Tuesday, 6 June 2023

Session IBO.5.2: Low carbon fuels for Aviation and Shipping

EUBCE 2023
31st European Biomass Conference & Exhibition
In-person, online, Bologna, Italy
5 - 8 JUNE CONFERENCE & EXHIBITION
9 JUNE TECHNICAL TOURS

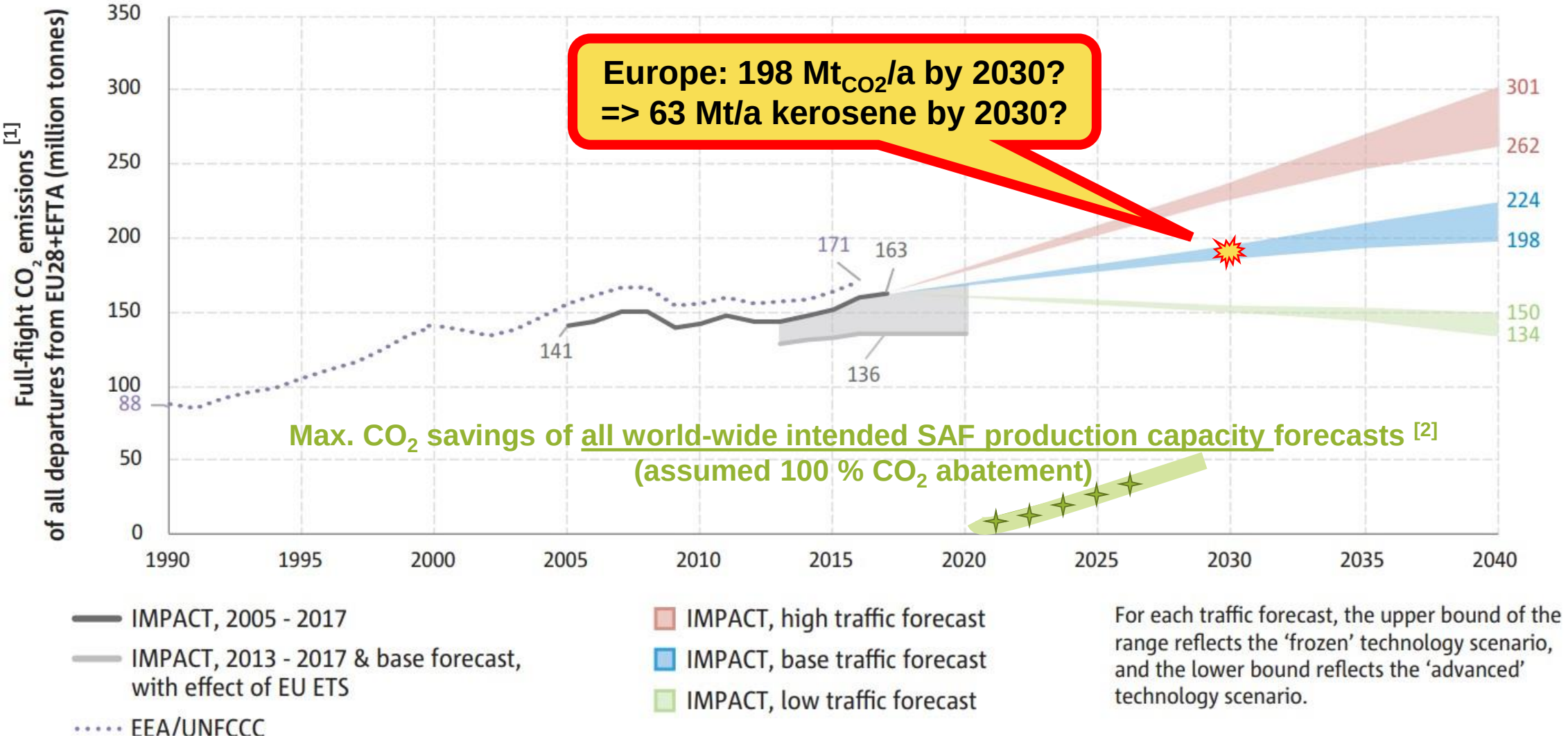
BIOFUELS PRODUCTION ROUTES ASSESSMENT FOR MARKET INTRODUCTION, INTEGRATION INTO ENERGY SYSTEMS AND POLICY BRIEFING

Techno economic assessment of sustainable aviation fuels (SAF) production and beyond

Ralph-Uwe Dietrich, Felix Habermeyer, Nathanael Heimann, Simon Maier, Moritz Raab, Julia Weyand (DLR e.V., www.DLR.de/tt)

DLR

SAF deployment too slow for significant CO_2 abatement



[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] S. Csonka, Aviation's Market Pull for SAF, https://www.caafi.org/focus_areas/docs/CAAFI_SAF_Market_Pull_from_Aviation.pdf.

Certified Alternative Jet Fuels ASTM D7566 – 21 [1]

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

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Biogenic lipids (e.g. algae, soya, palm	sion of fatty acids	Catalytic hydrothermolysis Jet (CHJ)
Sugar from Biomass	ydrocarbons (DSHC)	Synthetic iso-paraffins (SIP) / Farnesane
Bio-isobutanol (-methanol, -ethanol	ation+oligomerization+hydration lcohol-to-Jet, AtJ)	AD-SPK

Crop based 1st generation biofuels SAF
- Will never achieve sufficient amount
- Provide questionable GHG abatement
- Compete with food production

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

Certified Alternative Jet Fuels Favorite?

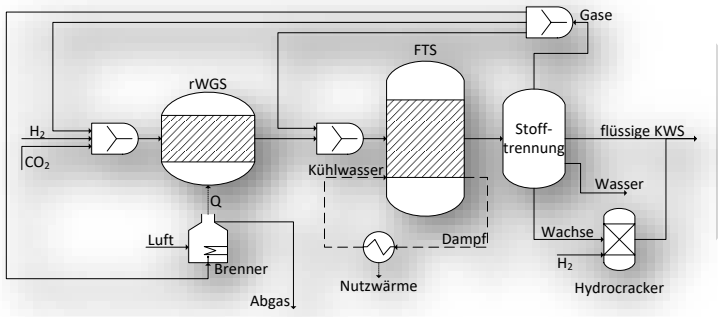
Feedstock availability towards 63 Mt/a

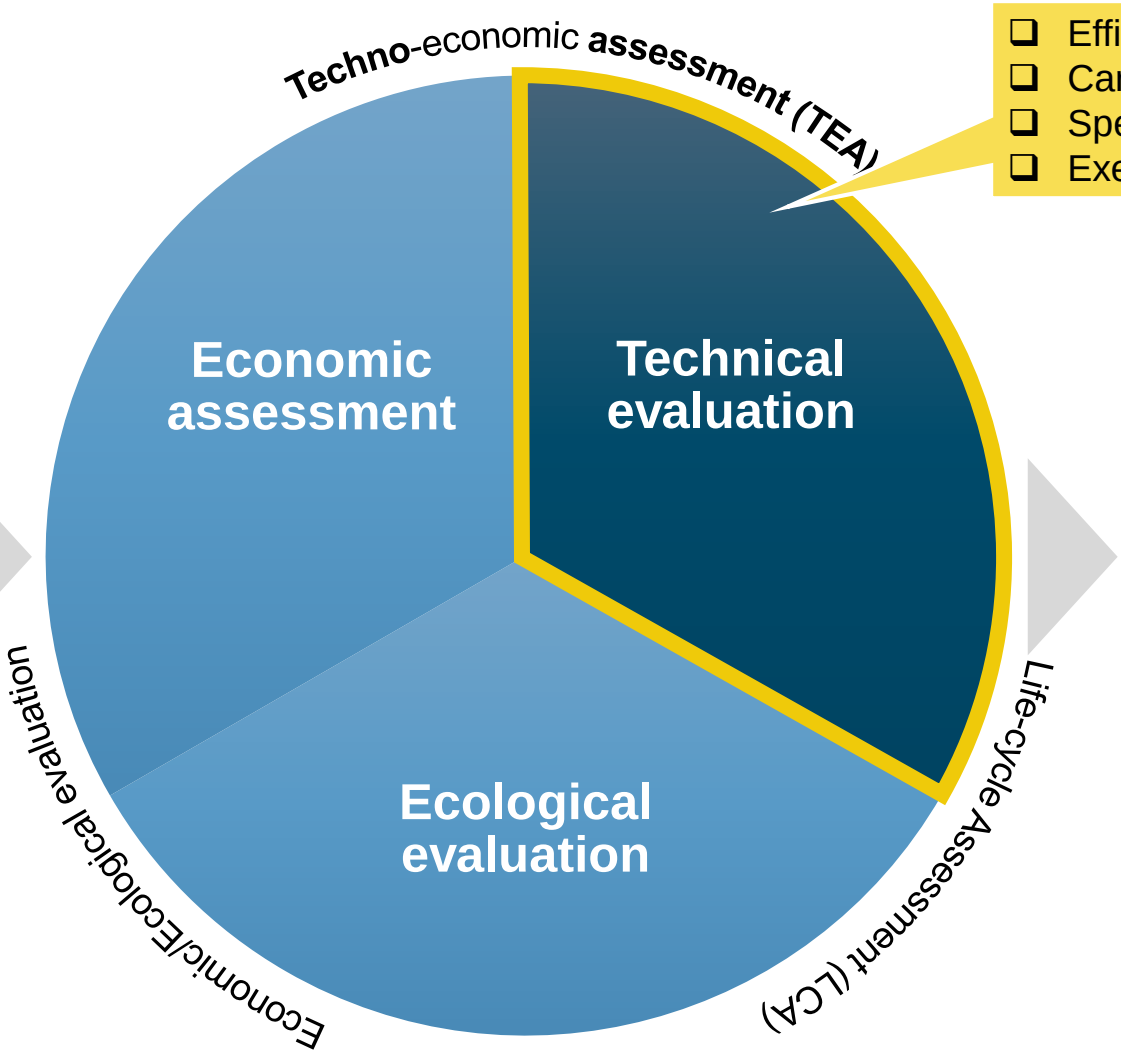
Feedstock	Synthesis technology	Fuel
~~Coal, natural gas~~, biomass, CO_2 & H_2	Fischer-Tropsch (FT) synthesis using Fe or Co catalyst,	Synthetic paraffinic kerosene (FT-SPK)

- Feedstock
  - SAF via the Fischer-Tropsch pathway not restricted to certain feedstocks
  - Synthesis gas available from almost any carbon and hydrogen source ➔ Sustainability?
    - Sustainable Hydrogen via RE: European wind power potential[1]: 12,200 – 30,400 TWh_e
      ≈ 10 - 20 times of SAF demand!
    - Sustainable Carbon: carbon sequestration in European forest biomass[2]: 155 Mt/a
      ≈ 3 times of SAF demand!
      - Fischer-Tropsch 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]

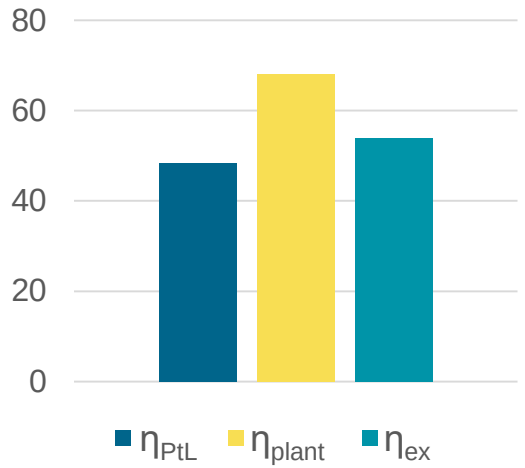
[1] European Environment Agency, “Europe's onshore and offshore wind energy potential,” 2009
[2] FOREST EUROPE, 2020: State of Europe’s Forests 2020
[3] UK Ministry of Defense, „DEF STAN 91-91: Turbine Fuel, Kerosene Type, Jet A-1“, UK Defense Standardization, 2011

Techno-Economic and ecological assessment - TEEA -





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



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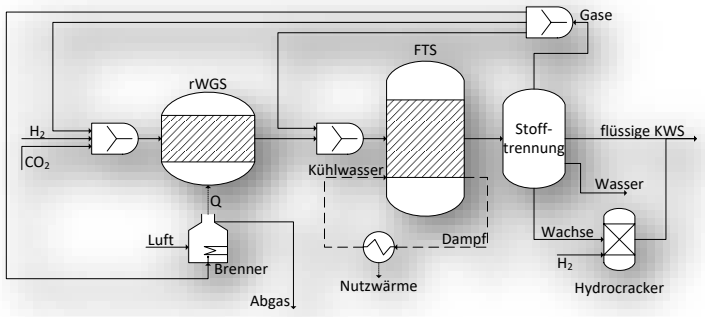
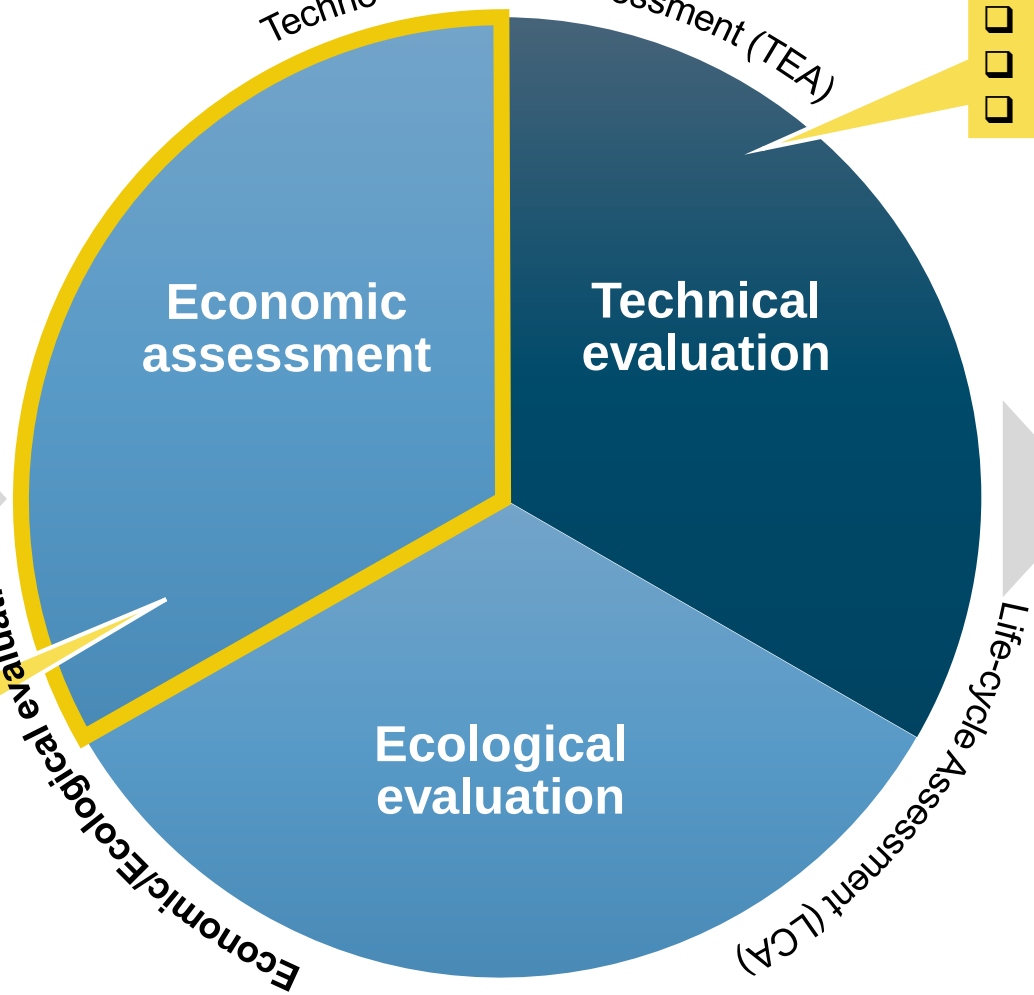
DLR





