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Technical, Economic and Environmental Aspects of Power-to-Liquid-fuels

– Statement –

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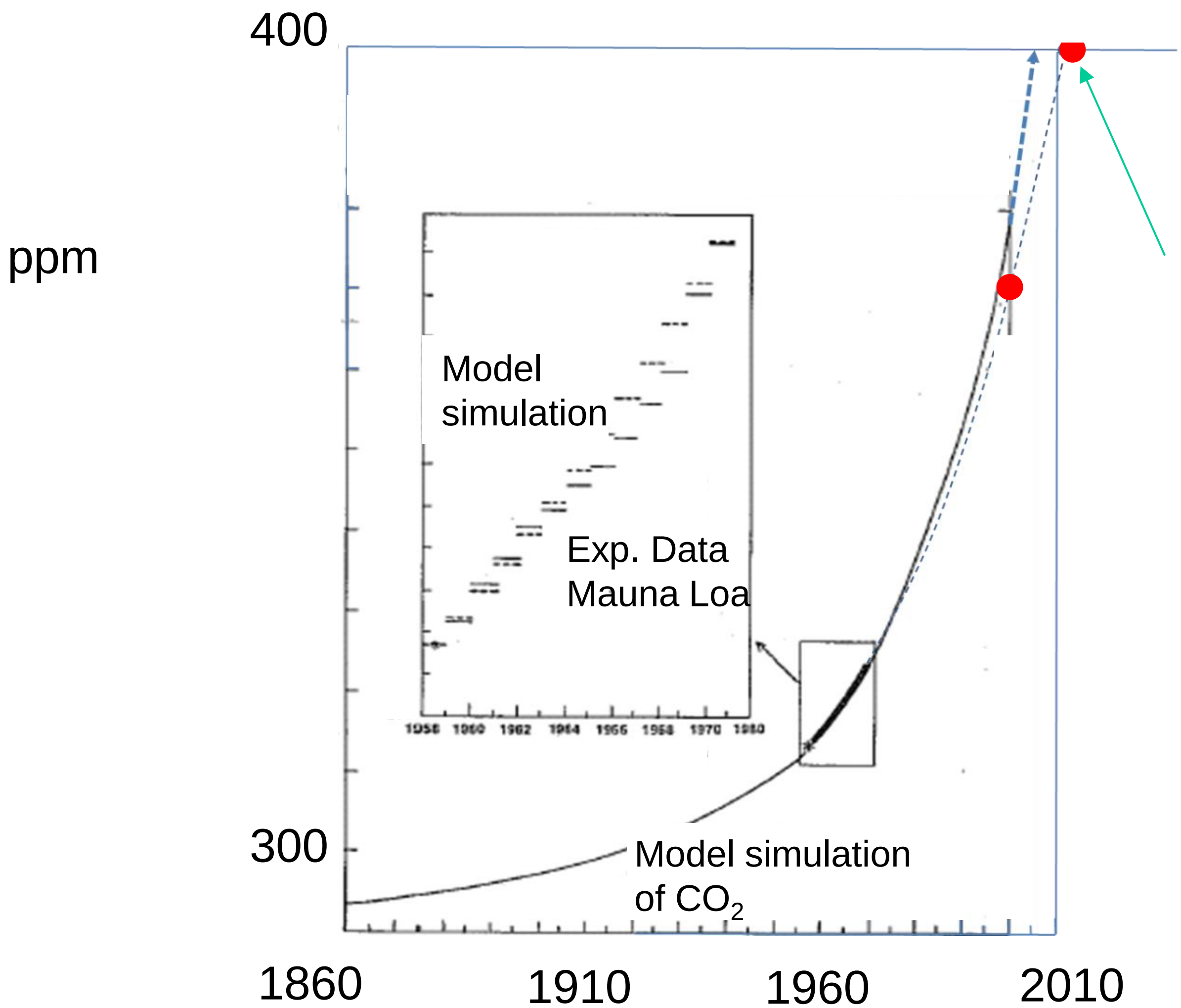
Content

- Climate Change
- Technical Options
- Environmental Side Effects
- Economic Aspects
- Summary

Atmospheric CO_2-Concentration (Model and Data)

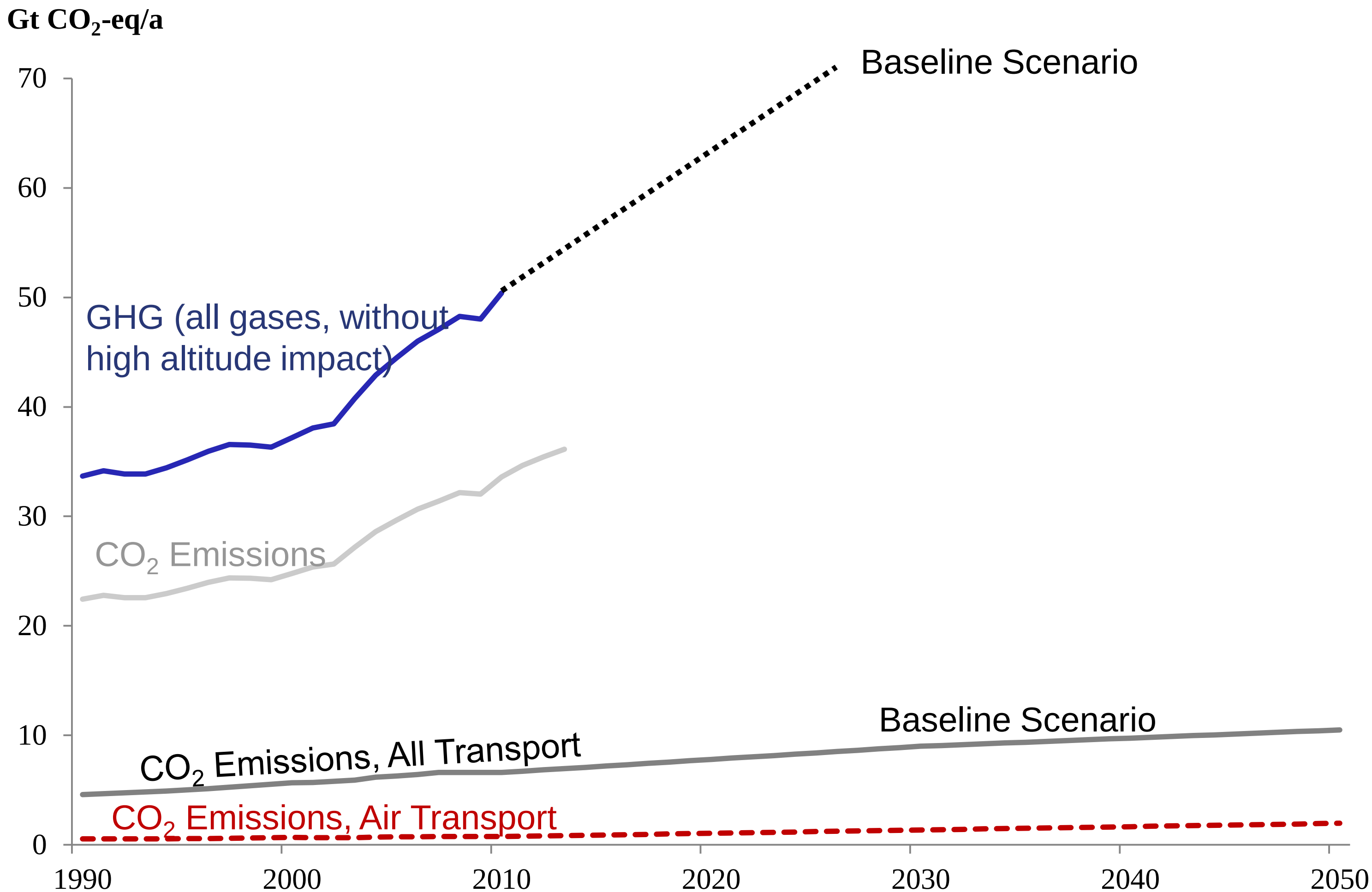


Conclusion:

