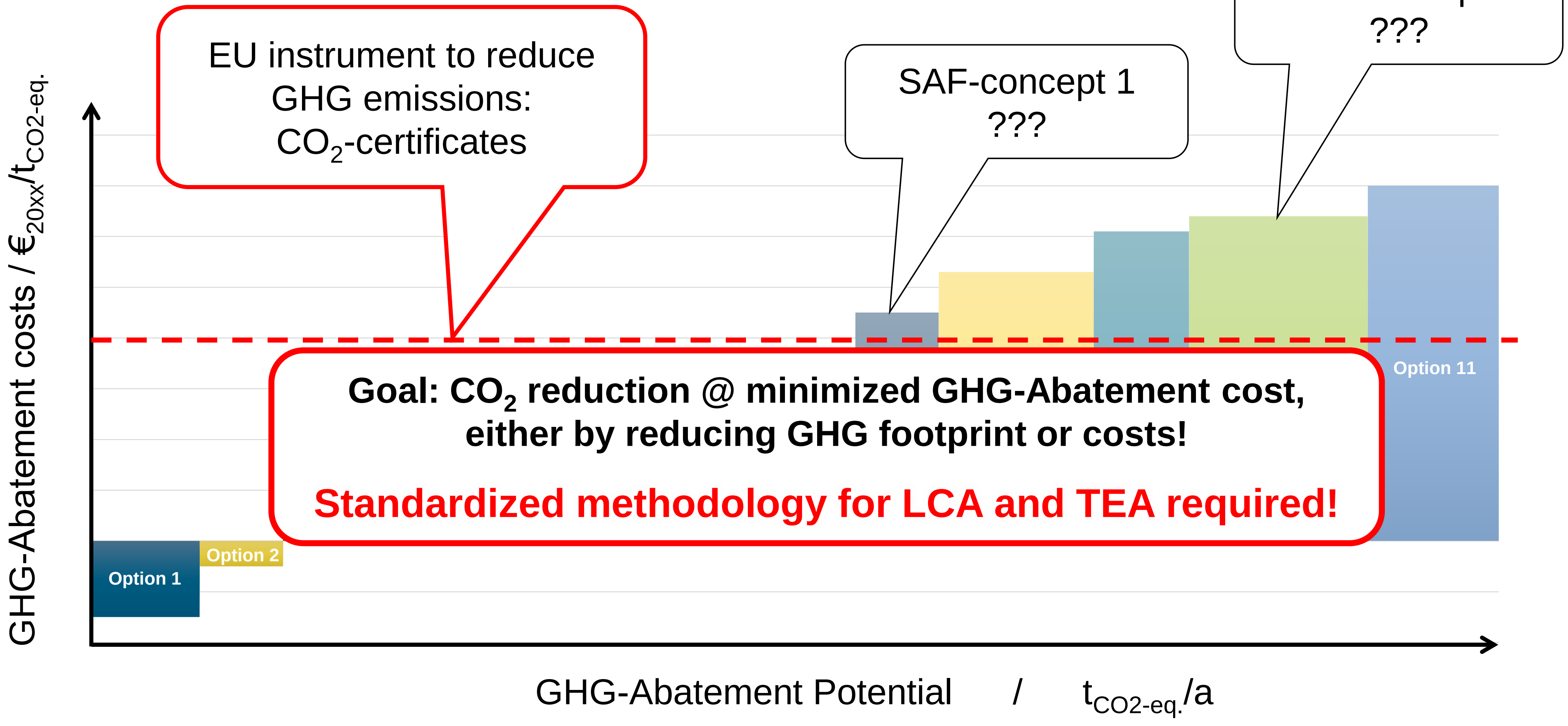

Certified Alternative Jet Fuels
ASTM D7566 – 21 [1]

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Feedstock	Synthesis technology	Fuel
~~Coal, natural gas~~, biomass, CO_2 & H_2	Fischer-Tropsch (FT) synthesis using Fe or Co catalyst,	Synthetic paraffinic kerosene (FT-SPK)
Non-petroleum derived light aromatics (primarily benzene)	Blend aromatics produced by alkylation to FT-SPK	FT-SPK plus Aromatics (SPK/A)
Biogenic lipids (e.g. algae, soya, palm oil, jatropha)	Hydrogenation and deoxygenation of fatty acids and esters (HEFA) + subsequent hydrocracking, hydroisomerization, isomerization, …	Synthetic paraffinic kerosene (HEFA-SPK)
Additional algae produced oil containing a high percentage of unsaturated hydrocarbons known as botryococcenes,	Blend botryococcenes hydrocarbons prior to hydroprocessing Esters and Fatty Acids (HC-HEFA)	SPK from Hydroprocessed Hydrocarbons, Esters and Fatty Acids (HC-HEFA)
Biogenic lipids (e.g. algae, soya, palm oil, jatropha)	Catalytic hydrothermal conversion of fatty acids and esters	Catalytic hydrothermolysis Jet (CHJ)
Sugar from Biomass	Direct Sugars to Hydrocarbons (DSHC)	Synthetic iso-paraffins (SIP) / Farnesane
Bio-isobutanol (-methanol, -ethanol, -propanol, …)	dehydration+oligomerization+hydration (Alcohol-to-Jet, AtJ)	AD-SPK

[1] ASTM International, „ASTM D7566-21 Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons“, 2021

Certified Alternative Jet Fuels
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Additional alg… percentage c… botryococcen…		…ons, …HEFA)
Biogenic lipic…		Jet
Sugar from E…		…IP)
Bio-isobutanol (…	(Alcohol-to-Jet, AtJ)	

Future role of 1st generation jet fuels within the aviation sector questionable due to:

- Direct competition with food markets
- Low area-related energy yields and limited cultivation area
- Low technical development potential

➔ How / Where / When to deploy 2nd generation SAF?

[1] ASTM International, „ASTM D7566-21 Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons“, 2021

Assessment of SAF concepts / options / configurations / locations / …

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Feedstock availability towards 63 Mt/a

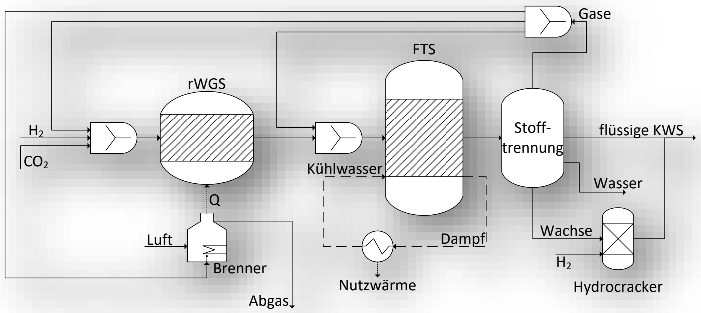
Feedstock	Synthesis technology	Fuel
~~Coal, natural gas~~, biomass, CO_2 & H_2	Fischer-Tropsch (FT) synthesis using Fe or Co catalyst,	Synthetic paraffinic kerosene (FT-SPK)

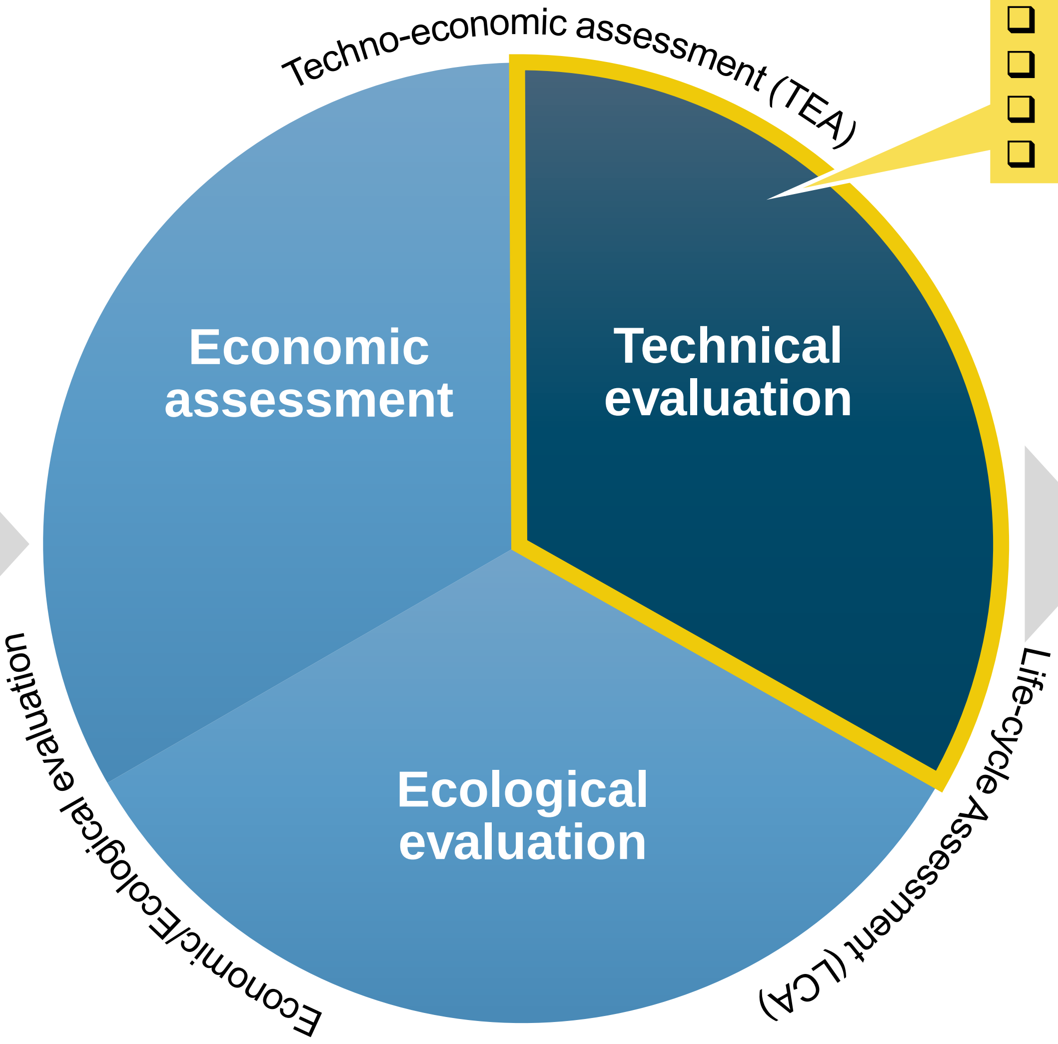
- Feedstock
  - Synthesis gas available from almost any carbon and hydrogen source ➔ Sustainability?
    - European wind power potential[1] for **sustainable H**:
      12,200 – 30,400 TWh_e **≈ 10 - 20 times of SAF demand!**
    - Annual sequestration of carbon in European forest biomass[2] for **sustainable C**:
      155 Mt/a **≈ 3 times of SAF demand!**
- FT synthesis
  - Large scale, commercial technology
    - Secunda CTL (Sasol): ca. 7 Mio.t/a – since 1980/1984
    - Pearl GTL (Qatar Petroleum + Shell): ca. 6 Mio.t/a – since 2011
- Fuel
  - Fully synthetic kerosene achievable [3]

[1] European Environment Agency, "Europe's onshore and offshore wind energy potential," 2009
[2] FOREST EUROPE, 2020: State of Europe's Forests 2020
[3] UK Ministry of Defense, „DEF STAN 91-91: Turbine Fuel, Kerosene Type, Jet A-1", UK Defense Standardization, 2011

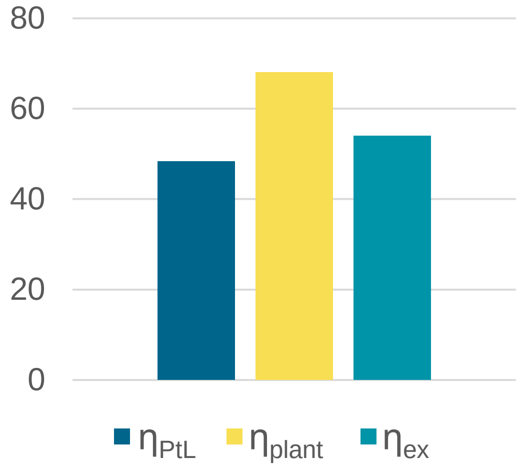
TECHNO-ECONOMIC AND LIFE CYCLE ANALYSIS

Techno-Economic and Life Cycle Assessment @ DLR





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



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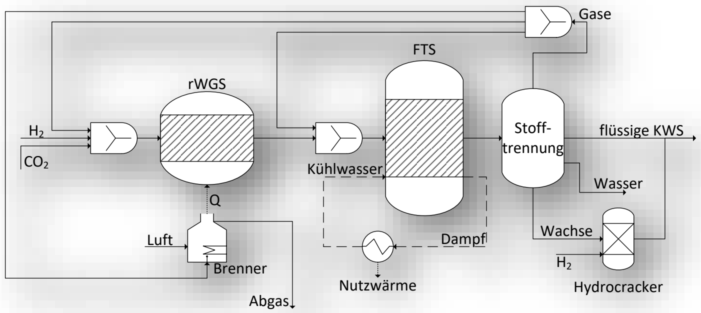

