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Sustainability & Circular Economy of CO_2 Utilization.

Crucial Precondition for the Transition from Fossil to Sustainable Aviation Fuels.

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How does aviation contribute to climate change?
Aviation is fastest growing transport sector!
Air traffic has more than doubled since 2000!

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Facts and figures.
Today's global air transport industry.

- 100 billion gals of JetFuel burned per year.
- More than a billion tons of CO_2 emitted per year.
- 23,000 aircraft worldwide in service.
- More than 150 airlines serving market requirements.
- A quarter of the world's urban population is responsible for more than a quarter of global GDP. Therefore Aviation Mega Cities already drive and will continue to drive the global aviation growth (Airbus).
- Air Traffic growing at 4.3% annually (Airbus Forecast 2019 -2038 /Sep. 2019).
- IATA expects passenger numbers will nearly double to 7.8 billion in 2036.
- Air Cargo - crucial enabler of the global economy: Only 1% of world trade by volume, but over 35% by value (ICAO).

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Airbus predicts strong growth of global airline fleets.

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- The world's passenger and freighter aircraft fleet is set to more than double from today's nearly 23,000 to almost 48,000 by 2038 (Airbus forecast)!

- By 2038, of the forecast 47,680 fleet, 39,210 are new and 8,470 remain from today.

ICAO: Aircraft contributing about 3.0 % of the anthropogenic 'Radiative Forcing'.

The findings related to aviation emissions in IPCC AR4 (2007) are inter alia:

- Due to the developing scientific knowledge and more recent data estimates (2005) of the climate effects of contrails, **aircraft are now estimated to contribute about 3.0 %** of the total of the anthropogenic Radiative Forcing by all human activities.
- Total CO_2 aviation emissions is approximately **2 % of the Global Greenhouse Gas Emissions**.
- The amount of CO_2 emissions from aviation is expected to grow around 3-4 % per year.
- Medium-term mitigation for CO_2 emissions from the aviation sector can potentially come from improved fuel efficiency.
- However, such improvements are expected to only partially offset the growth of CO_2 aviation emissions.

Source: ICAO

Atmospheric impact of fossil aviation fuels.

Emissions of GHG and particles in aviation

- Emission of CO_2
- $No_{x,}$-emissions in higher altitudes (8–13 km) foster the formation of O_3 increasing global warming.
- Water vapor.
- Soot and sulfate: Emission of soot particles, which - under certain atmospheric conditions and altitudes - serve as condensation nuclei for ice crystals, easy to observe as short or long living contrails in the wake of jet aircraft and – some times later on as cirrus clouds.

Radiative Forcing (RF)

- Number, size and shape of particles determine the effects that contrails have on radiation, especially the so-called Radiative Forcing Index (IPCC).

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Factor of ‘three’: Total climate effects of fossil aviation fuels.

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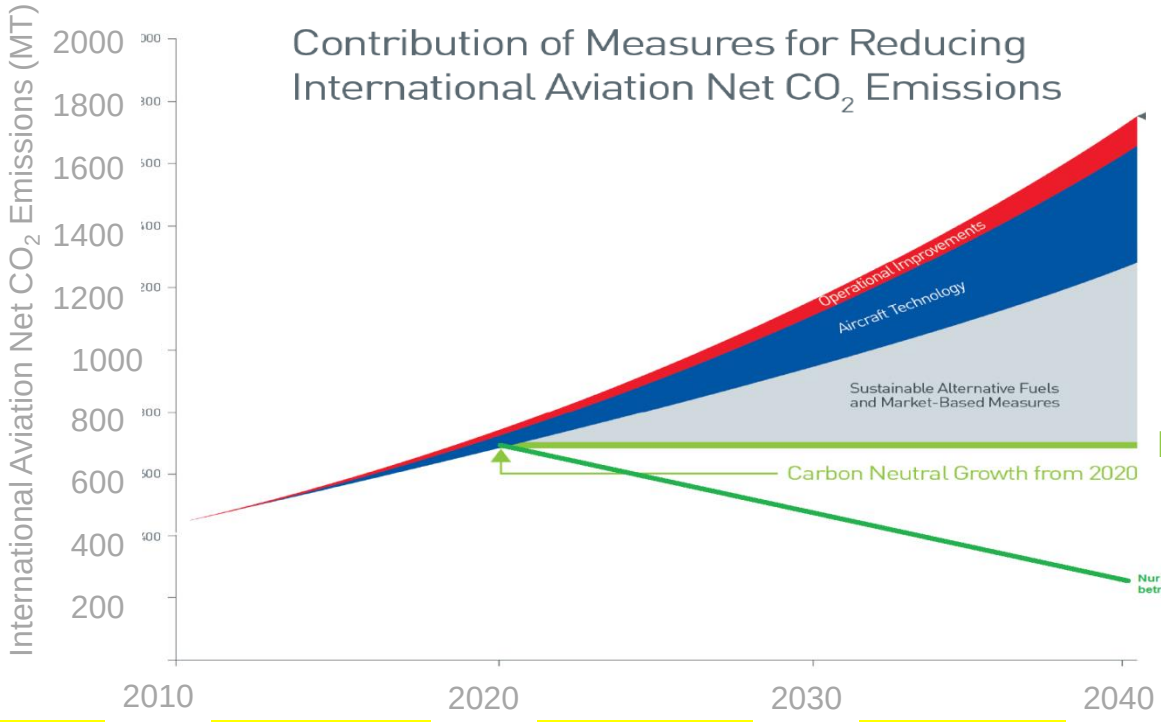
- IPCC has estimated that aviation's total climate impact is some **two to four times that of its direct CO_2 emissions** alone, without considering the potential impact of cirrus clouds caused by contrails.