The CO_2 concentration in 2015 was almost as high as the trend between 1958 – 1972 already indicated

Historical Data: Limits to Growth, D. Meadows et al., 1972

GHG Emissions and Contribution from (Air) Transport



Data: Scenario IPCC, 5th Assessment Report 2013
Scenario Air Transport, DLR/Airbus Global Market Forecast 2011-2030 with Extrapolation to 2050
Simplified Emission Calculation Air Transport, LBST 2014

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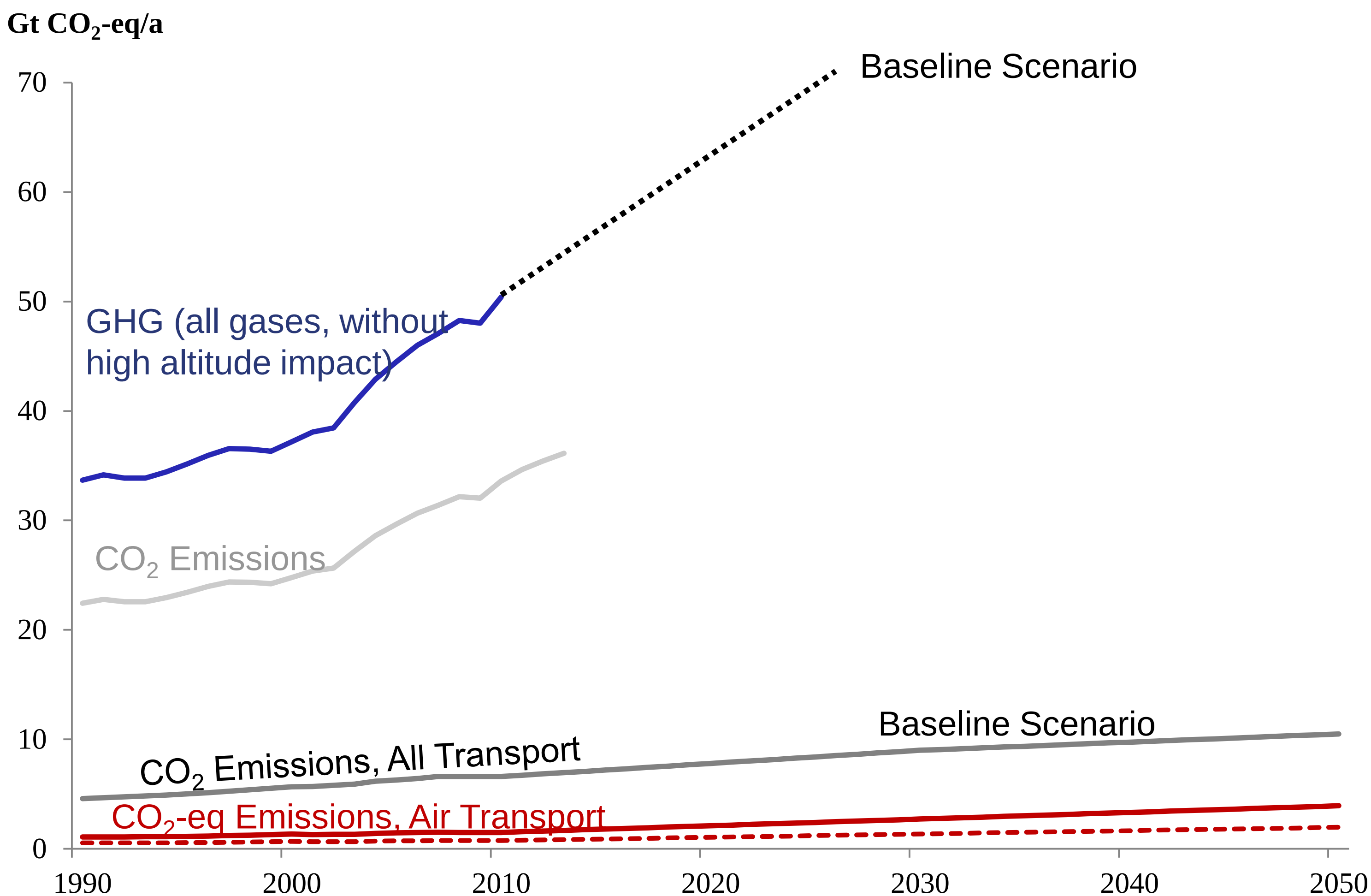

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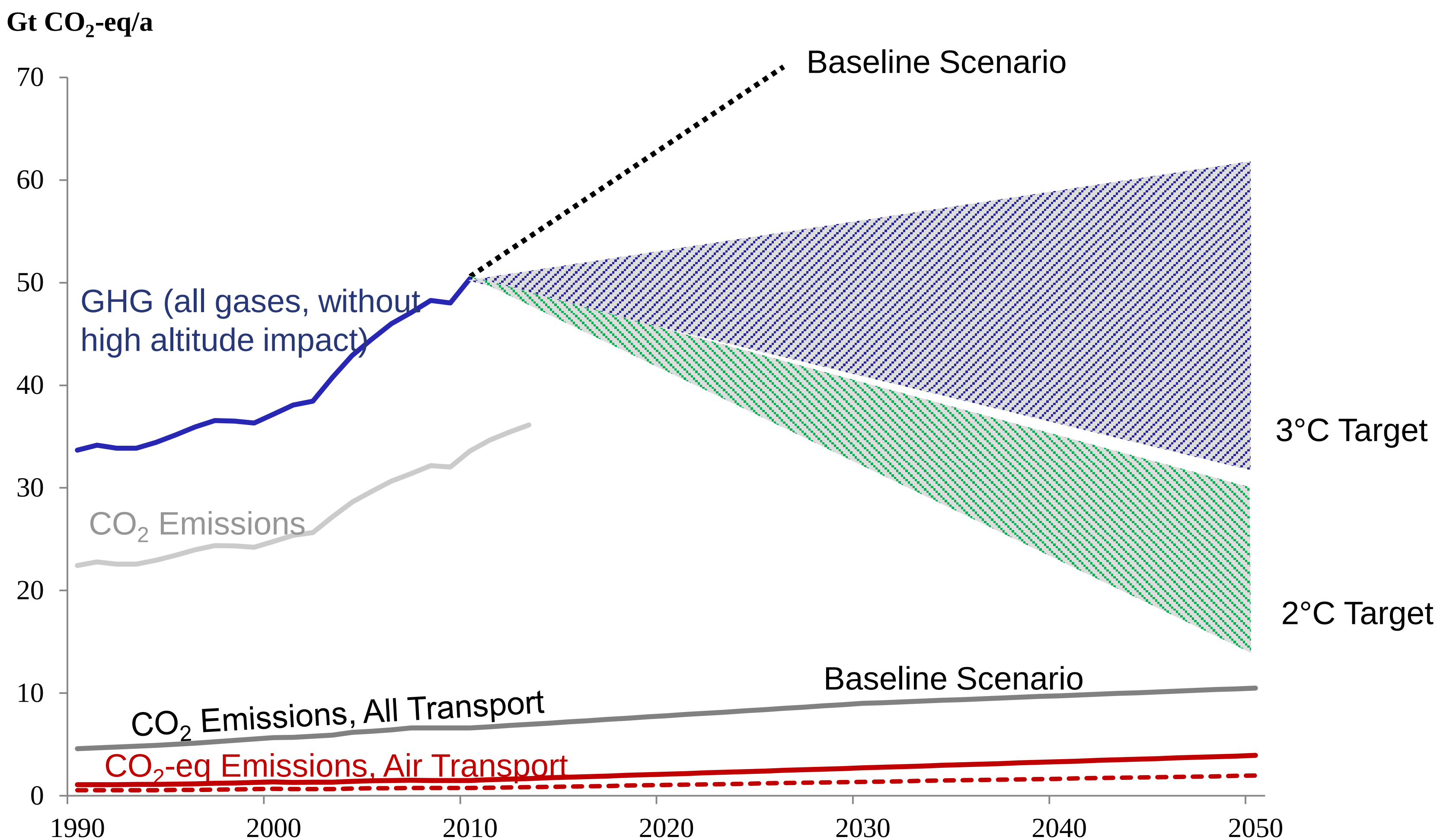