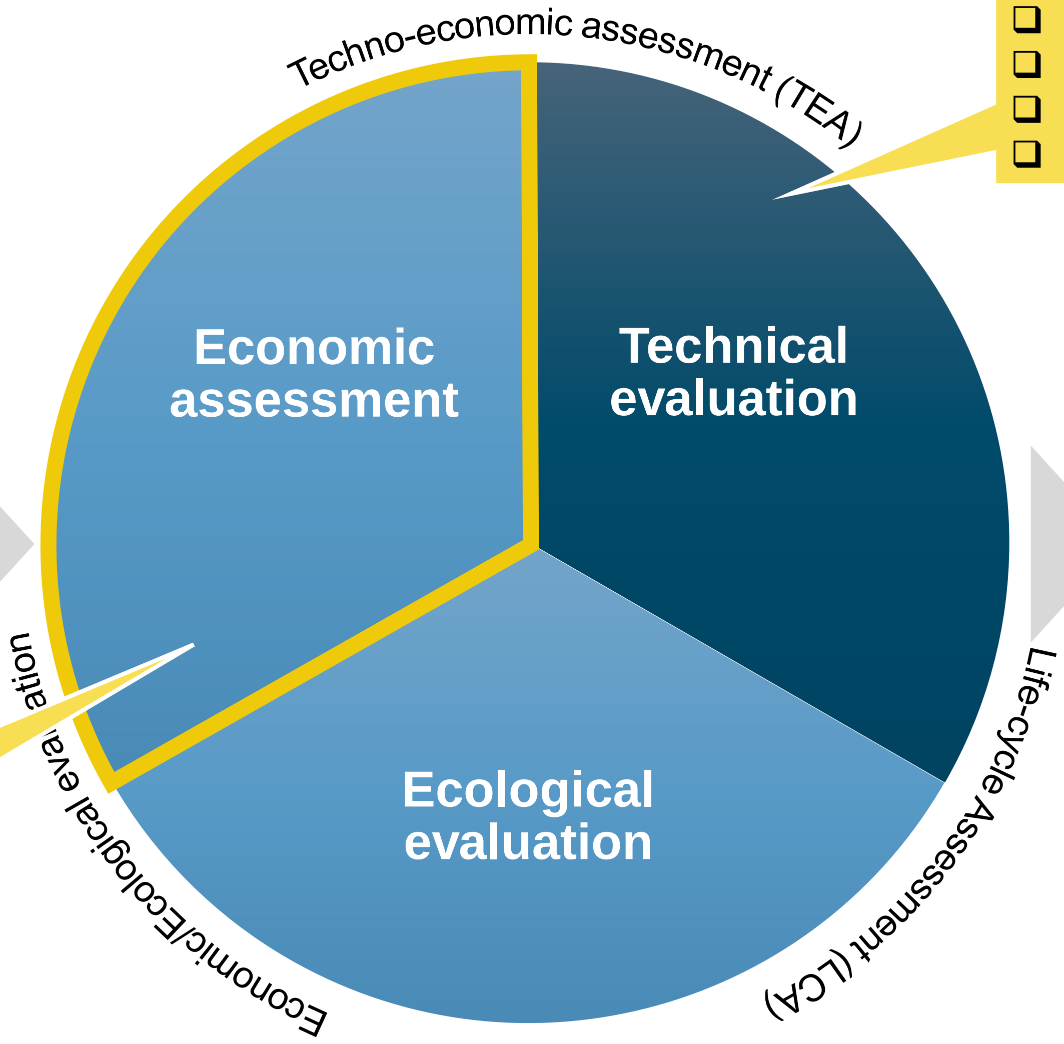

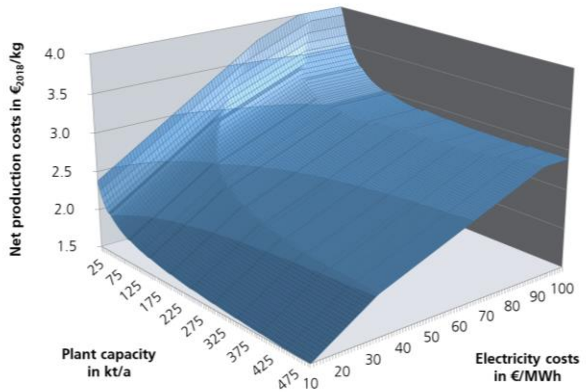

- CAPEX, OPEX, NPC
- Sensitivity analysis
- Identification of most economic feasible process design

Techno-Economic and Life Cycle Assessment @ DLR

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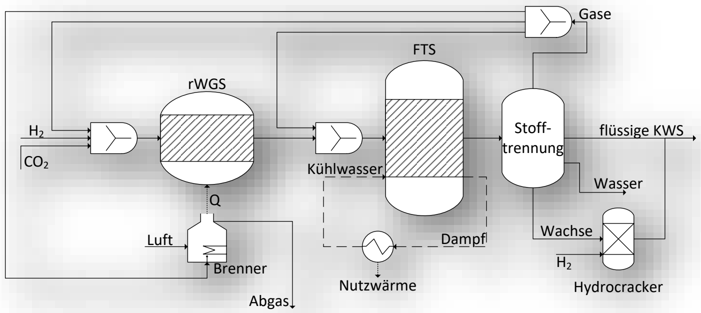

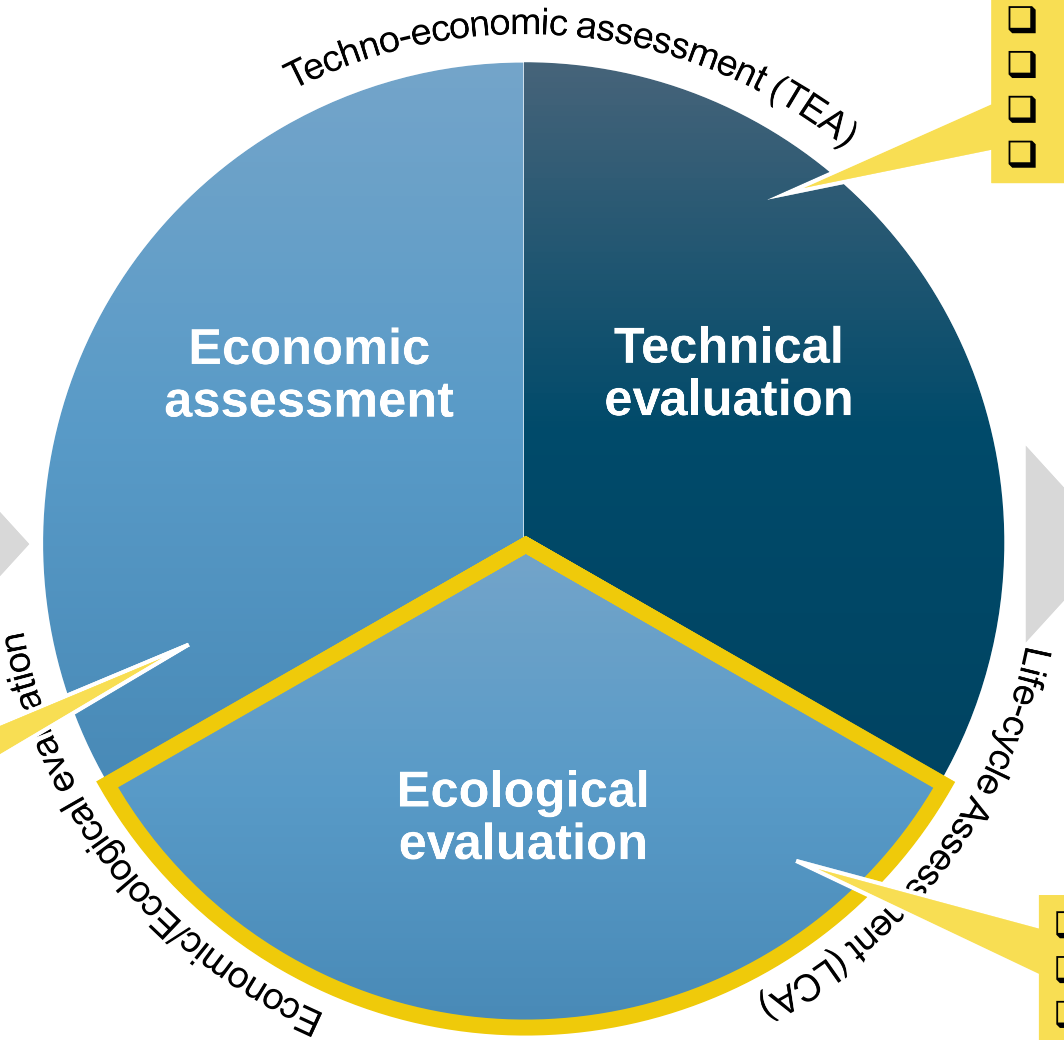

- CAPEX, OPEX, NPC
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- Identification of most economic feasible process design

- GWP
- Other impact categories
- Identification of impact drivers

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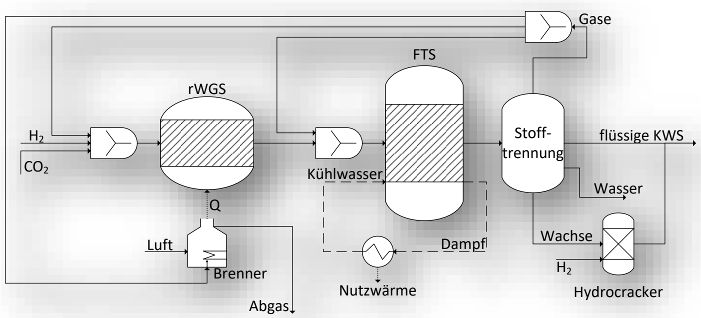