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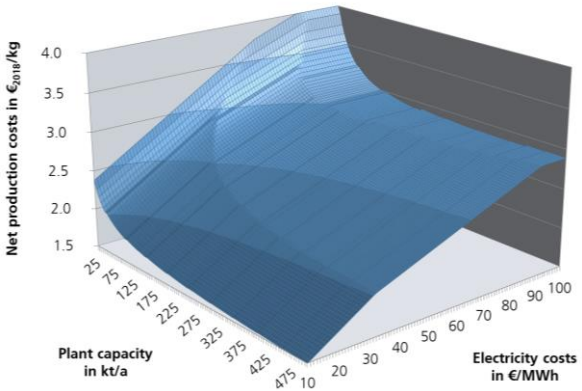
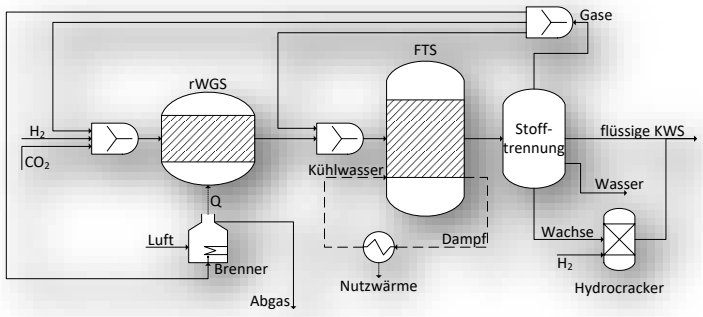
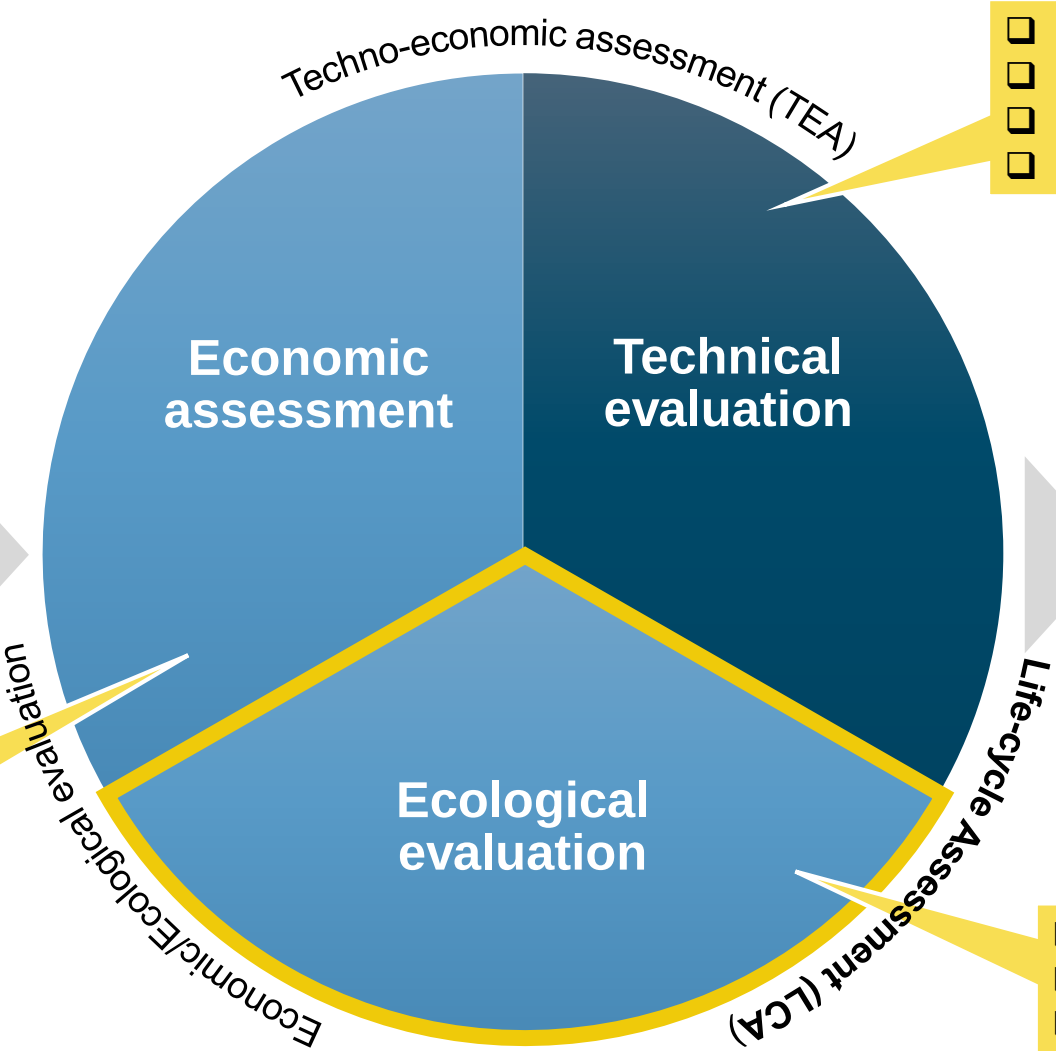


- ❑ CAPEX, OPEX, NPC
- ❑ Sensitivity analysis
- ❑ Identification of most economic feasible process design

Techno-Economic and ecological assessment - TEEA -





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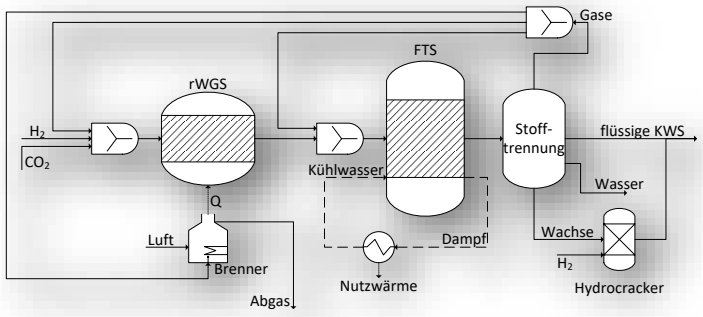
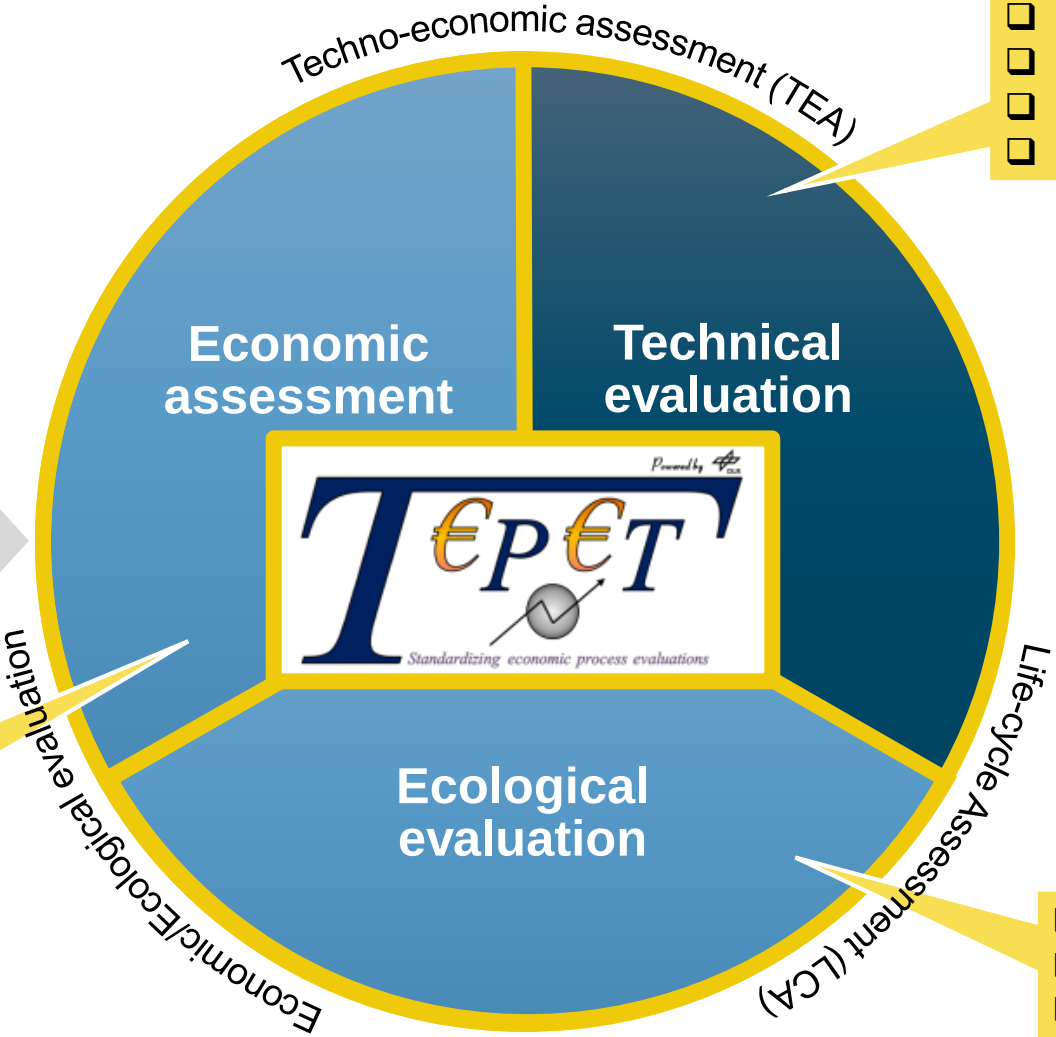
- ❑ GWP
- ❑ Other impact categories
- ❑ Identification of impact drivers

Techno-Economic and ecological assessment - TEEA -





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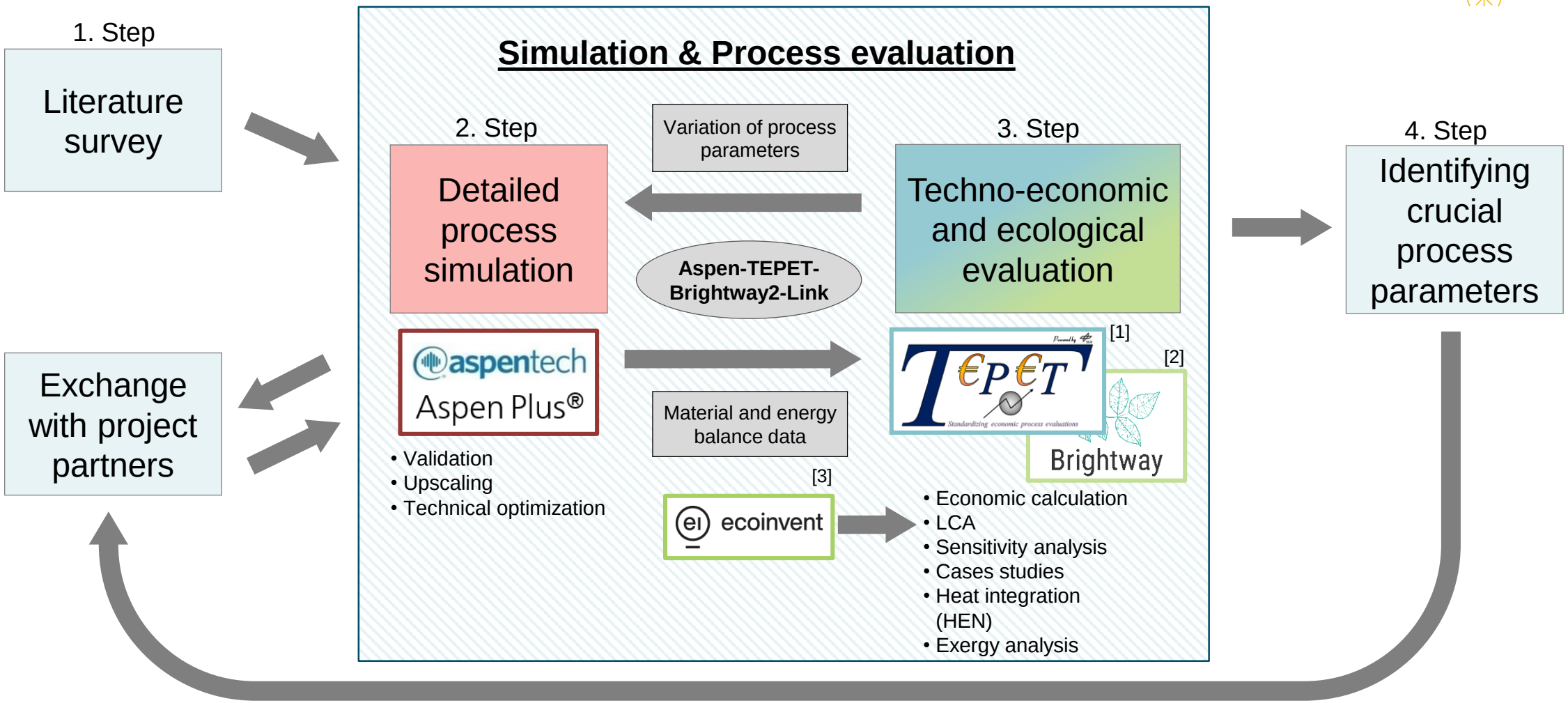
TEEA approach @DLR



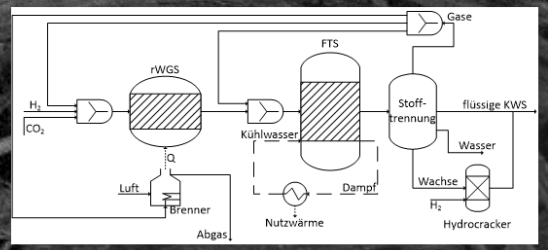
[1] Albrecht et al. (2016) - A standardized methodology for the techno-economic evaluation of alternative fuels – A case study, Fuel, 194: 511-526
[2] Mutel (2017) - Brightway: An open source framework for Life Cycle Assessment, Journal of Open Source Software, 2(12): 236
[3] Wernet, G et al. (2016)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

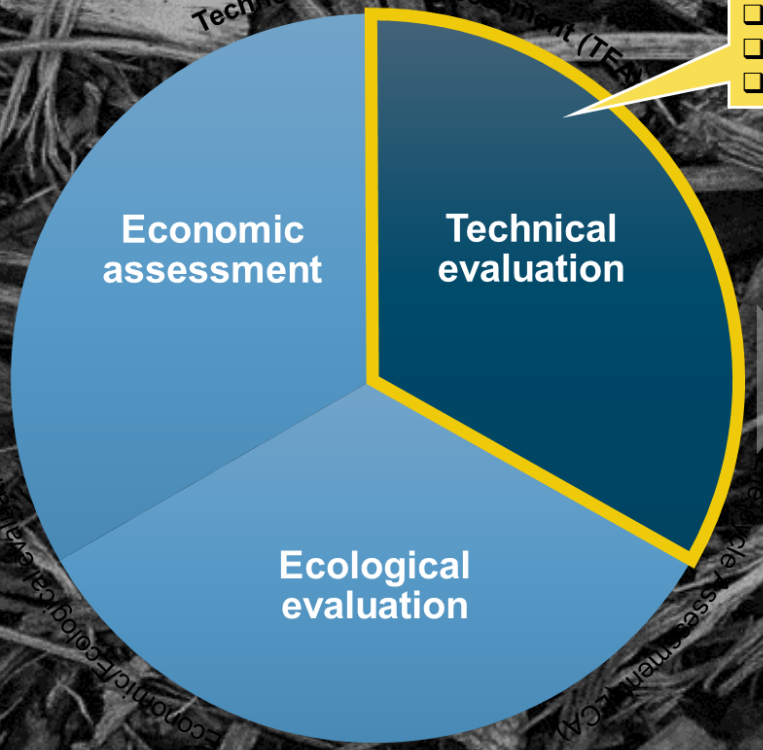
COMSYN

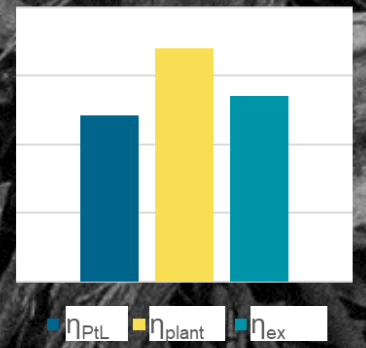
COMSYN project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727476

