Wednesday, September 11, 2024

Novel technological approaches

Thema: B - Entwicklung nachhaltiger Prozesse

TECHNO ECONOMIC ASSESSMENT OF PTX PRODUCTION OFFSHORE

How to transform onshore steady state to offshore dynamic

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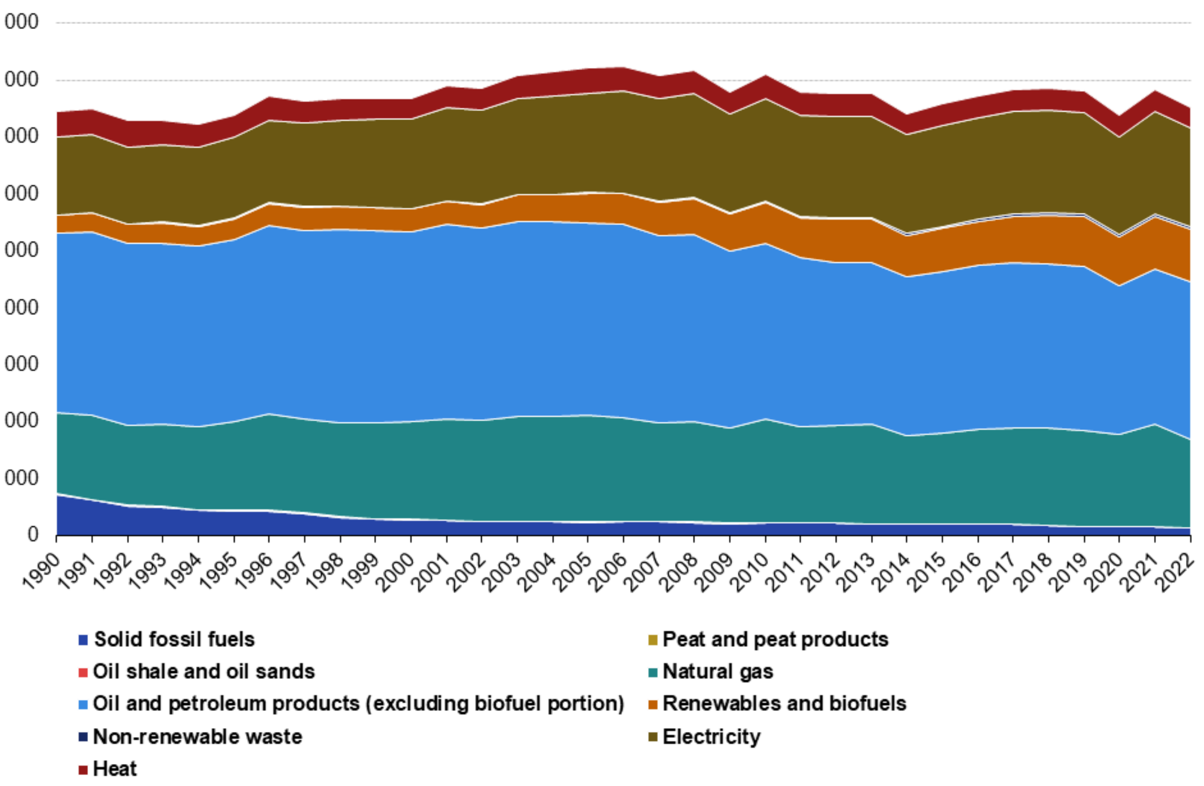
(DLR e.V., www.DLR.de/tt)

Motivation

- EU Climate Neutral Goal by 2050 (Germany already by 2045)[1,2]
- Reduction and substitution
- Energy security
- Hard to abate sectors:
  - Chemical industry
  - Ships, trucks, planes
- Investment opportunity?
  - CO_2 abatement

Final energy consumption by fuel, EU, 1990-2022
(Petajoules (PJ))



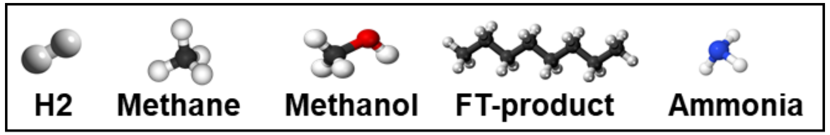
Source: Eurostat (online data code: nrg_bal_c)

[1] European Climate Law (europa.eu)
[2] Jedamzik et al. (2020) Energiewende in Deutschland: Definition, Kosten & Ziele | co2online
[3] Unleashing Europe’s offshore wind potential -A new resource assessment 2017 Wind Europa

Motivation

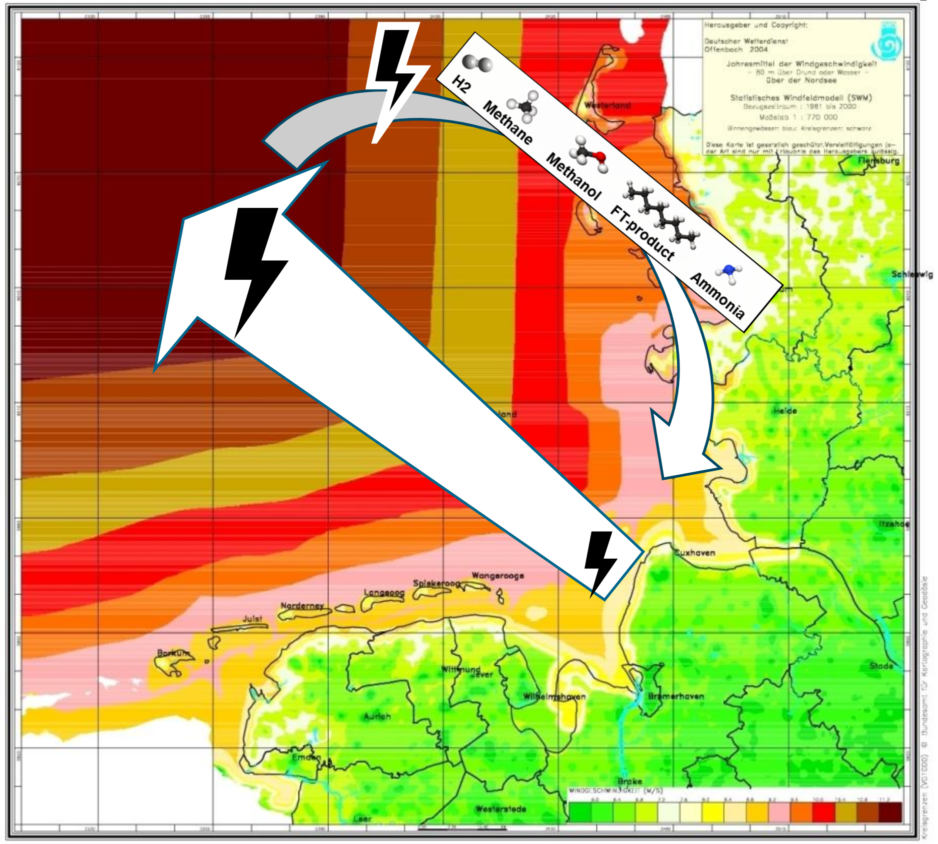
Dr. Ralph-Uwe Dietrich
12.09.
Topic: C - Aufbau der Wasserstoffwirtschaft