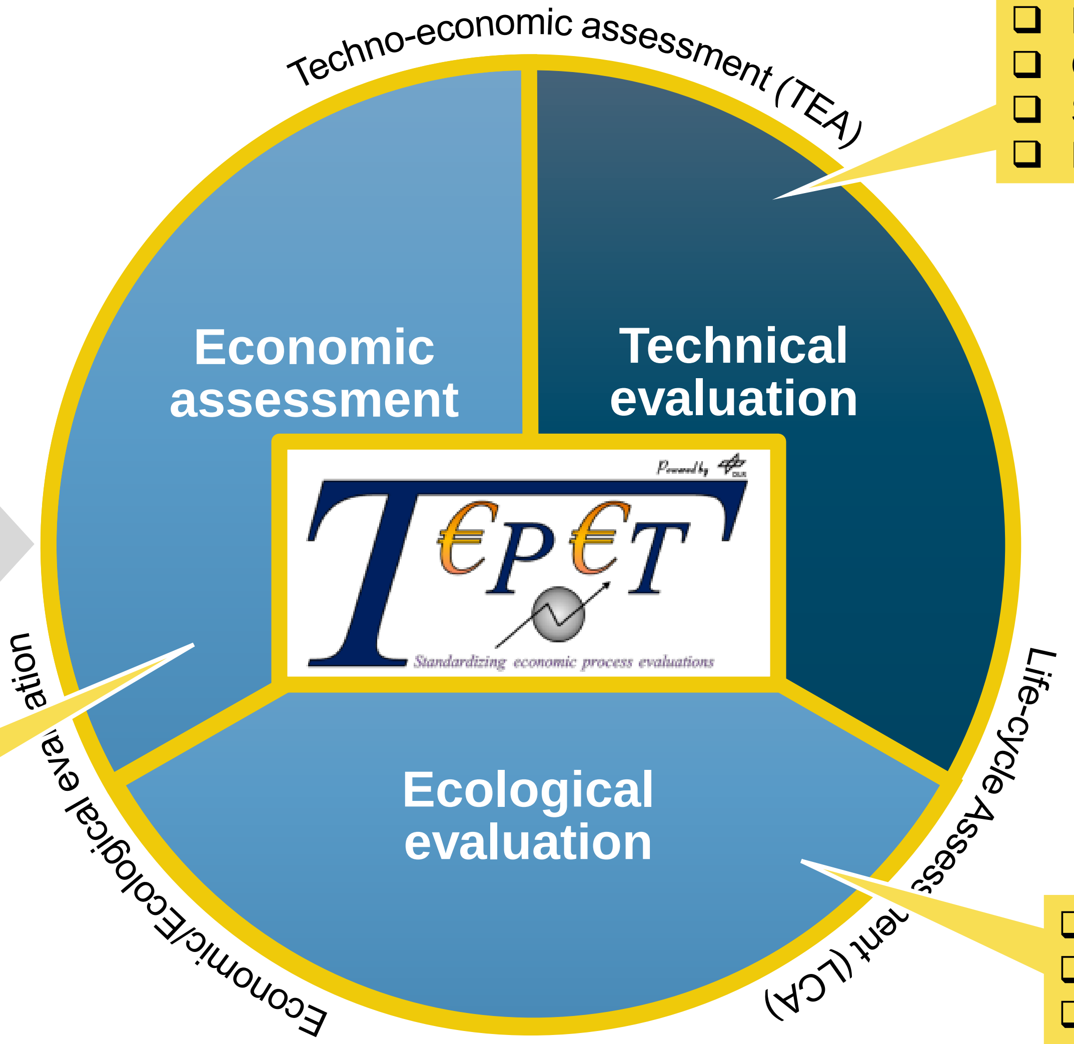

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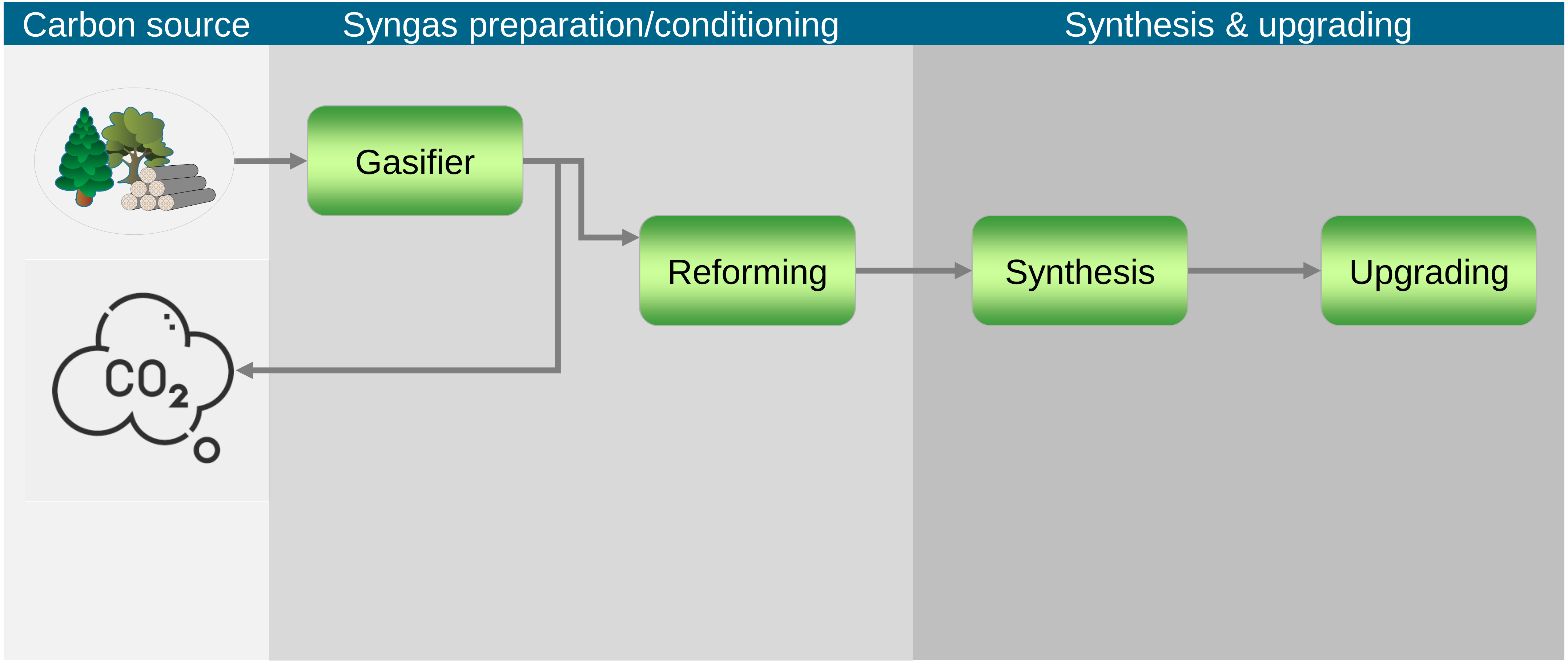
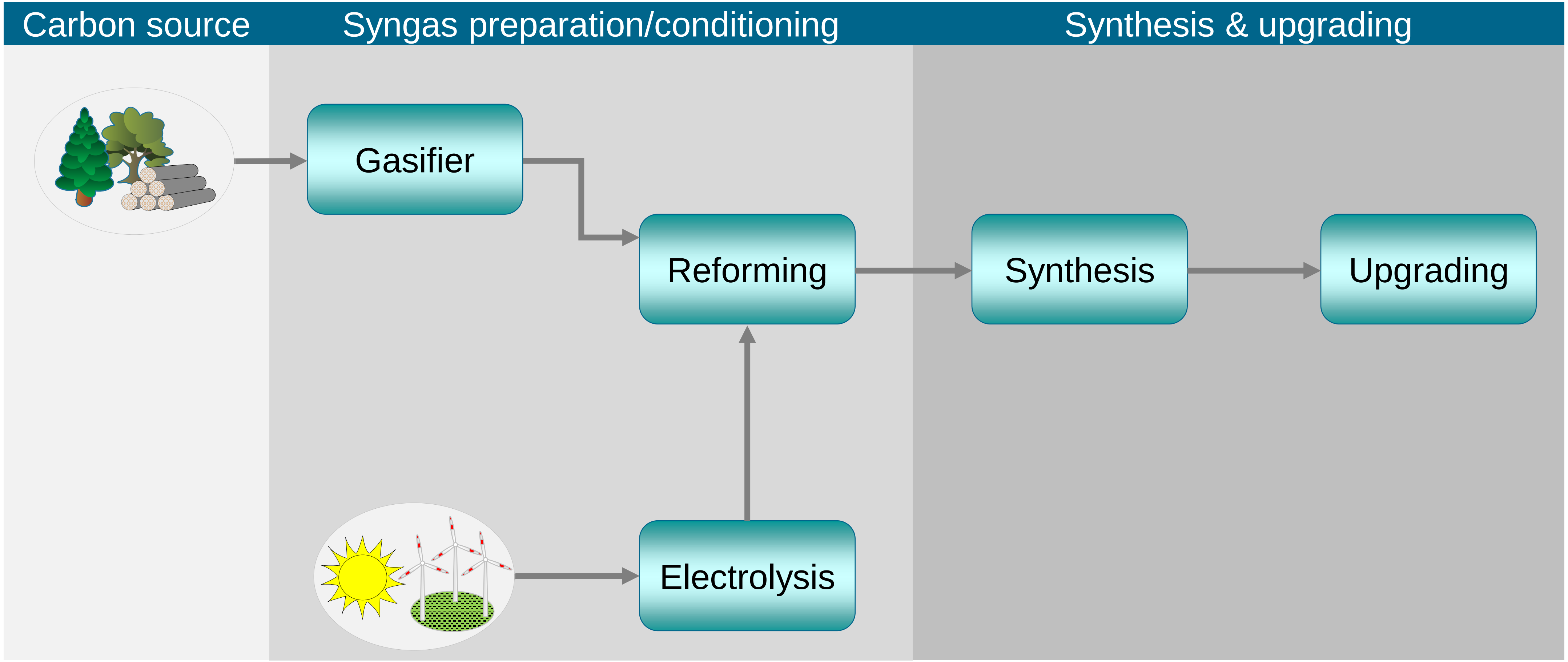
3 generic FT-based SAF concepts

Biomass-to-Liquid



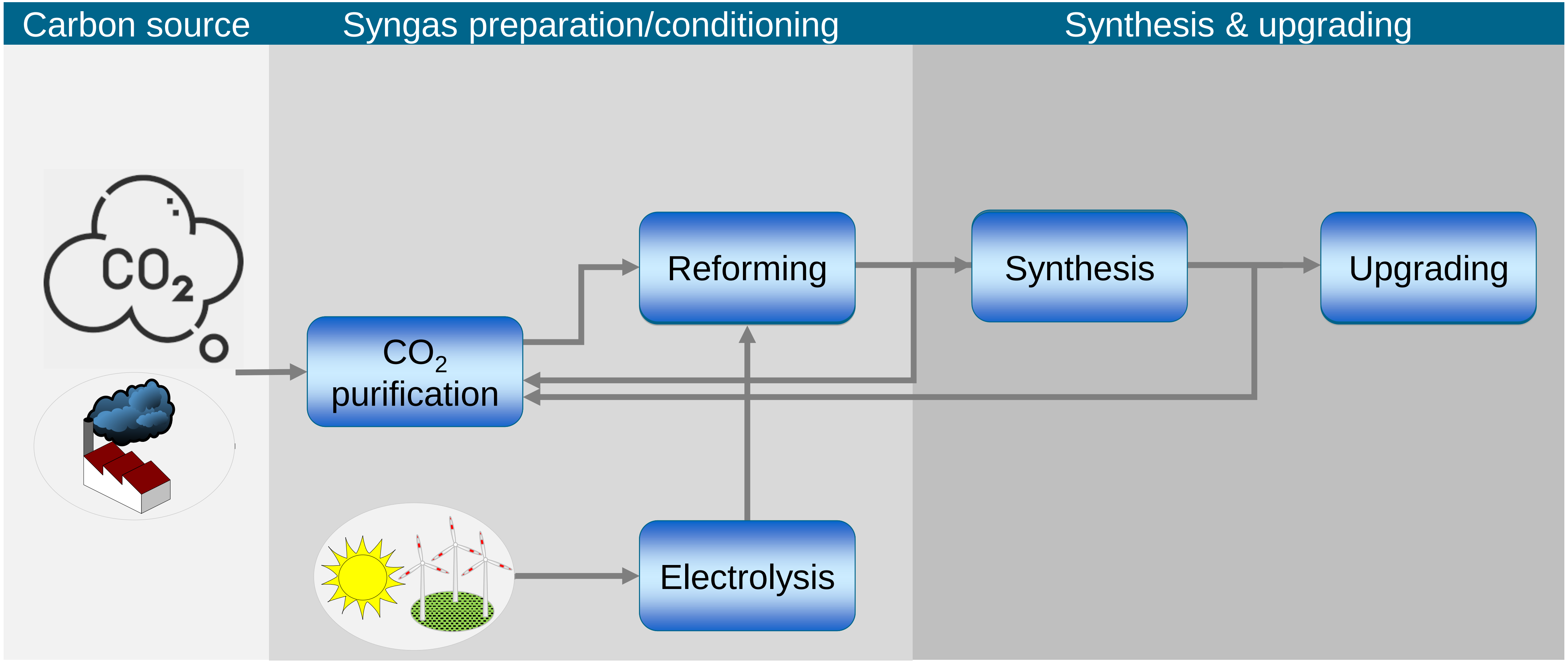
3 generic FT-based SAF concepts

Power&Biomass-to-Liquid



3 generic FT-based SAF concepts

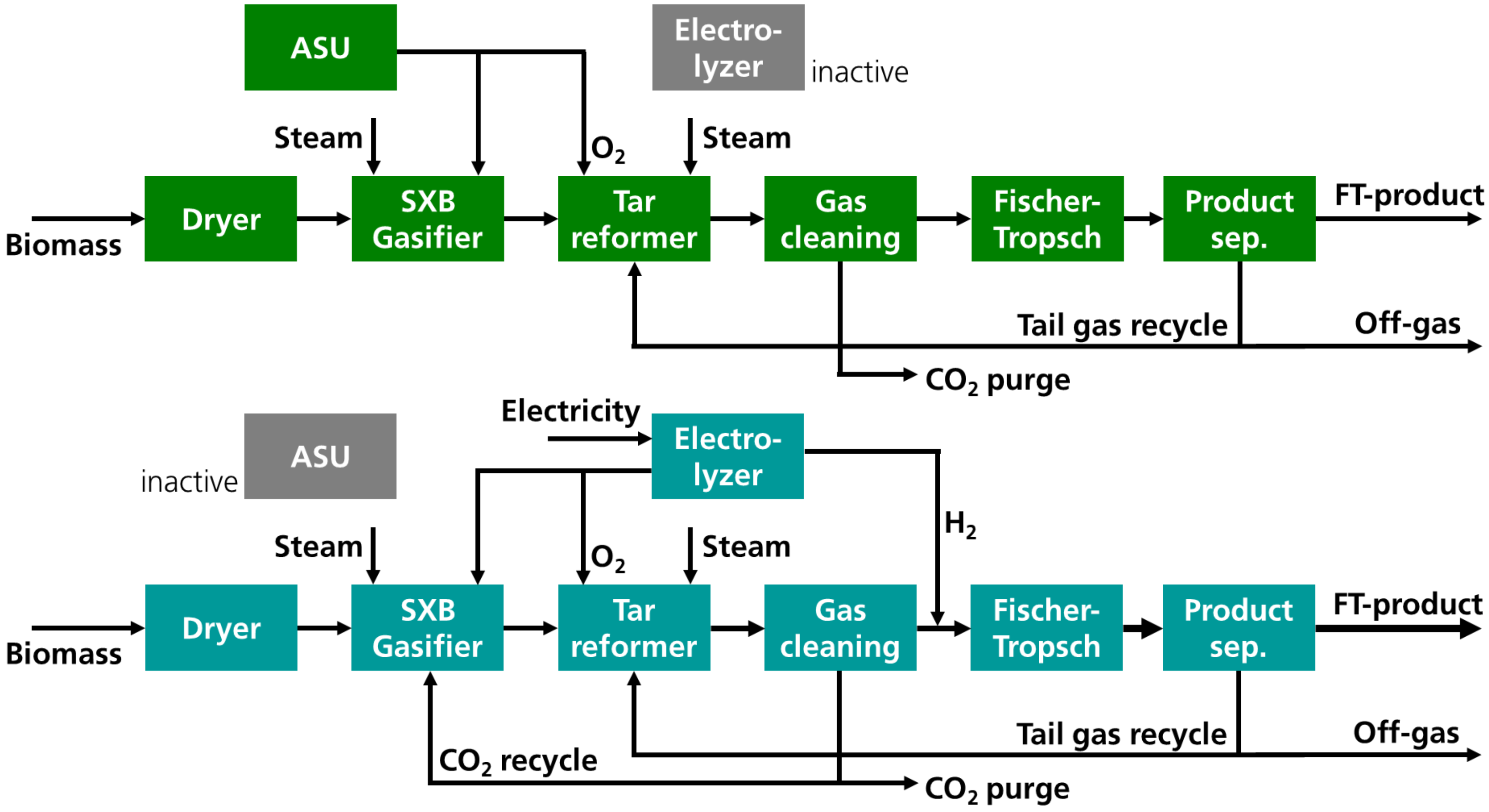
Power-to-Liquid



ENVIRONMENTAL ASSESSMENT OF SAF (PBTL)

Dual configuration for Biomass-to-Liquid and Power&Biomass-to-Liquid SAF [1]

FlexCHX project has received funding from the European Union's Horizon 2020 research and innovation Programme under Grant Agreement No 763919



BtL with ASU:

- high heat demand
- low renewable power

PBtL with electrolyzer :

- no heat demand
- renewable power available

[1] Habermeyer et. al (2023) Sustainable aviation fuel from forestry residue and hydrogen. A techno-economic and environmental analysis for an immediate deployment of the PBtL process in Europe. Sustainable Energy and Fuels, 7, p. 4229-4246. doi: 10.1039/d3se00358b.

Global Warming Potential (GWP) of Dual configuration SAF plant

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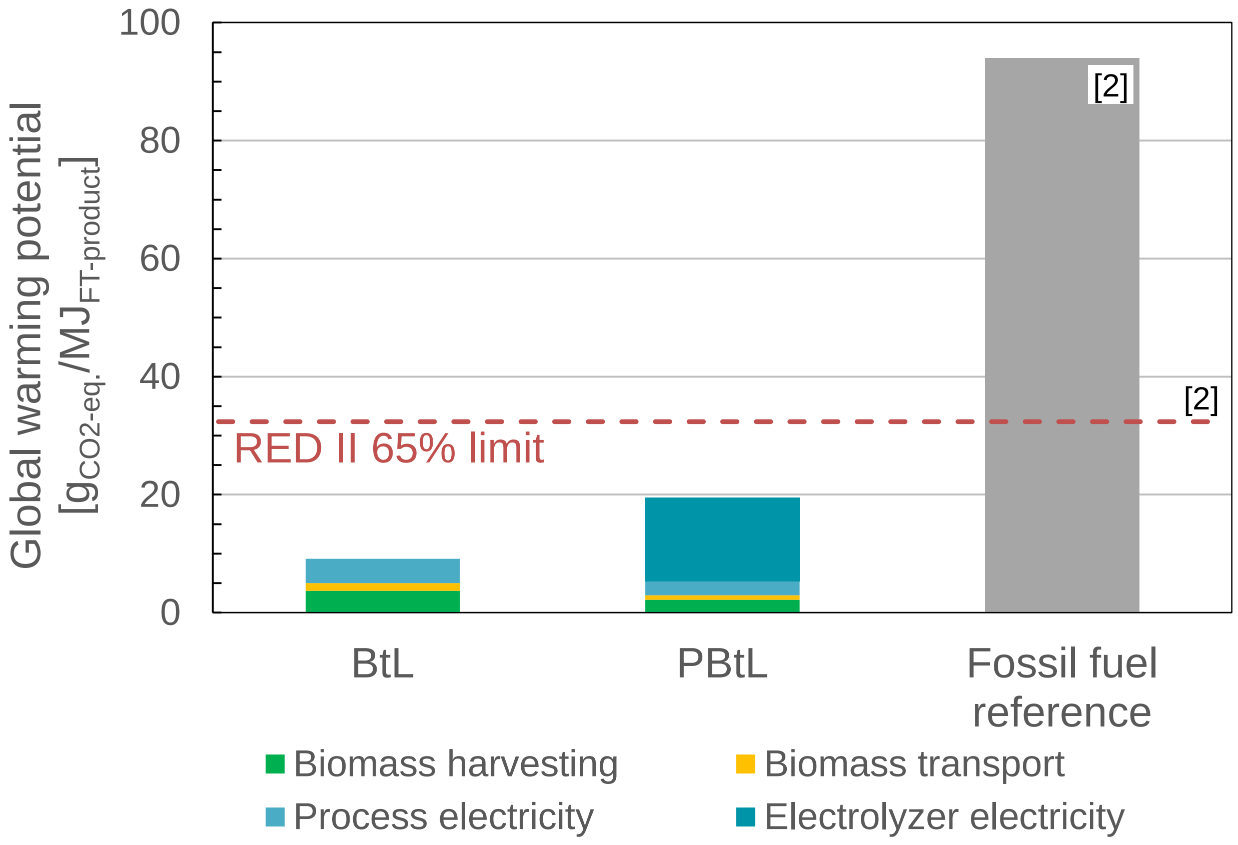

