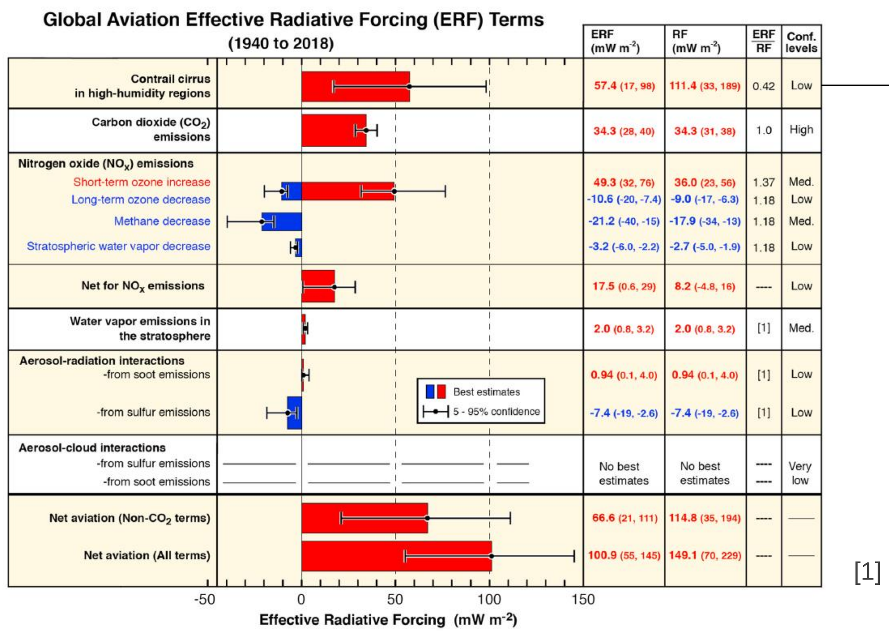
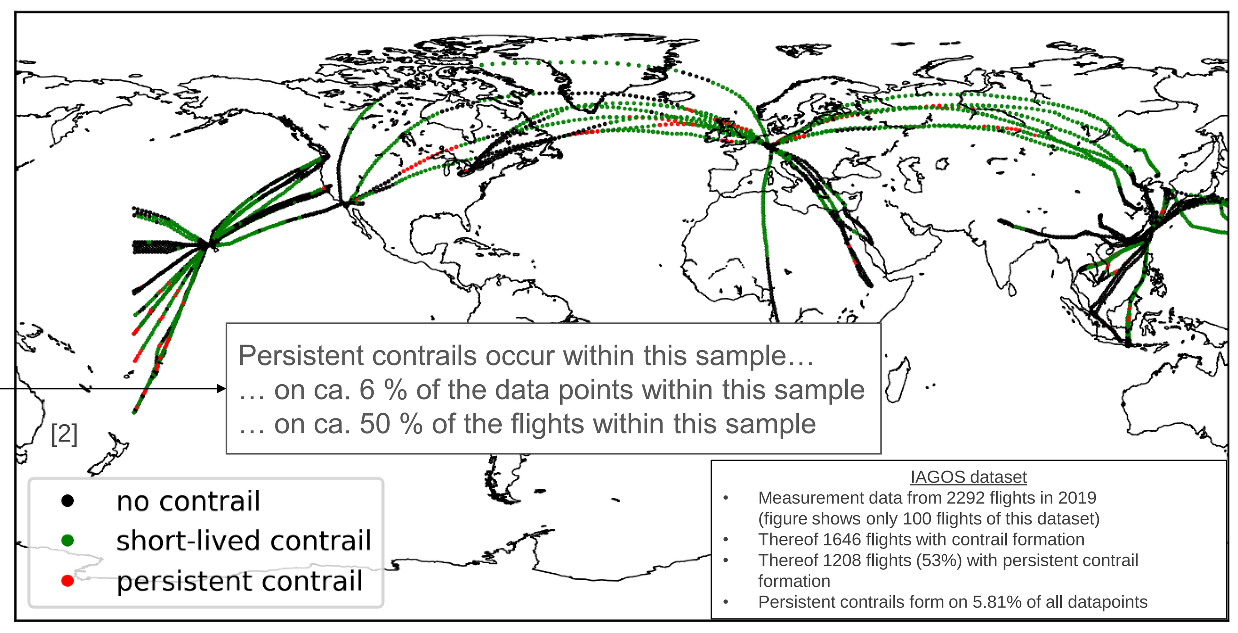
Techno-economic analysis of a smart use of low-soot aviation fuels – options and cost