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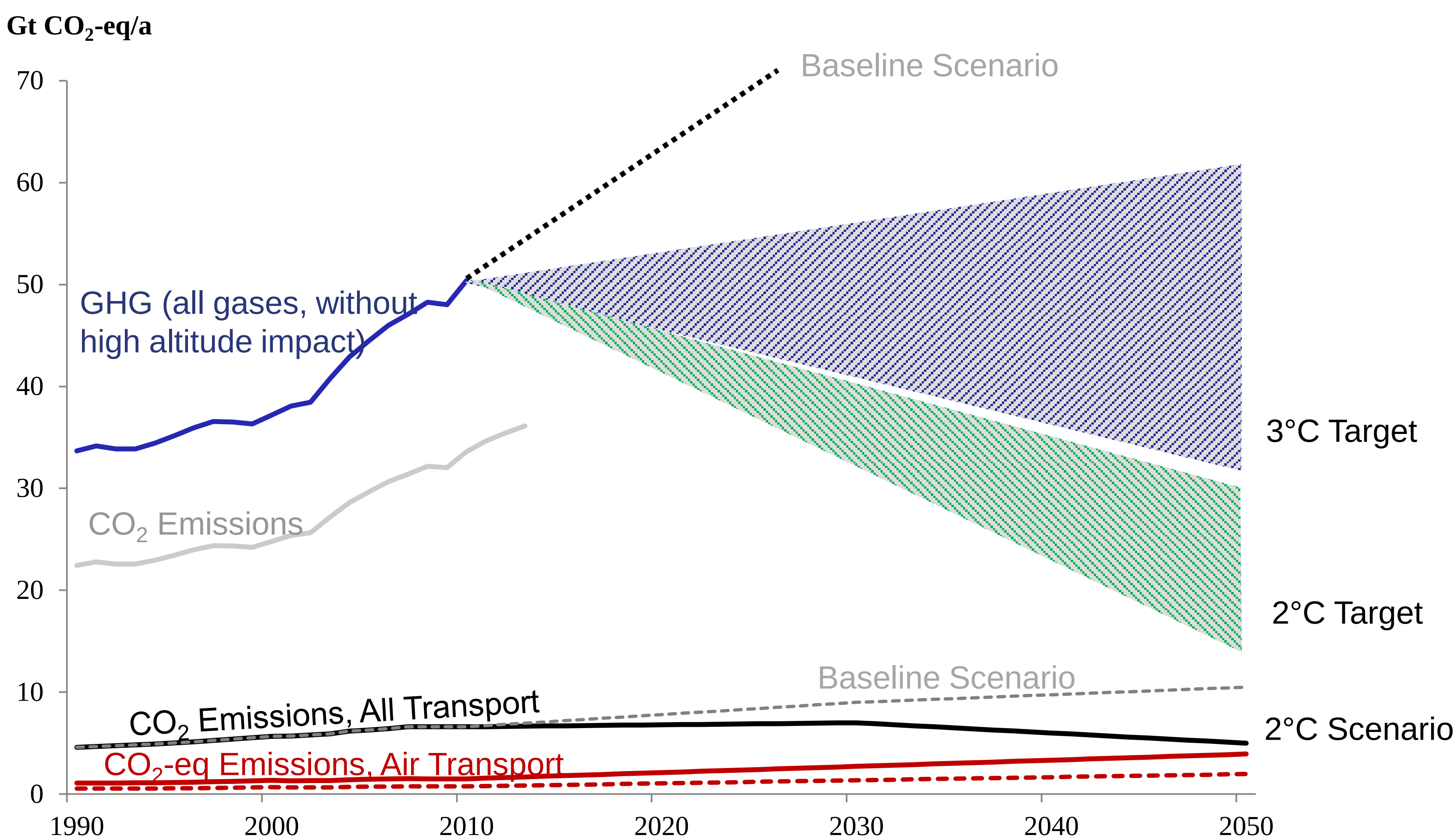

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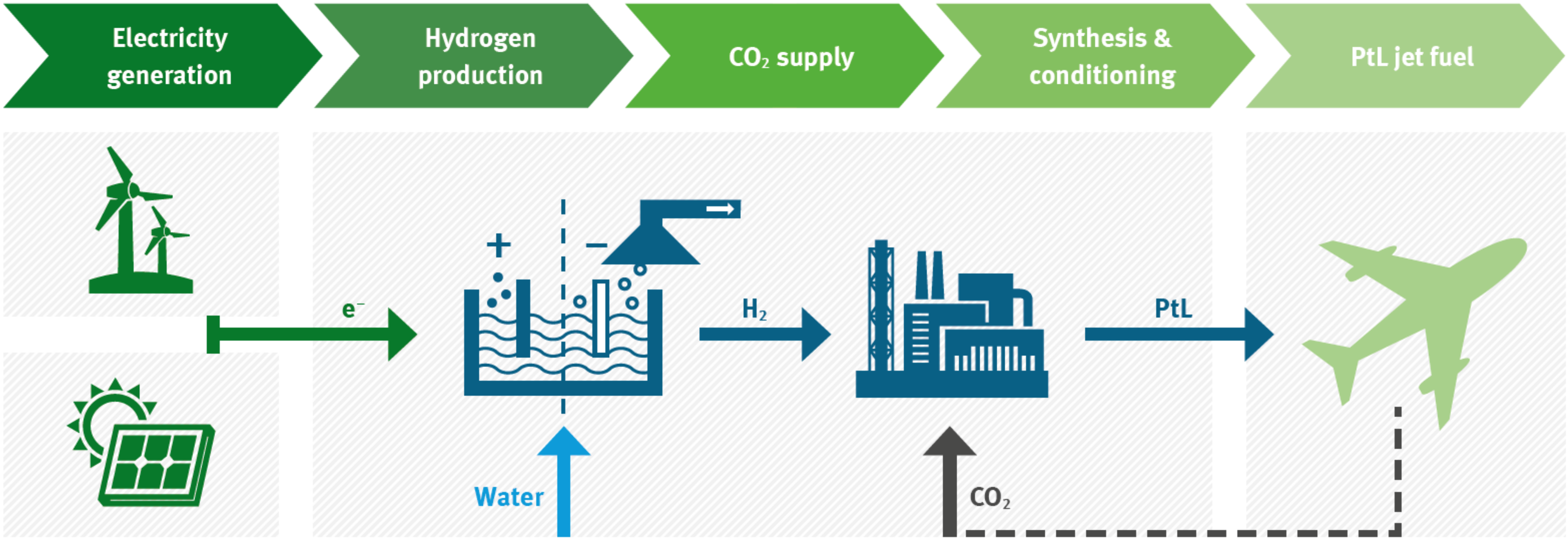
Technical Options

