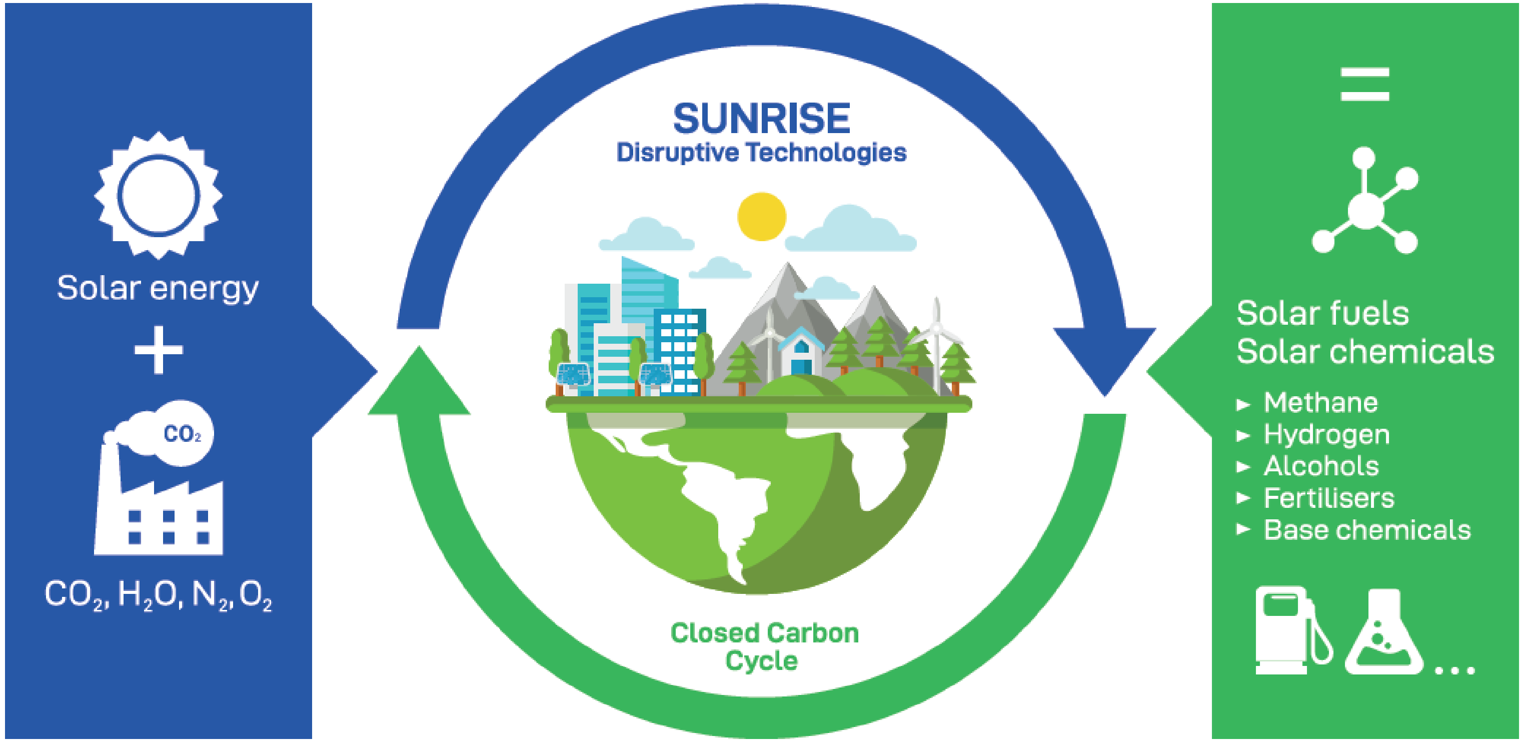
SUNRISE Approach 1 - Electrochemical conversion with renewable power (for jet fuel production)