DLR

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







TECHNICAL ASSESSMENT OF COMSYN BTL CONCEPT

Process Concept

COMSYN project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727476

DFB pilot plant @ VTT

5 m³/h
Slip stream to synthesis unit

Mobile synthesis unit

Process Steps & Responsibilites

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DFB pilot plant @ VTT

5 m³/h
Slip stream to synthesis unit

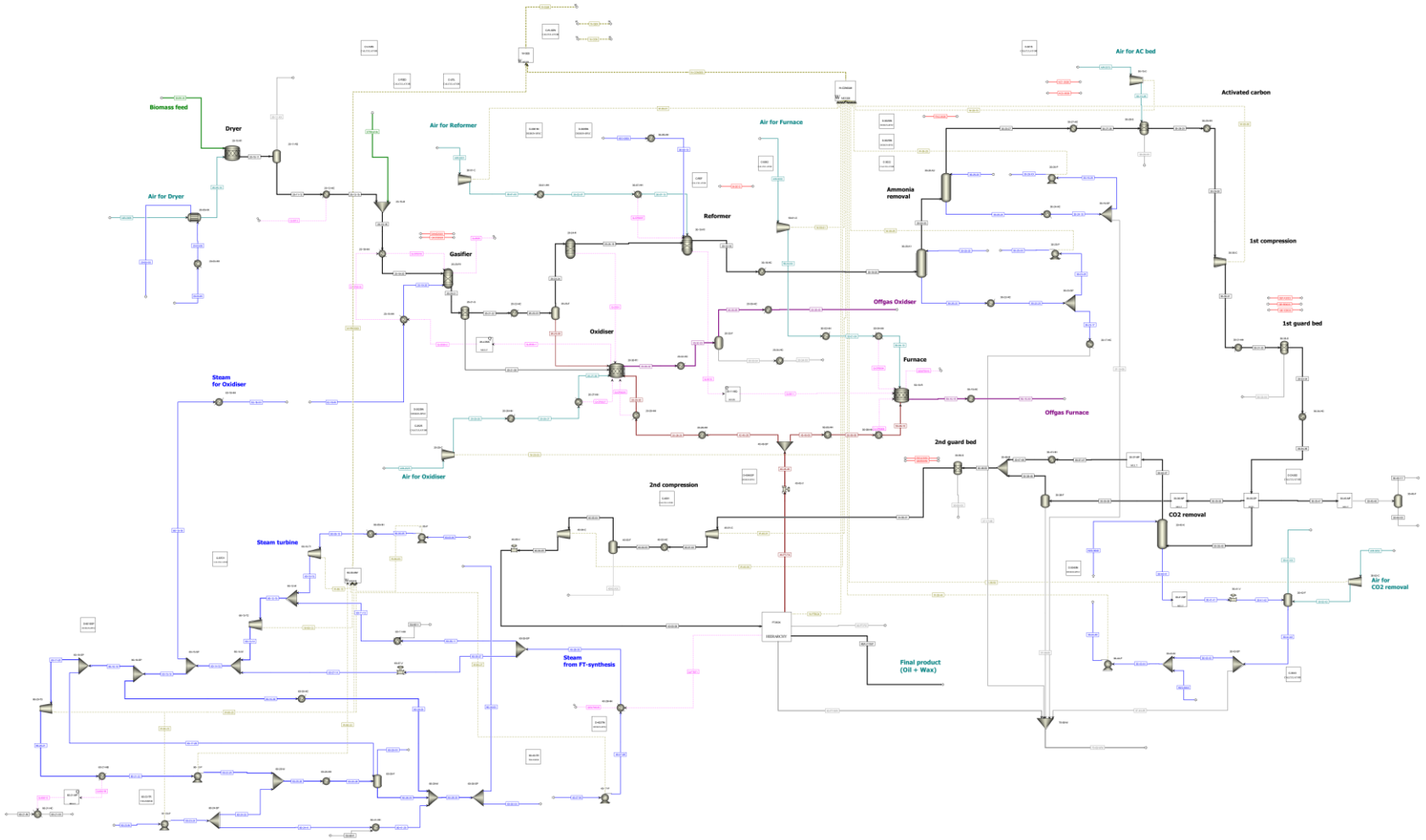
Mobile synthesis unit

DFB Gasifier → Filter → Reformer → Ultracleaning steps → FT synthesis → Product Upgrading

VTT | GKN SINTER METALS | VTT | VTT | VTT | INERATEC | UniCRE

PFD model [1]

COMSYN project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727476



[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

PFD model [1] unit representation

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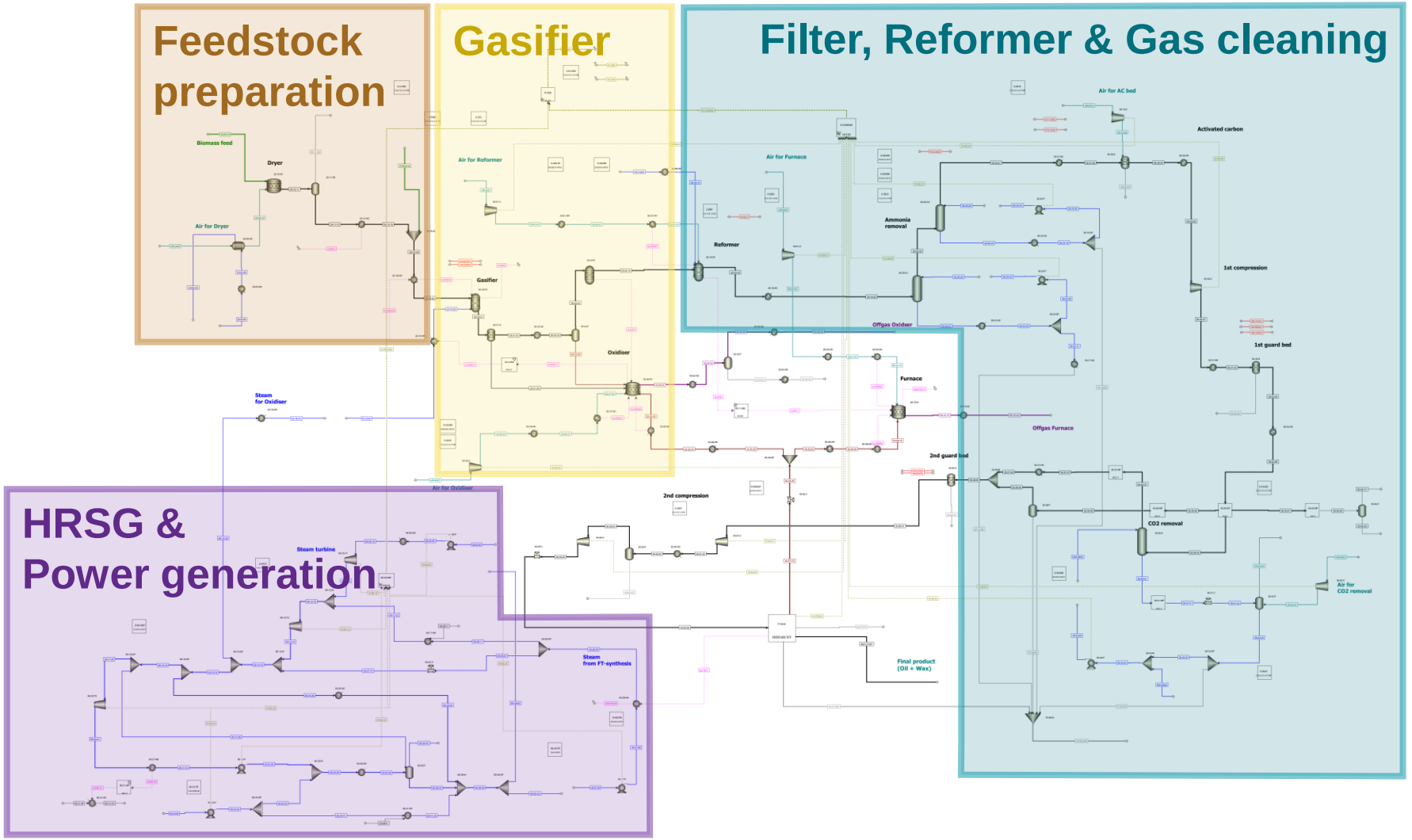

[1] Maier et al. (2021), Techno-economically-driven identification of ideal plant configurations for a new biomass-to-liquid process – A case study for Central-Europe

PFD model [1]
Heat sources/sinks

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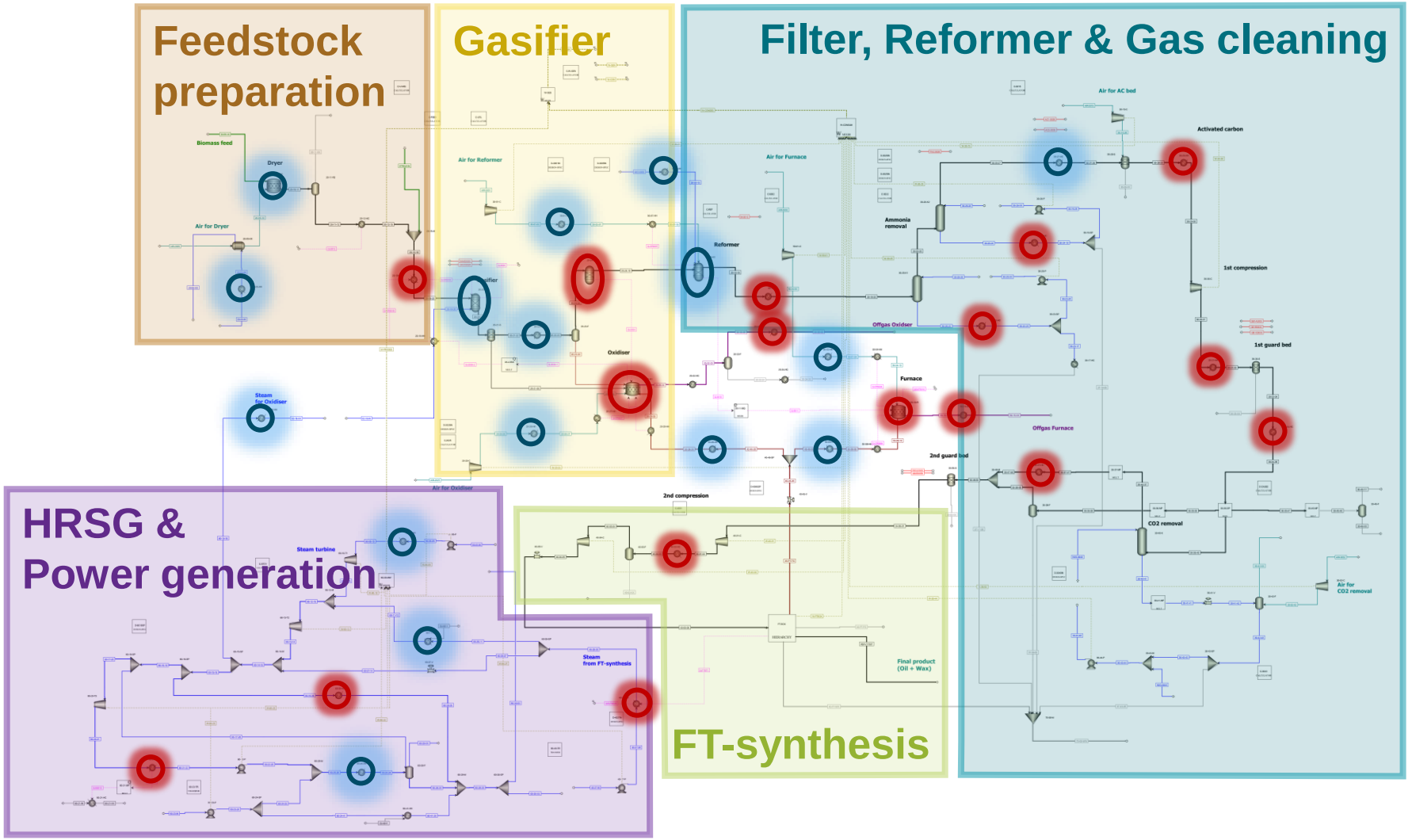


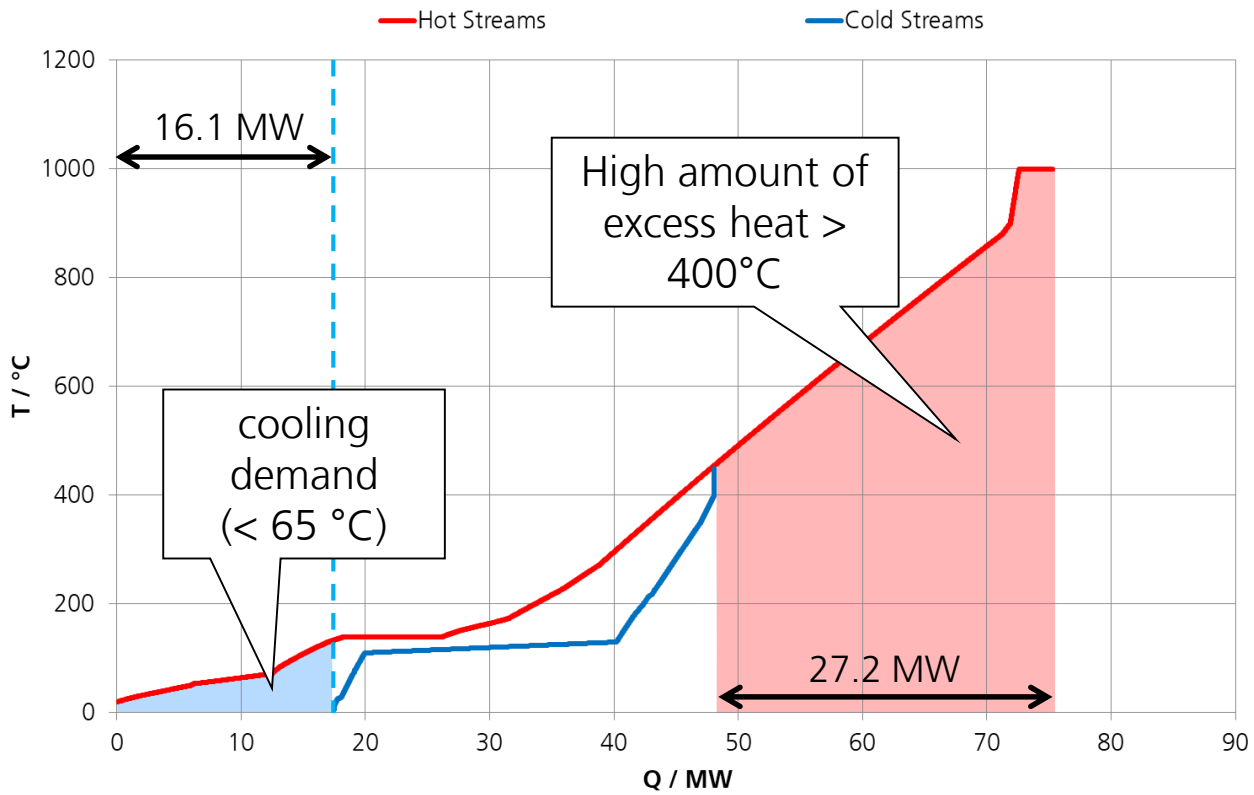
[1] Maier et al. (2021), Techno-economically-driven identification of ideal plant configurations for a new biomass-to-liquid process – A case study for Central-Europe