- Sweet spots needed
- European offshore wind potential: 2,600 - 6,000 TWh/a at ≤ 65 €/MWh[1]
  - ~60% of total Energy demand
- Far offshore higher wind loads
- Transport of energy:
  - Cable
  - Molecules



- For investment decisions:
  - Fair comparison of options necessary

[2]



[1] Unleashing Europe’s offshore wind potential -A new resource assessment 2017 Wind Europa
[2] https://www.dwd.de/DE/leistungen/windkarten/deutschland_und_bundeslaender.html#buehneTop

Current status of chemical engineering cost estimation

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- Chemical engineering cost estimation[1-3]
  - ✓ Standard onshore stationary[4-5]
  - ✓ Class 3-4: feasibility study [2]
  - ✓ Adaption for PtX[4-5]
- Open questions:
  - ? Standard for cost calculation offshore
  - ? Experimental validation
  - ? Platform costs
  - ? Dynamics

[1] 1955, McGraw-Hill, Chemical Engineering Cost Estimation
[2] CHRISTENSEN, P., DYSERT, L. R., BATES, J., BURTON, D., CREESE, R. & HOLLMANN, J. 2005. Cost Estimate Classification system-as applied in engineering, procurement, and construction for the process industries. AACE
[3] International Recommended Practices, 1-30.PETERS, M., TIMMERHAUS, K. & WEST, R. 2004. Plant Design and Economics for Chemical Engineers, New York McGraw-Hill.
[4] 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
[5] Heimann, N. et al (2023) Standardized techno-economic assessment of synthetic compressed natural gas (sCNG) and synthetic hydrogen compressed natural gas (sHCNG) production for German transport sector. submitted.

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[1]
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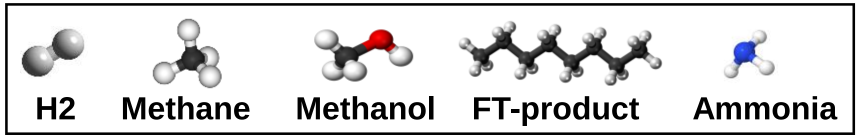
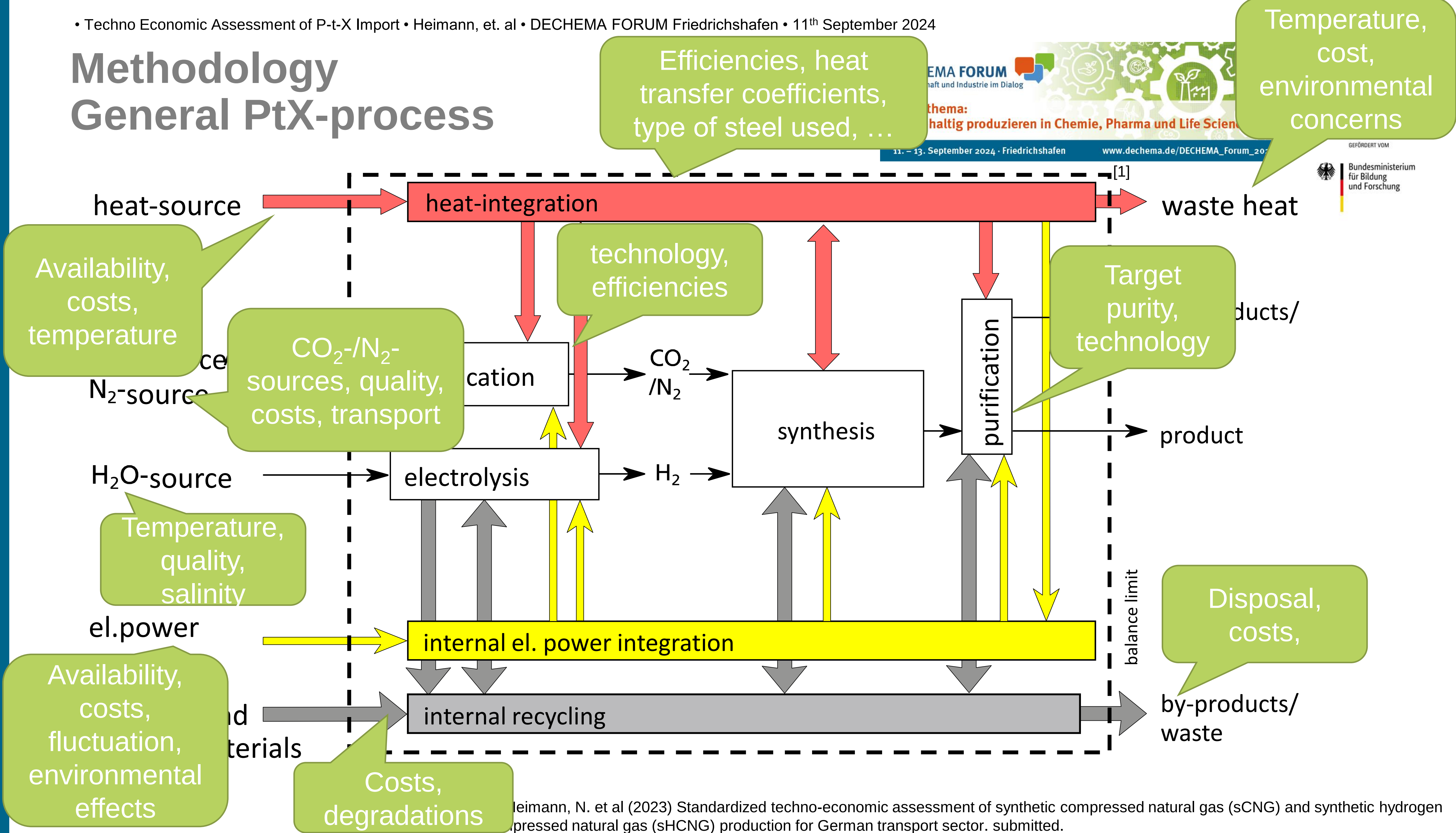