SUNRISE Finland Stakeholder Workshop, Turku, December 9, 2019

Arne Roth, Fraunhofer Society

From a fossil linear towards a solar circular economy



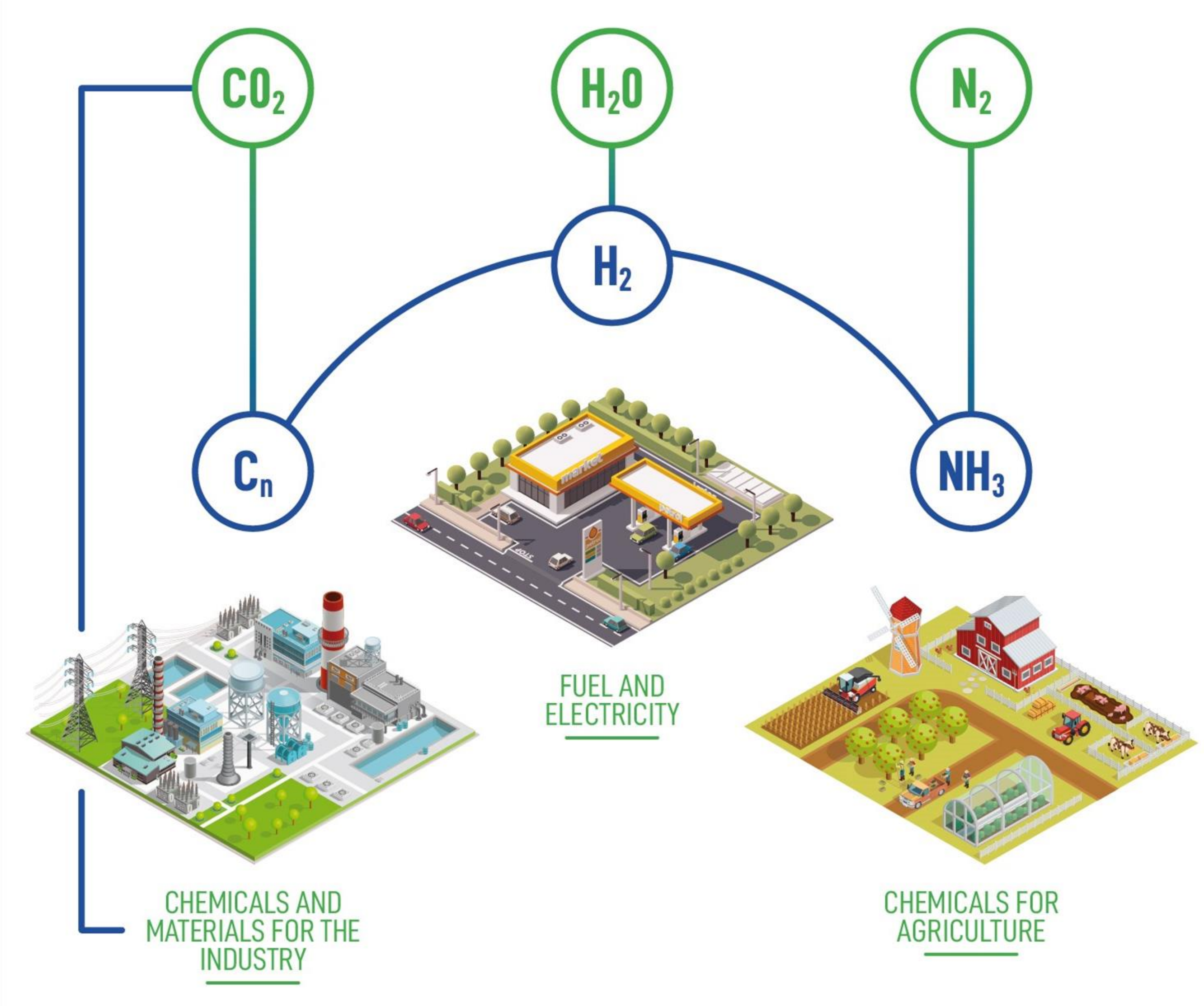
Solar Power is a massive resource ≈120 PW

The challenge: efficient solar energy harvesting & storage and closing the carbon cycle