Gunnar Quante, Nils Bullerdiek, Martin Kaltschmitt

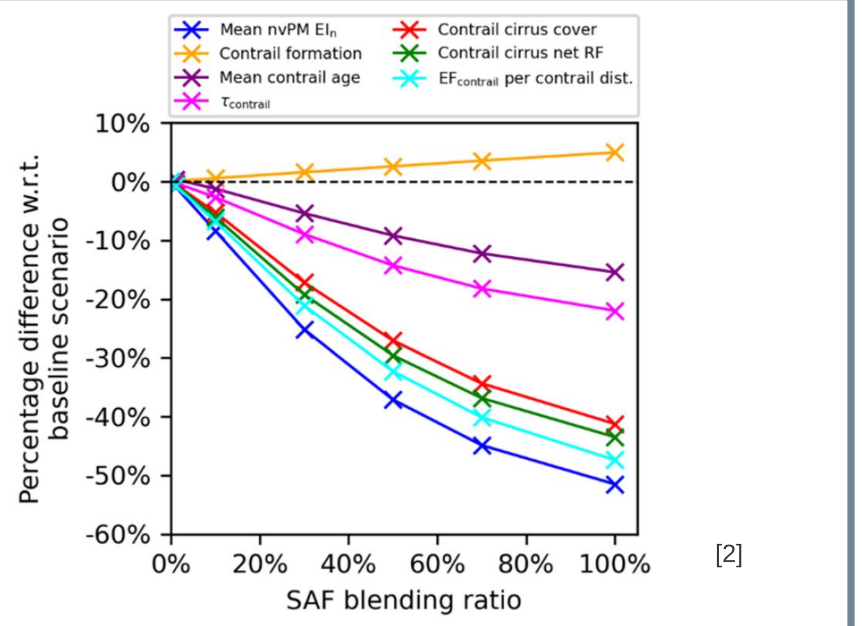
Climate impact of aviation



Contrails are estimated to be the largest contributor to aviation induced radiative forcing…

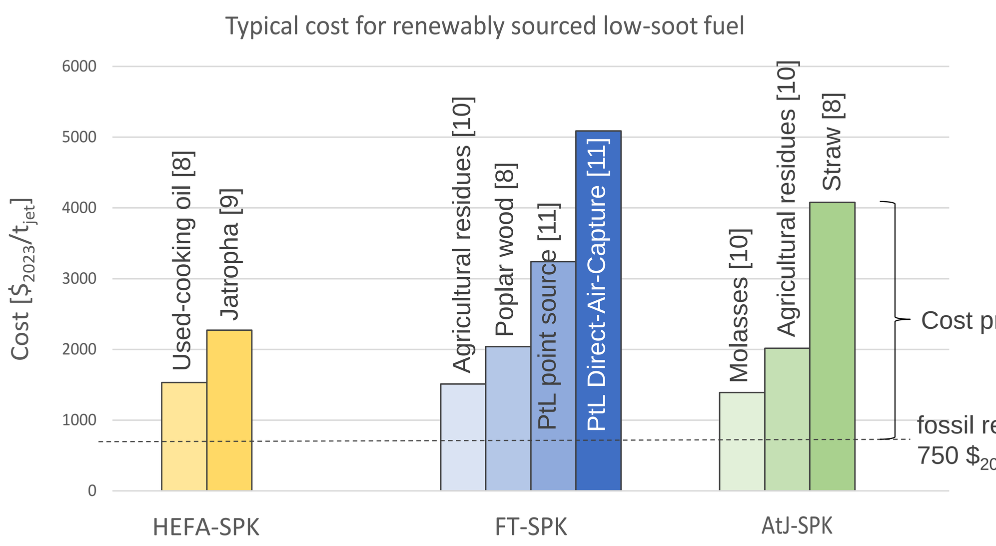


… but persistent contrails occur only on few parts of some flights …



… and their climate impact can be reduced by using low-soot fuel.

Renewably sourced low-soot fuel



ReFuelEU blending mandate

2025	2030	2050
2 %	6 %	70 %

Also lowers CO_2-emissions, but incurs high cost … … and its short-term availability is limited.