- Transportation: 100 km, one-way by truck (69 $g_{CO2-eq.}/(t*km)$)
- Biomass: Forest residues harvesting (19.7 $g_{CO2-eq.}/kg$)
- Electricity: Finnish grid @2020 (68.6 $g_{CO2-eq.}/kWh$)

Conclusion

REDII target accomplished @ FLEXCHX base case

[1] Habermeyer et. al (2023) Sustainable aviation fuel from forestry residue and hydrogen. A techno-economic and environmental analysis for an immediate deployment of the PBtL process in Europe. Sustainable Energy and Fuels, 7, p. 4229-4246. doi: 10.1039/d3se00358b.
[2] European Union (2018) "Directive 2018/2001 of the European Parliament …on the promotion of the use of energy from renewable sources (recast)", Official Journal of the European Union

GWP sensitivity of Biomass-to-Liquid / Power&Biomass-to-Liquid

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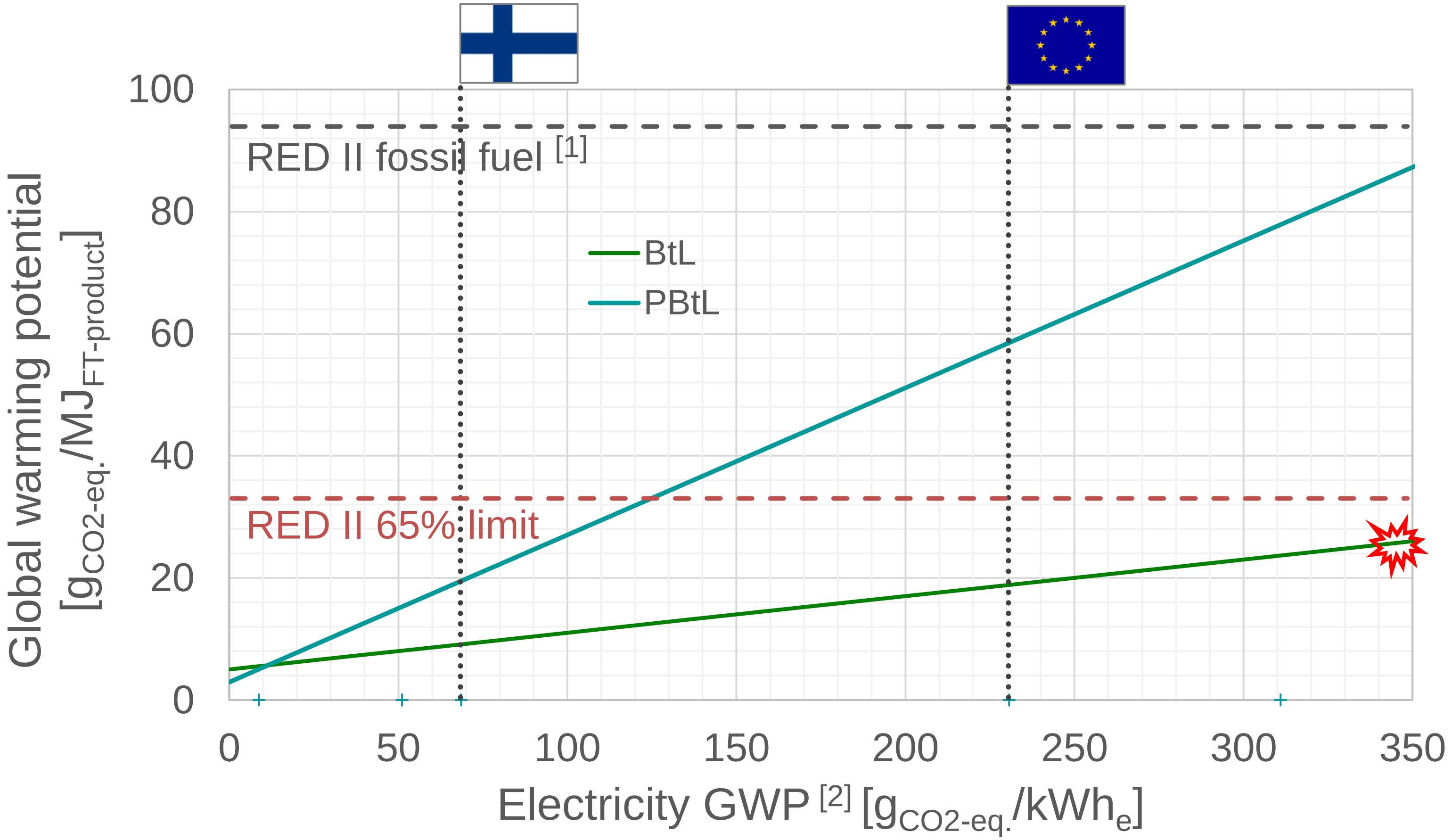

- REDII 65 % limit can be reached for all depicted electricity grid mixes for BtL

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[2] https://www.eea.europa.eu/data-and-maps/daviz/co2-emission-intensity-9/#tab-googlechartid_googlechartid_googlechartid_chart_1111

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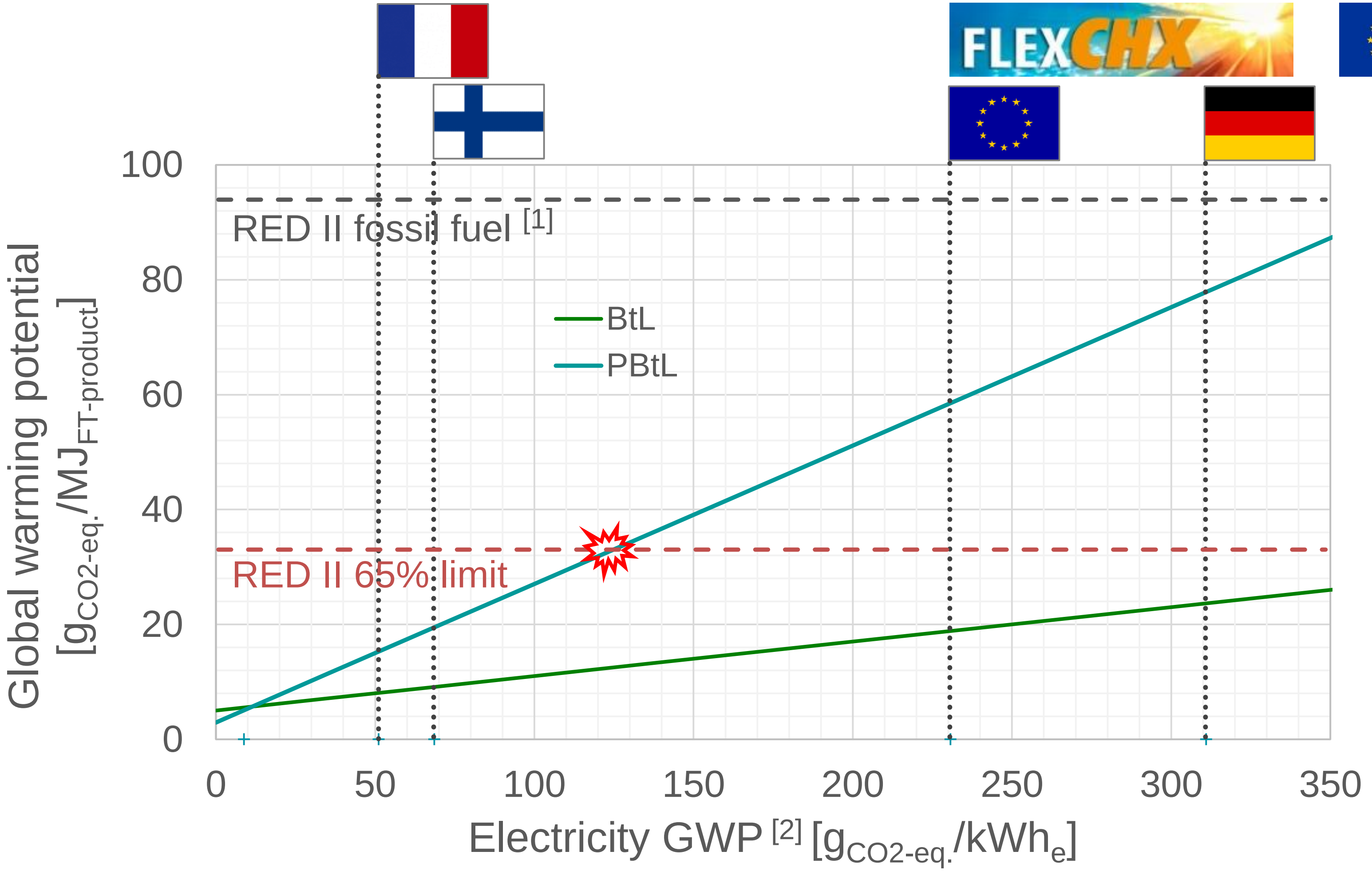

- REDII 65 % limit can be reached for all depicted electricity grid mixes for BtL
- PBtL requires electricity with GWP <120 $g_{CO2\text{-}eq.}/kWh_e$ to reach REDII 65 % limit

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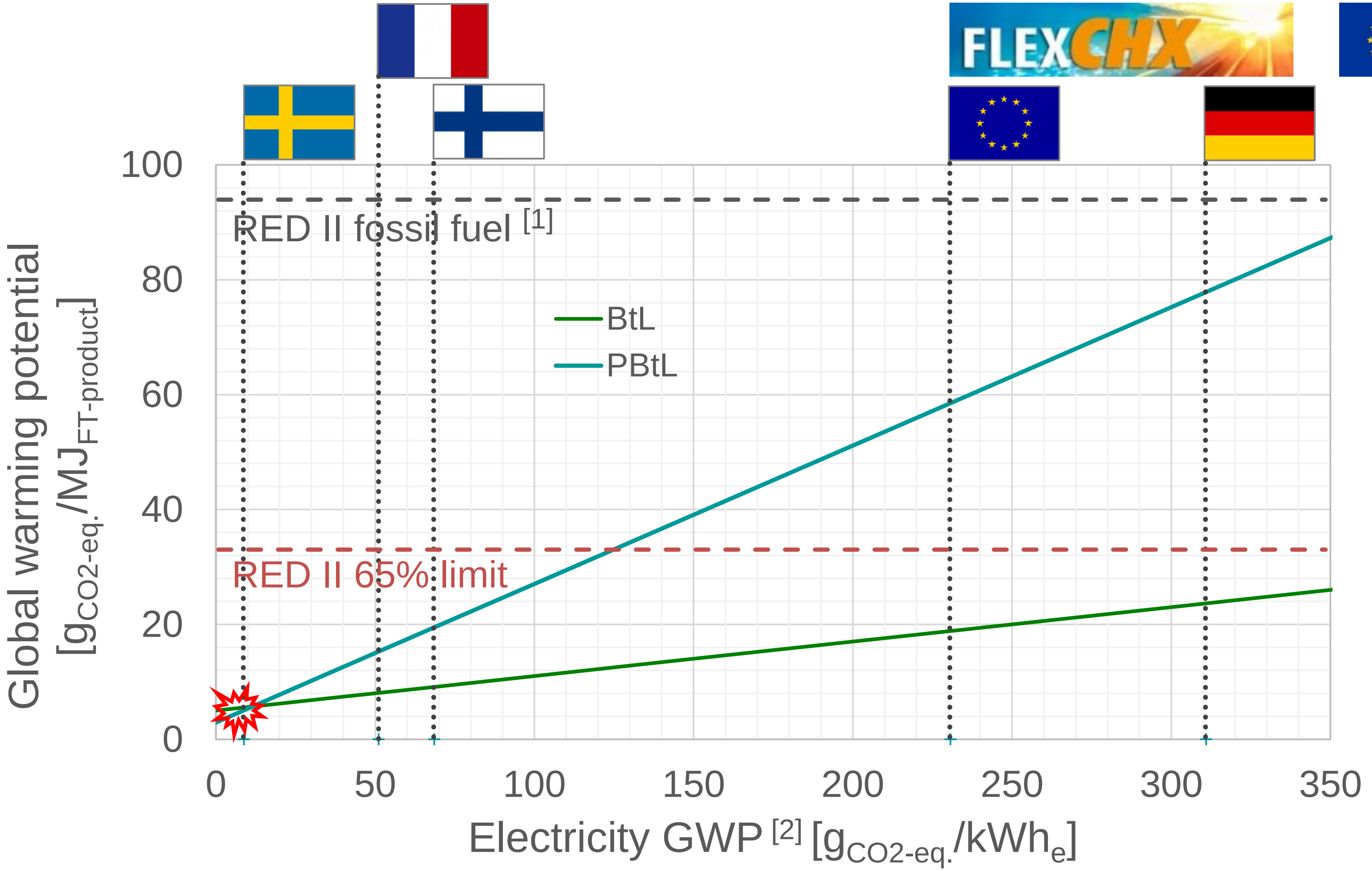