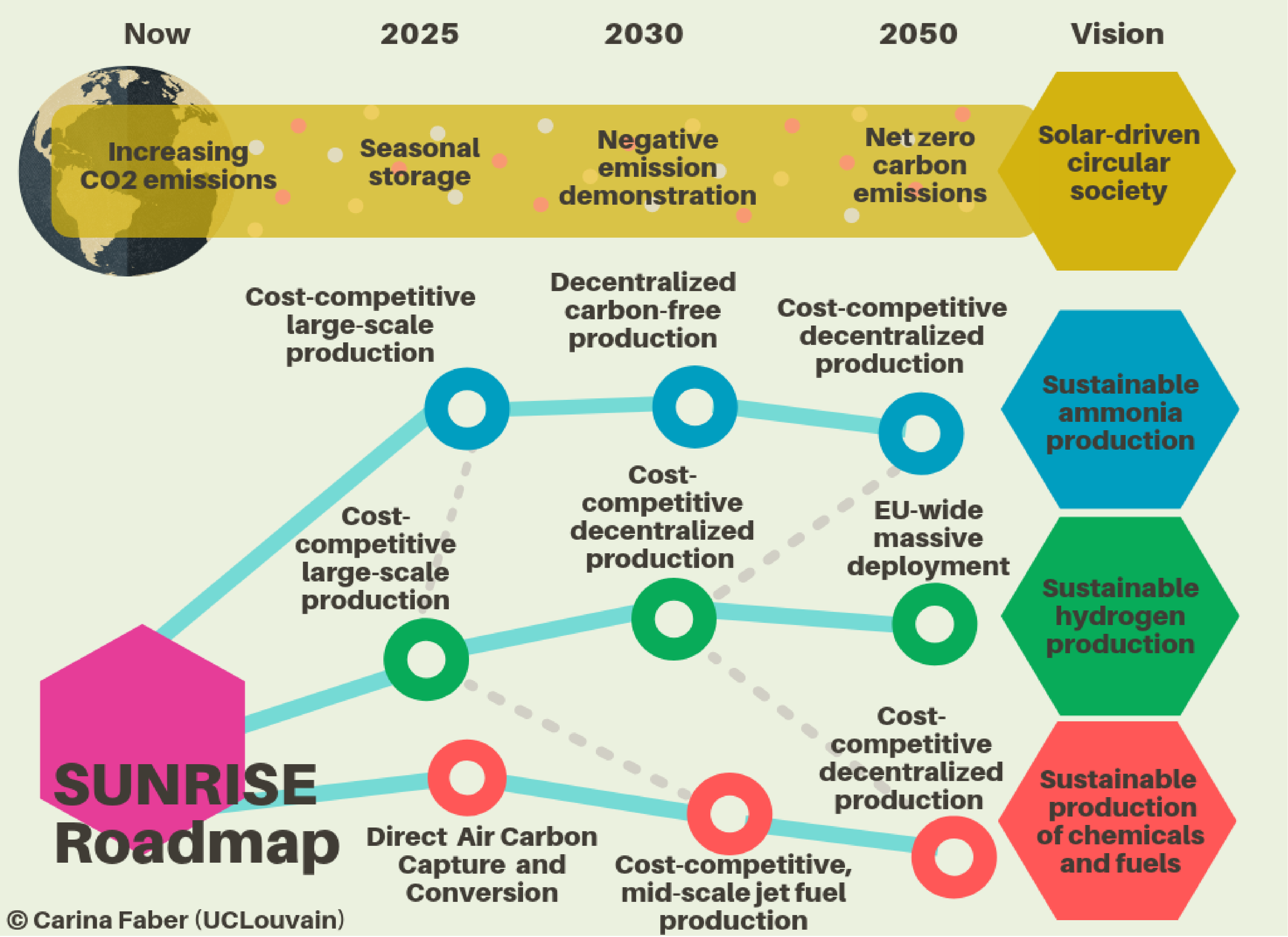
www.sunriseaction.eu

SUNRISE Roadmap

Structured around the products we can provide to society, not the technologies.

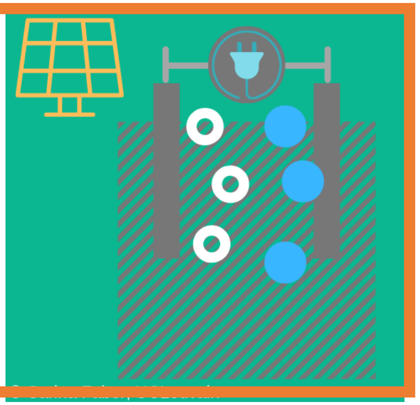


SUNRISE Roadmap



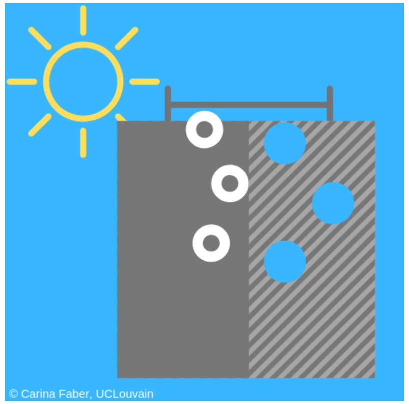
Electro- and thermochemical processes

- high TRL, ready for the short-term
- storage of electric energy from renewable sources



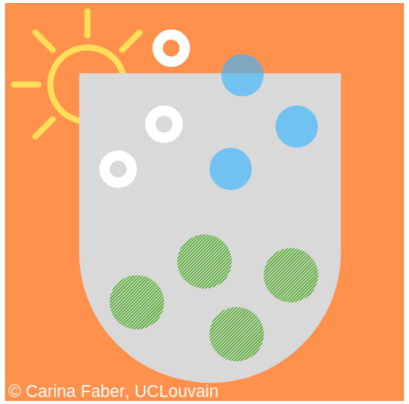
Direct conversion via photo(electro)chemical systems

- grid-independent: go directly from sunlight to final chemical products
- decentralized solutions