COMSYN heat integration need

The process concept yields in a high amout of excess heat [1]

→ Heat integration options have to be evaluated technically and economically

100 MW_{th} biomass input		Case
Electricity demand	MW	11.4
Steam + Distr. heating	MW	39.6
Product output	kt/a	35.6
BtL efficiency	%	46.1
Energetic efficiency	%	81.7



[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

COMSYN heat integration options [1]

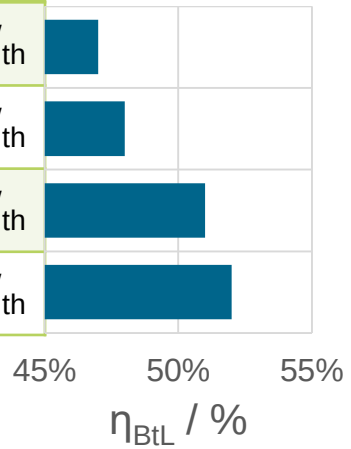
SC3: Maximized electricity generation

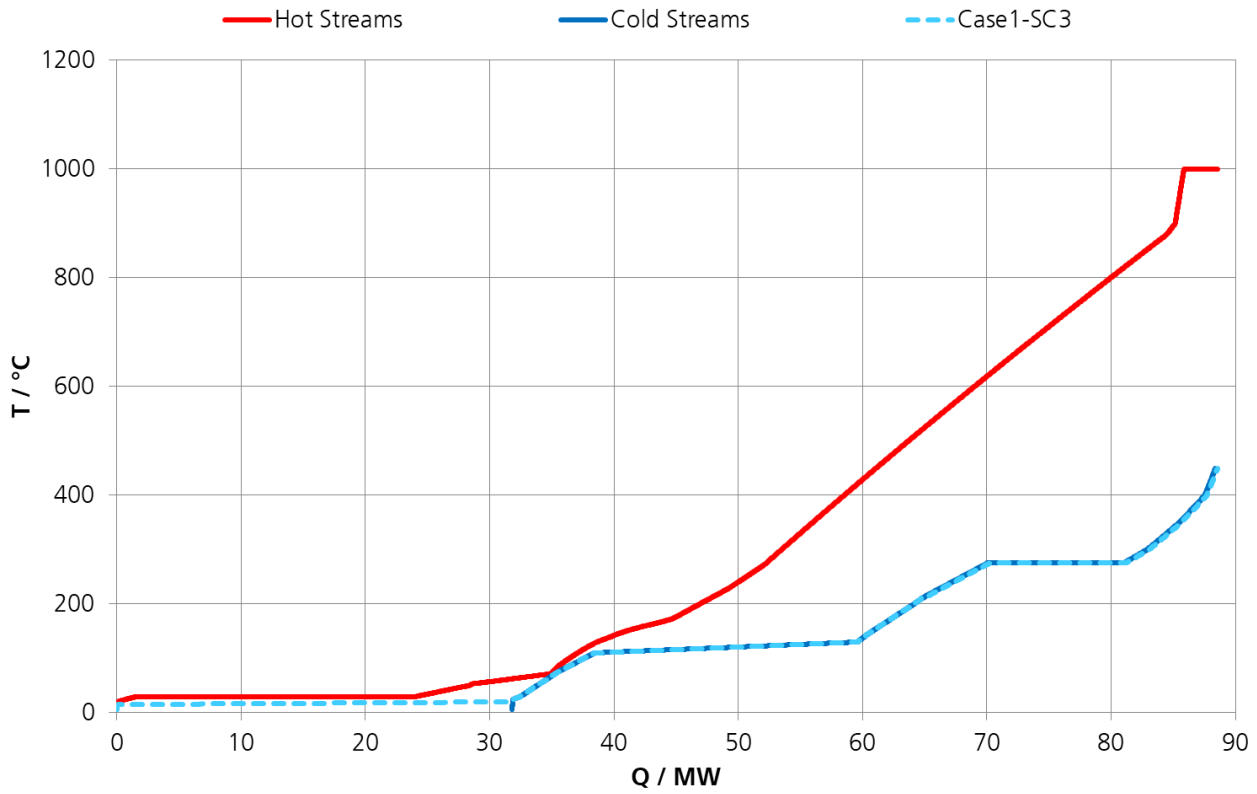
→ Backpressure of steam turbine set to 0.04 bar

→ Highest electricity generation

→ No heat products available

Case Mod.	Electricity generation	Process steam / District heating
SC0	0.0 MW_{el}	31.3 / 5.6 MW_{th}
SC1	3.0 MW_{el}	21.2 / 13.1 MW_{th}
SC2	9.0 MW_{el}	0.0 / 27.9 MW_{th}
SC3	11.4 MW_{el}	0.0 / 0.0 MW_{th}





[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

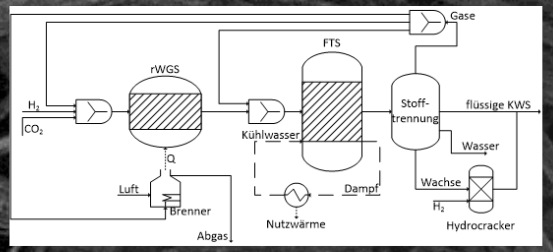
FLEXCHX

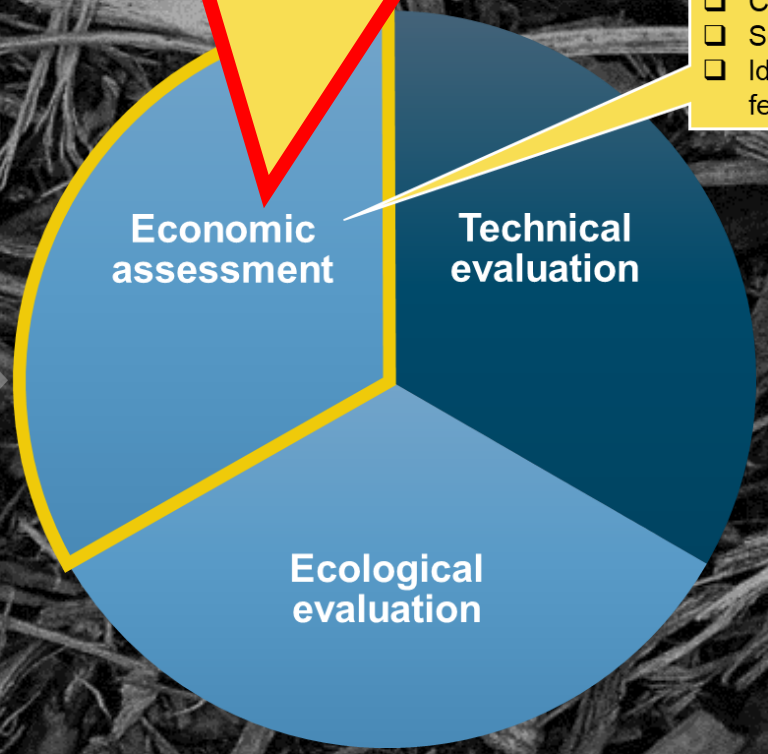
FLEXCHX project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 763919.

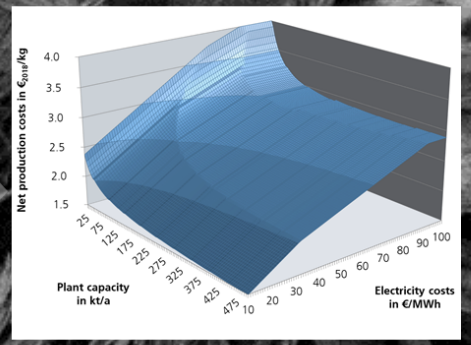
Session: 5BO.14.3, Room: ITALIA
Tuesday, 06 June 2023, 17:30 - 18:30
F. Habermeyer et al.

DLR

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







ECONOMICAL ASSESSMENT OF FLEXCHX PBTL CONEPT

Process Concept

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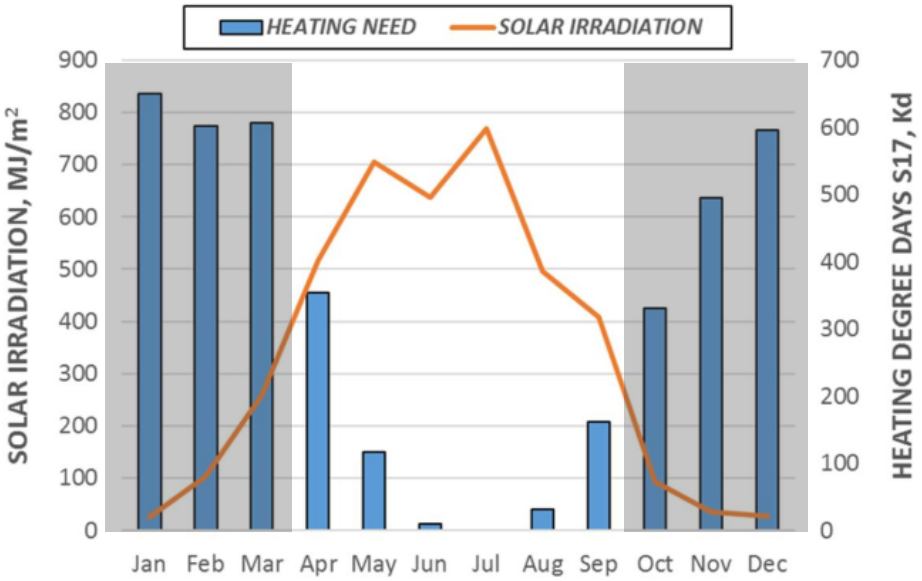
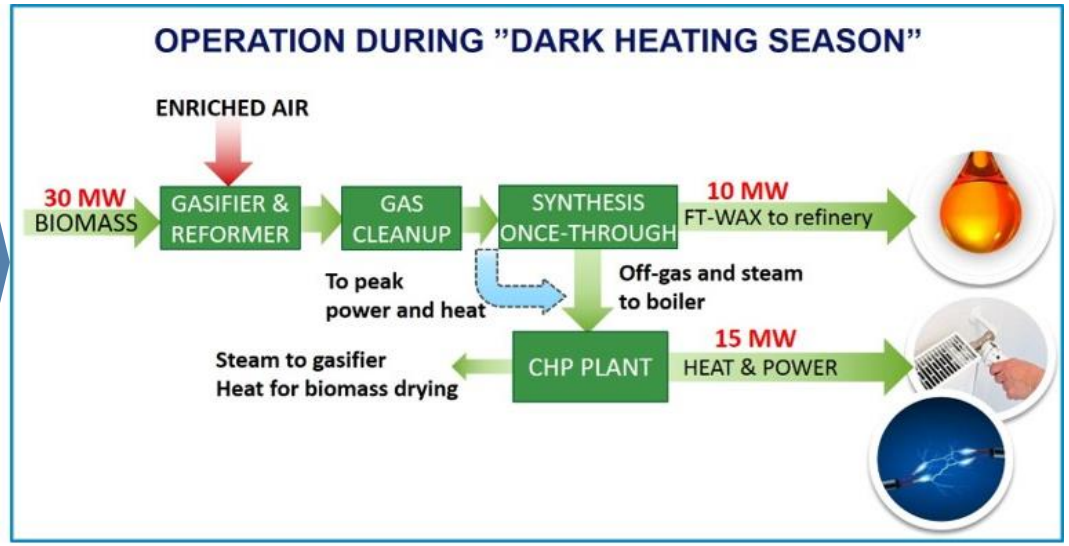


High heat demand & Low renewable electricity availability



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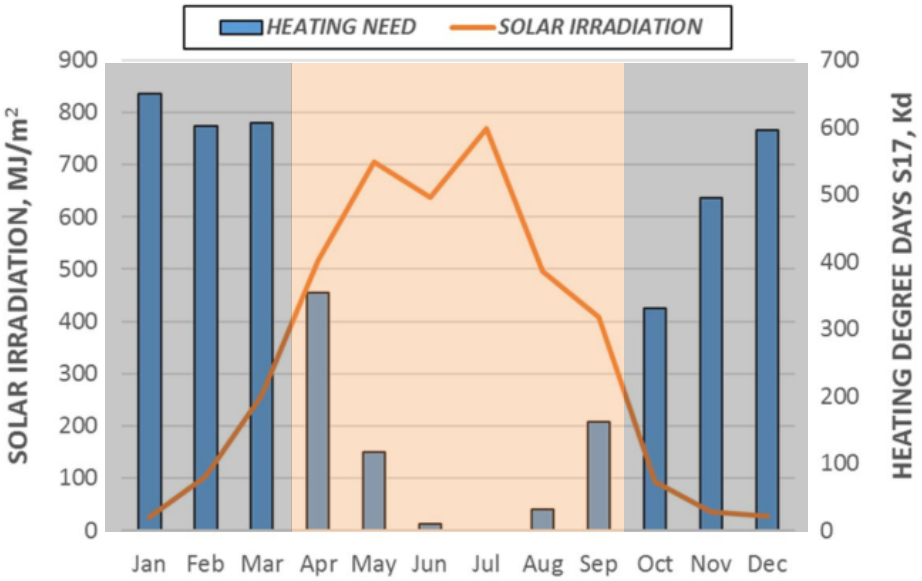
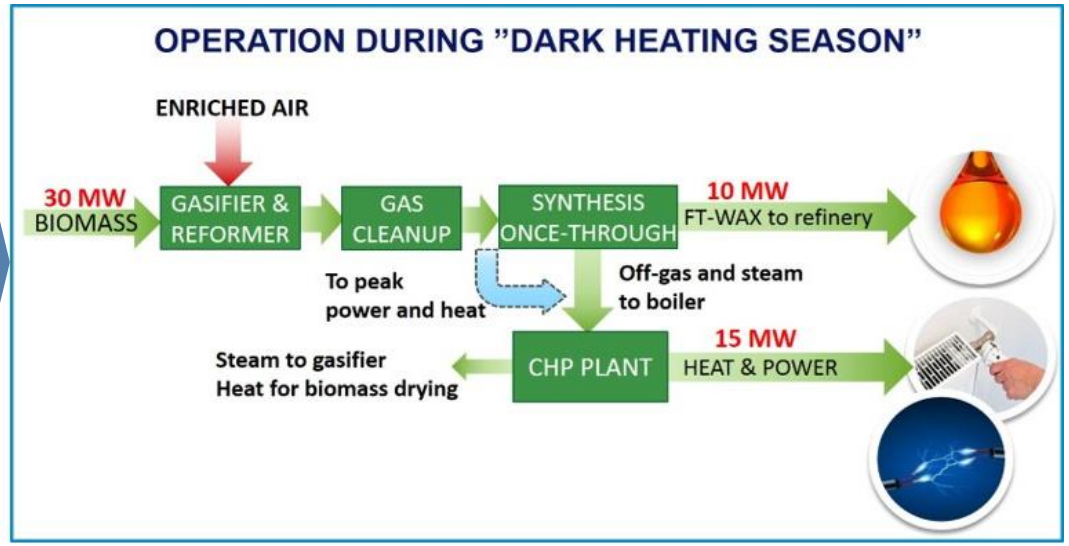
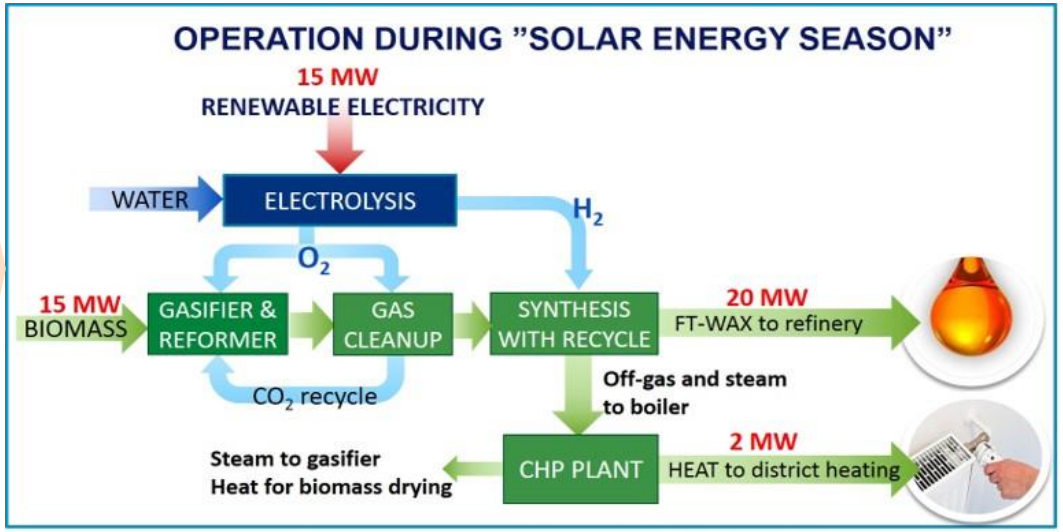