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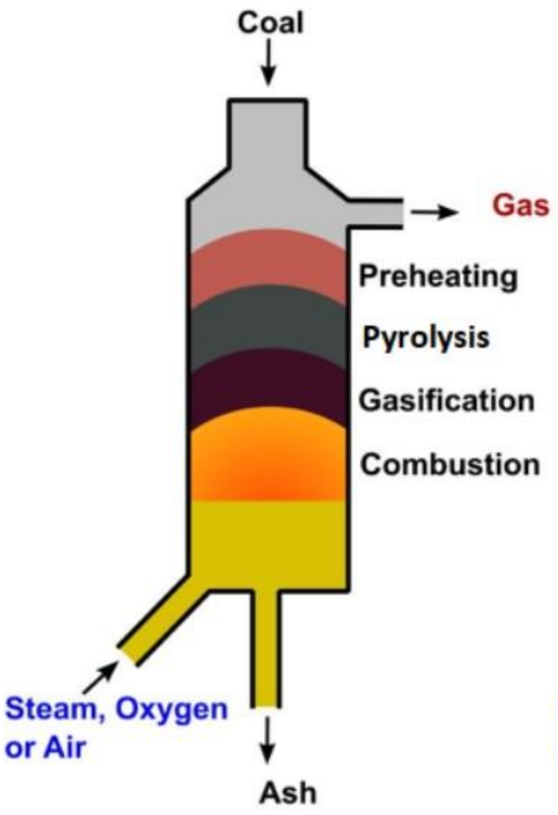
- PBtL could have lower GWP than BtL with Swedish grid mix

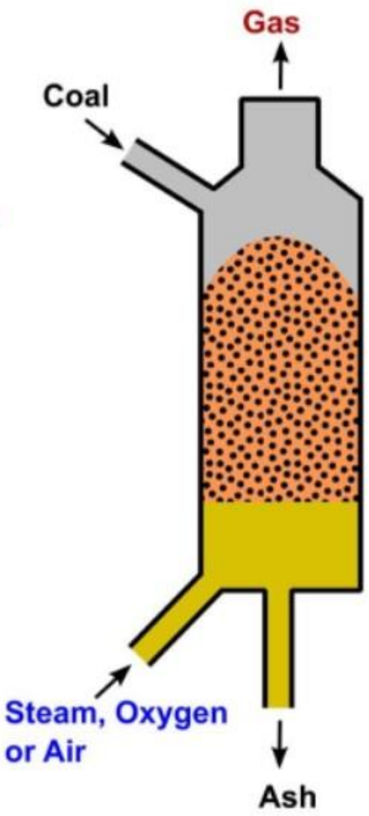
[1] European Union (2018) "Directive 2018/2001 of the European Parliament … on the promotion of the use of energy from renewable sources (recast)", Official Journal of the European Union
[2] https://www.eea.europa.eu/data-and-maps/daviz/co2-emission-intensity-9/#tab-googlechartid_googlechartid_googlechartid_chart_1111

TECHNOLOGY READINESS OF PBTL SAF

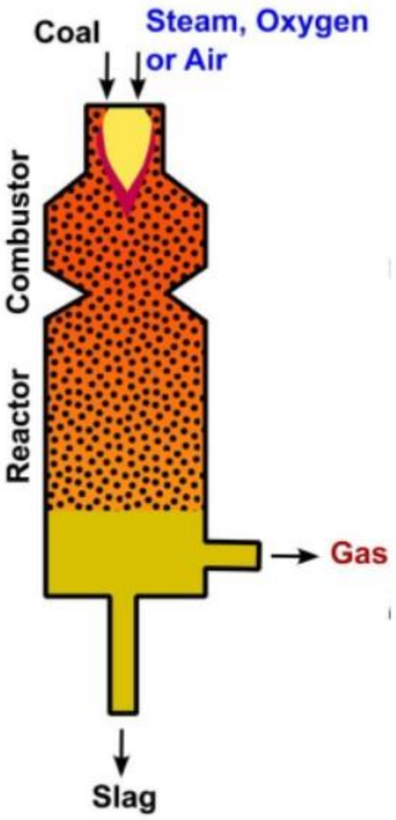
Gasifier: state-of-the-art coal technology



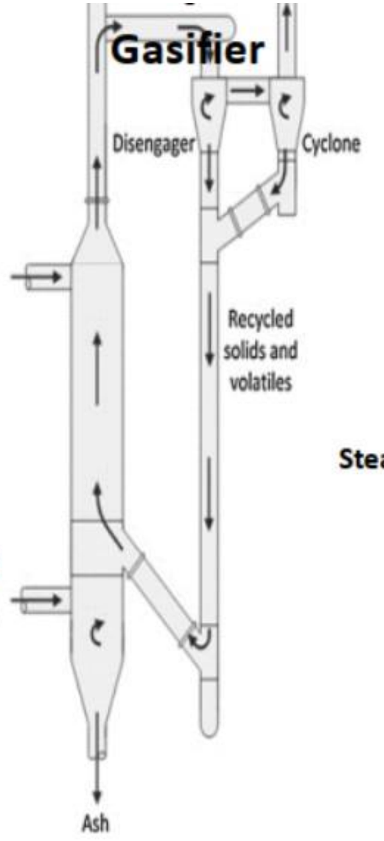
Fixed (moving) bed



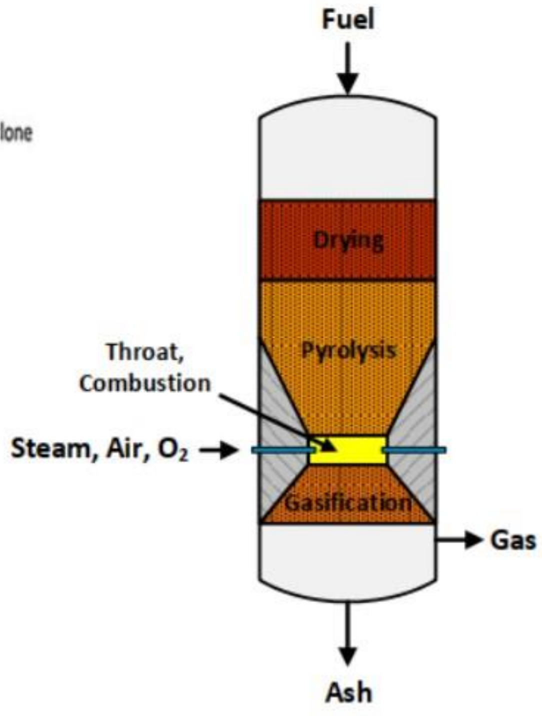
Fluidized bed



Entrianed flow



Transport Integrated



Downdraft

Gasifier: multiple installations,
➔ biomass applications proven

[1]

[1] Dr. Alexander Schulz, Green methanol, part of Uhde’s green technologies, Aachen, 13.09.2022

Electrolysis
Ongoing research

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Table 2. Summary of parameters of state-of-the-art water electrolysis.

Technology	AEL	PEM	SOEC
Electrolyte	20–40 wt % KOH	water	steam
Operating temperature [°C]	60–90	50–80	700–900
Typical operating pressure [bar]	10–30	20–50	1–15
Current density [$A\,cm^{-2}$]	0.2–0.4 / 1.2[b)]	0.6–2.0	0.3–2.0
Cell area [m^2]	<4	<0.3	<0.01
Specific energy consumption (stack) [$kWh_{el}\,Nm^{-3}\,H_2$]	4.2–4.8	4.4–5.0	>3.0
Specific energy consumption (system) [$kWh_{el}\,Nm^{-3}\,H_2$]	5.0–5.9	5.0–6.5	3.7–3.9 (4.7 $kWh\,Nm^{-3}\,H_2$)
Lower dynamic range [%][a)]	10–40 / <10 [c)]	0–10	>30
Gas purity [%]	> 99.5 / > 99.95[b)]	99.99	99.90
System response	seconds	milliseconds	seconds
Cold time start [min]	<60 / <1–50 %[b)]	<20	<60
Stack lifetime [h]	60 000–90 000	20 000–60 000	<10 000
Maturity	mature	commercial	demonstration
Investments costs [$€\,kW^{-1}$]	800–1500	1400–2100	>2000

a) Minimum operable hydrogen production rate relative to maximum specified production rate; b) thyssenkrupp system installed at Carbon2Chem®; c) Lüke and Zschocke [14].

[1] Tenhumberg, Ecological and Economic Evaluation of Hydrogen Production by Different Water Electrolysis Technologies, Chem. Ing. Tech. 2020, 92, No. 10, 1586–1595

Electrolysis
State-of-the-art / GW installations in Europe

[1]

Electrolysis technology is state-of-the-art

[1] Source: tkUCE/tkis

Electrolysis
State-of-the-art / GW installations in Europe

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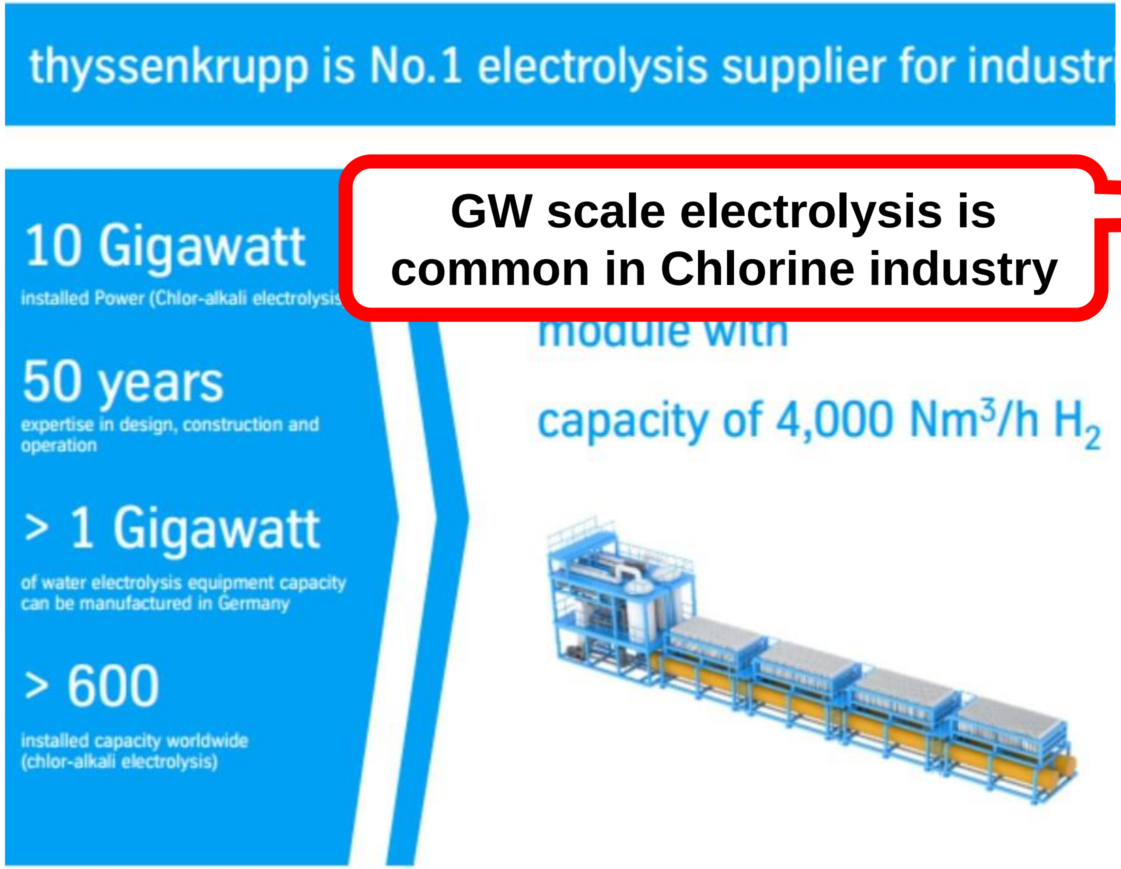

GW scale electrolysis is common in Chlorine industry

[2]

Location	Country	Operator	Capacity Chlorine (in 1000 t)	Diaphrag.	Membr.	Other	Electrolys. D **MW**	Electrolys. M **MW**
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		**2.970**	**1.560**
Runcorn	UK	Runcorn MCP	430		430			**1.118**
Rotterdam-Botlek	NL	Nobian	637		637			**1.656**
Dormagen	GER	Covestro	480		400	80[5]		**1.040**
Lillo	BE	INNOVIN	500		500			**1.300**
Tessenderlo	BE	Inovyn (INEOS)	400		400			**1.040**
Ludwigshafen	GER	BASF	595					**0**
Leverkusen	GER	Covestro	390		390			**1.014**
Lavera	FR	Kem One	341	341			**989**	**0**
Tavaux	FR	INNOVIN	370		370			**962**
Fos	FR	Kem One	333	178	155		**516**	**403**
Kazincbarcika	HUN	BorsodChem	480	384	96		**1.114**	**250**
Uerdingen	GER	Covestro	290		290			**754**
Marl	GER	Vestolit	260		260			**676**
Rafnes (Bamble)	NOR	Inovyn (INEOS)	315		315			**819**
Schkopau	GER	Dow	252		252			**655**
Knapsack	GER	Westlake Vinnolit	250		250			**650**
Rheinberg	GER	Inovyn (INEOS)	220	110	110		**319**	**286**

[1] Source: tkUCE/tkis

[2] Eurochlor: Chlorine Industry Review 2021-2022, www.chlorineindustryreview.com

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Fischer-Tropsch Technology
State-of-the-art / refinery size proven

Shell Qatar GTL facility, built in 2012, produces 140,000 barrels a day

Do you call 7 Mt/a FT production "commercial"?