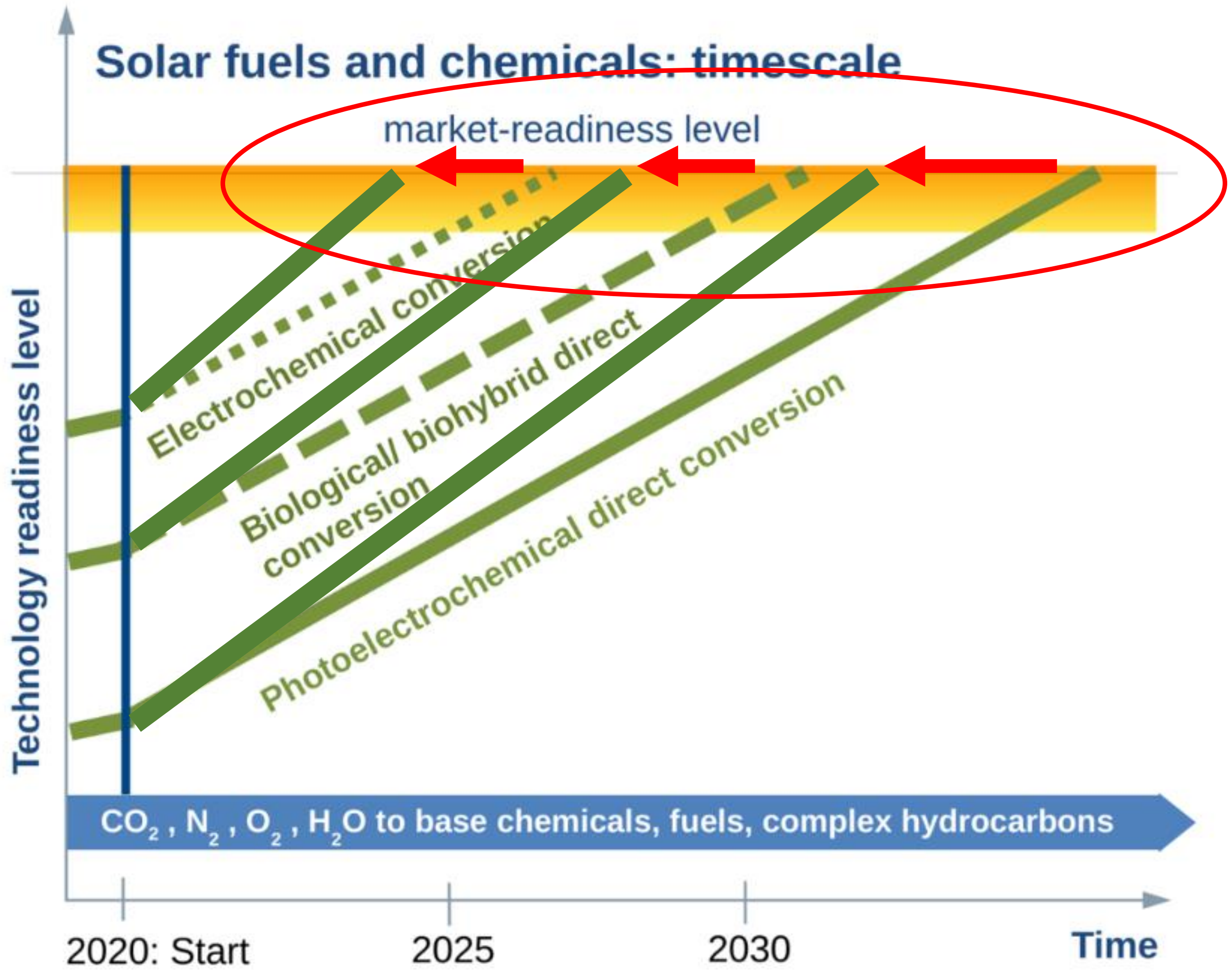


Direct conversion via bio(hybrid) systems

- living photosynthetic cell factories
- allows for simple, cheap devices



SUNRISE Approaches



SUNRISE Approach 1: Electrochemical processes

- Utilization of renewable (solar, wind, hydro, etc.) electric energy to "re-energize" carbon dioxide (CO_2) and water (H_2O)