[2]

METHODOLOGY

Concept by Sherin Ismail
[1] DLR e.V. DLR (CC BY-NC-ND 3.0)
[2] EBMS TU Berlin

Methodology
General PtX-process



[1] Heimann, N. et al (2023) Standardized techno-economic assessment of synthetic compressed natural gas (sCNG) and synthetic hydrogen compressed natural gas (sHCNG) production for German transport sector. submitted.

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Cost relevant questions in H2Mare PtX

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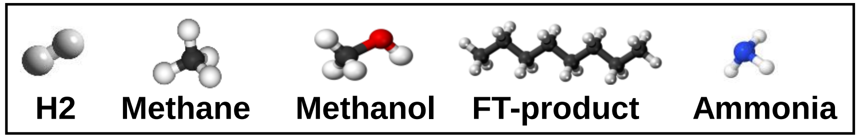
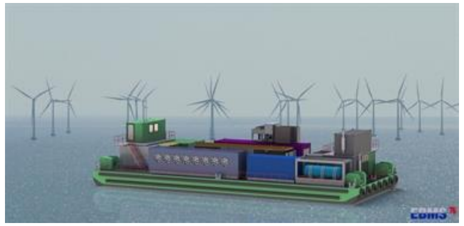
Intermitting electricity supply,

energy storage,





storage optimization

Weather Conditions

Economics

Logistics

Transport,

Safety

Additional space requirements

Sewage/brine disposal

Environment

Corrosion

Technology, Maintenance and Repair

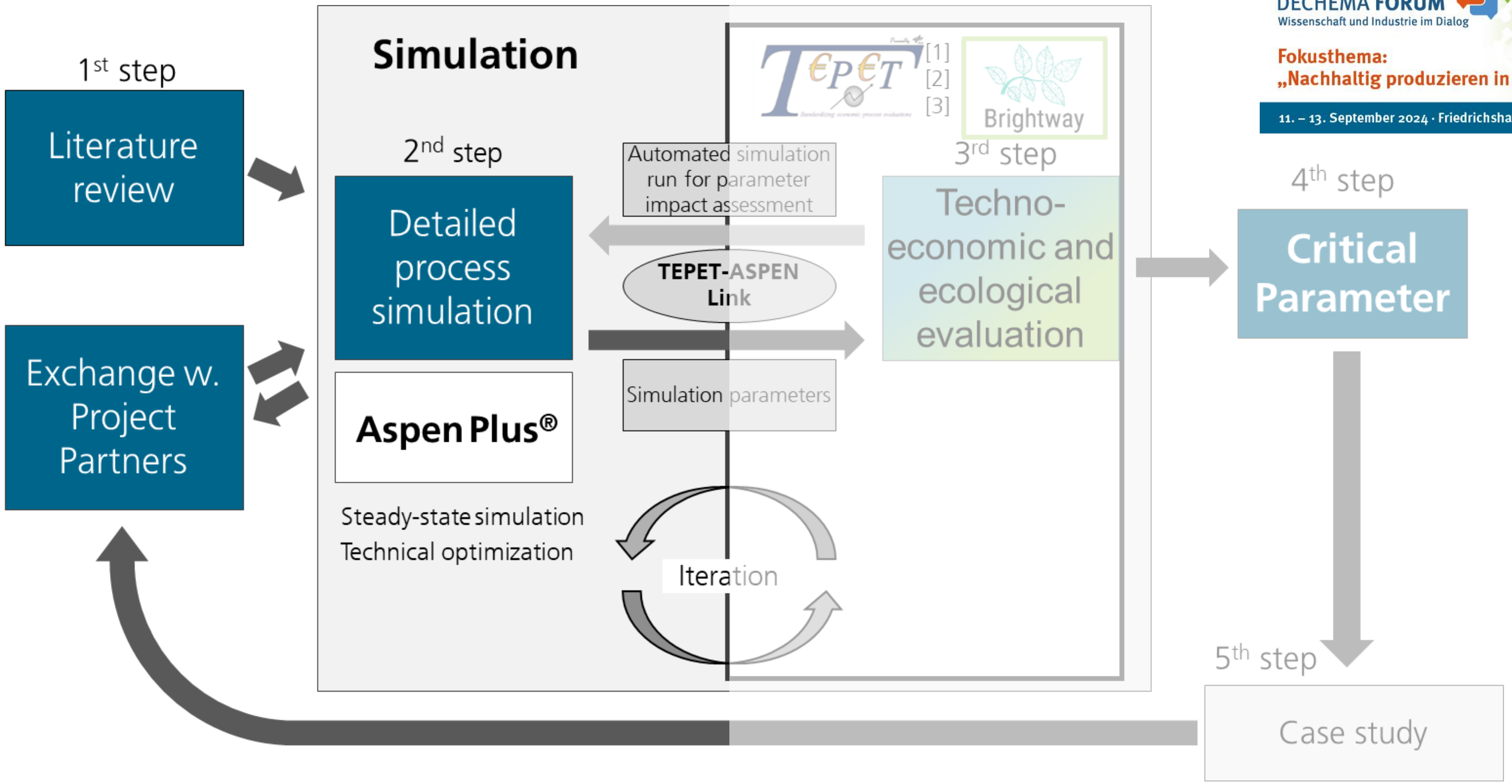
Materials, maintenance intervals, heat management, reliability

Legal Requirements

Personell

income,
number of staff

[2] EBMS TU Berlin
Concept by Sherin Ismail



EXAMPLE: METHANOL

[1] Albrecht et al. (2017). A Standardized Methodology for the Techno-Economic Evaluation of Alternative Fuels
[2] Maier et al. (2021) Techno-economically-driven identification of ideal plant configurations for a new biomass-to-liquid process
[3] Weyand et al. (2023) Process design analysis of a hybrid Power-and-Biomass-to-Liquid process

