Standardized environmental impact and cost estimation of future sustainable aviation fuels

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Methodology

The methodology of standardized techno-economic and environmental assessment is applied to compare all pathways towards sustainable aviation fuels (SAF). Its seamless integration into DLR's assessment tool TEPET is shown in Fig. 1.

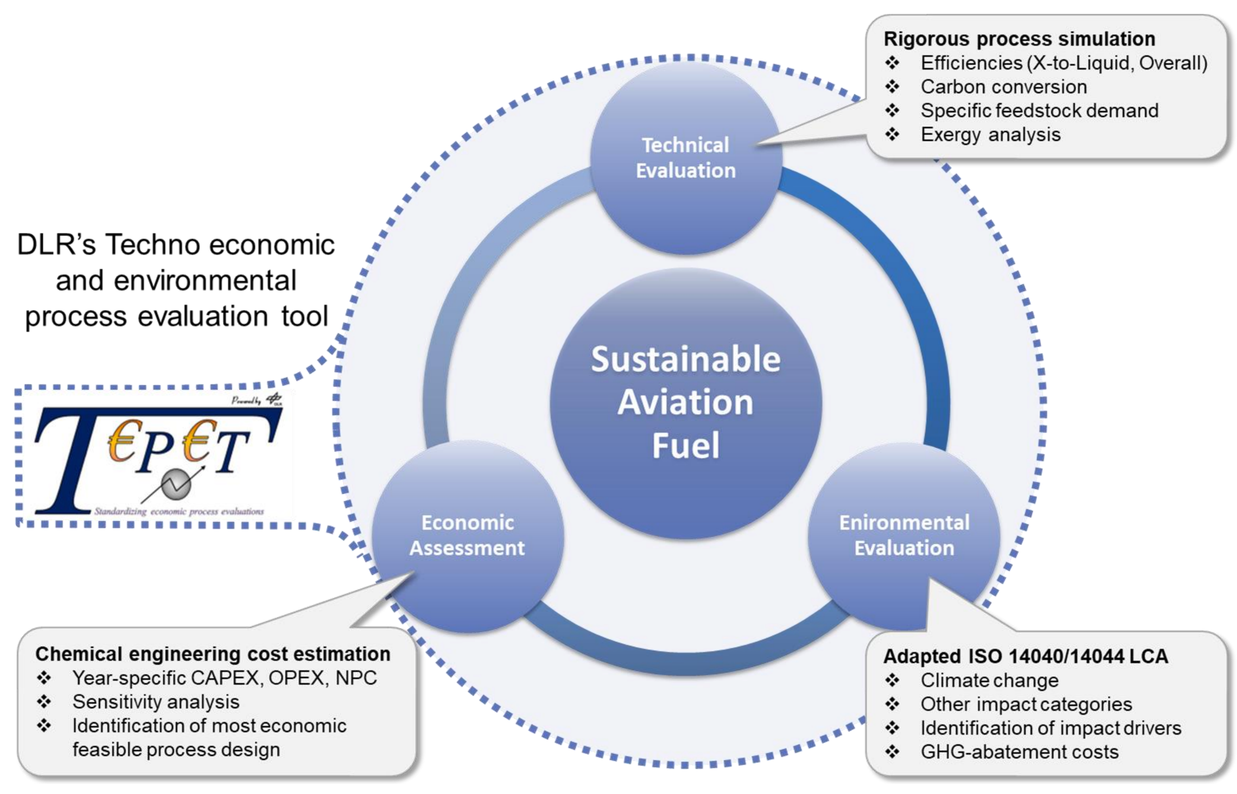

Fig. 1: Methodology of techno-economic and environmental assessment @ DLR

- ### Technical assessment

Based on validated steady-state process simulation the efficiency of sustainable aviation fuels (SAF) production processes will be optimized. Energy, carbon and hydrogen efficiency of each process will be considered.

- ### Economic assessment

Standard chemical engineering cost estimation is applied and automated. TEPET links process simulation results directly with equipment cost data and cost estimation framework to determine investment, operation and net production cost.

- ### Environmental assessment

ISO 14040/44 standards are applied to assess environmental impacts of SAF production based on steady-state process simulation results. TEPET links process simulation results directly with background data from established LCA databases, and performs environmental impact calculations using the open-source framework Brightway2. Beside climate change (global warming) additional impact categories are quantified.