Generic PtL production pathway



- PtL production via Fischer-Tropsch (FT) or Methanol (MeOH) synthesis.
- Both pathways can be made 'drop-in' with conventional jet fuel.
- Fischer-Tropsch synthetic petroleum fuels (SPKs) are ASTM compliant.

Image: LBST & BHL, Power-to-Liquids – Potentials and Perspectives for the Future Supply of Renewable Aviation Fuel; UBA (ed.), September 2016

The three key constituents of PtL jet fuel

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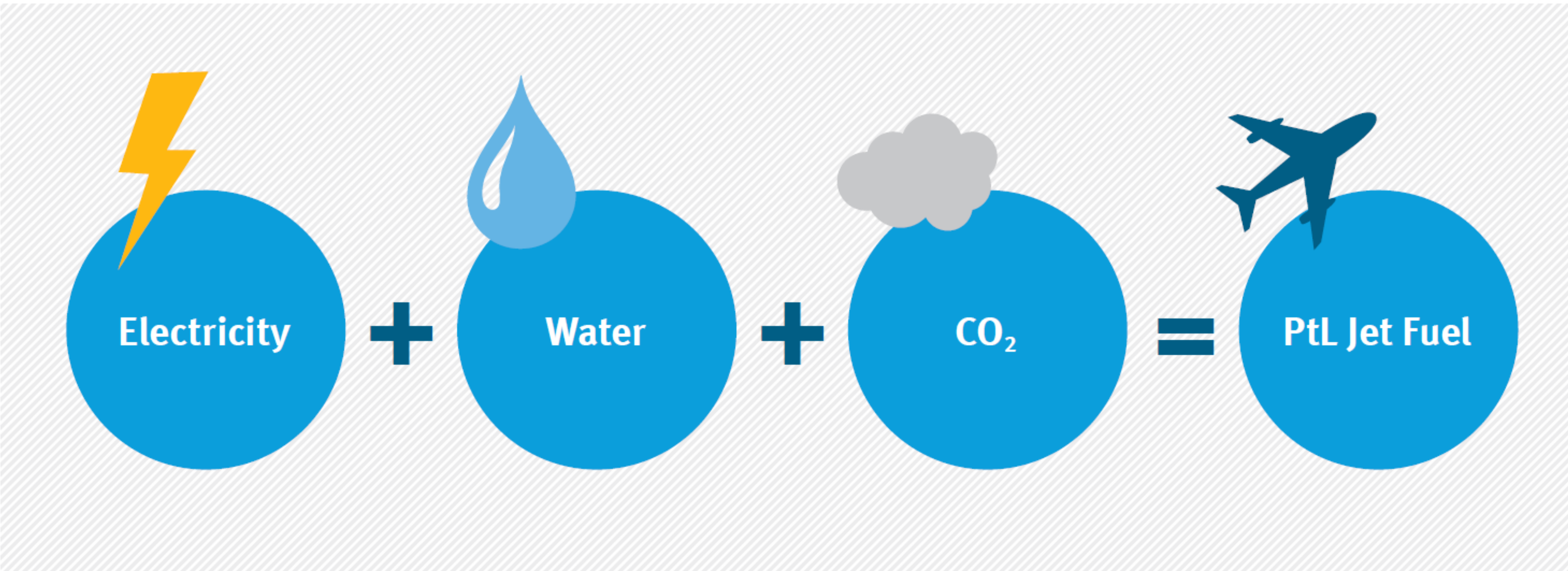

Source: Ludwig-Bölkow-Systemtechnik GmbH

PtL production efficiencies

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PtL production efficiencies 'gate-to-gate' (fuel output vs. electricity input)

Pathway*	PtL production efficiency today → improved, using CO_2 from different sources		
	Air	Exhaust gas, e.g. wood burner	Fermentation, e.g. biogas upgrading
PtL with low-temperature electrolysis	38 % → 41 %	47 % → 51 %	48 % → 53 %
PtL with high-temperature electrolysis	45 % → 46 %	60 % → 61 %	62 % → 63 %

* Differences between the Fischer-Tropsch and the methanol pathway are negligible.

Source: LBST

- When using **renewable electricity** for fuel production, efficiency is
  - one aspect among others in the 'big picture';
  - a parameter influencing fuel production costs.
- When using **high-temperature electrolysis cells** (SOEC), rather high fuel production efficiencies can be achieved. Plant operation is less flexible compared to low-temperature.

Image: LBST & BHL, Power-to-Liquids – Potentials and Perspectives for the Future Supply of Renewable Aviation Fuel; UBA (ed.), September 2016

Environmental Side Effects

PtL environmental performance | GHG well-to-wake (g_{CO2eq}/MJ)

Jet fuel pathway	GHG emissions without land-use change	GHG emissions including direct land-use change
Crude oil (reference)	87.5	–
Crude oil (ultra-low sulfur)	89.1	–
Oil sand (e.g. Canada)	103.4	–
Oil shale (in situ)	121.5	–
Natural gas (GtL)	101.0	–
Coal (CtL)	194.8	–
Switchgrass (BtL)	17.7	-2.0*
Soybean oil (HEFA)	37	97.8–564.2
Palm oil (HEFA)	30.1	39.8–698.0
Rapeseed oil (HEFA)	54.9	97.9
Jatropha oil (HEFA)	39.4	–
Algae oil (HEFA)	50.7	–
PtL (wind/PV in Germany)	~1 11–28**	– –

-70% (heute) bis
-99% (Perspektive)

Source: This study (LBST & BHL) for PtL fuels; data for all other listed pathways from (Stratton 2010)
* Negative value because soil carbon from former vegetation lower compared to soil carbon for switchgrass
** Including construction of power plants and production facility (today)

Table: LBST & BHL, Power-to-Liquids – Potentials and Perspectives for the Future Supply of Renewable Aviation Fuel; UBA (ed.), September 2016