High heat demand & Low renewable electricity availability



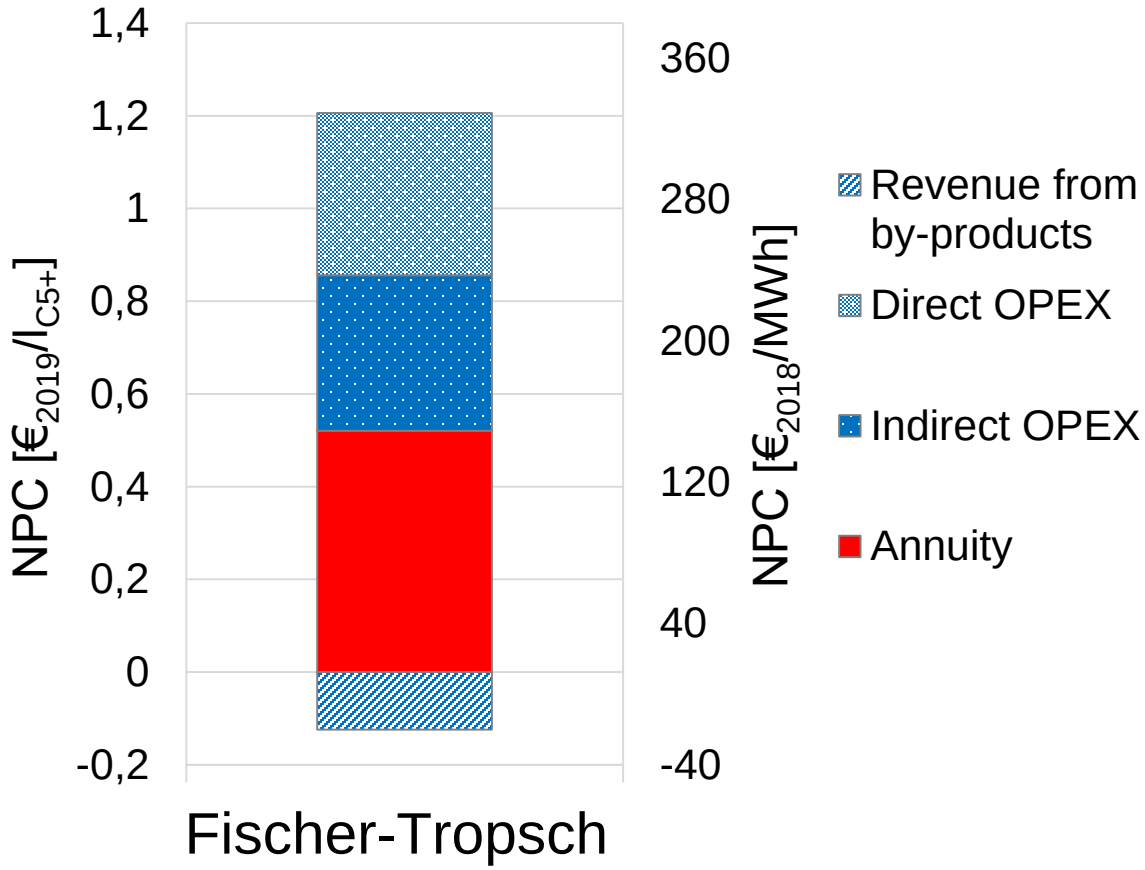
Low heat demand & High renewable electricity availability



Cost Breakdown [1]

FLEXCHX project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 763919

NPC (BA): 1.08 €$_{2019}$/l$_{C5+}$



[1] Habermeyer, et. al (2021). Techno-economic analysis of a flexible process concept for the production of transport fuels and heat from biomass and renewable electricity. Front. Energy Res., Nov. 2021 | Volume 9 | Article 723774

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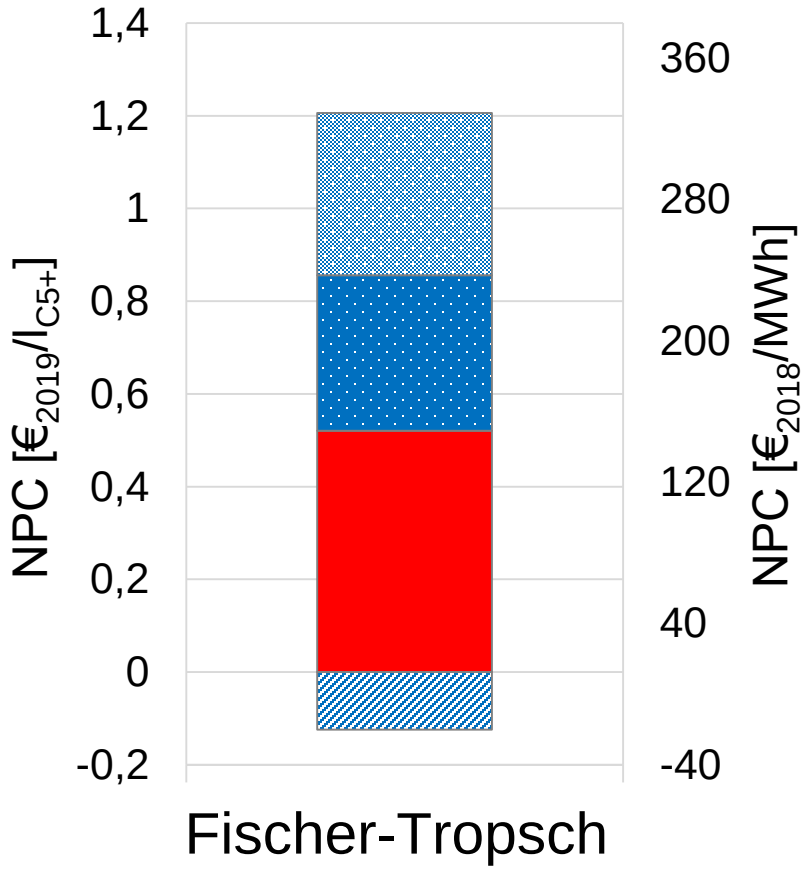
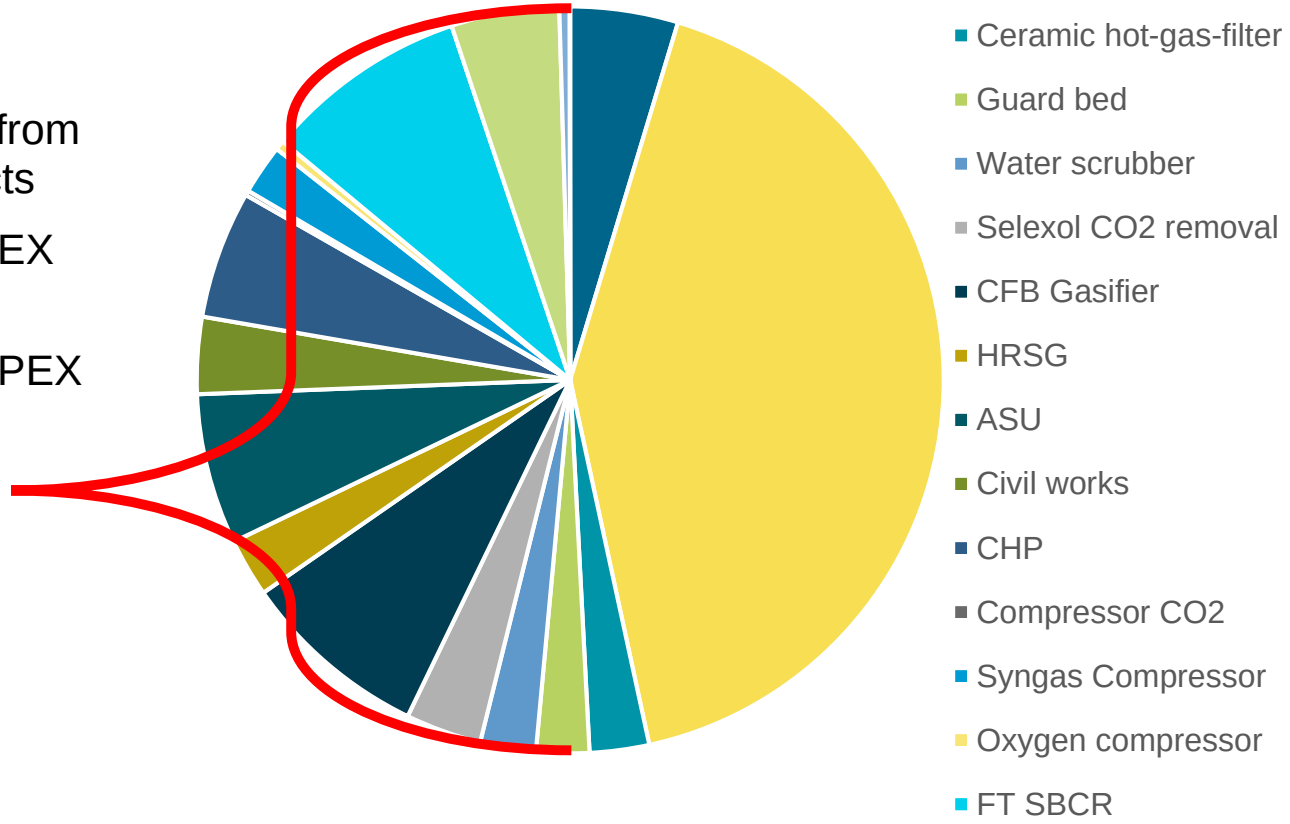


FCI (132 kt/a SAF): 535 M€$_{2018}$



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BA versus EA [1]

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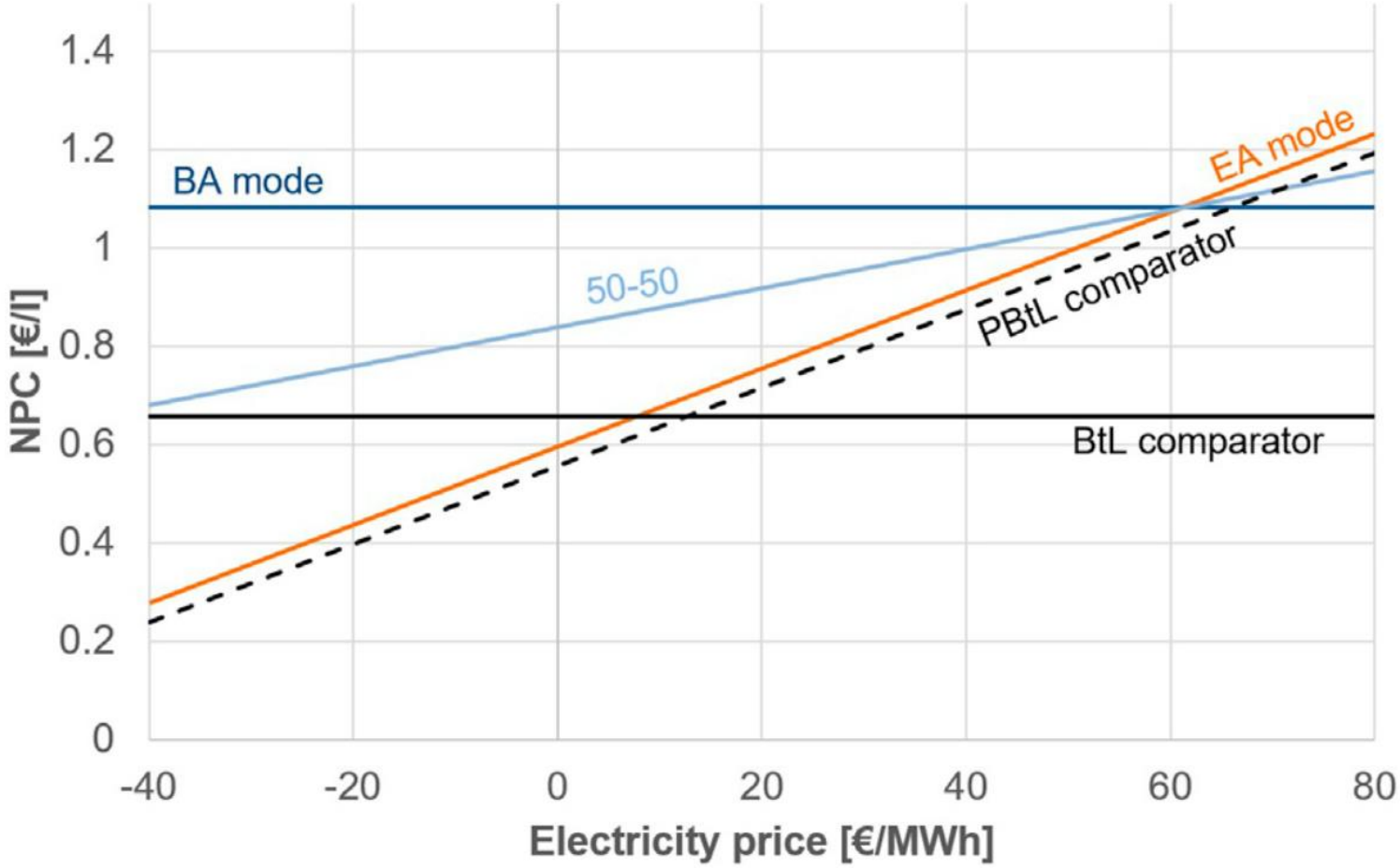
Net production cost sensitivity:



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FLEXCHX

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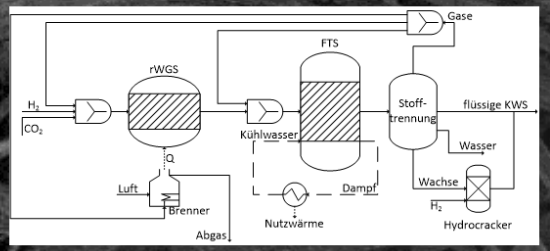
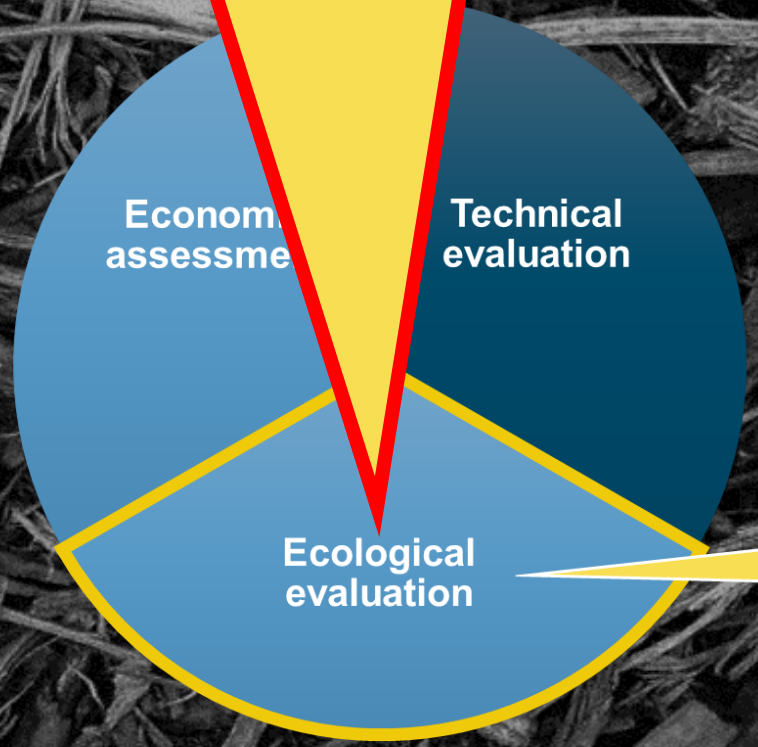
Session: 5CO.13.1, AUDITORIUM EUROPA
Wednesday, 07 June 2023, 17:30 - 18:30
J. Weyand et al.