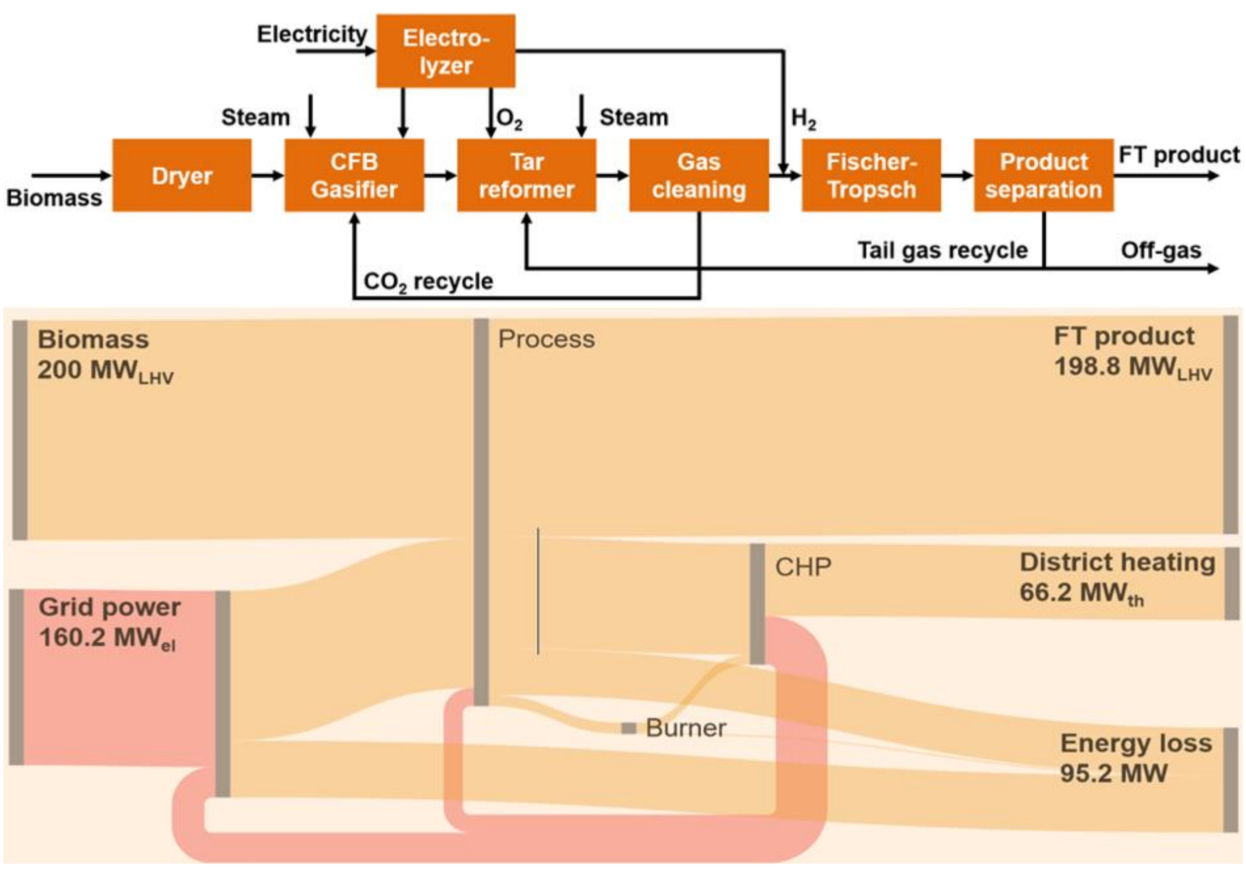

Fig. 2: Schematic flow diagram for the power+biomass to SAF process (top) and energy flow diagram (bottom) [1]

Technical Assessment Results

Fig. 2 shows the schematic flow diagram for the biomass conversion to SAF. Woody forestry residue is converted to raw syngas with oxygen and steam. Hydrogen produced by a grid-connected electrolyzer is added to enhance the fuel output of the process. Syngas is cleaned and reacts over the Fischer-Tropsch catalyst to hydrocarbon chains that will be upgraded to SAF in subsequent processes. Waste heat is partially used for power production in order to increase the process efficiency to 55 % as shown in the energy flow diagram (bottom).