[1] https://alfin2300.blogspot.com/2011/11/gas-to-liquids-carbon-sciences-provides.html

TOWARDS A EUROPEAN SAF ROADMAP

Fischer-Tropsch based SAF concepts
Stochiometric preference

Power-to-Liquid $\Delta H^0_{F,byproduct} = -484\ kJ \rightarrow -484 \frac{kJ}{(CH_2)}$

$$CO_2 + 3\ H_2 \rightarrow -CH_2- + 2\ H_2O$$

Biomass-to-Liquid $\Delta H^0_{F,byproduct} = -394\ kJ \rightarrow -131 \frac{kJ}{(CH_2)}$

$$2\ C_2H_3O^* \rightarrow 3\ -CH_2- + CO_2$$

Power&Biomass-to-Liquid $\Delta H^0_{F,byproduct} = -484\ kJ \rightarrow -121 \frac{kJ}{(CH_2)}$

$$2\ C_2H_3O^* + 6\ H_2 \rightarrow 4\ -CH_2- + 2\ H_2O$$

Palmoil-to-HEFA $\Delta H^0_{F,byproduct} = -484\ kJ \rightarrow -30 \frac{kJ}{(CH_2)}$

$$C_{16}H_{32}O_2^{**} + 2\ H_2 \rightarrow 16\ -CH_2- + 2\ H_2O$$

* Woody biomass elemental mass composition: $C_{52.1}H_{6.1}O_{38.5}X_{2.9}$

** Example: palmitic acid elemental molar composition: $C_{16}H_{32}O_2$

PBtL potential analysis for Europe
Finding the sweet spots

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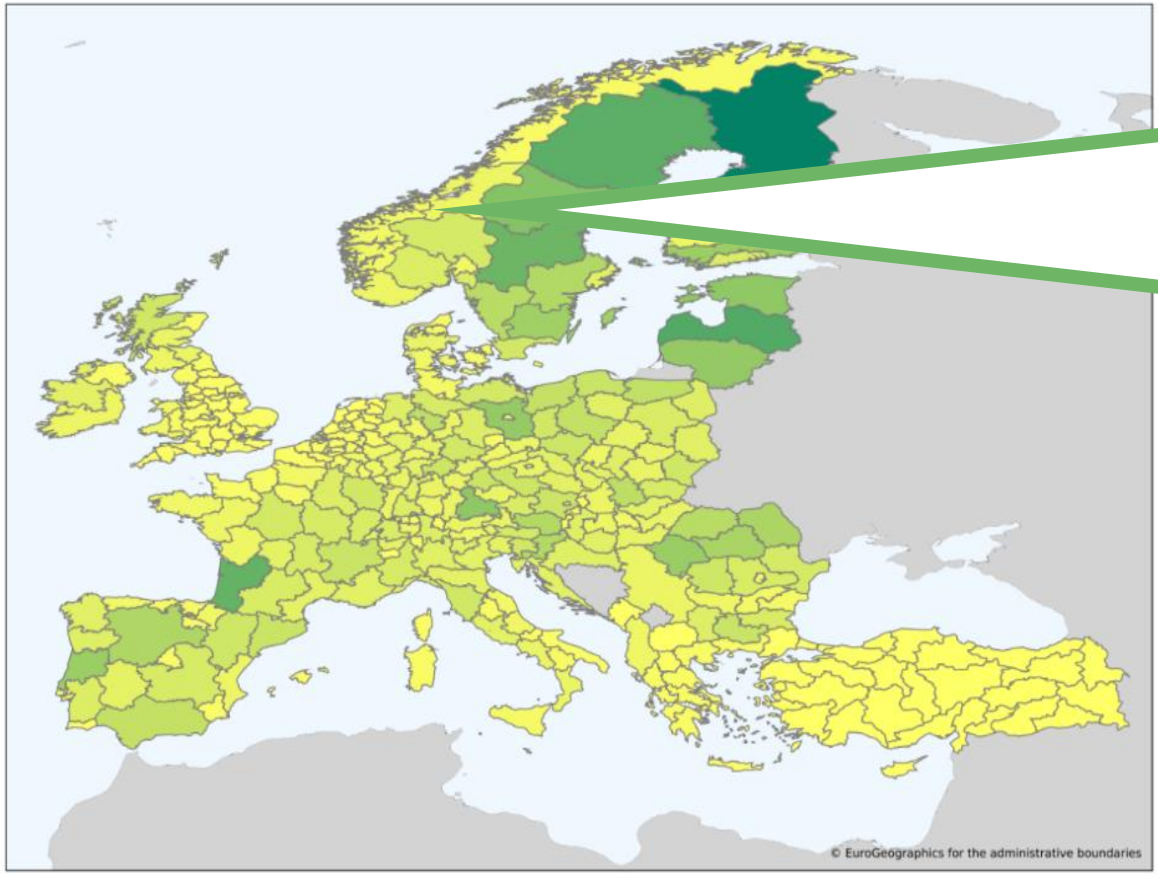

NUTS2 region specific conditions:

Economic
- 2020 National grid electricity prices [1]
- Woody biomass prices & availability [2]
- Transport distance = f(biomass density)
- Nation-specific transport & labor costs

Ecological
- 2020 National grid mix GWP [3]
- Region-specific transport emissions

[1] Eurostat, Electricity prices for non-household consumers - bi-annual data. 2021.
[2] Ruiz, P., Nijs, W., Tarvydas, D., Sgobbi, A., Zucker, A., Pilli, R., ... & Thrän, D. (2019). ENSPRESSO-an open, EU-28 wide, transparent and coherent database of wind, solar and biomass energy potentials. *Energy Strategy Reviews*, *26*, 100379
[3] https://www.eea.europa.eu/data-and-maps/daviz/co2-emission-intensity-6 [Accessed 14.9.21]

Large scale PBtL SAF plant: 400 kt_{SAF}/a
incl. 900 MW_e Electrolyzer / 400 MW_{th} CFB gasifier

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Key economic Assumptions

Investment costs:		
AEL-Electrolyzer	**1**	$M€_{2020}$/MW [1]
Fischer-Tropsch SBCR:	**5.9**	$k€_{2020}/m^3$ [2]
Selexol:	**5.5**	$k€_{2020}/kmol_{CO2}$/h [3]
Fluidized bed gasifier:	**0.5**	$M€_{2020}/(kg_{dry\ biomass}/s)$ [4]
Raw materials and utility costs		
Selexol:	**4.4**	$€_{2020}$/kg [5]
FT catalyst:	**33**	$€_{2020}$/kg [6]

General economic assumptions:

Year:	2020	*Plant lifetime:*	20 years
Full load hours:	8,100 h/a	*Interest rate:*	7 %

[1] Buttler, A., & Spliethoff, H. (2018). Current status of water electrolysis for energy storage, grid balancing and sector coupling via power-to-gas and power-to-liquids: A review. Renewable and Sustainable Energy Reviews, 82, 2440-2454.
[2] Gasification, B. B. (1998). Aspen Process Flowsheet Simulation Model of a Battelle Biomass-Based Gasification, Fischer-Tropsch Liquefaction and Combined-Cycle Power Plant.
[3] Hamelinck, C. N., & Faaij, A. P. (2002). Future prospects for production of methanol and hydrogen from biomass. *Journal of Power sources*, *111*(1), 1-22.
[4] Hannula, I. (2016). Hydrogen enhancement potential of synthetic biofuels manufacture in the European context: A techno-economic assessment. *Energy*, *104*, 199-212.
[5] Albrecht, F. G., König, D. H., Baucks, N., & Dietrich, R. U. (2017). A standardized methodology for the techno-economic evaluation of alternative fuels–A case study. *Fuel*, *194*, 511-526.
[6] Swanson, R. M., Platon, A., Satrio, J. A., & Brown, R. C. (2010). Techno-economic analysis of biomass-to-liquids production based on gasification. *Fuel*, *89*, S11-S19.

European SAF Roadmap
Scandinavia ➔ Lowest NPC (electricity price)

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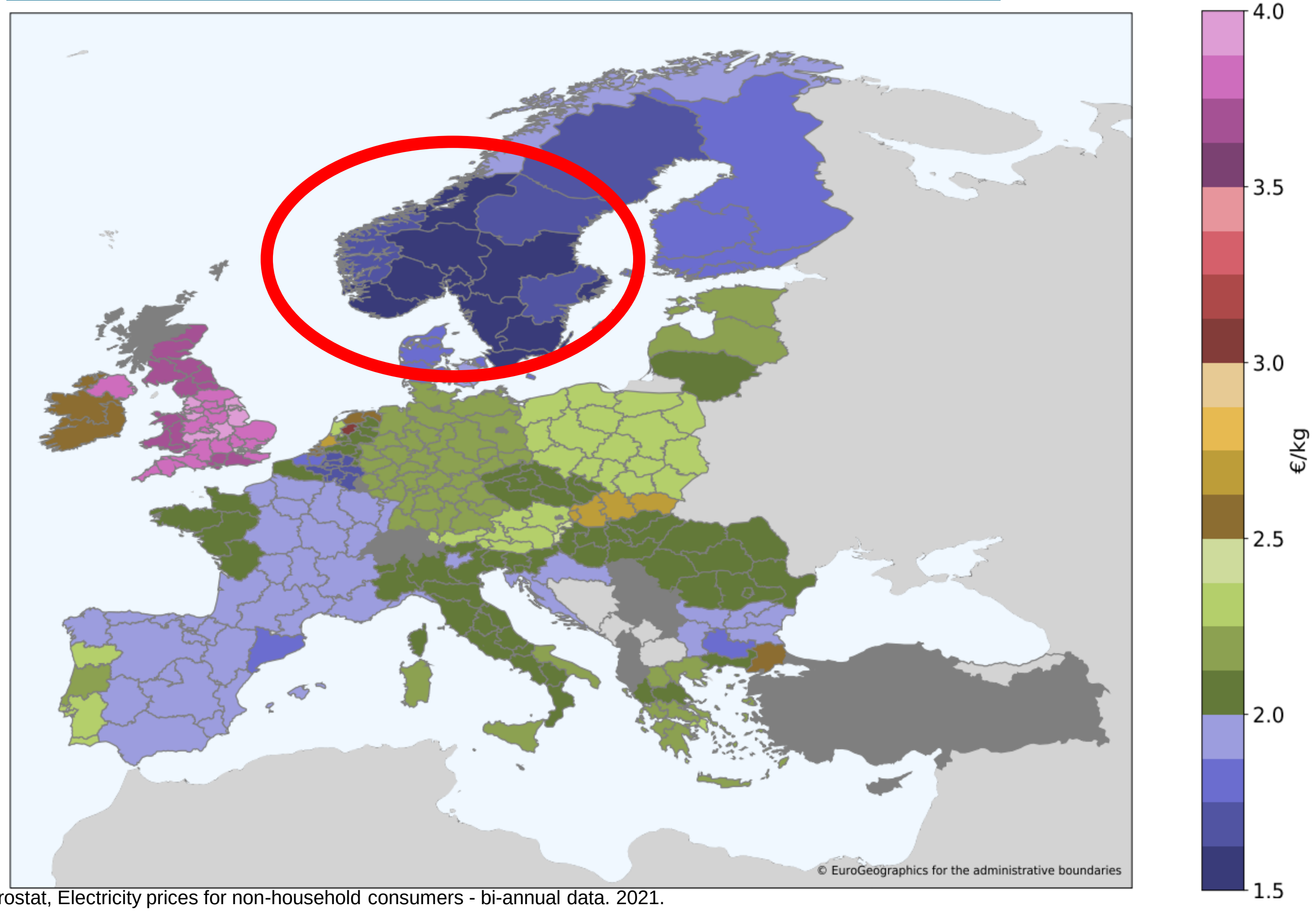
Net Production Costs of PBtL SAF / $€_{2020}$/kg



Standard **PBtL** plant

- 900 MW_e Electrolyzer
- 400 MW_{th} CFB gasifier
- 400 kt/a SAF output

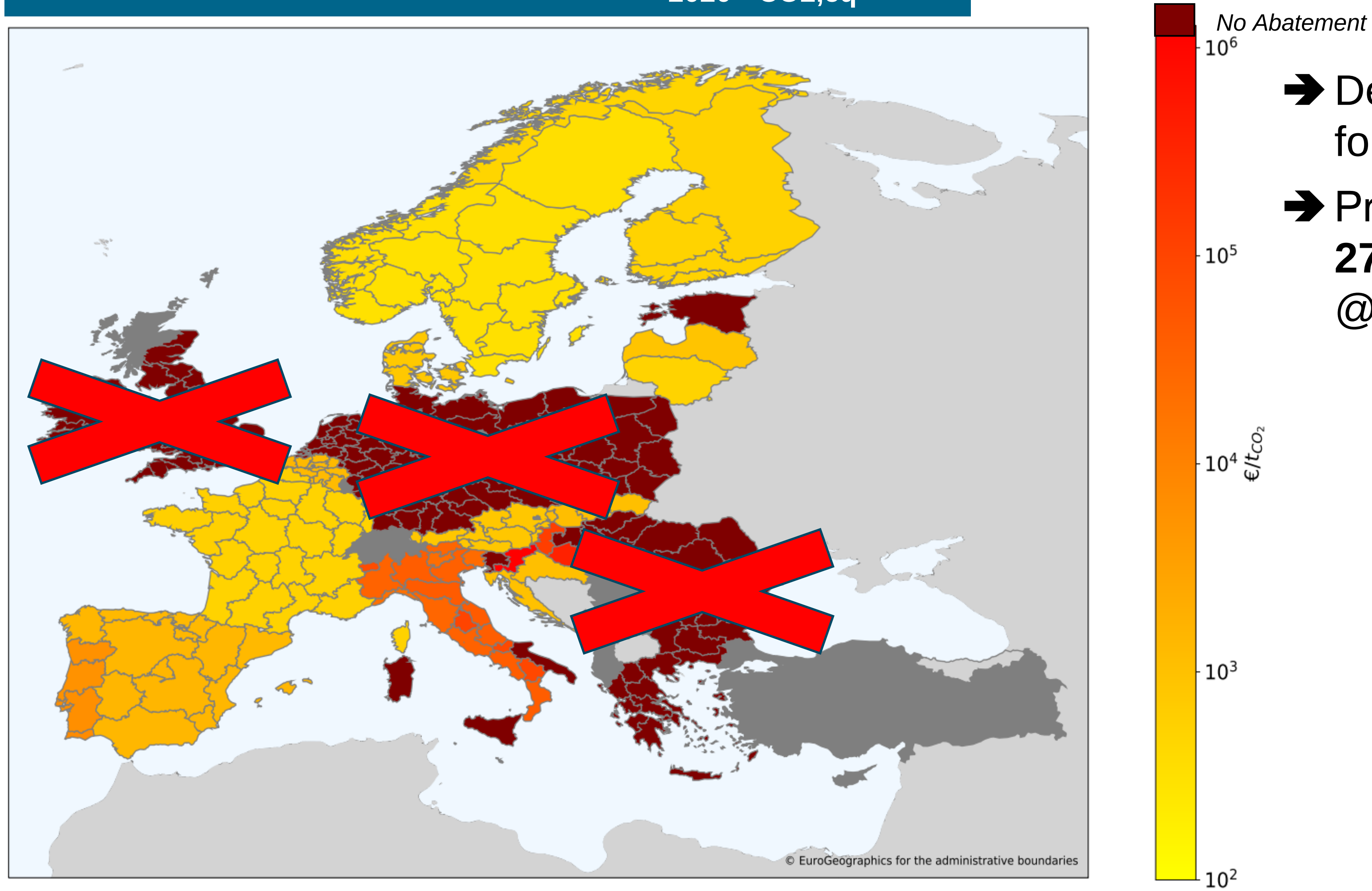
➔ Search for cheap biomass residue and inexpensive (renewable) power [1,2]