DLR





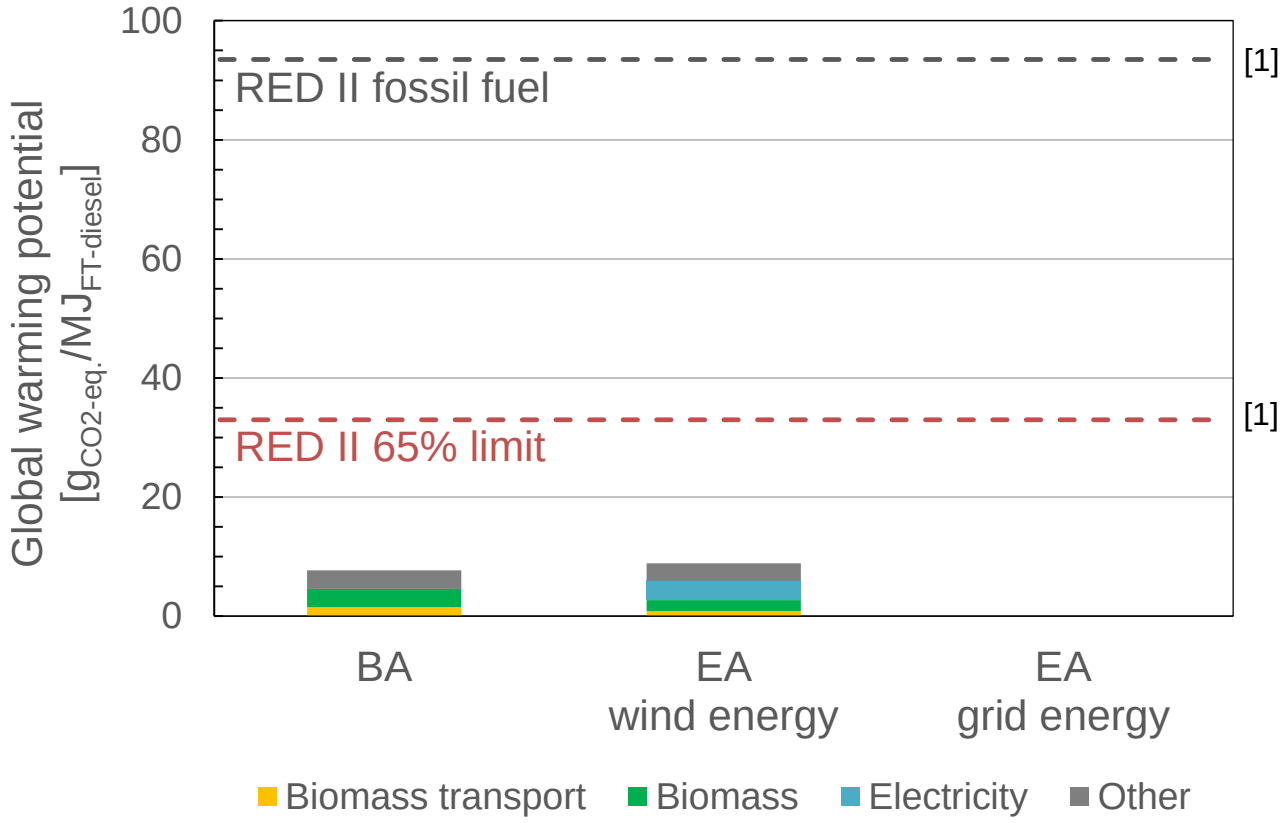
- GWP
- Other impact categories
- Identification of impact drivers

ECOLOGICAL ASSESSMENT OF FLEXCHX PBTL CONEPT

BA versus EA

FLEXCHX project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 763919

Global Warming Potential (GWP):



- **Transportation: truck (one-way)**
  - 100 km biomass
  - 200 km FT-products
- **Biomass: Harvesting woody residues (bark, saw dust, wood chips)**
- **Electricity: Finnish wind energy**

Conclusion

REDII target **accomplished** under FLEXCHX base case assumptions

[1] European Union (2018) "Directive 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast)", Official Journal of the European Union,

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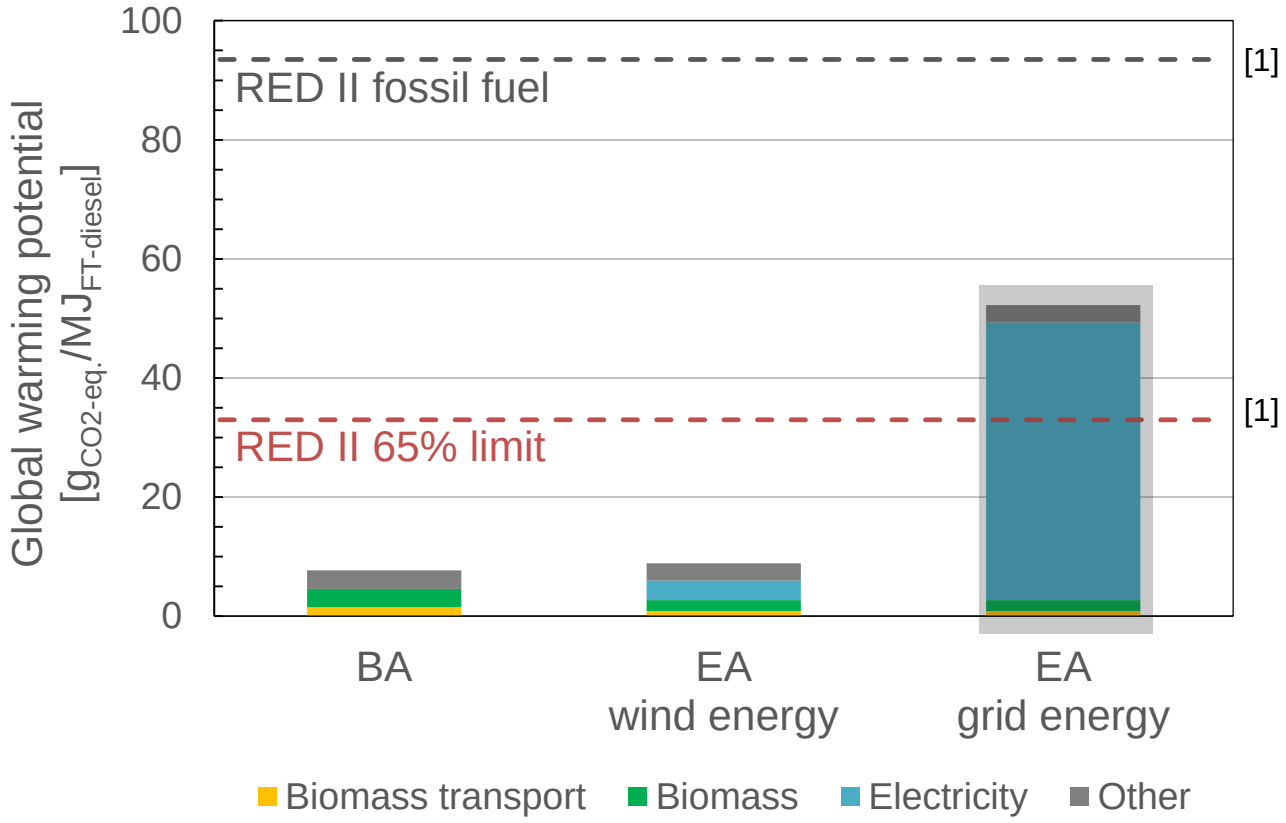

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  Finnish grid energy

Conclusion

REDII target **doubtful** using current Finnish grid power

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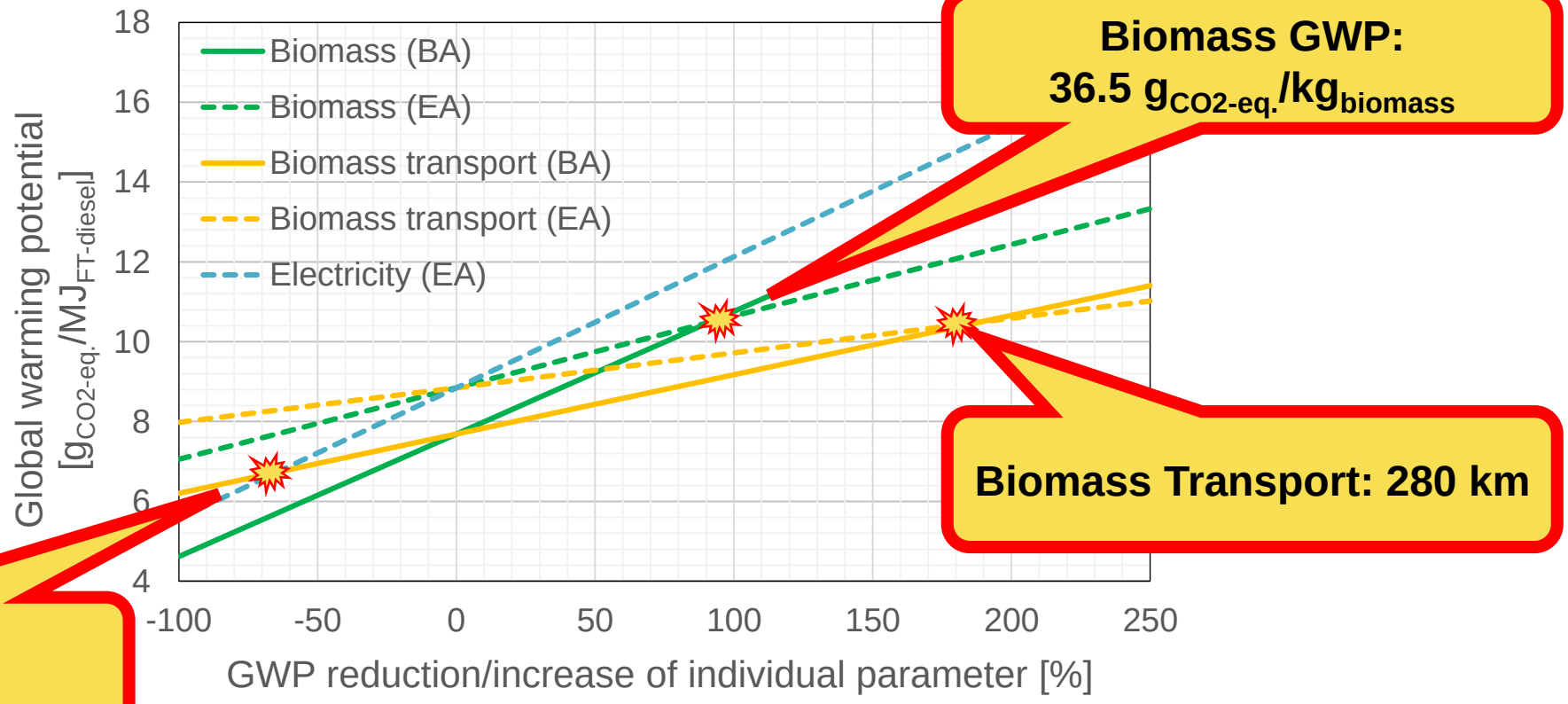
GWP sensitivity



Biomass GWP: 36.5 $g_{CO2\text{-}eq.}/kg_{biomass}$

Biomass Transport: 280 km

Electricity GWP: 10.9 $g_{CO2\text{-}eq.}/kWh_e$

BA versus EA environm. tradeoffs

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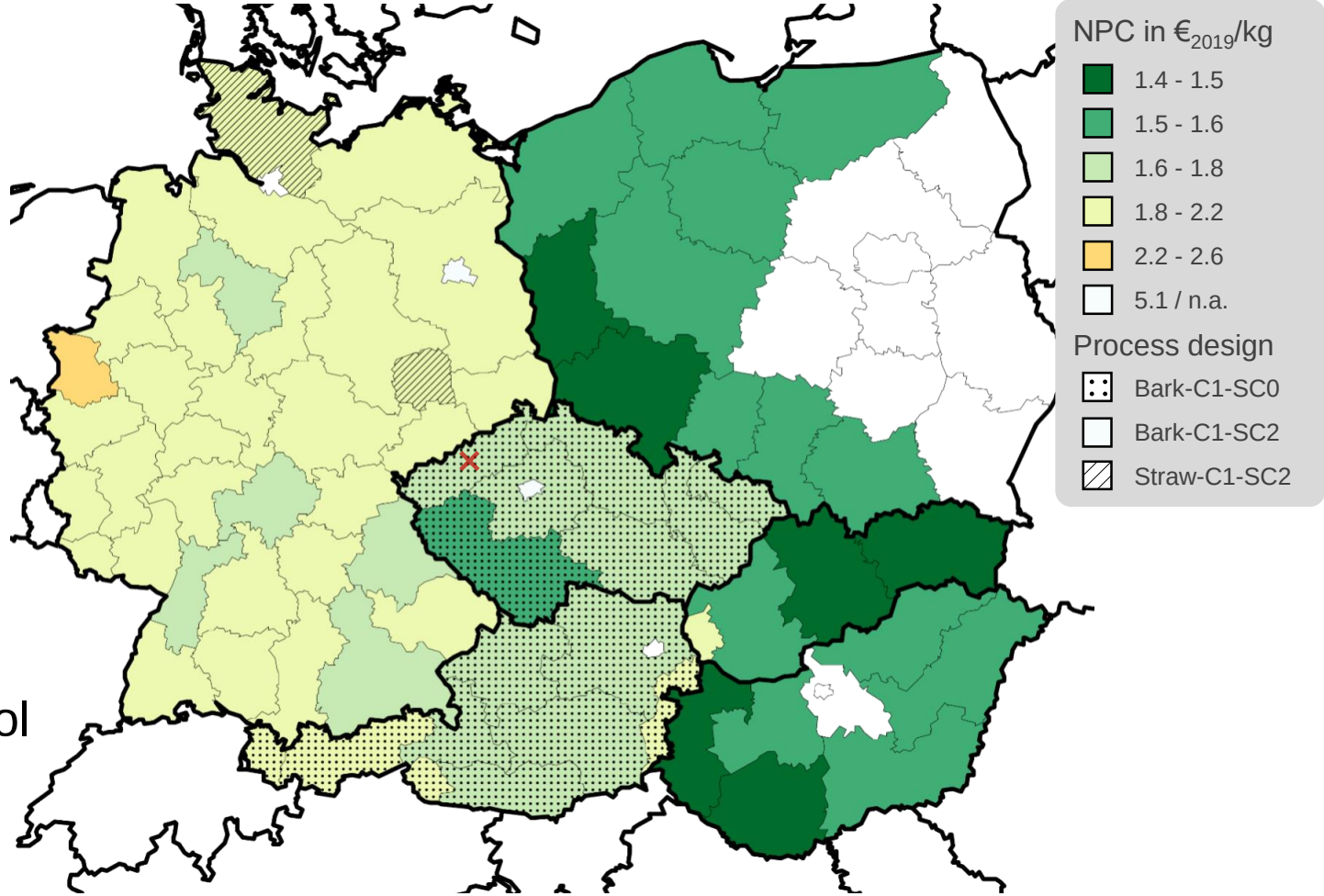
Normalized Environmental Impacts