PtL environmental performance | Land demand

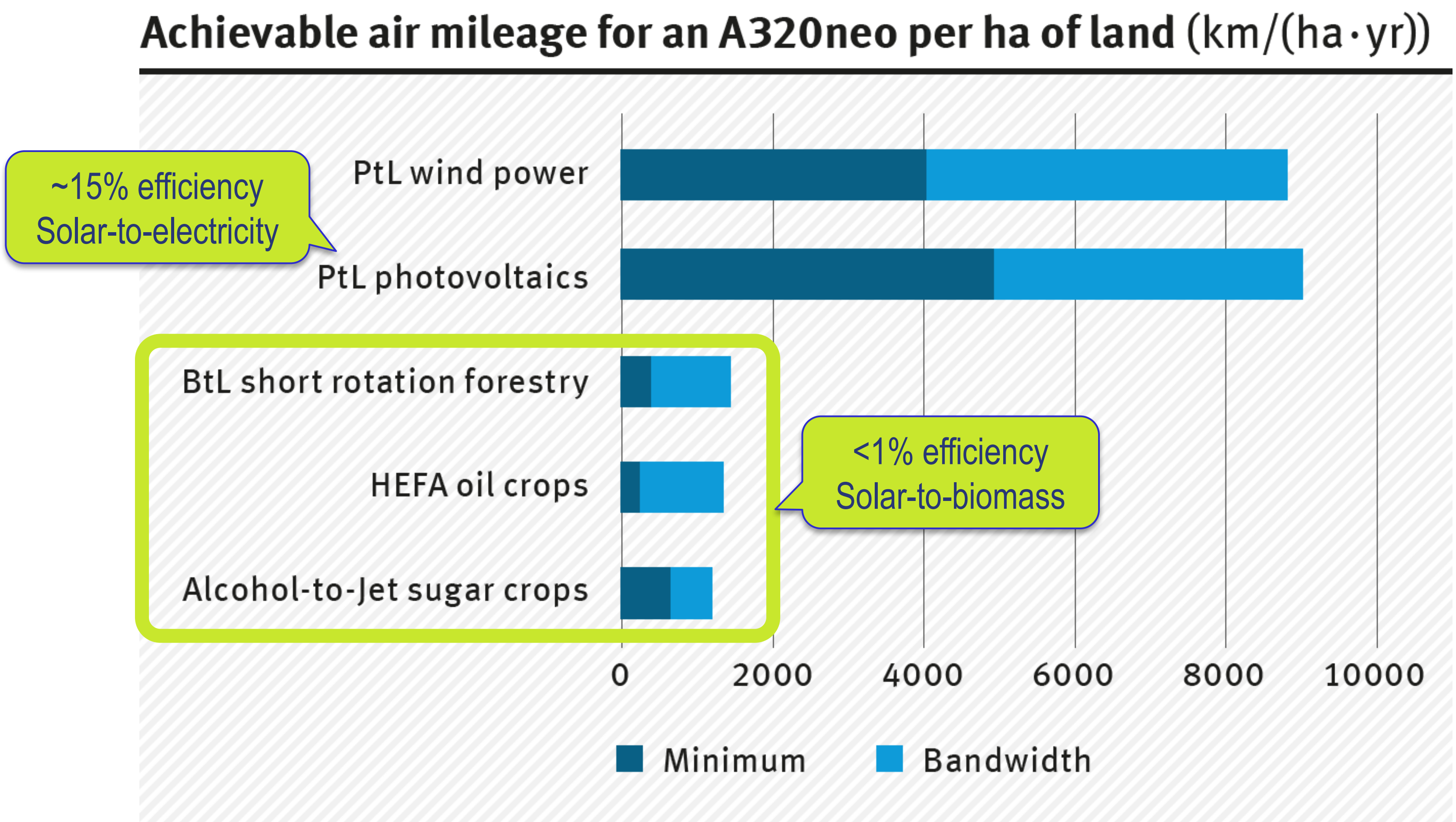

Image: LBST & BHL, Power-to-Liquids – Potentials and Perspectives for the Future Supply of Renewable Aviation Fuel; UBA (ed.), September 2016

PtL environmental performance | Water demand

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PtL water demand compared to selected biofuels
(volume representation, PtL water demand ~ 1.4 $L_{H_2O}/L_{jet fuel}$)

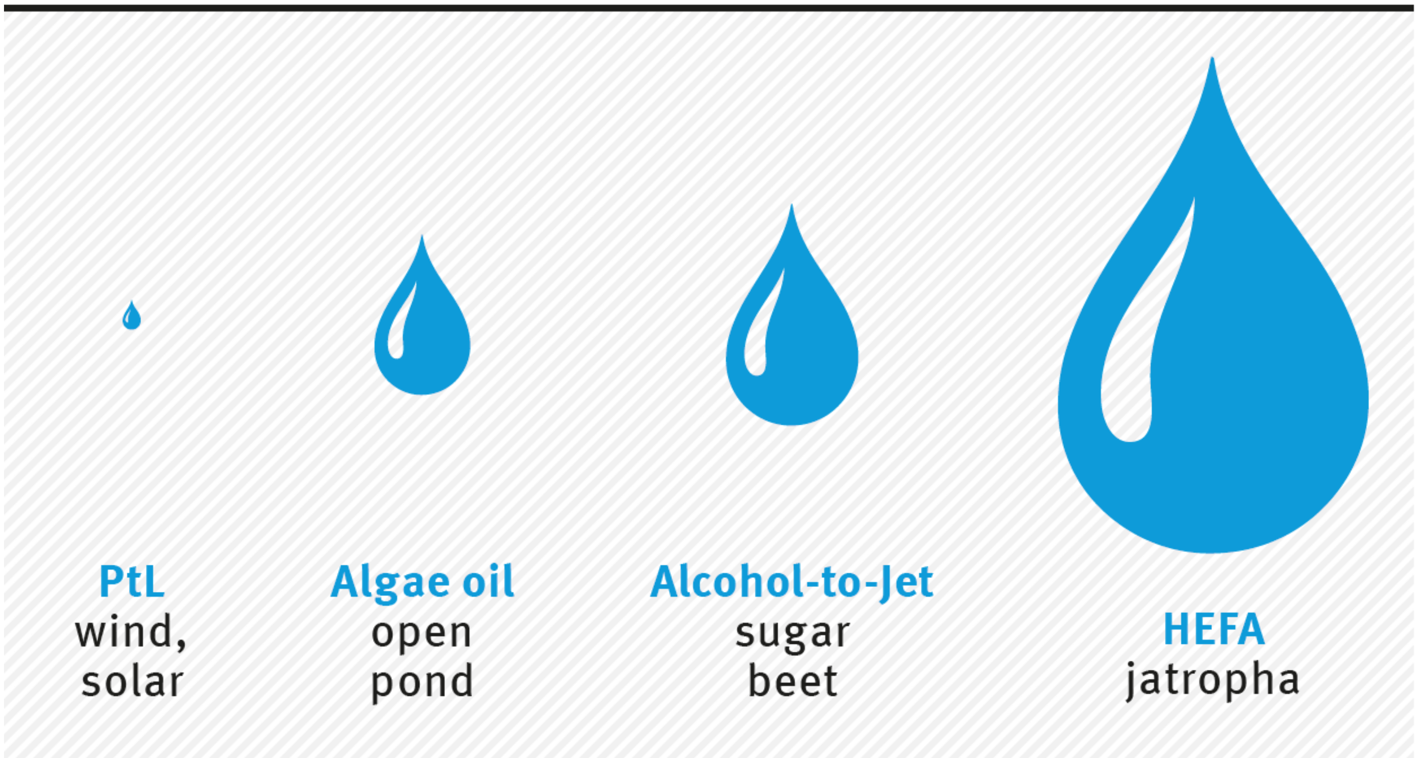

Image: LBST & BHL, Power-to-Liquids – Potentials and Perspectives for the Future Supply of Renewable Aviation Fuel; UBA (ed.), September 2016