Economic Assessment Results

Fig. 3 shows the cost breakdown of a (mid-size) 130 kt/a SAF production plant from forestry residues (42.2 $€_{2020}/t_{wet}$) and Finish grid power (50.4 $€_{2020}$/MWh). The major cost driver is (grid) electricity, major investment cost is the electrolyzer.
Techno-economic assessment provides not only the cost breakdown, but also the sensitivity of each input parameter.

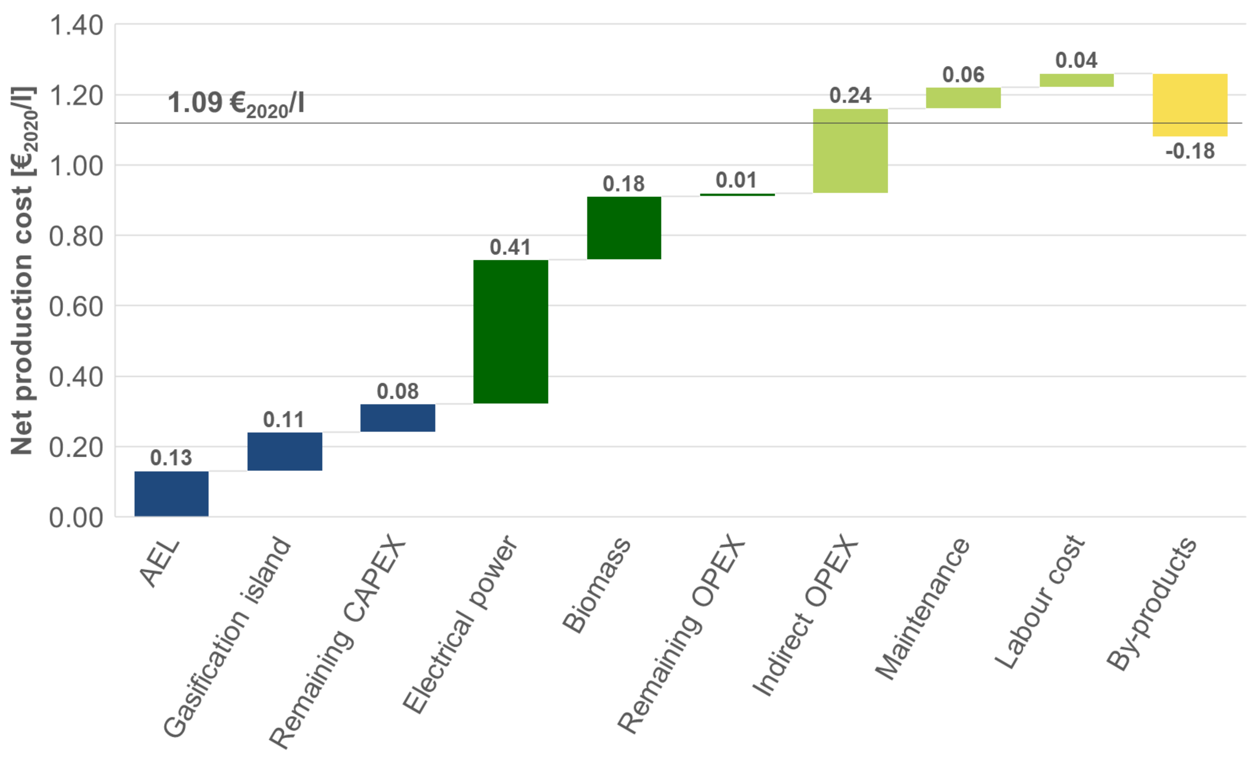

Fig. 3: Net Production Cost break-down per Liter SAF from biomass and electricity for Finish base case [2]

Environmental Assessment Results

Fig. 4 shows five selected environmental impacts normalized to fossil kerosene for the biomass conversion to SAF. Environmental assessment provides not only each individual environmental impact, but also the sensitivity of each input parameter like electricity and biomass transport.