Fossil based low-soot fuel

Hydrotreatment
→Hydrogenation *without* breaking of C-C bonds

270-340 °C
15-30 bar

1. Heteroatom removal
2. Saturation of olefins
3. **Saturation of aromatics**

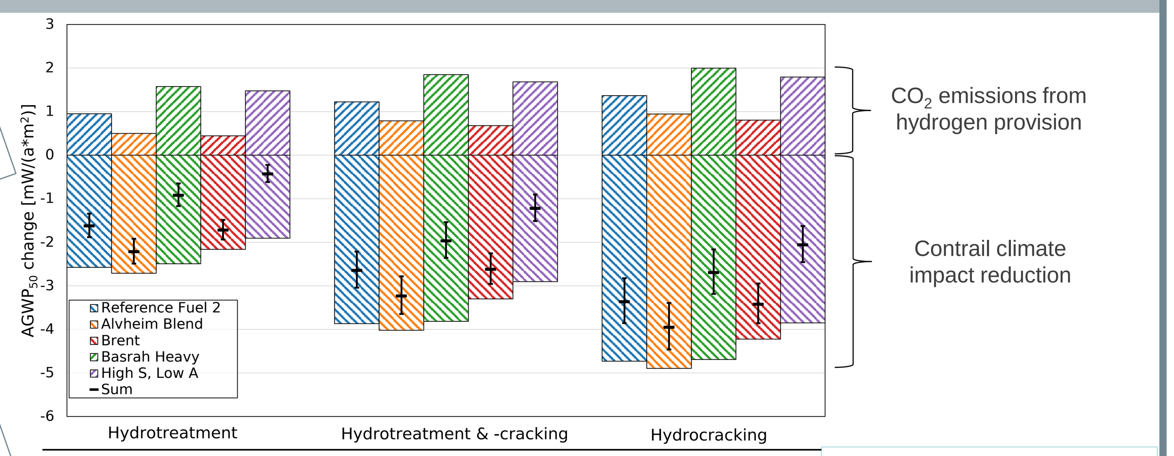
Investment – 800kt/a plant: 300 (270-450) M$2023 [2-4]

Hydrocracking
→Hydrogenation *and* breaking of C-C bonds

370-510 °C
140-170 bar

1. Heteroatom removal
2. Saturation of olefins
3. **Saturation of cyclic molecules**
4. Cracking of naphtenes
5. Cracking of paraffins

Investment – 800kt/a plant: 450 (330-570) M$2023 [2,3,5]



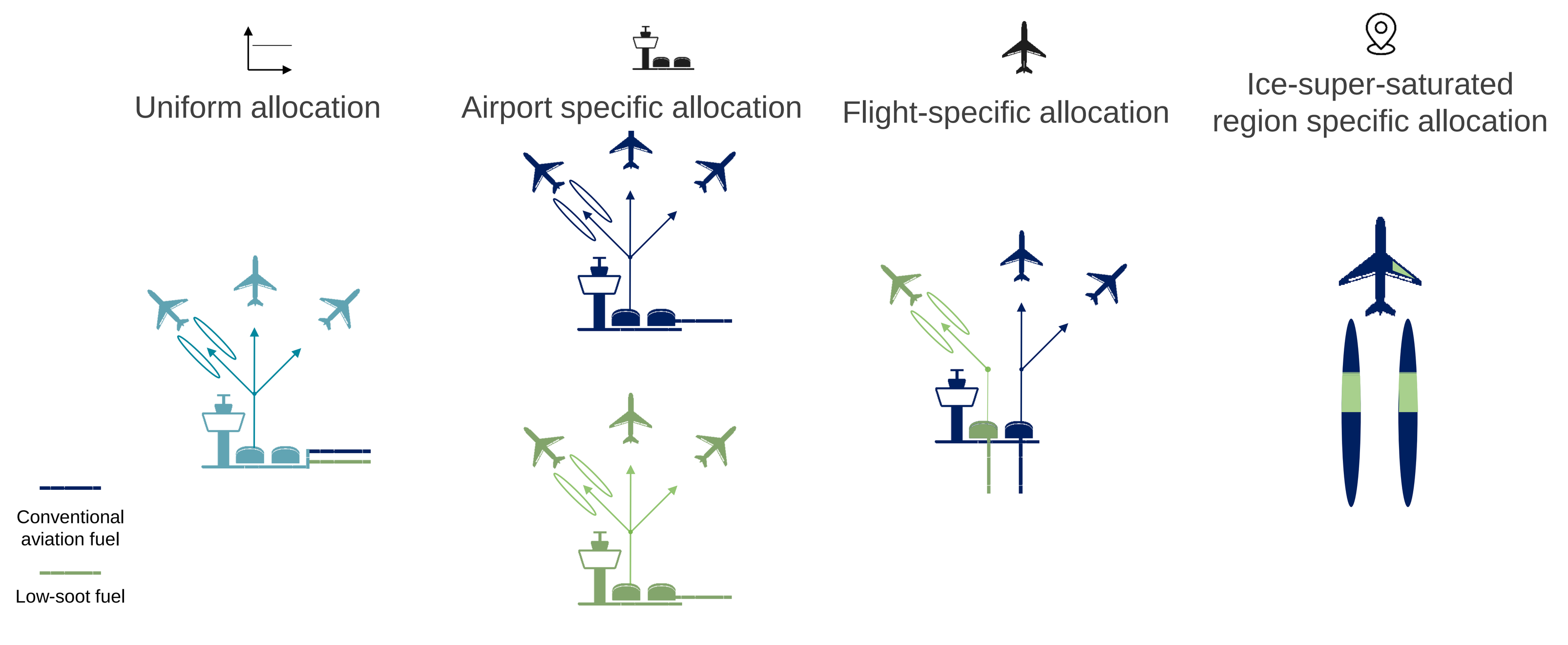
Case	Cost premium [$_{2023}$/t_{jet}]
Hydrotreatment in existing capacities	13.3 (7.0-27.1)
Hydrotreatment in new capacities	66.6 (49.2-89.7)
Hydrocracking in new capacities	89.5 (64.7-113.6)