General input values
Technical

- Stationary simulation, industrial design
- Technical standard values
  - As in BEniVer[1] or defined by industrial design
  - Materials, efficiencies, technical coefficients
- No redundancies
- No decommissioning
- Germany 2020: SEN 1
- PEM 100 MWel $\eta_{electrolyzer} \approx 69\ \%(\text{LHV})$
- Reverse osmosis
  - Brine disposal not regulatory defined yet

[1] Heimann et.al. 2024, Contribution to a standardized economic and ecological assessment methodology for e-fuel production in Germany; submitted

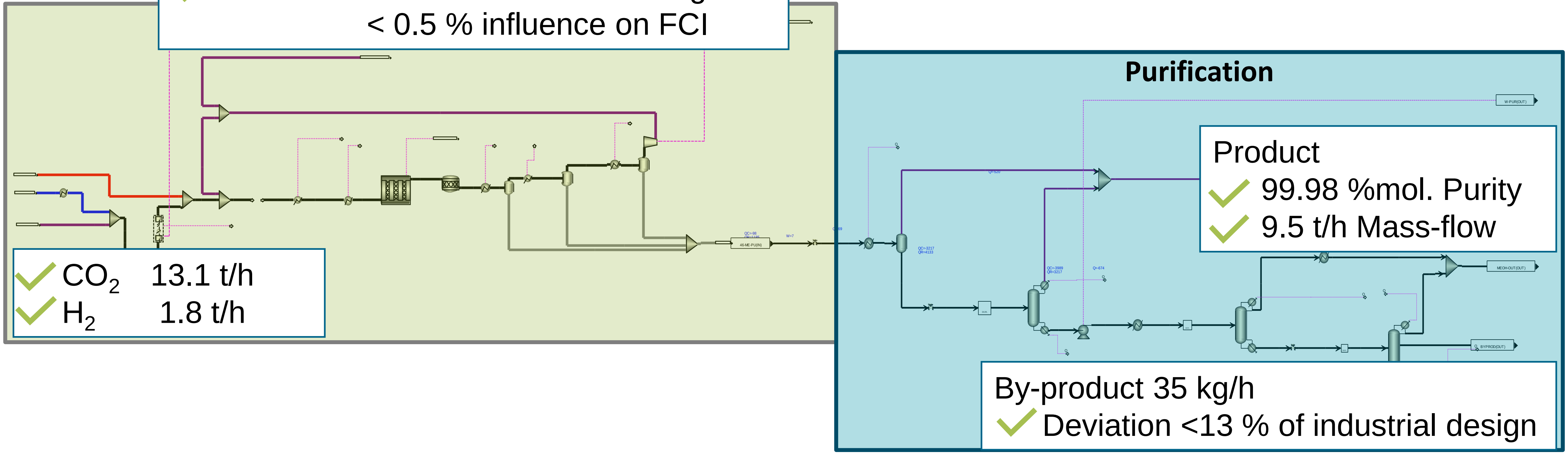
2nd step Simulation

Onshore steady state industrial design met

Recycle

✓ Deviation <12 % of industrial design

< 0.5 % influence on FCI



✓ CO_2 13.1 t/h