Economic Aspects

PtL production costs

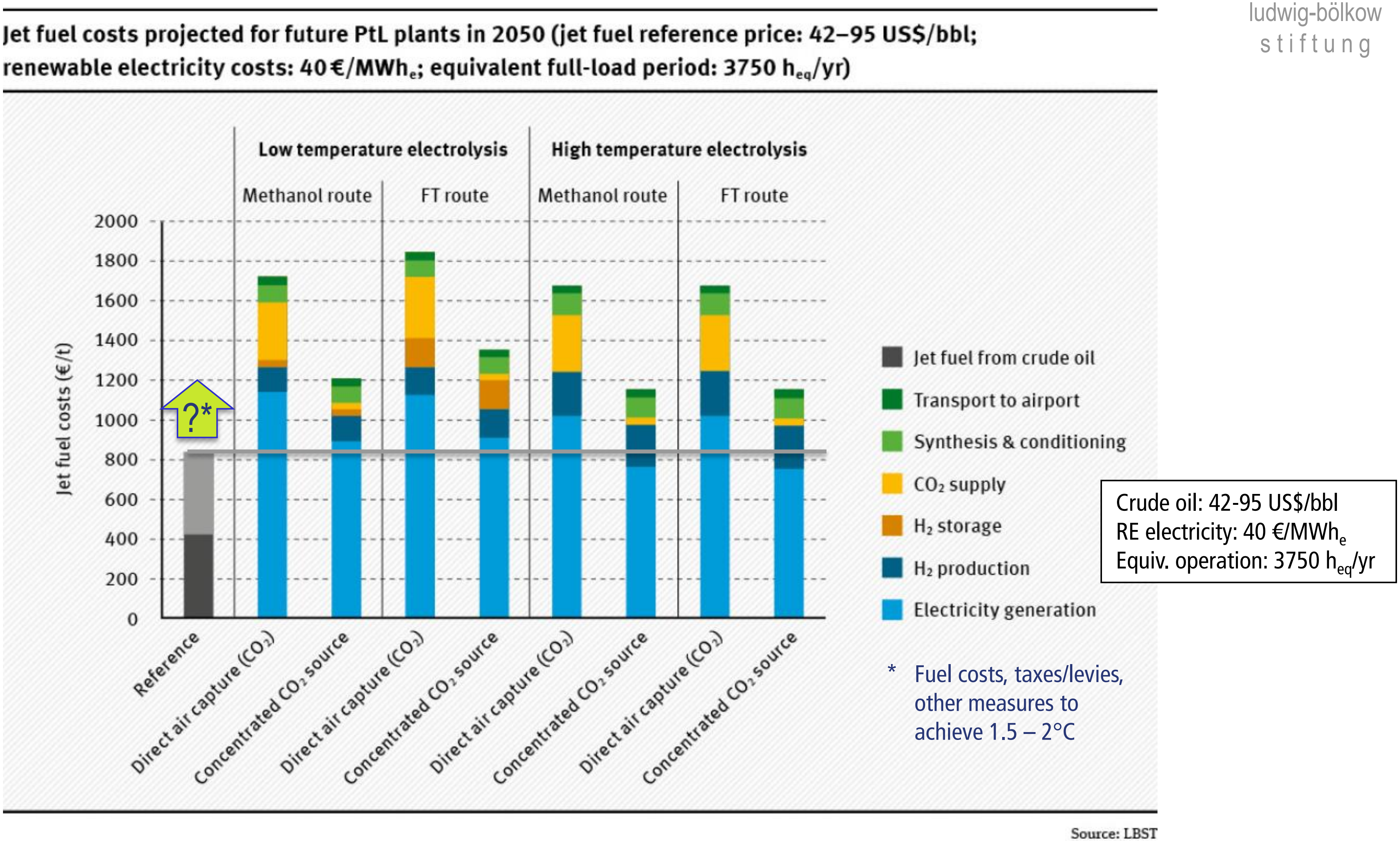

Image: LBST & BHL, Power-to-Liquids – Potentials and Perspectives for the Future Supply of Renewable Aviation Fuel; UBA (ed.), September 2016

Summary

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- Aviation is a major future driver for climate-relevant emissions as long as aircrafts use fossil fuels in combustion engines.

- Energy crops are a dead end solution.
  (competition with food; low conversion efficiency; huge water consumption)

- Call for a robust double strategy:
  - Evolutionary drop-in strategy for PtL jet fuel based on renewable electricity production
    (renewable energy based; high conversion efficiency, low water consumption)
  - Reduction of high-altitude impacts
    (hybridization/electrification; climate-optimal routes; rethink growth strategies)

- Under present market conditions PtL will not come by itself.

=> Supportive framework is needed, ideally competition-neutral

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Thank you!

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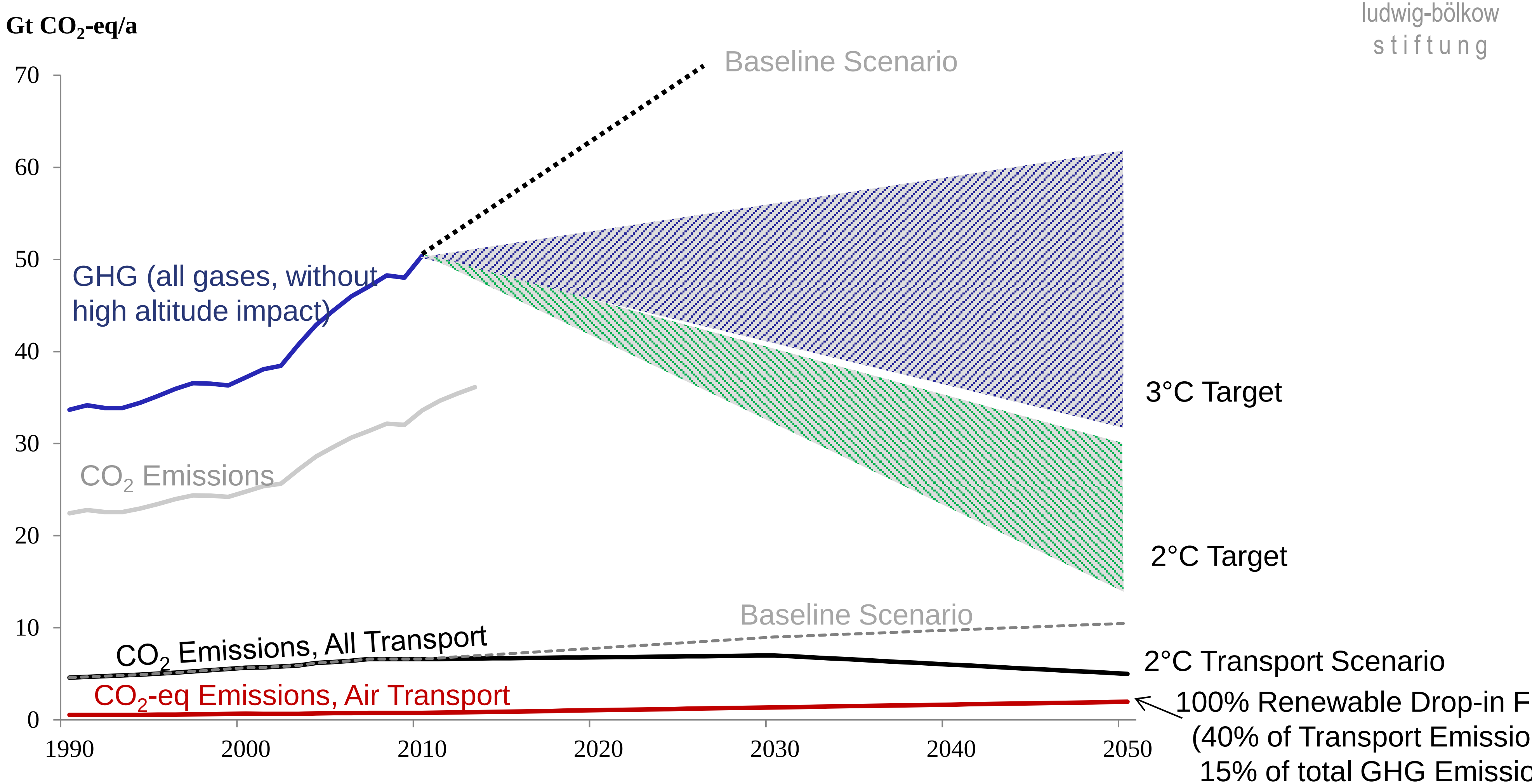
Fundus