[3-7]

Hydrogen provision cost:
Steam Methane Reforming: 1.9-2.1 $_{2023}$ /kg_{H2} [5,6]
Electrolysis:
3-7 $_{2023}$ /kg_{H2} [5-7]

Hydroprocessing of fossil kerosene might provide another cost-efficient option to mitigate the climate impact of contrails.

Allocation strategies



The more specific the low-soot fuel is allocated to airports / flights / ice-super-saturated regions, the less low-soot fuel is needed…

	Uniform allocation	Airport specific allocation	Flight-specific allocation	Ice-super-saturated region specific allocation
Land-side	No change required	increased transport distances → excluded	increased transport distances → excluded	increased transport distances → excluded
Airport air-side	No change required	No change required	Segregation: storage, truck/pipeline +6.5 $_{2023}$/t_{jet}	Segregation: storage, truck/pipeline +6.5 $_{2023}$/t_{jet}
Aircraft	No change required	No change required	No change required	Modification of fuel system and associated control logic +8 to +200 $_{2023}$/t_{jet}

[12-14]

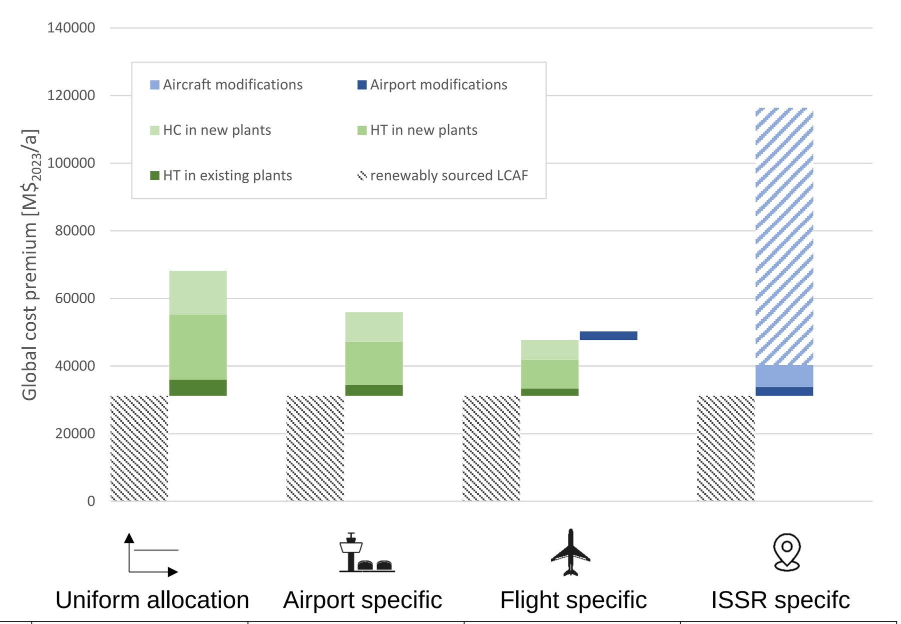
… but cost for infrastructure and / or aircraft modifications increase.