✓ H_2 1.8 t/h

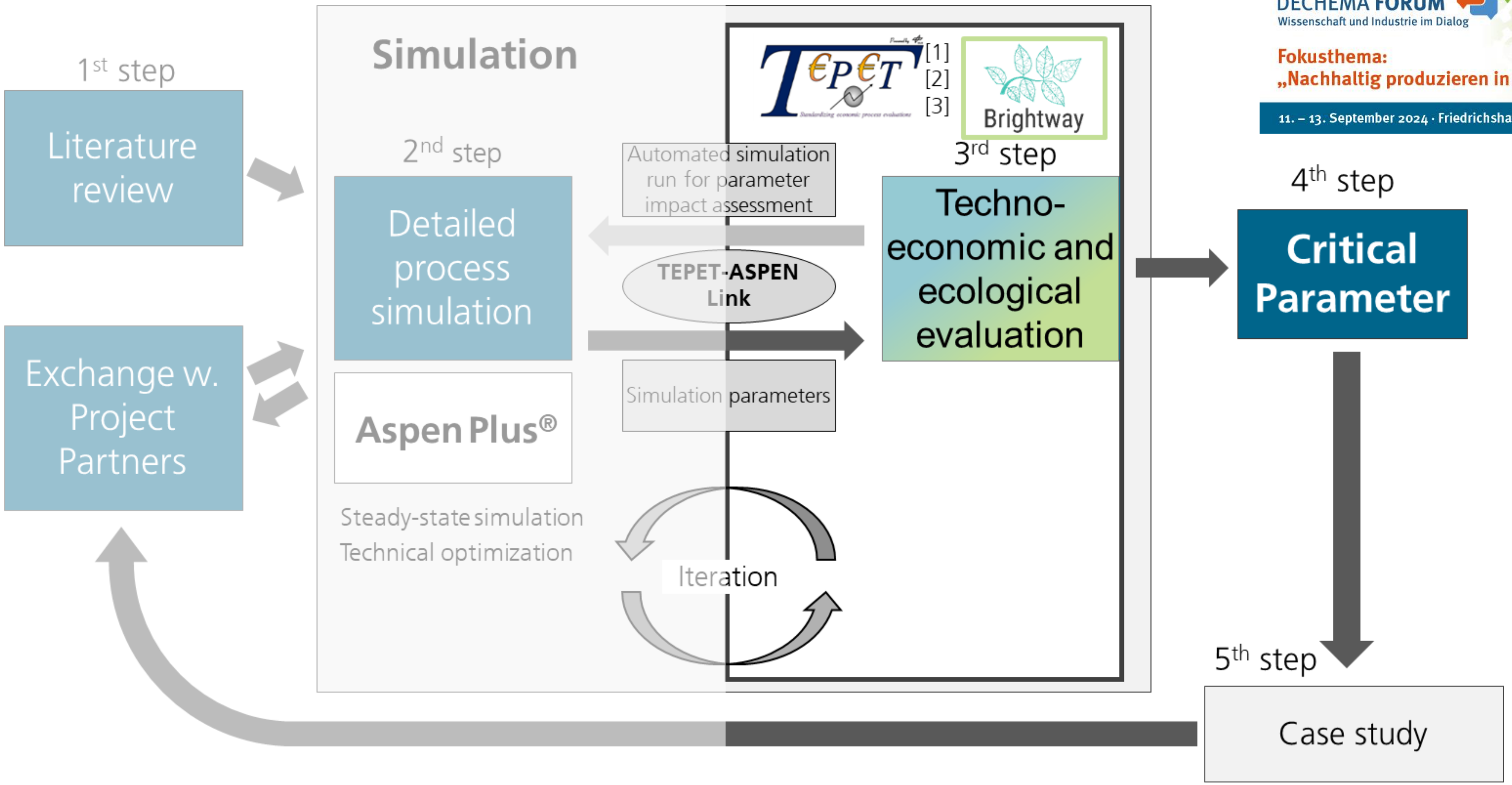
Product

✓ 99.98 %mol. Purity

✓ 9.5 t/h Mass-flow

By-product 35 kg/h

✓ Deviation <13 % of industrial design



METHANOL: TECHNICAL ANALYSIS

[1] Albrecht et al. (2017). A Standardized Methodology for the Techno-Economic Evaluation of Alternative Fuels
[2] Maier et al. (2021) Techno-economically-driven identification of ideal plant configurations for a new biomass-to-liquid process
[3] Weyand et al. (2023) Process design analysis of a hybrid Power-and-Biomass-to-Liquid process

3rd step Analysis:

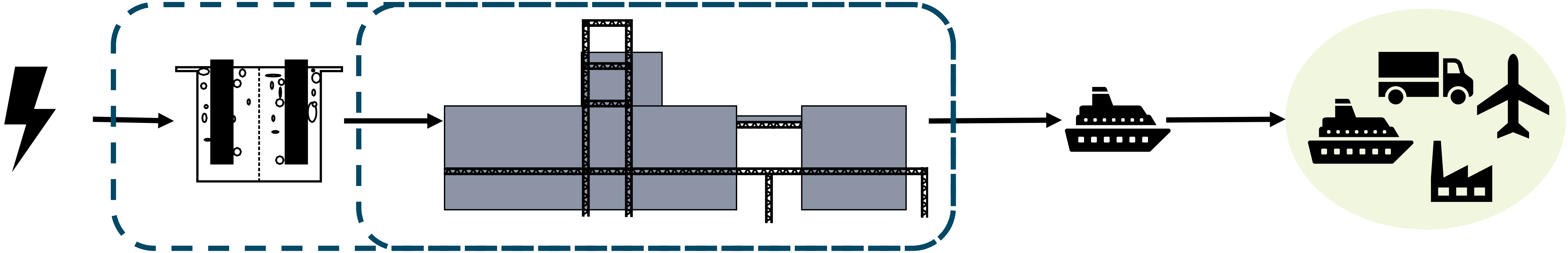
KPI

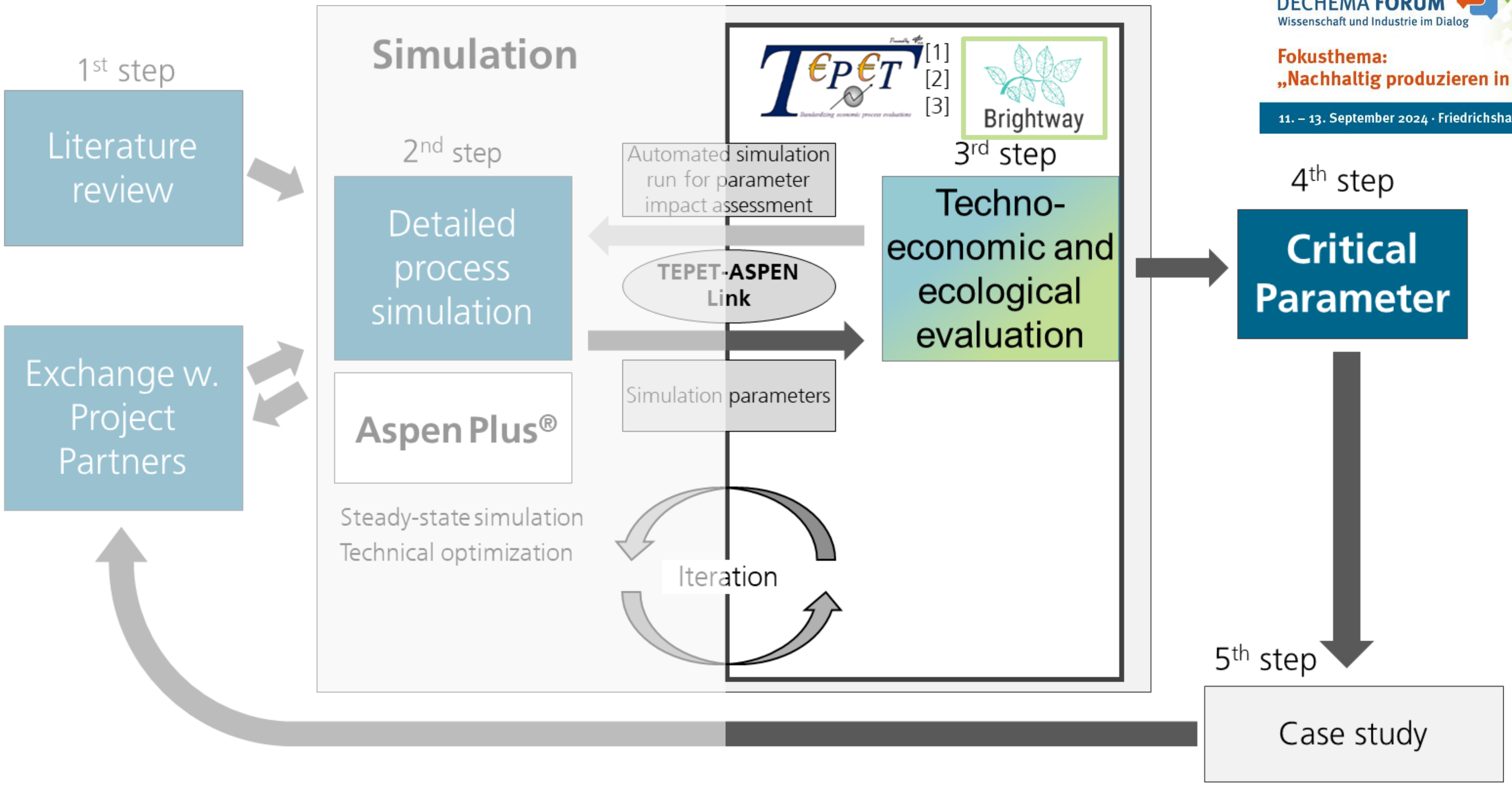
$$\eta_{HtF} = \frac{\sum \dot{m}_{Prod} \cdot LHV_{Prod}}{\dot{m}_{H_2} \cdot LHV_{H_2}} = 87\ \%$$