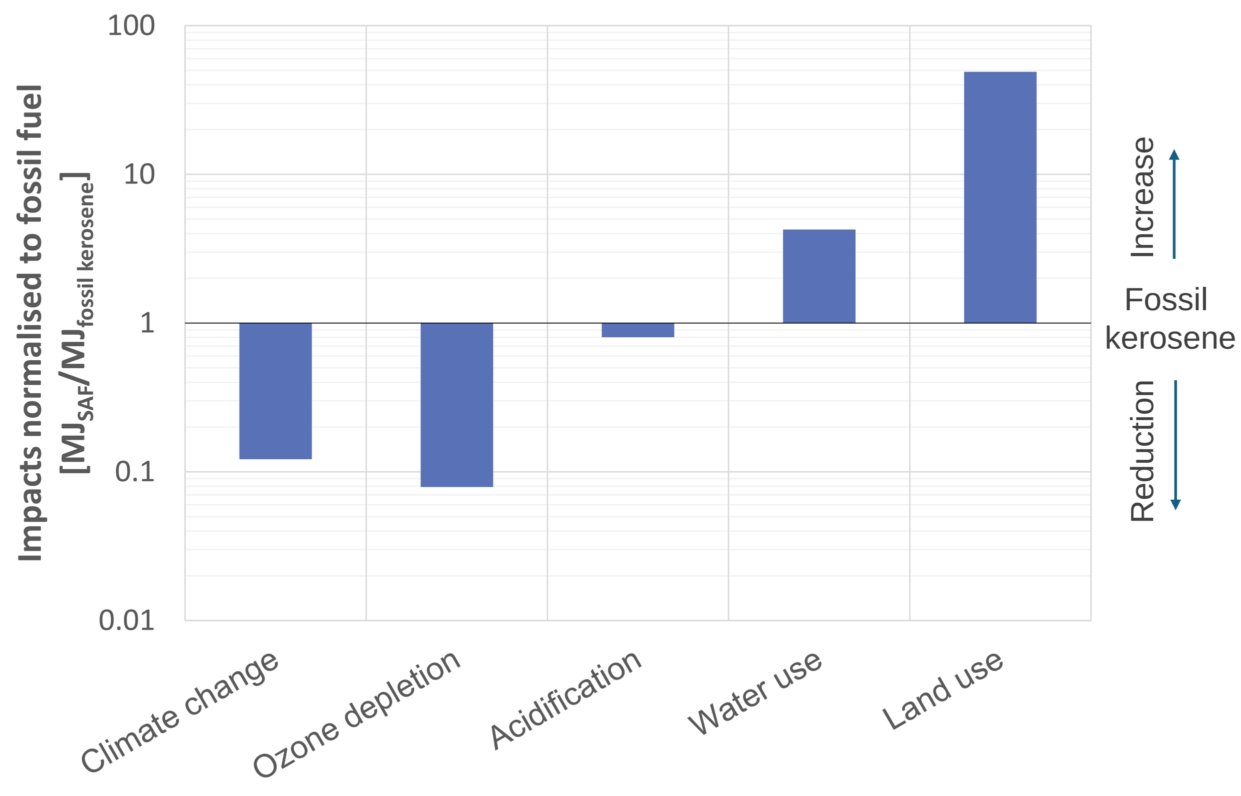

Fig. 4: Selected environmental impacts of power+biomass to SAF compared to fossil kerosene [4]

Towards a European SAF Roadmap

With the expertise in techno-economic and environmental assessment of SAF from woody biomass residues and renewable electricity a deployment vision can be derived for a European SAF industry. Implementing 440 small-scale decentral PBtL plants (50 MW_{th} biomass) could yield to 14 Mt/a SAF[3], sufficient to fulfill the ReFuelEU Aviation blending demand up to 2039. Similar projections for other SAF types, feedstocks, plant sizes and configurations are available on request.

[1] Habermeyer F., Kurkela E., Maier S., Dietrich R.-U. (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. 9:723774. doi: 10.3389/fenrg.2021.723774
[2] Habermeyer F., Papantoni V., Brand-Daniels U., Dietrich, R.-U. (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, 4229-4246. Royal Society of Chemistry. doi: 10.1039/d3se00358b.
[3] Habermeyer F., Weyand J., Maier S., Kurkela E., Dietrich R.-U. (2023) Power Biomass to Liquid — an option for Europe's sustainable and independent aviation fuel production. Biomass Conversion and Biorefinery. Springer Nature. doi: 10.1007/s13399-022-03671-y
[4] Weyand J., Habermeyer F., Dietrich R.-U. (2023) Process design analysis of a hybrid power-and-biomass-to-liquid process – An approach combining life cycle and techno-economic assessment, Fuel 342:127763. doi: 10.1016/j.fuel.2023.127763.

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