1. Norway (57 $PJ_{dry\ biom}$/a)
   @ 50.5 – 51.0 $€_{2020}/t_{biom.dry}$
   @ 30.8 $€_{2020}$/kWh grid power
2. Sweden (276 $PJ_{dry\ biom}$/a)
   @ 57.5 – 64.8 $€_{2020}/t_{biom.dry}$
   @ 35.6 $€_{2020}$/kWh grid power
3. Finland (201 $PJ_{dry\ biom}$/a)
   @ 61.5 – 61.9 $€_{2020}/t_{biom.dry}$
   @ 45.9 € $€_{2020}$/kWh grid power

[1] Eurostat, Electricity prices for non-household consumers - bi-annual data. 2021.
[2] Ruiz, P., Nijs, W., Tarvydas, D., Sgobbi, A., Zucker, A., Pilli, R., ... & Thrän, D. (2019). ENSPRESSO-an open, EU-28 wide, transparent and coherent database of wind, solar and biomass energy potentials. *Energy Strategy Reviews*, *26*, 100379

European SAF Roadmap
No GHG abatement for high GWP grid

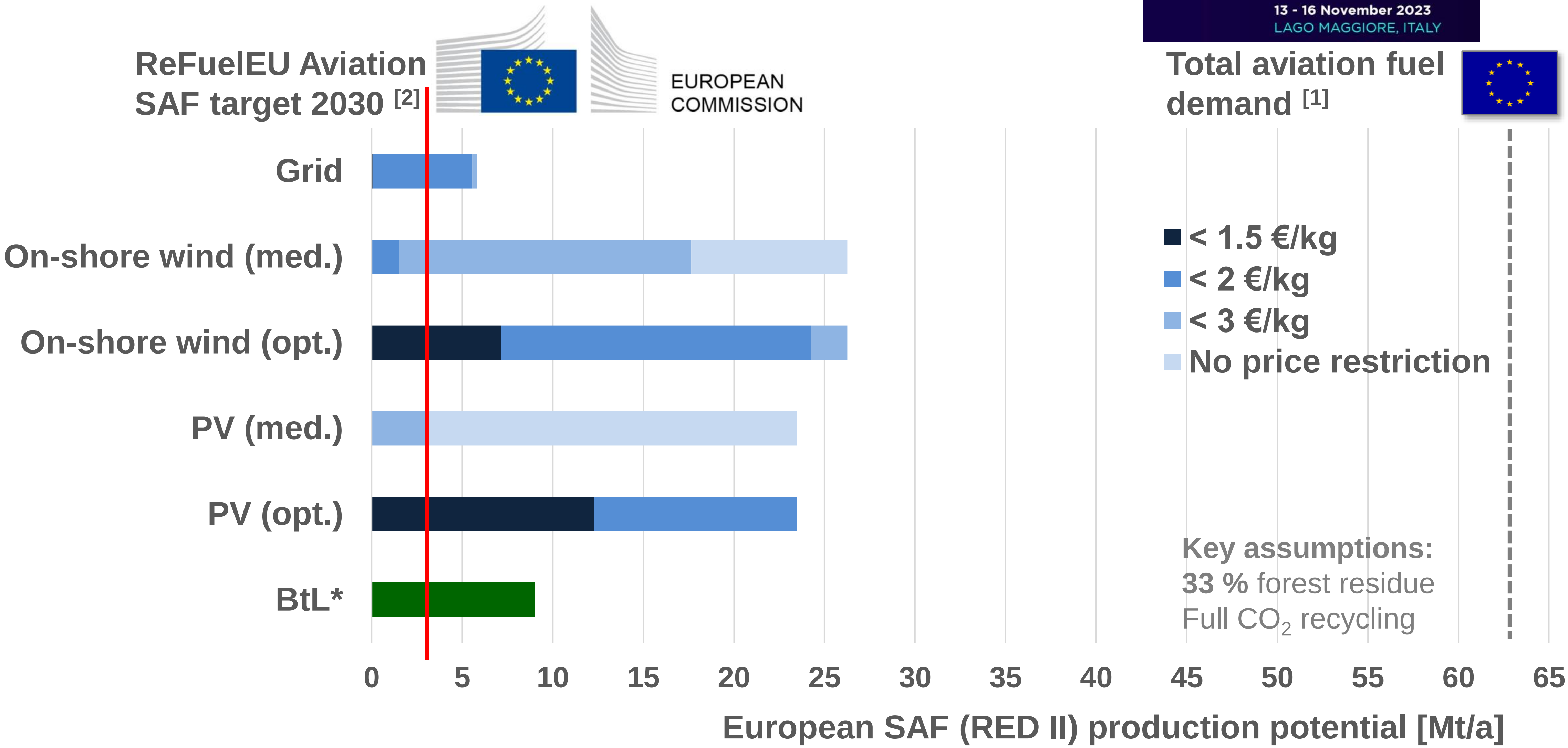
GHG Abatement of PBtL SAF / $€_{2020}/t_{CO2,eq}$



- ➔ Decarbonized national grids necessary for effective PBtL roll-out
- ➔ Production volume <1'000 $€/t_{CO2\text{-}eq.}$:
  27 Mt_{C5+}/a (all biomass residue to fuel)
  @ average NPC of **1.84 $€_{2020}/kg_{C5+}$**

Country	SAF / Mt_{C5+}/a	Av. NPC / $€_{2020}/kg_{C5+}$
	8.3	1,63
	7.3	1.95
	6.1	1.83
	1.7	1.66

Aggregated SAF production potential



[1] S. Csonka, Aviation's Market Pull for SAF, https://www.caafi.org/focus_areas/docs/CAAFI_SAF_Market_Pull_from_Aviation.pdf. *Assumptions: 19.9 % biomass conversion, entire potential under RED II limit
[2] https://www.easa.europa.eu/en/light/topics/fit-55-and-refueleu-aviation

AN AMBITIOUS SAF DEPLOYMENT PLAN

SAF deployment plan for Europe
ReFuelEU Aviation: too little too late

EUROPEAN COMMISSION

	ReFuelEU Aviation SAF targets [1]	ReFuelEU Aviation Synfuel target [1]
2025	2 % (≈ 1 Mt/a)	
2030	6 % (≈ 3.8 Mt/a)	0.7 % (≈ 0.4 Mt/a)
2035	20 % (≈ 13 Mt/a)	5 % (≈ 3.3 Mt/a)
2050	70 % (≈ 54 Mt/a)	35 % (≈ 27 Mt/a)

[1] https://www.consilium.europa.eu/en/press/press-releases/2023/10/09/refueleu-aviation-initiative-council-adopts-new-law-to-decarbonise-the-aviation-sector/

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Compare with 3.4 Mt/a growth[2] since 2020!

Preference palm oil?
Not enough palm oil on earth!

Paris 1.5 degree commitment intentionally violated!

[1] https://www.consilium.europa.eu/en/press/press-releases/2023/10/09/refueleu-aviation-initiative-council-adopts-new-law-to-decarbonise-the-aviation-sector/

SAF deployment plan for Europe
Optimistic way forward (personal view)

EUROPEAN COMMISSION

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25 plants across Europe á
- **3.3 GW Wind (5.0 b€) or 6.3 GW PV (5.0 b€)**
- **FT plant 400 kt_{SAF}/a (1.5 b€) incl. 0.9 GW Electrolyzer**
- **Construction period: 2025 – 2028**
- **Full operation before 2030**

Total Investment?
- **less than 6 months of Europe's (OECD) crude oil spending**

[1] https://www.consilium.europa.eu/en/press/press-releases/2023/10/09/refueleu-aviation-initiative-council-adopts-new-law-to-decarbonise-the-aviation-sector/

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- **About 50 % SAF blending rate achievable with learning curve**
- **100 % SAF certification required for further growth**

[1] https://www.consilium.europa.eu/en/press/press-releases/2023/10/09/refueleu-aviation-initiative-council-adopts-new-law-to-decarbonise-the-aviation-sector/

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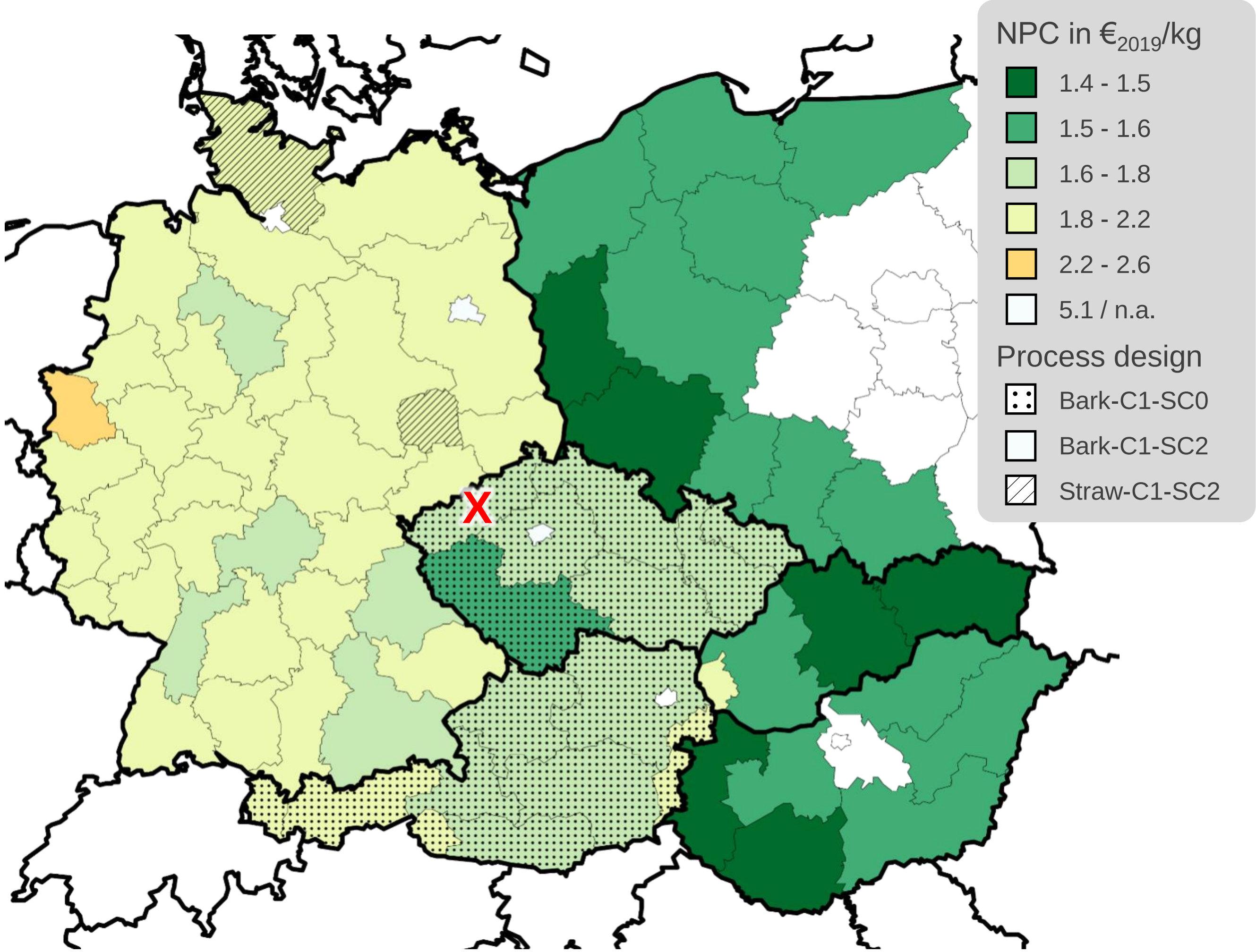
- **Backup, if H_2 aviation won't fly**
- **additional SAF routes / feedstocks from 2035 onwards? Or ➔ Less air traffic?**
- **How about climate neutrality by 2045?**

[1] https://www.consilium.europa.eu/en/press/press-releases/2023/10/09/refueleu-aviation-initiative-council-adopts-new-law-to-decarbonise-the-aviation-sector/

SAF QUICKSTART: EXPLORE THE BIOMASS FROM YOUR NEIGHBORHOOD

BtL production options for Central Europe [1]
200 MW_{th} DFB Gasifier w. steam, 1 bar, µ-FT

- Assumptions:
  - Bark & straw as biomass feedstock
  - 20 years of plant lifetime
  - 8260 h/a operation
  - 10 persons per shift
  - 10% interest rate
  - Product refining at ORLEN UniPetrol Litvínov – Záluží refinery (X)



[1] Maier et al. (2021), Techno-economically-driven identification of ideal plant configurations for a new biomass-to-liquid process – A case study for Central-Europe

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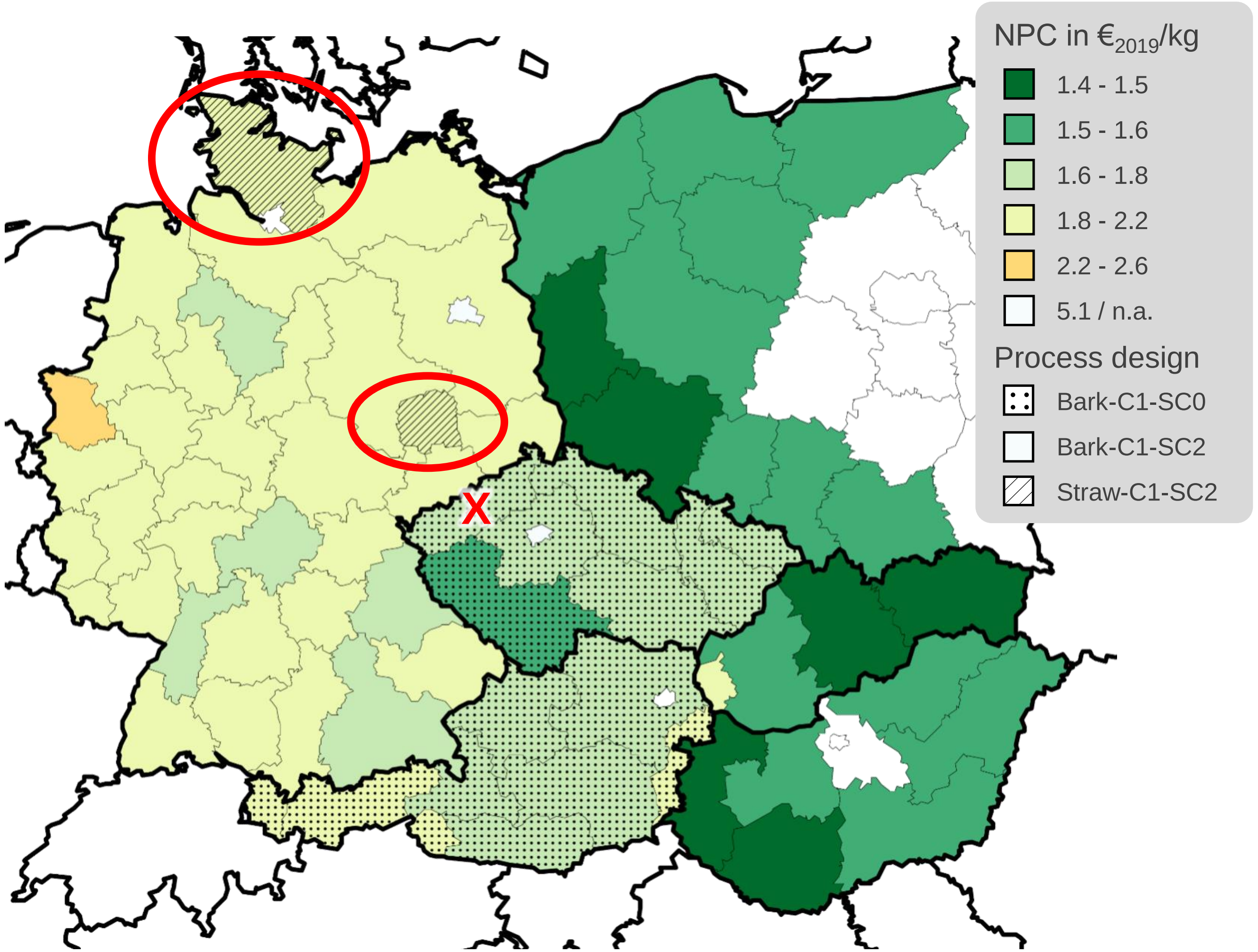