$\eta_{H_2tF,\,ideal} = 87.9\ \%$

$$\eta_{PtF} = \frac{\sum \dot{m}_{Prod} \cdot LHV_{Prod}}{P_{el}} = 52\ \%$$

$$Y_C = \frac{\sum \dot{n}_{CP}}{\sum \dot{n}_{CE}} = 99\ \%$$





METHANOL: ECONOMIC ANALYSIS

[1] Albrecht et al. (2017). A Standardized Methodology for the Techno-Economic Evaluation of Alternative Fuels
[2] Maier et al. (2021) Techno-economically-driven identification of ideal plant configurations for a new biomass-to-liquid process
[3] Weyand et al. (2023) Process design analysis of a hybrid Power-and-Biomass-to-Liquid process

General required input data[1]

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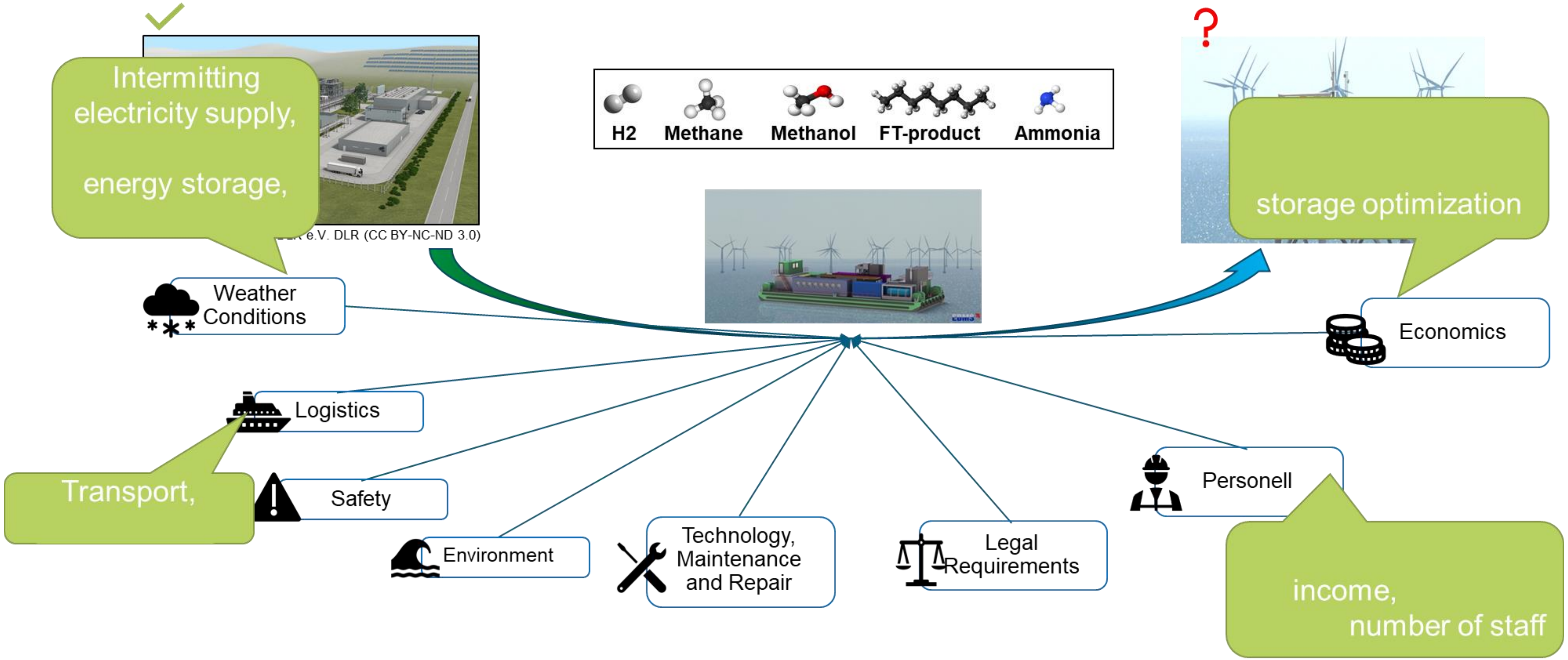


Important input values

- **Included:**
  - Electrolyzer:
    - 1,800 €$_{2020}$/kWh[1]
  - H_2-pressure-storage tank
    - ~613 €$_{2020}$/kg[2]
  - Platform
    - Jack-up: mass-based cost calculation[3] ;
    - Process weight: 1st assumption: Ecoinvent weights[4]
  - Cost calculation: Peters et. al.[6,7]

- **Excluded:**
  - hore

[5]

*Assumption

[1] KRISHNAN, S., KONING, et. al. 2023. Present and future cost of alkaline and PEM electrolyser stacks. *International Journal of Hydrogen Energy*.
[2] Raab et.al. Techno-economic assessment of renewable hydrogen production and the influence of grid participation https://doi.org/10.1016/j.ijhydene.2022.06.038
[3] DENA, COST AND PERFORMANCE DATA FOR OFFSHORE HYDROGEN PRODUCTION, 2023
[4] ecoinvent 3.10 cutoff-unit
[5] Maersk Giant, image: Maersk Drilling http://offshore-fleet.com/data/jackup-rig.htm
[6] Peters, Max S. 2004, Plant Design and Economics for Chemical Engineers
[7] Heimann et.al. 2024, Contribution to a standardized economic and ecological assessment methodology for e-fuel production in Germany; submitted