GHG Emissions and Contribution from (Air) Transport



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PtL production | Fischer-Tropsch pathway

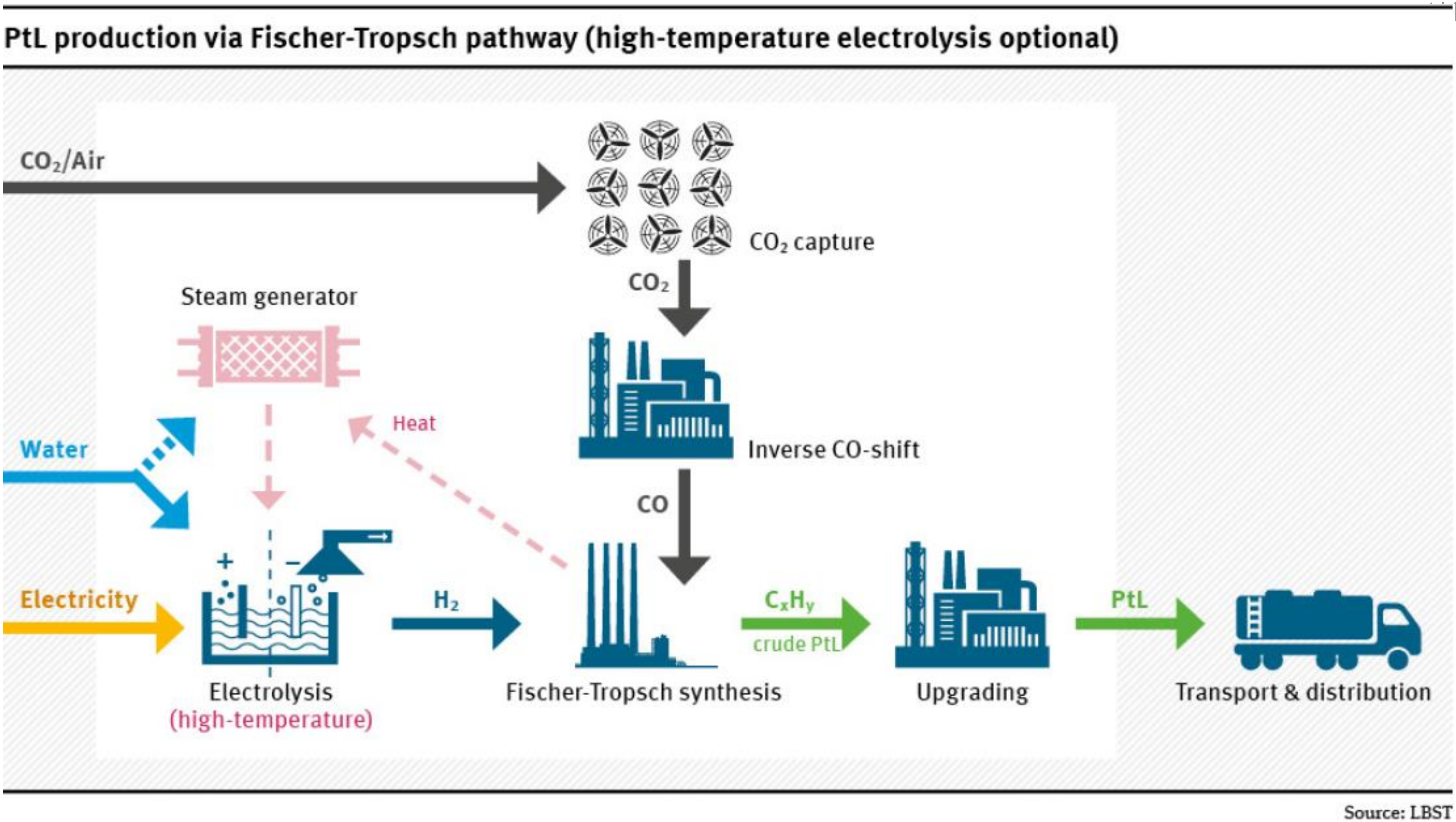


Image: LBST & BHL, Power-to-Liquids – Potentials and Perspectives for the Future Supply of Renewable Aviation Fuel; UBA (ed.), September 2016