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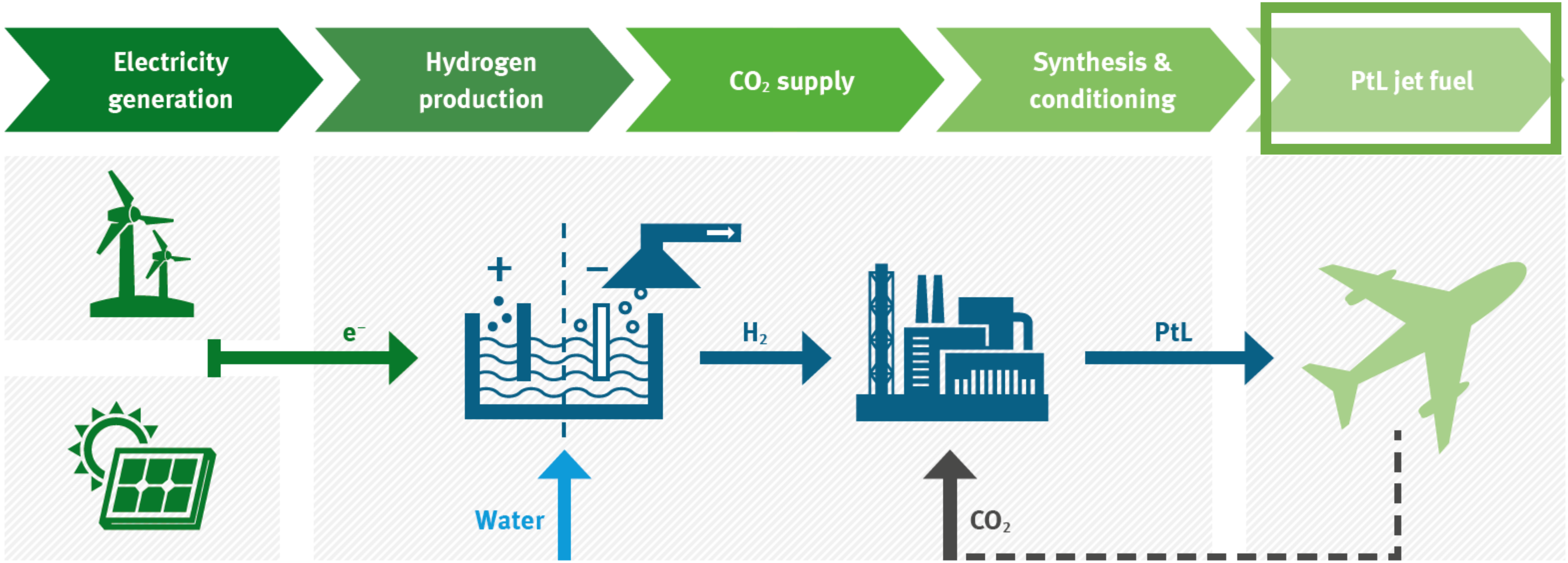
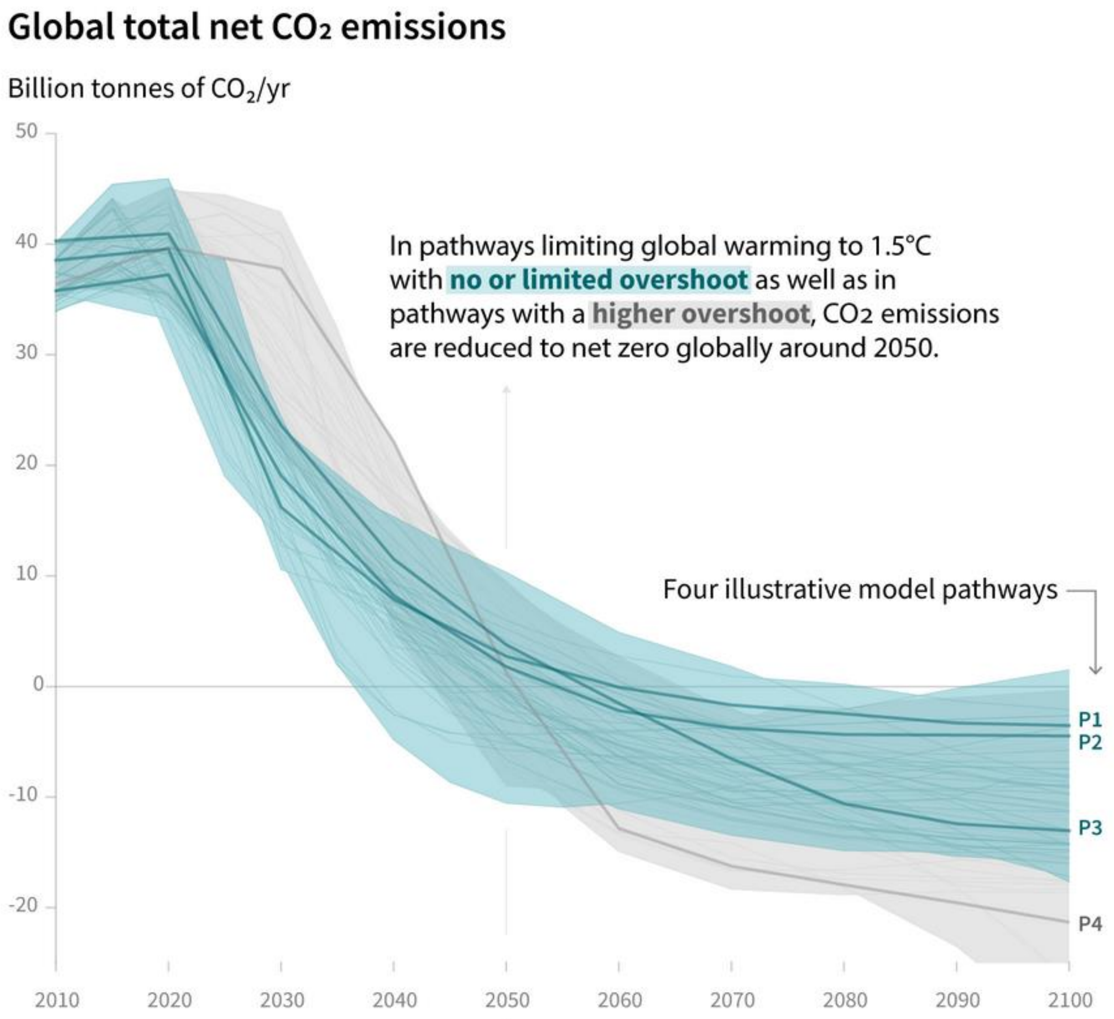
C-based chemicals/fuels