TEEA FACILITATING INVESTMENT DECISIONS

BtL site search for Central Europe [1]

- Assumptions:
  - Bark & straw as biomass feedstock
  - 200 MW_{th} max. plant scale (84 t/h)
  - 20 years of plant lifetime
  - 8260 h/a operation
  - 10 persons per shift
  - 10% interest rate
  - Heat market for district heating available
  - Product refining at ORLEN UniPetrol Litvínov – Záluží refinery (**X**)



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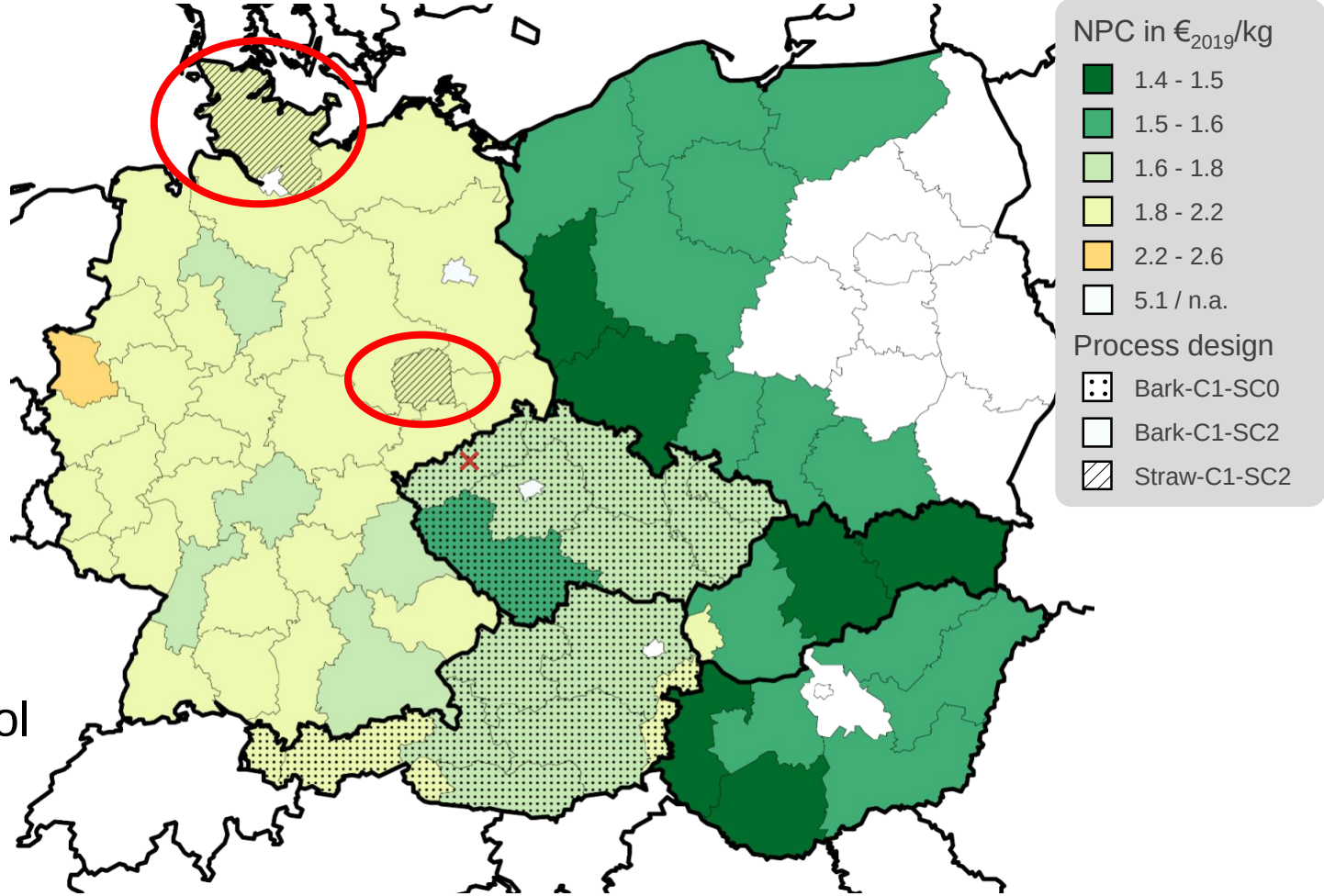

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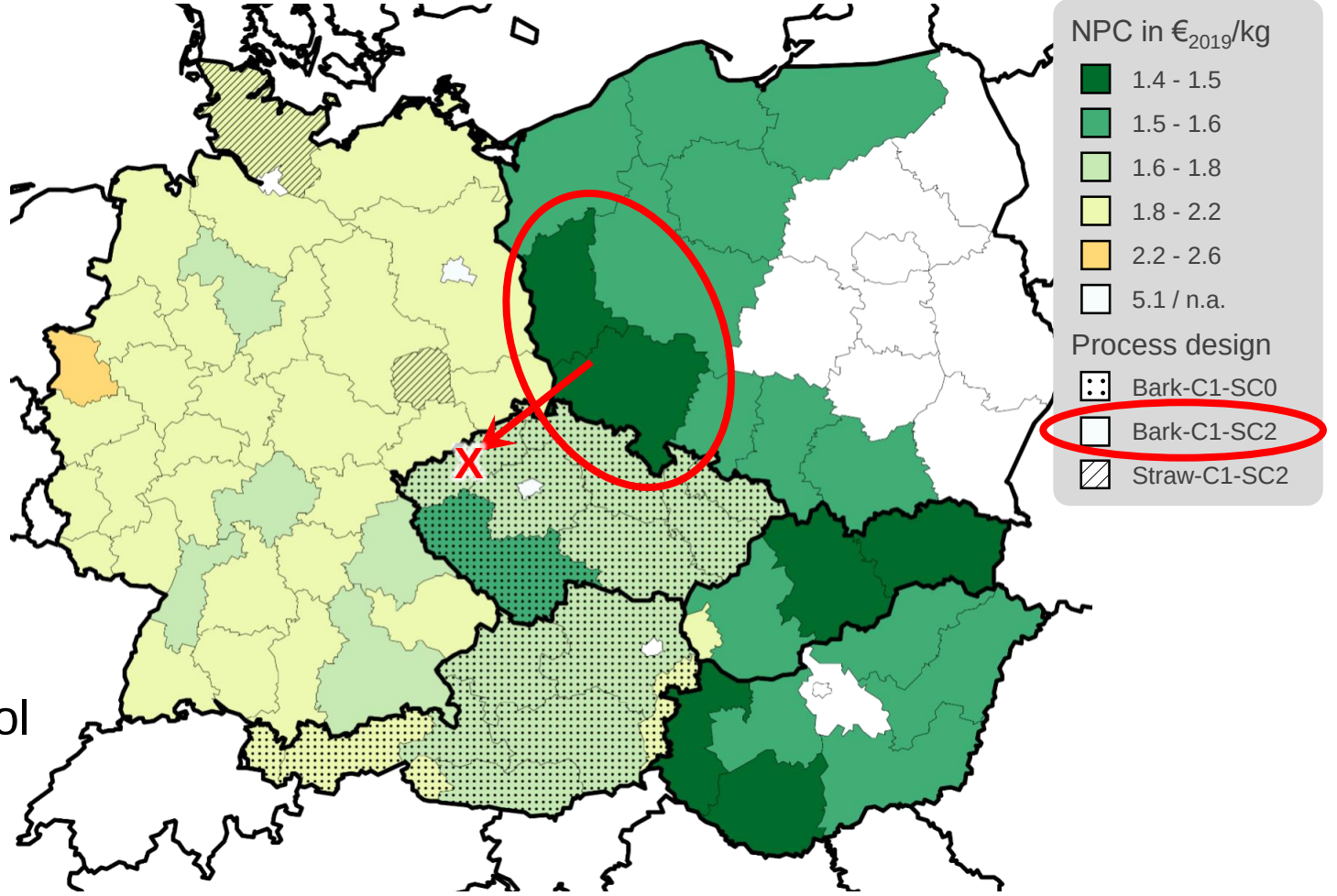

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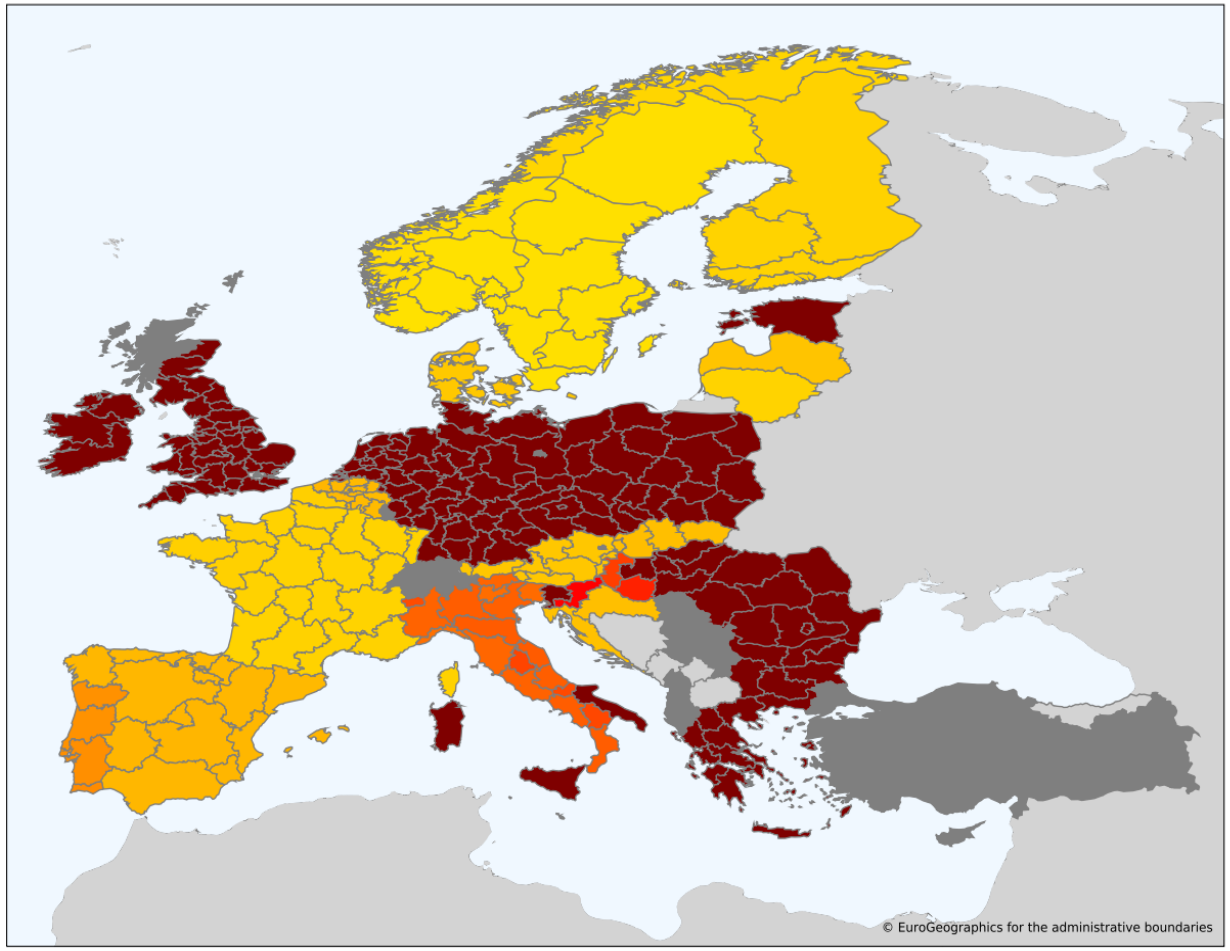
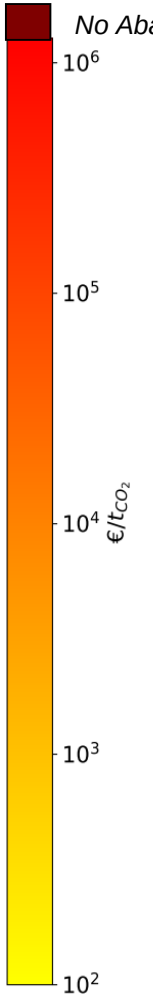
European PBtL production capacity

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





NUTS 2 region specific conditions:

- National grid mix GWP [1]
- Region-specific power & biomass price, labor cost, transport emissions, …
- No GHG abatement for countries with high GHG power grid

[1] Online https://www.eea.europa.eu/data-and-maps/daviz/co2-emission-intensity-6 [Accessed 14.9.21]