PtL production | Methanol pathway

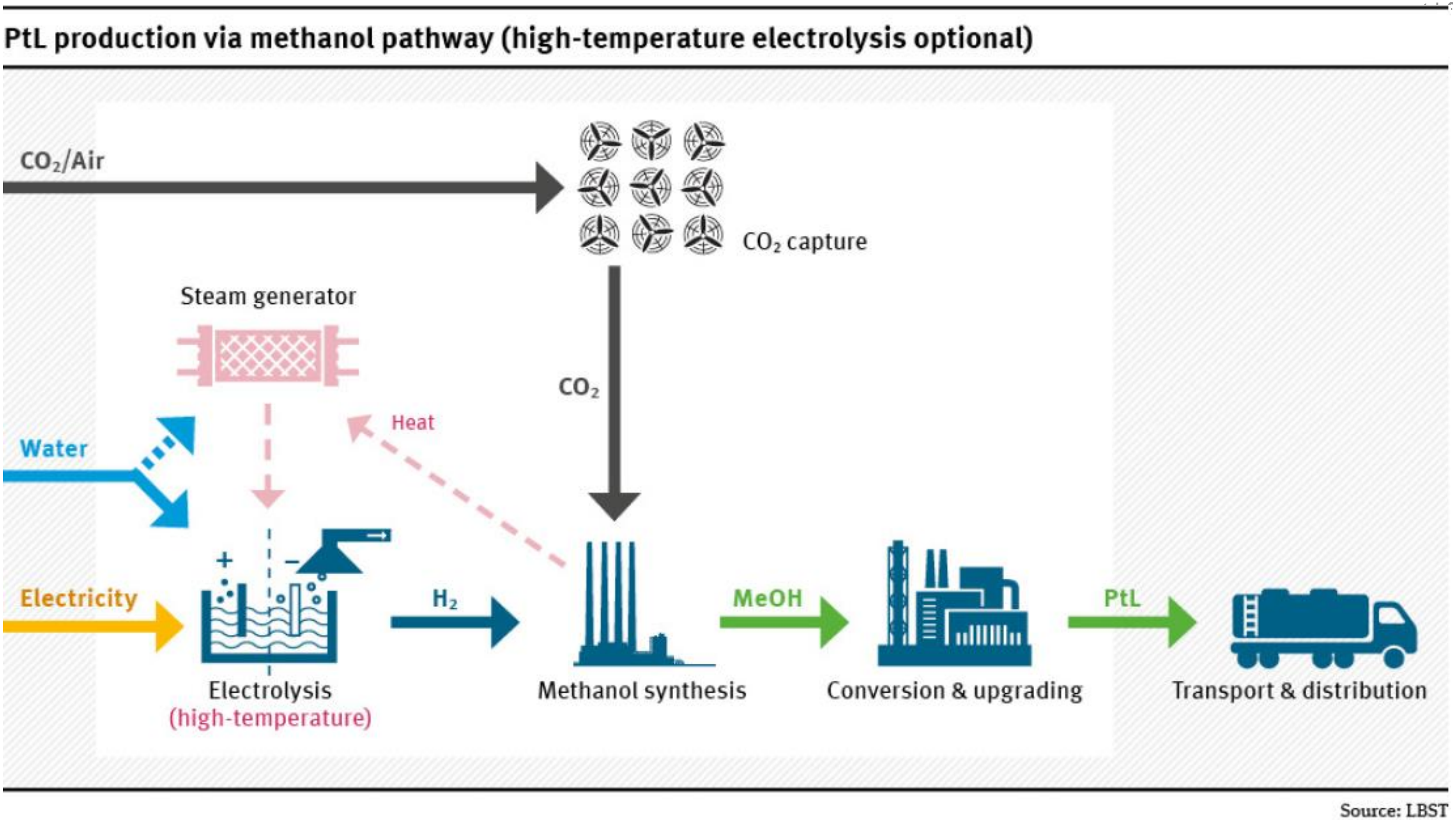
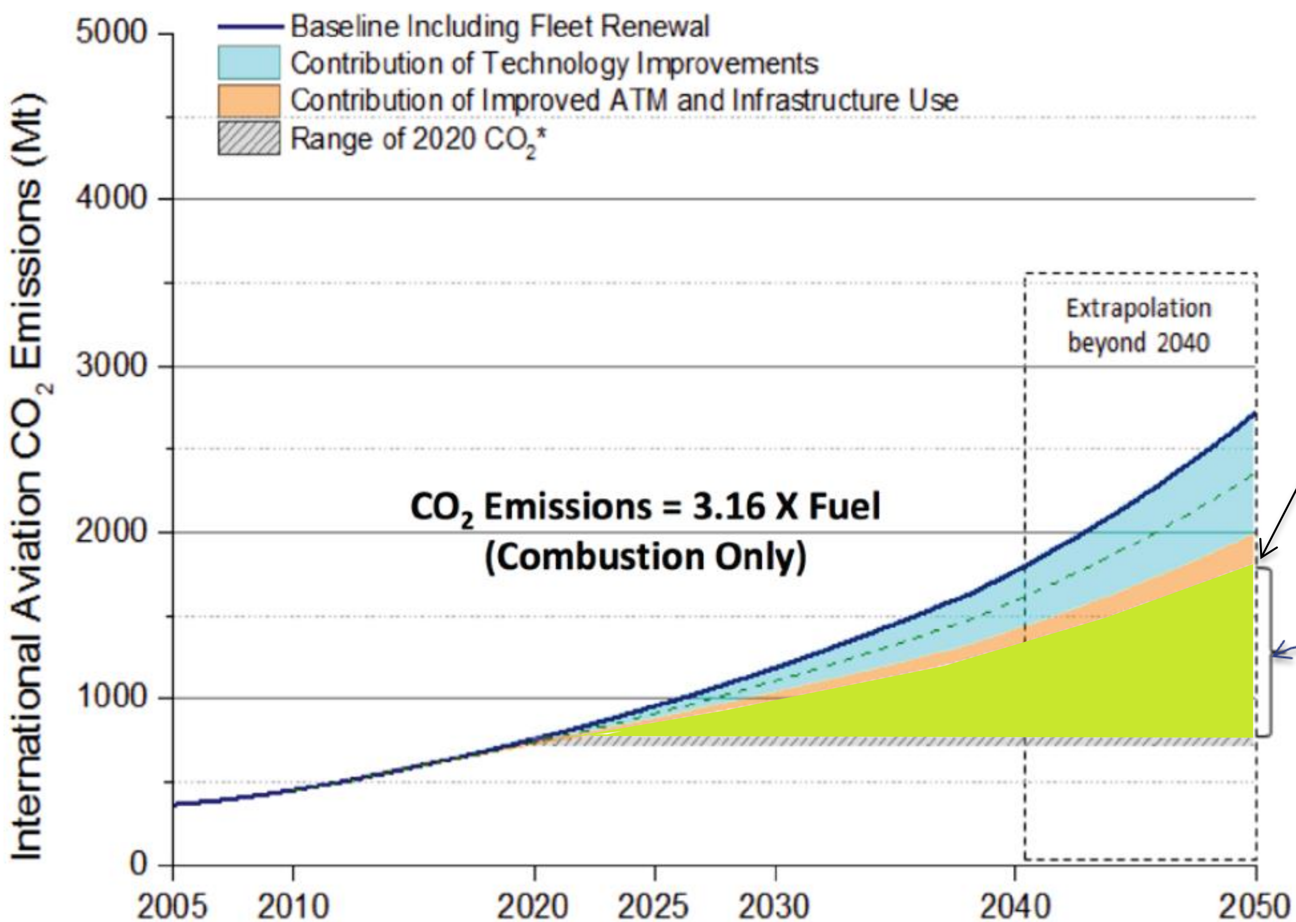


Image: LBST & BHL, Power-to-Liquids – Potentials and Perspectives for the Future Supply of Renewable Aviation Fuel; UBA (ed.), September 2016

Aviation CO_2 mitigation gap (without non-CO_2 effects)



Assuming 1.38 %/yr efficiency improvement

2050 CO_2 emissions gap to 'Carbon Neutral Growth 2020':

1039 Mt CO_2
≈ 330 $Mt_{Kerosene}$
≈ 3400 $TWh_{Kerosene}$

η=42% (LT-EL, CO_2 from air): ~9500 TWh_e
η=48% (HT-EL, CO_2 from air): ~8300 TWh_e

Renewable power production 2016:
~6000 TWh_e

Image: ICAO Environmental Report 2016

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