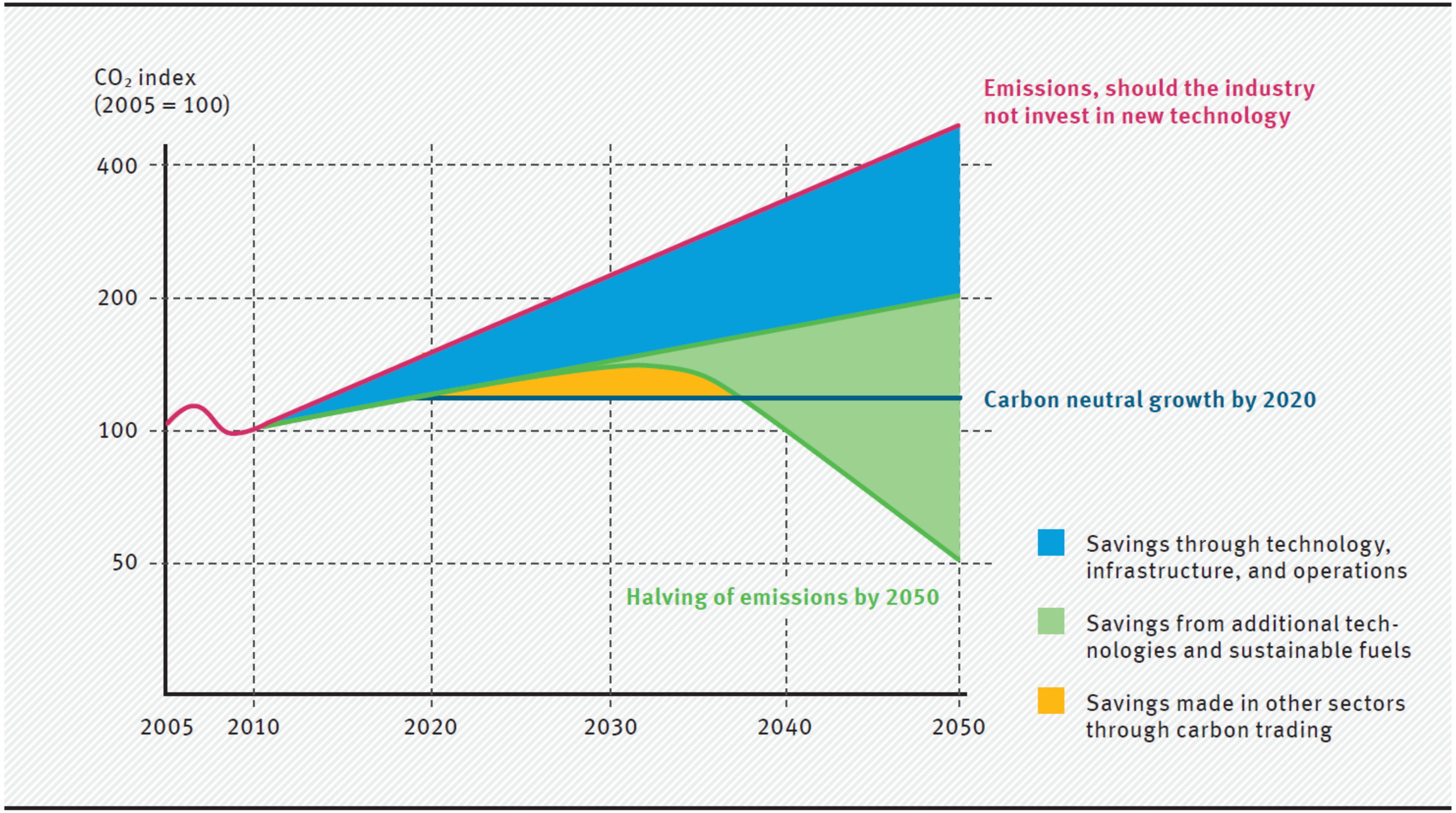
Source: Power-to-Liquids: Potentials and Perspectives for the Future Supply of Renewable Aviation Fuel, Umweltbundesamt, 2016, http://bit.ly/2cowOyf

”Paris Agreement“ (COP 21)



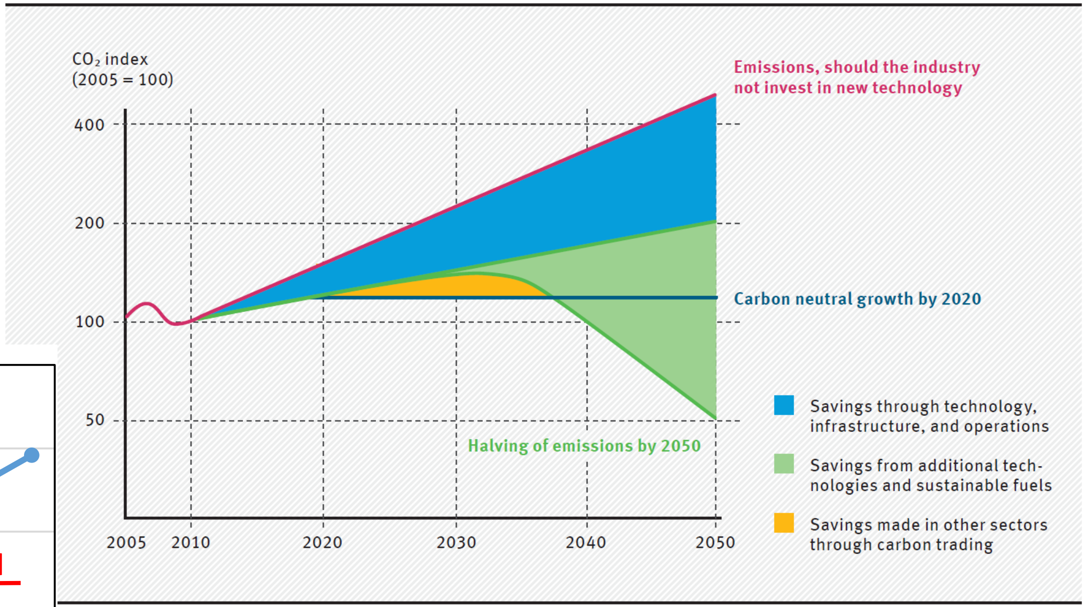
Source: Global Warming of 1.5 ºC (Special Report), Intergovernmental Panel on Climate Change, 2018.