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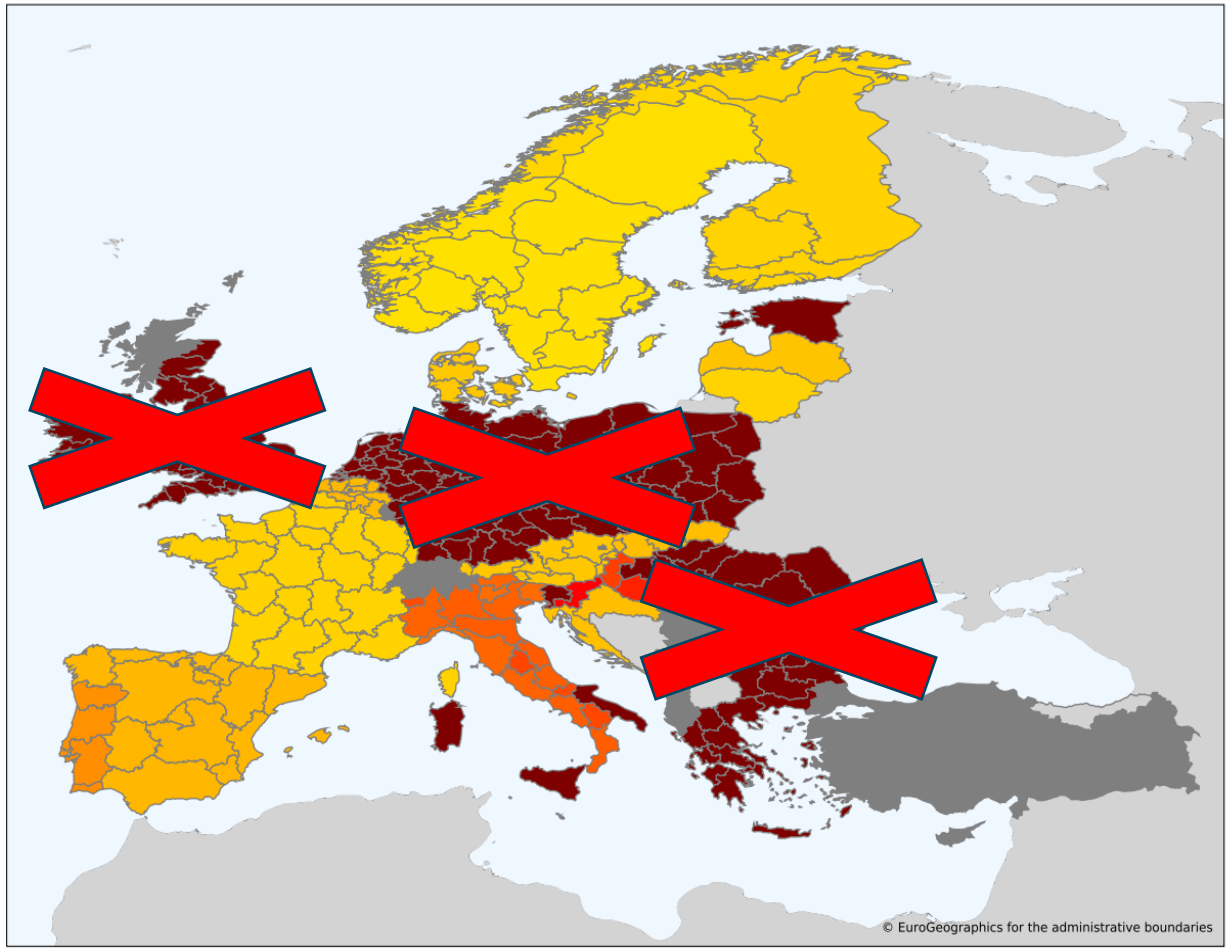

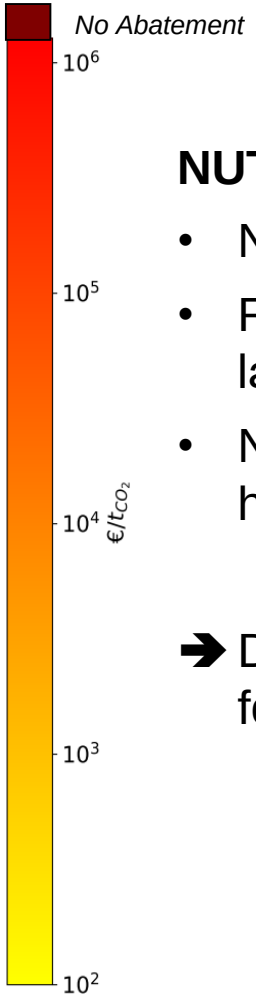

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➔ Decarbonized national grids necessary for effective PBtL roll-out

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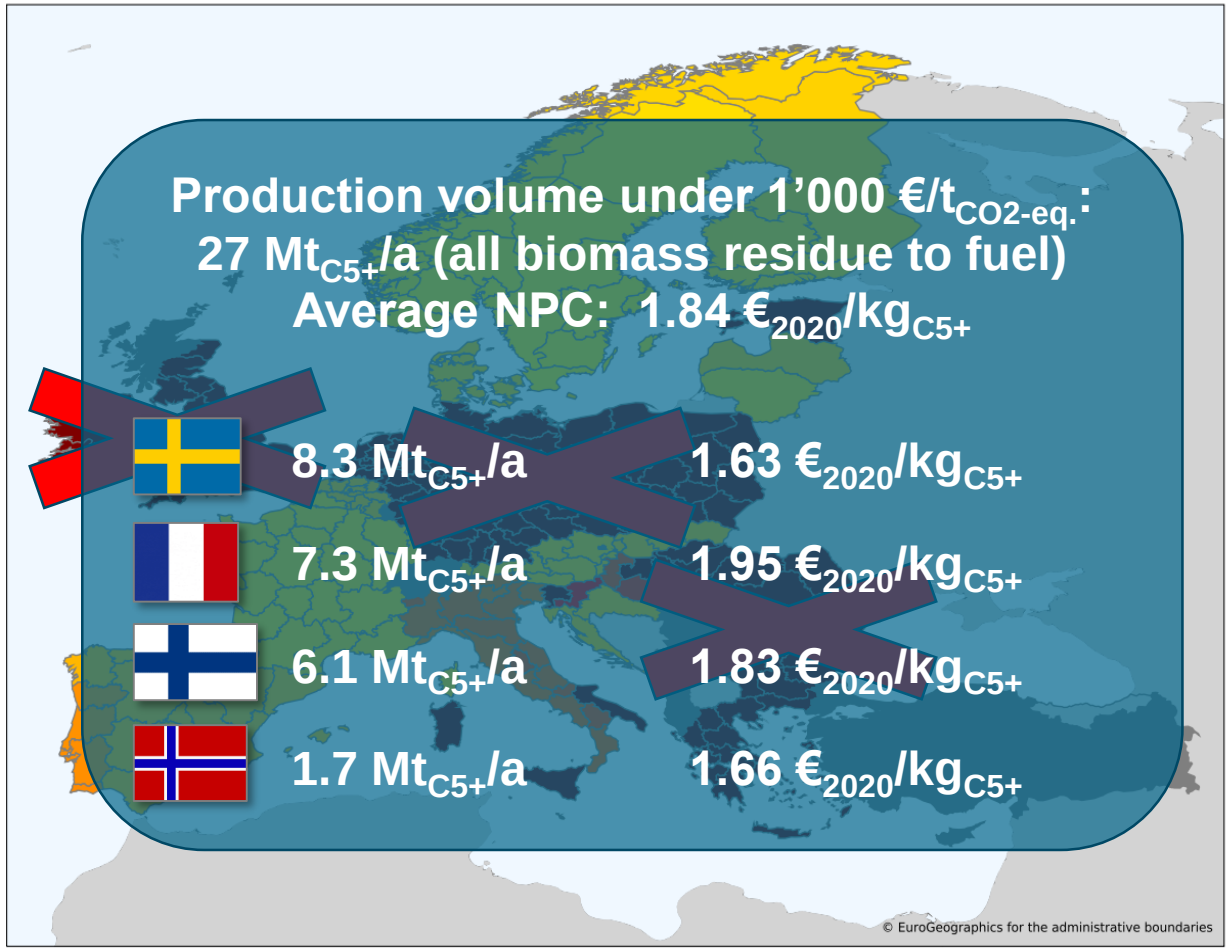

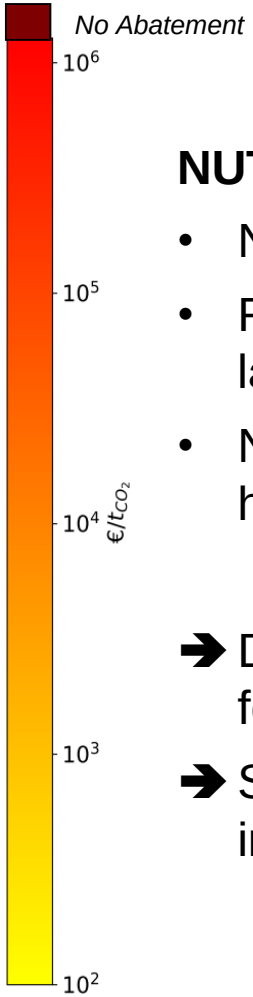

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➔ Substantial PBtL roll-out possible NOW in regions with low-carbon grid

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European SAF production capacity

EUBCE 2023
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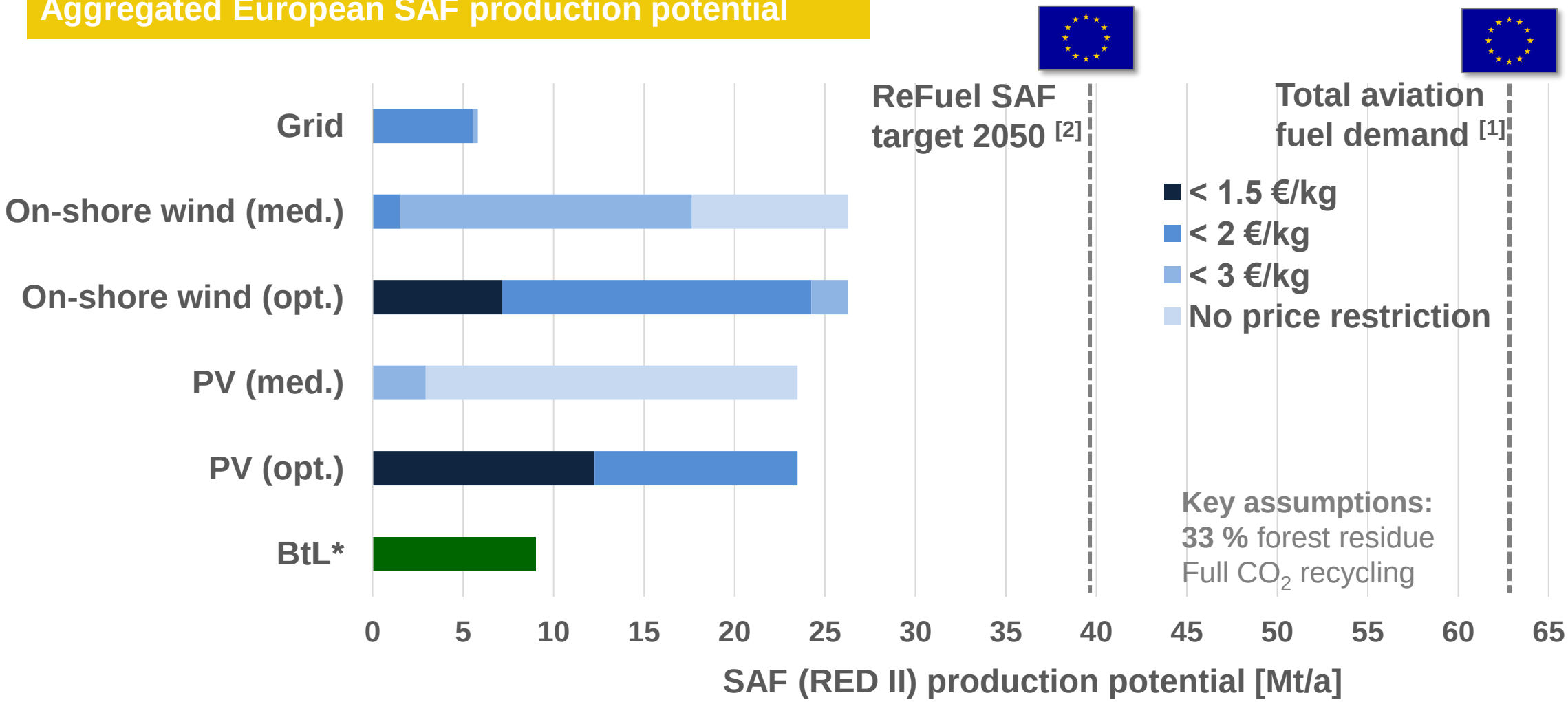
In-person, online, Bologna, Italy
5 - 8 JUNE CONFERENCE & EXHIBITION
9 JUNE TECHNICAL TOURS

DLR

Aggregated European 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

Biofuels production routes assessment for market introduction, policy briefing

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DLR

Summary

- Biofuels are required to defossilize transport towards European climate change mitigation goals, especially in aviation and shipping
  - Crop-based 1st generation biofuels fail (amount, GHG abatement, food competition)
- Transparent, standardized DLR assessment methodology available
  - each technology option, roadmap creation, tracking of progress
- Sweet spots can be found in Europe,
  technology choice depend on feedstock availability
- Regulation defines biofuels introduction success, high blending targets are feasible and possible

European SAF ramp up will follow political enforcement!

Thank you to the team!
THANK YOU FOR YOUR ATTENTION !

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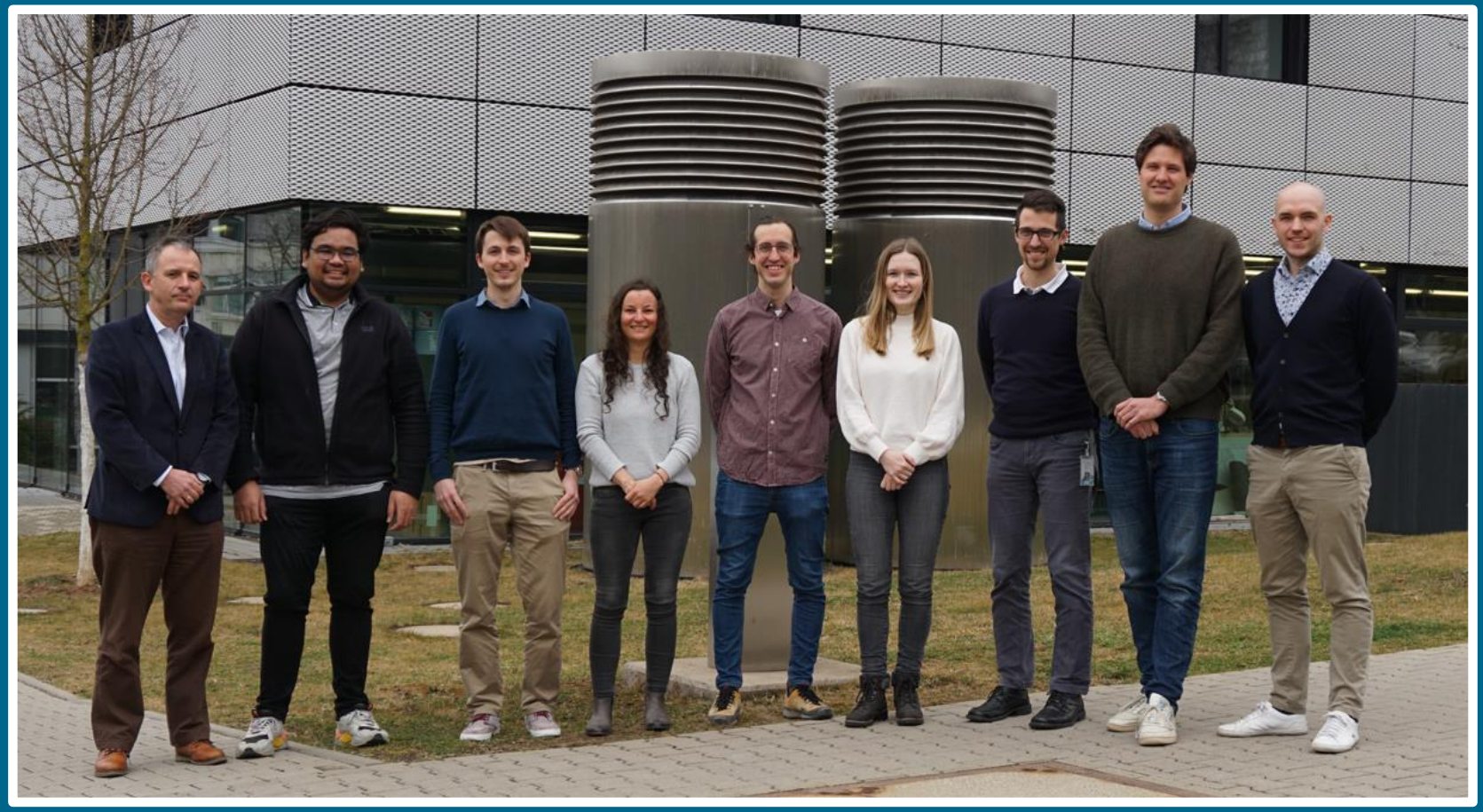

Questions? ralph-uwe.Dietrich@dlr.de