Cost premium [$_{2023}$/t_{jet}]

	Cost premium [$_{2023}$/t_{Fuel}]		Uniform allocation	Airport specific	Flight specific	ISSR specific	
			0	0	7	17	207
fossil LCAF	Hydrotreatment existing capacities	13	13	13	20	30	220
fossil LCAF	Hydrotreatment new capacities	67	67	67	74	84	274
fossil LCAF	Hydrocracking new capacities	90	90	90	97	107	297
renewable LCAF	HEFA-SPK	780	780	780	787	797	987
renewable LCAF	AtJ-SPK	1264	1264	1264	1271	1281	1471
renewable LCAF	FT-SPK (agricultural residues)	760	760	760	767	777	967
renewable LCAF	FT-SPK (PtL point source)	2490	2490	2490	2497	2507	2697
renewable LCAF	FT-SPK (PtL DAC)	4340	4340	4340	4347	4357	4547

Very low cost premium | Low cost premium | Moderate cost premium | High cost premium

Global cost premium [M$_{2023}$]



	Uniform allocation	Airport specific	Flight specific	ISSR specifc
share fossil low-soot fuel	90%	60%	40%	0%
share renewable low-soot fuel	10%	10%	10%	10%

References:
[1] Lee, D. S.; Fahey, D. W.; Skowron, A.; Allen, M. R.; Burkhardt, U.; Chen, Q. et al. (2021): The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018. In *Atmospheric environment (Oxford, England : 1994)* 244, p. 117834. DOI: 10.1016/j.atmosenv.2020.117834.
[2] Teoh, Roger; Schumann, Ulrich; Voigt, Christiane; Schripp, Tobias; Shapiro, Marc; Engberg, Zebediah et al. (2022): Targeted Use of Sustainable Aviation Fuel to Maximize Climate Benefits. In Environmental science & technology. DOI: 10.1021/acs.est.2c05781.
[3] Towler, Gavin; Sinnott, R. K. (2013): Chemical Engineering Design. Principles, Practice and Economics of Plant and Process Design. 2nd ed. Oxford [etc.]: Academic Press.[3] Peters (2003)
[4] Barrett, Steven R. H.; Yim, Steve H. L.; Gilmore, Christopher K.; Murray, Lee T.; Kuhn, Stephen R.; Tai, Amos P. K. et al. (2012): Public health, climate, and economic impacts of desulfurizing jet fuel. In Environmental science & technology 46 (8), pp. 4275-4282. DOI: 10.1021/es203325a.
[5] Müller-Langer, Franziska (2011): Analyse und Bewertung ausgewählter zukünftiger Biokraftstoffoptionen auf der Basis fester Biomasse. Dissertation. Hamburg.[5] IEA (2019)
[6] Sens, Lucas; Piguel, Yannick; Neuling, Ulf; Timmerberg, Sebastian; Wilbrand, Karsten; Kaltschmitt, Martin (2022): Cost minimized hydrogen from solar and wind - Production and supply in the European catchment area. In *Energy Conversion and Management* 265, p. 115742. DOI: 10.1016/j.enconman.2022.115742.
[7] Schimmel, M.; Kerres, P.; Jörling, K.; Klessmann, C. (2020): Making renewable hydrogen cost-competitive. Agora Energiewende.
[8] Jong, Sierk de; Antonissen, Kay; Hoefnagels, Ric; Lonza, Laura; Wang, Michael; Faaij, André; Junginger, Martin (2017): Life-cycle analysis of greenhouse gas emissions from renewable jet fuel production. In Biotechnology for biofuels 10, p. 64. DOI: 10.1186/s13068-017-0739-7.
[9] Neuling, Ulf; Kaltschmitt, Martin (2018): Techno-economic and environmental analysis of aviation biofuels. In Fuel Processing Technology 171, pp. 54-69. DOI: 10.1016/j.fuproc.2017.09.022.[10] Pavlenko2019
[10] König, Daniel Helmut (2016): Techno-ökonomische Prozessbewertung der Herstellung synthetischen Flugturbinentreibstoffes aus CO2 und H2. Dissertation.
[11] Schäfer, Andreas W.; Evans, Antony D.; Reynolds, Tom G.; Dray, Lynnette (2016): Costs of mitigating CO2 emissions from passenger aircraft. In *Nat. Clim. Chang.* 6 (4), pp. 412-417. DOI: 10.1038/NCLIMATE2865.
[12] Pereira, G. B. (2021): Jet Fuel Distribution System: Lisbon Airport Caser Study. Master's Thesis.
[13] Airbus list prices, 2018; Press Release
[14] Embraer list prices, 2023 - https://www.aeroflap.com.br/en/find-out-how-much-an-embraer-plane-and-jet-costs/; retrieved on 20.04.23 11:17

gunnar.quante@tuhh.de
+49 040/42878-4831
www.tuhh.de/iue

Institute of Environmental Technology and Energy Economics
University of Technology Hamburg
Eißendorfer Straße 40, D-21073 Hamburg