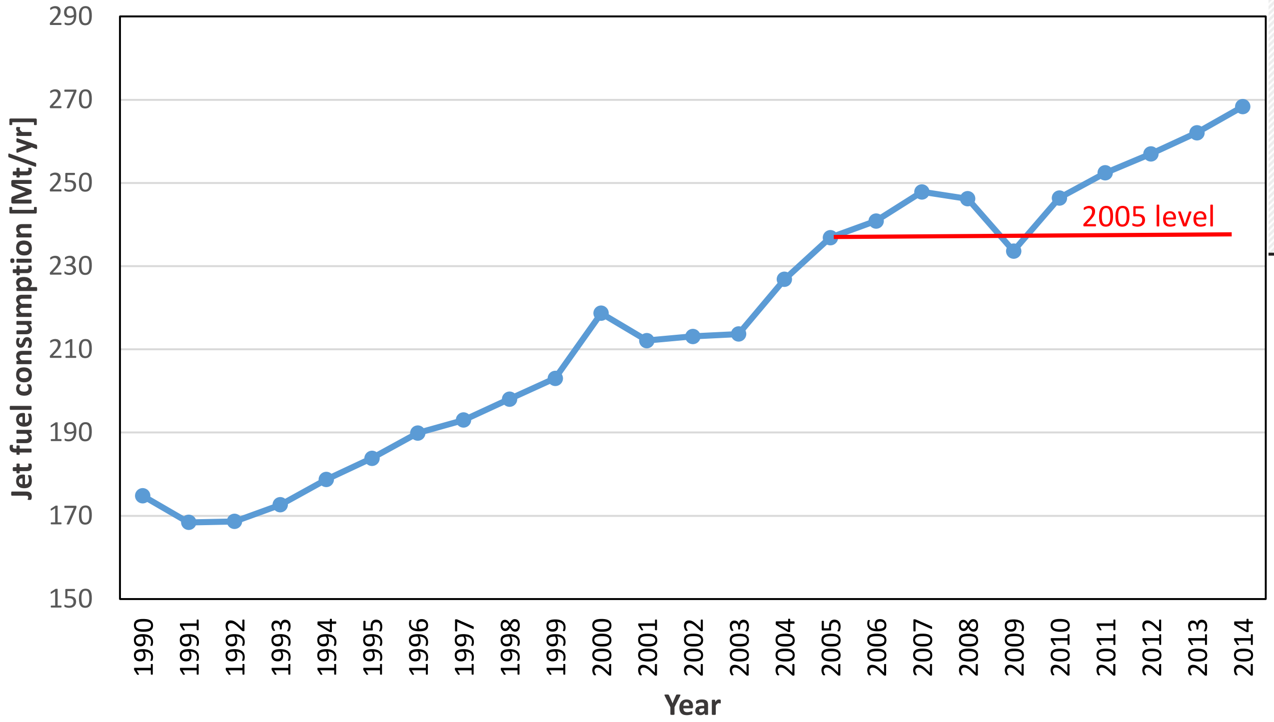
Aviation industry's targets (ATAG targets)



Source: UBA, LBST, BHL, 2016 adapted from ATAG 2012

Aviation industry‘s targets vs. current demand





Source: U.S. Energy Information Agency (www.eia.gov)

- Growth outpacing efficiency gains
- Annual increase in fuel consumption (and CO_2 emissions) 4 – 5% in 2014 – 2017 (IATA)

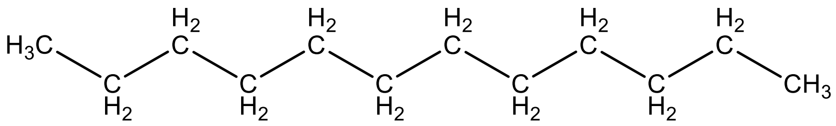
- Aviation will continue to rely on liquid fuels
  - Fully electric flight limited by battery mass
  - Hybrid electric aircraft concepts still rely on liquid fuel
  - Liquid cryogenic gasses (LH_2 and LNG)

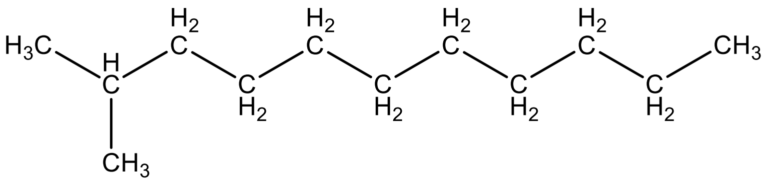
Sources: M. Hornung, *Ce-Liner – Case Study for eMobility in Air Transportation*, Aviation Technology, Integration and Operations Conference. Los Angeles. 12.8.2013
EU-H2020 Project Centreline: http://cordis.europa.eu/project/rcn/209713_en.html; M.K. Bradley, *Subsonic Ultra Green Aircraft Research: Phase II N+4 Advanced Concept Development*, 2012. doi:2060/20150017039, Tupolev Tu-155 experimental aircraft: wikipedia