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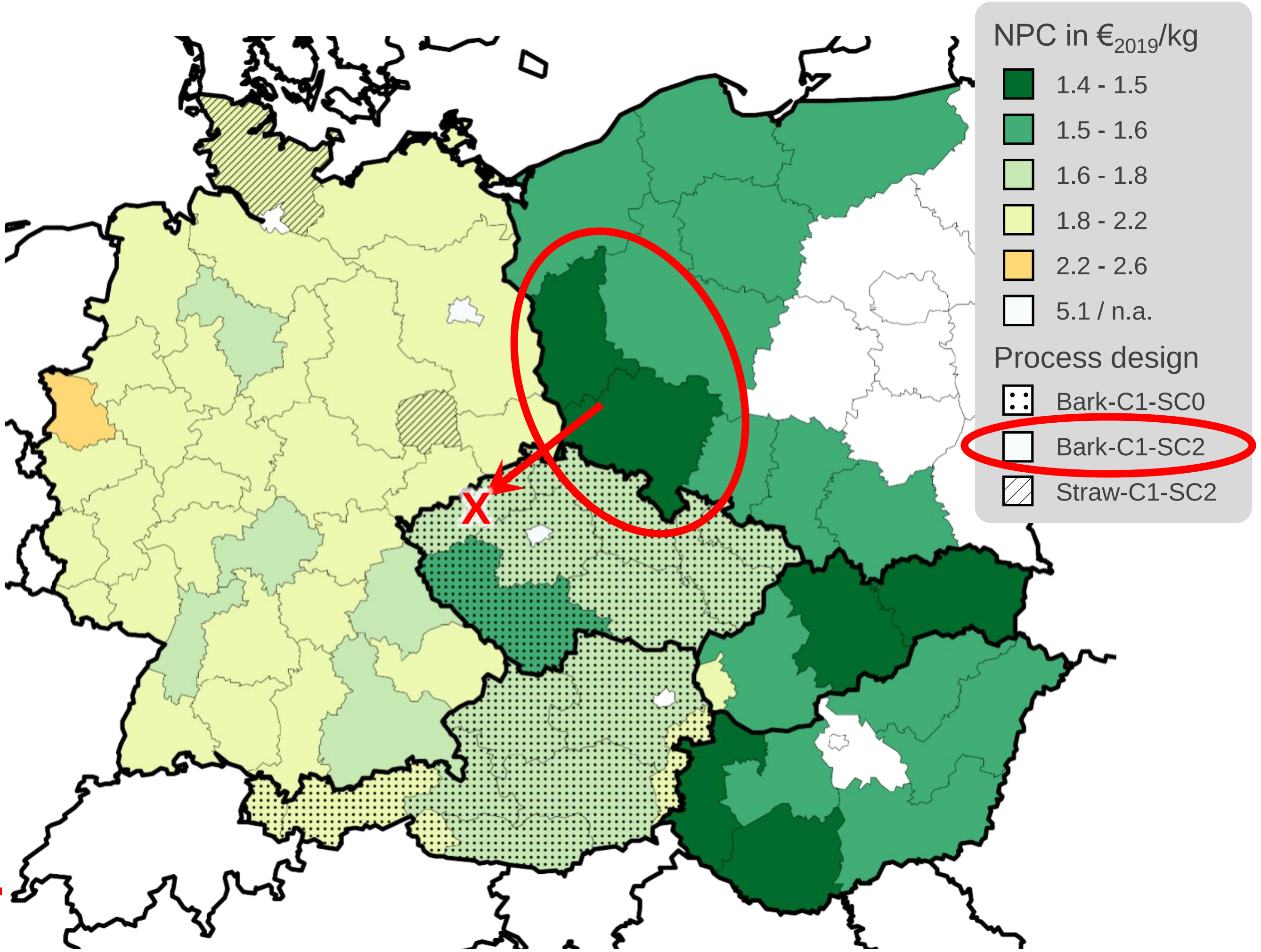
Preferred:

- C1: process configuration "basic"
- SC2: steam cycle & district heating



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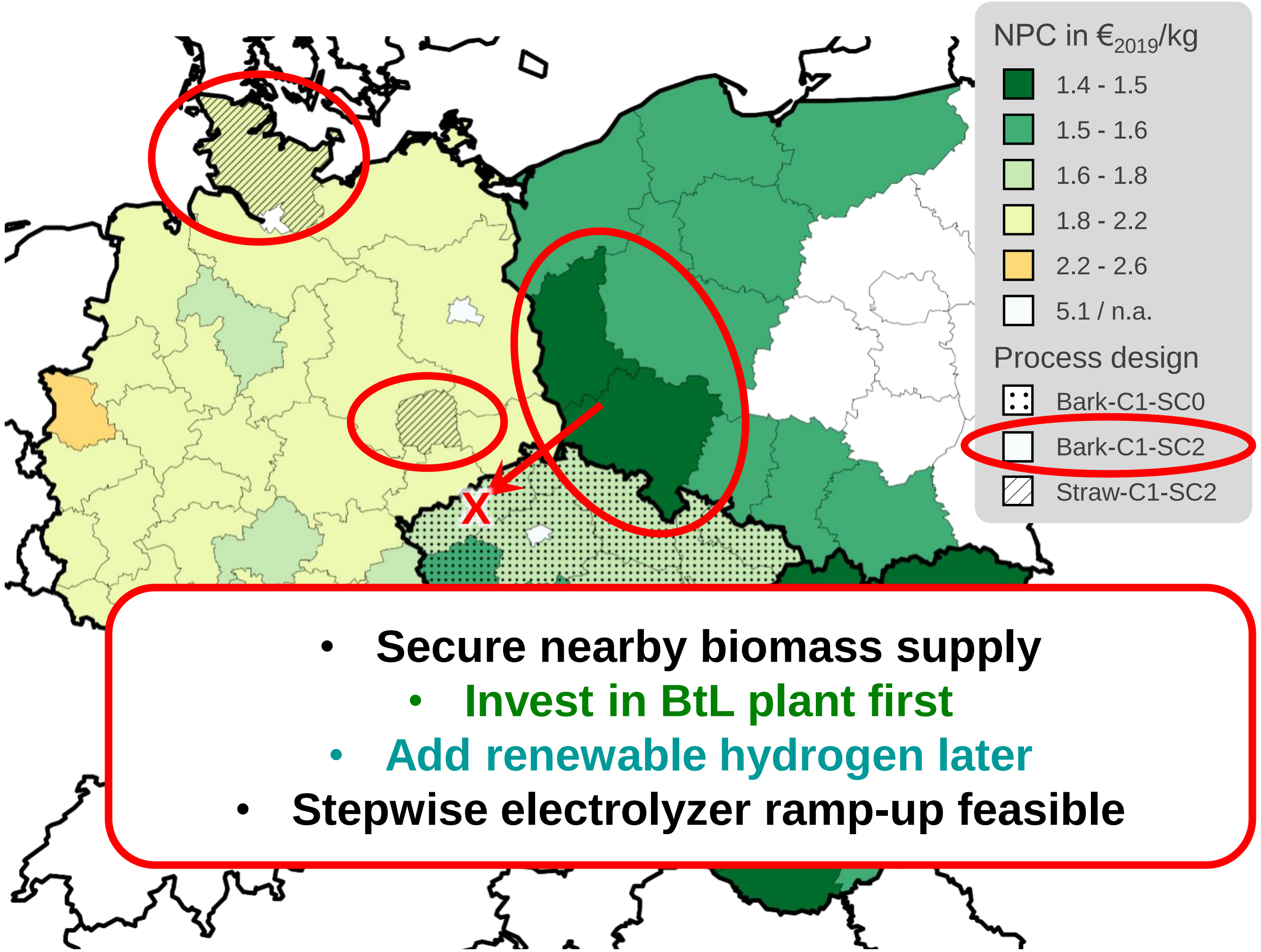

- **Secure nearby biomass supply**
- **Invest in BtL plant first**
- **Add renewable hydrogen later**
- **Stepwise electrolyzer ramp-up feasible**

[1] Maier et al. (2021), Techno-economically-driven identification of ideal plant configurations for a new biomass-to-liquid process – A case study for Central-Europe

CONCLUSION & OUTLOOK

Refinery integration of SAF

Summary

- SAF required ➔ aviation contribution towards Europe’s climate obligations
  - REGULATION will end fossil fuels utilization
- European refineries can largely produce SAF locally,
  - utilizing biomass residues -> BtL quick start
  - & investing in renewable power -> PBtL large scale rollout
- Expose any excuses for SAF deployment delay
  - PtX research, development, demonstration: reinventing the wheel?
  - All technologies mature and available

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Transparent, standardized DLR assessment methodology can help

➔ Feedstock search, technology selection, refinery integration, …!

THANK YOU FOR YOUR ATTENTION !
Questions?

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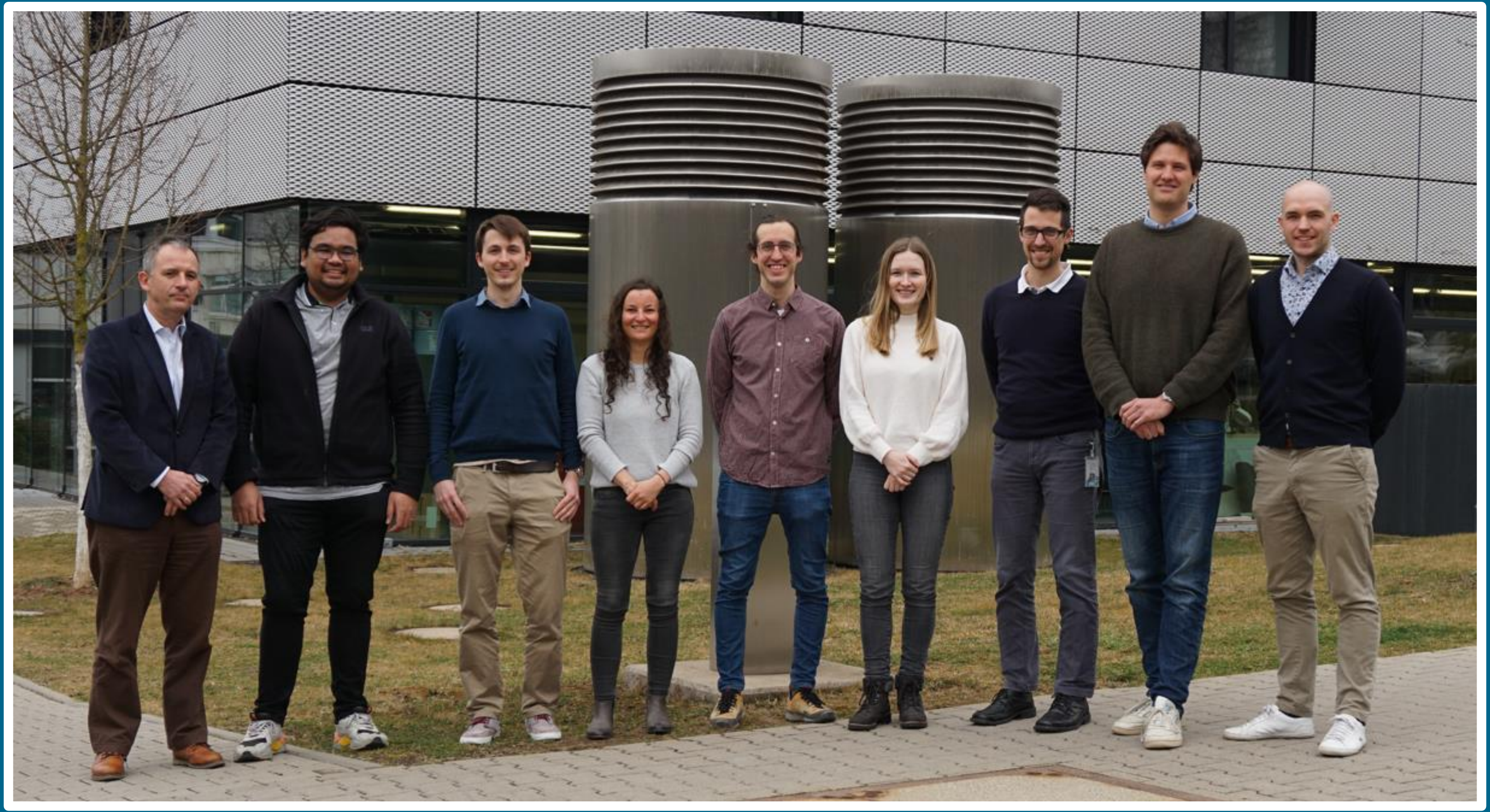

Moritz Raab, Felix Habermeyer, Nathanael Heimann, Julia Weyand, Simon Maier, Sandra Adelung, Francisco Moser, Yoga Rahmat, Ralph-Uwe Dietrich