Case Study

- 4,000 (energetic) full-load-hours:

$$FLH = \frac{W}{P}\left[\frac{MWh/a}{MW}\right]$$

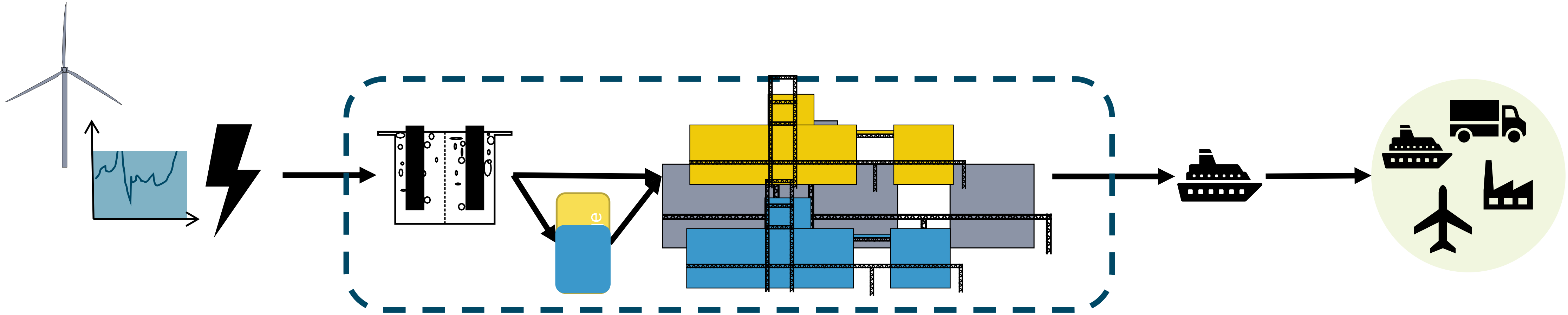
Base: 4,000 h/a at full-load

Storage: Electrolysis full dynamical, synthesis steady-state ½ size, no curtailment:

- Electrolyzer follows load, H2-pressure-storage for 3.5 days, plant built at ½ capacity

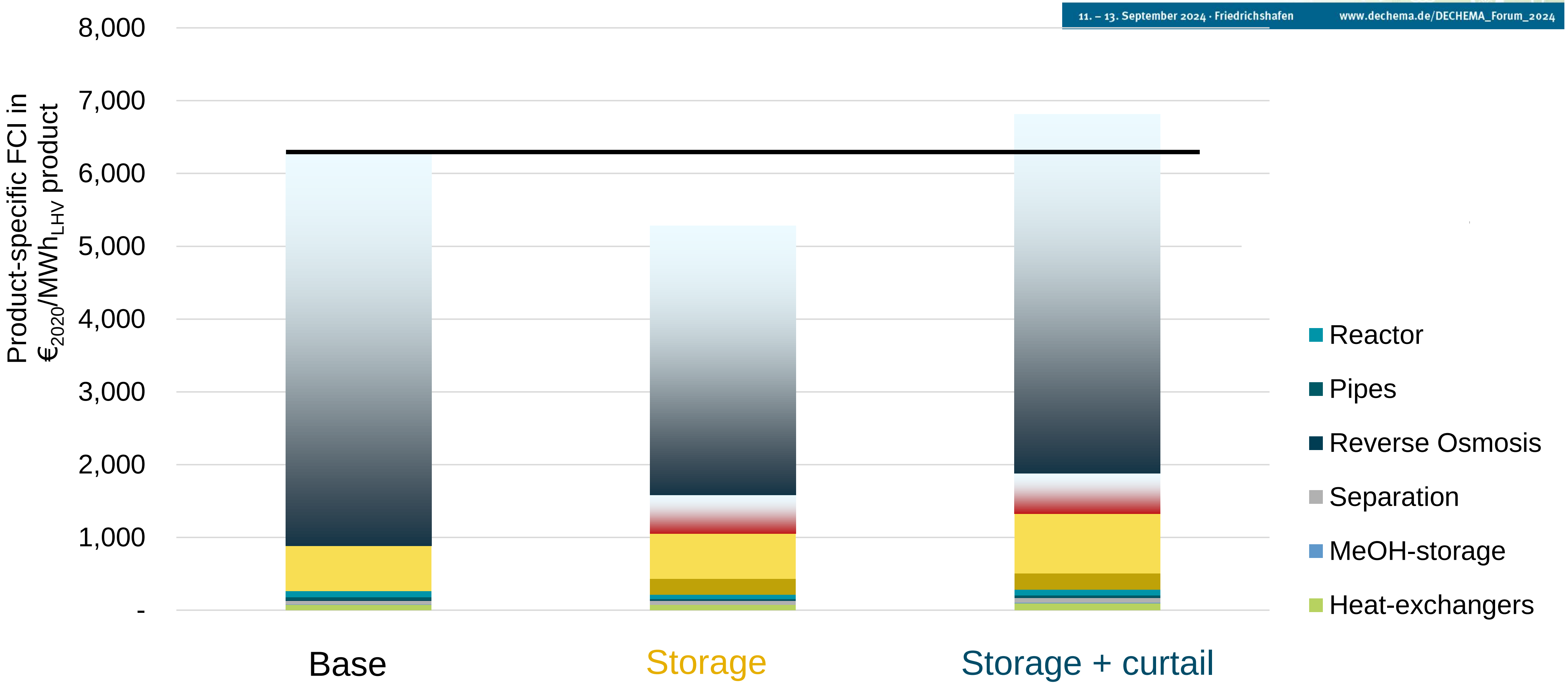
Storage + curtail: 25 % Curtailment Electrolysis full dynamical, synthesis steady-state, no curtailment:

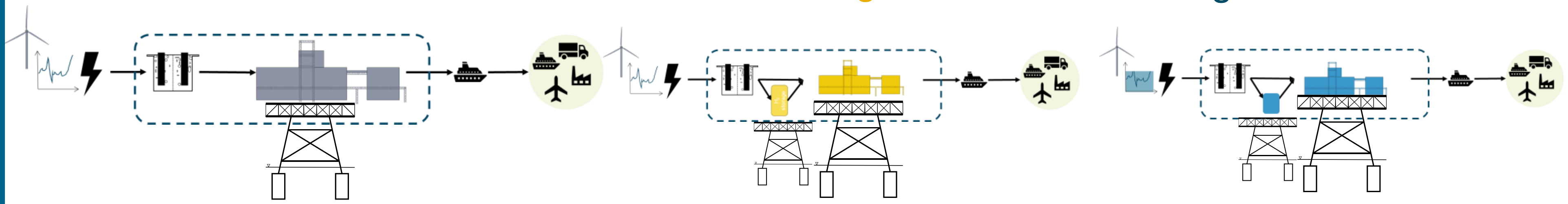
- Electrolyzer follows load, H2-pressure-storage for 3.5*75 % days, plant built at ½ capacity