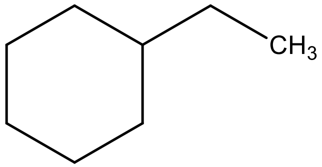
Technical requirements

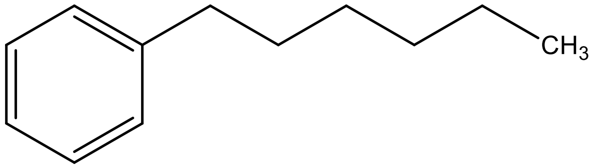
Designation: D1655 – 10

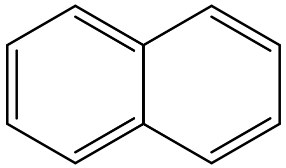
Standard Specification for Aviation Turbine Fuels[1]











- Developed based on assumption that jet fuel is produced from crude oil
- Conventional Jet A-1/Jet A composed of hydrocarbons
  - Alkanes (paraffins; linear, branched, cyclic)
  - Aromatics

Technical requirements

Designation: D1655 – 10

Standard Specification for Aviation Turbine Fuels[1]

Designation: D7566 – 12a

Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons[1]

- Developed based on assumption that jet fuel is produced from crude oil
- Conventional Jet A-1/Jet A composed of hydrocarbons
  - Alkanes (paraffins; linear, branched, cyclic)
  - Aromatics

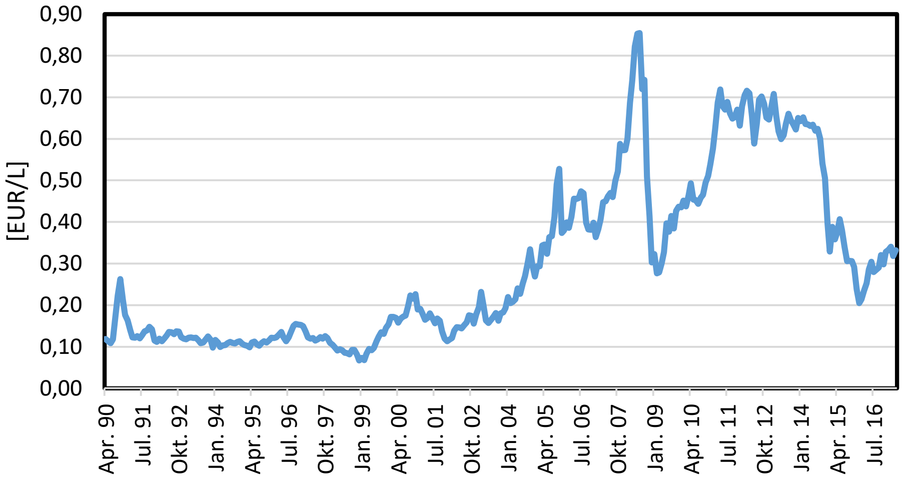
- Requirements for synthetic components of drop-in capable alternative jet fuel:
  - Hydrocarbons (alkanes, aromatics)
  - No oxygenated compounds (alcohols, esters, etc.)
  - „Conventional“ boiling range
  - Diverse composition (for high blending ratio)

SUNRISE Approach 1 for jet fuel production?

- Suitability
  - Drop-in capable
- Sustainability
  - Highly favorable GHG balance
  - No biomass needed
- Scalability
  - „Unlimited“ energy availability
  - No arable land needed
- Economic competitiveness

Economic competitiveness

US jet fuel spot price



Source: U.S. Energy Information Agency (www.eia.gov)

Production pathway	Feedstock	MFSP (EUR L^{-1})
HEFA	Soybean oil	1.04
	Used cooking oil	1.02
Gasification/FT	Municipal solid waste	1.00
	Forestry residues	1.33
	Wheat straw	1.93
AtJ	Forestry residues	1.82
	Wheat straw	2.74
DSHC (SIP)	Forestry residues	3.65
	Wheat straw	4.91
Power-to-Liquids (PtL)	Electric energy, CO_2, water	1.47
Solar-thermochemical	Solar heat, CO_2, water	2.23

Sources: Bann et al., *Bioresour. Technol.* 2017, *227*, 179–187.
de Jong at al., *Biofuels, Bioprod. Biorefining* 2015, *9 (6)*, 778–800.
Schmidt et al., *Chemie Ing. Tech.* 2018, *90 (1–2)*, 127–140.
Falter at el., *Environ. Sci. Technol.* 2016, *50 (1)*, 470–477.

SUNRISE Approach 1 for jet fuel production?

- Suitability
  - Drop-in capable
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  - Highly favorable GHG balance
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- Scalability
  - „Unlimited“ energy availability
  - No arable land needed
- Economic competitiveness
  - Not competitive under current economic boundary conditions

Conclusions

- As all other sectors, aviation has to drastically reduce its GHG emissions
- Aviation needs renewable drop-in fuels to meet its GHG targets
  - „Renewable versions“ of conventional jet fuel
- Renewable jet fuel production must be scalable AND sustainable
  - Sustainable in terms of emissions, water and land use, social issues etc.
- SUNRISE Approach 1: PtL-derived jet fuel holds great potential
  - Suitable, scalable and potentially sustainable
- Economic competitiveness is key challenge
  - Not necessarily cost competitiveness
  - Sustainable and scalable options generally more expensive than conventional jet fuel

Sunrise

Thank you very much!

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