Results: Product-specific FCI MeOH

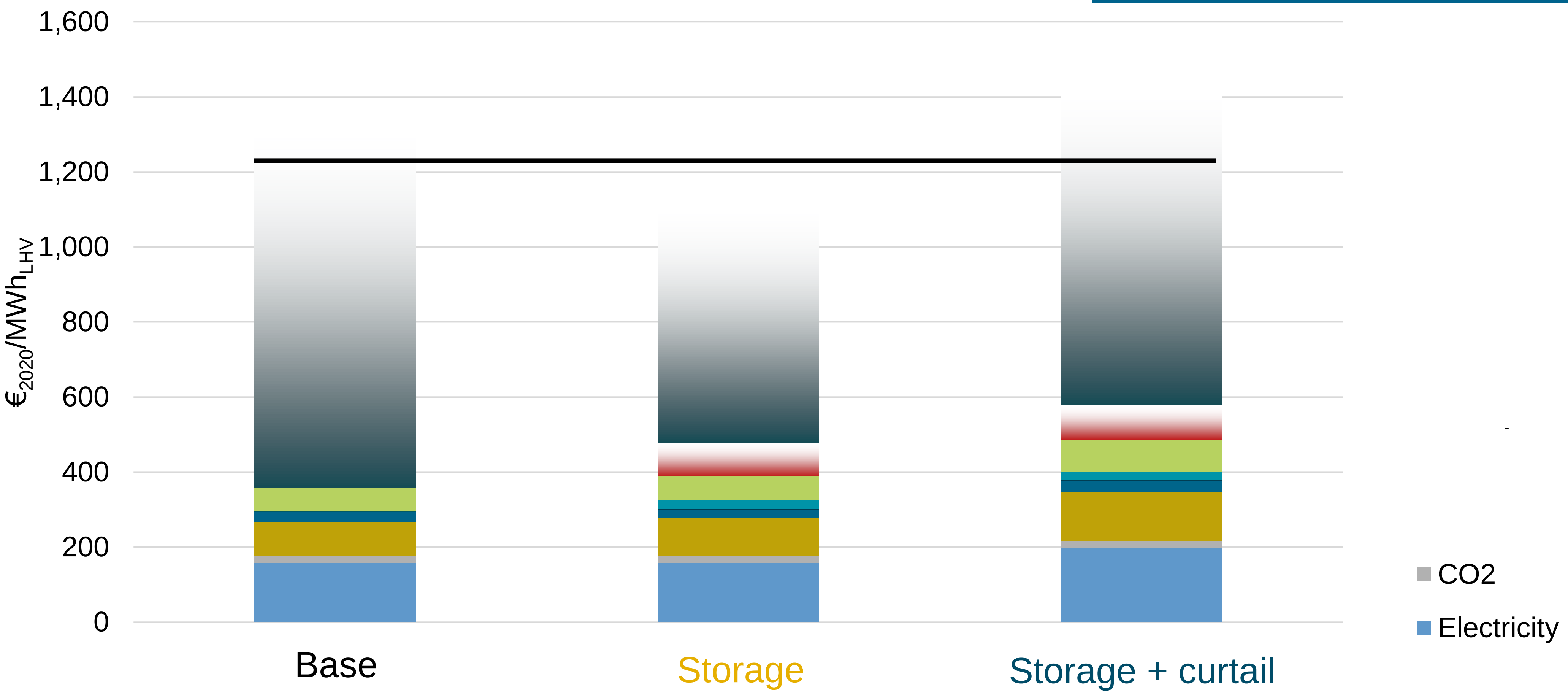
to be confirmed

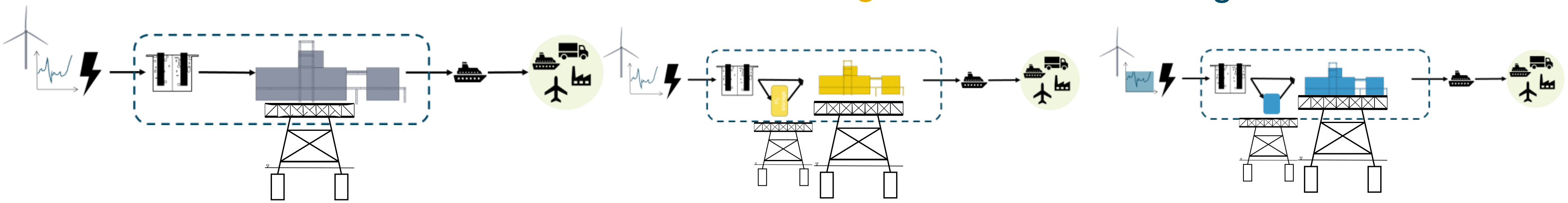




Results: NPC MeOH

to be confirmed





Conclusion

- TEA of offshore production not yet standardized
  - Adaptation from onshore-steady-state production feasible and under development
- Current biggest uncertainties:
  - Platform
  - Surcharge factors
  - Optimized storage
- Methanol:
  - Industry process
  - TEA offshore: 1st prediction offshore analyzed
  - Storage positive effect on production costs
  - Curtailment not preferable

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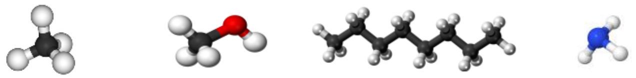
Outlook



Methane Methanol FT-product Ammonia

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- For investment recommendation: TEA + LCA combined necessary
  - LCA by DECHEMA
- 1st analysis of all products (offshore steady state)
- Continue adaptation offshore:
  - Platform cost
  - Surcharge factors
  - Cost optimized storage
- Dynamic simulation input
  - Additional equipment offshore (Storage, compressors, recycles,…)
  - Reduced product output due to fluctuation
- H2Mare 2.0?

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THANK YOU FOR YOUR ATTENTION!

Impressum

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- Autor: Nathanael Heimann
- Institut: Institute of Engineering Thermodynamics
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