- In order to quantify the total climate impact of aircraft emissions, the German government presently multiplies airborne CO_2 emissions with a **factor of three**.

Mitigating the impact of aviation on climate change
Source: ICAO / Supplementation by Dr. Lehmann (UBA)



Betriebliche Verbesserungen

Technische Verbesserungen

Nachhaltige alternative Kraftstoffe und markt-basierte Maßnahmen

ICAO-Pfad (nur CO_2)

Paris-Pfad (nur CO_2)

Limiting climate change to 2°C (if possible 1,5°C) requires in aviation a nearly complete switch to renewable fuels!!

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The one and only solution: Sustainable Aviation Fuels.

- Required solutions must include existing aircraft fleets and currently produced aircraft families!

- Sustainable aviation fuels have the potential to make an important contribution to mitigate current and future environmental impacts of aviation (EASA).

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The good news: Proven Fischer-Tropsch Synthesis can be combined with latest process engineering.

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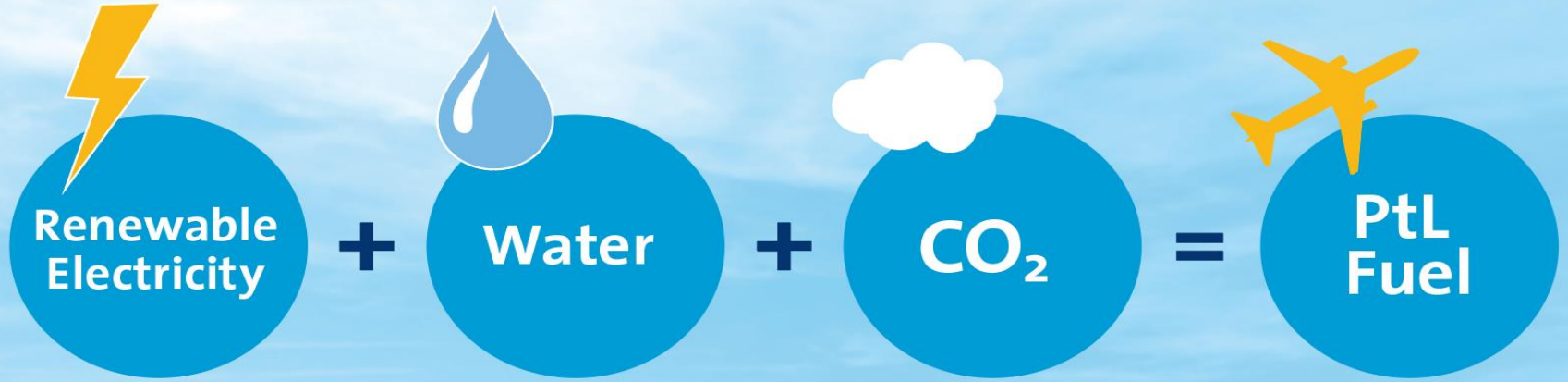
Grafik-Vorlage: Umwelt-Bundesamt



Fischer-Tropsch hydro-processed synthesized paraffinic kerosene already ASTM-certified since 2009 for a up to 50% blend (ASTM D75665).

But: Carbon capture technologies and systems subject to further improvements!

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The paramount advantages of PtL-based aviation fuels!

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Less GHG-emissions and less particles

- Re-utilization of CO_2. Later on use of CO_2 captured from the air.
- $No_{x,}$-emissions in higher altitudes (8–13 km) may be significantly reduced by adjusted combustion chambers and optimized engine modifications. Will reduce the formation of high tropospheric $O_{3.}$ Subsequently less global warming.
- Water vapor (less important with less condensation nuclei)
- Less soot! No sulphur! Therefore less or only short living contrails. Less cirrus clouds.

Less Radiative Forcing

- Number, size and shape of particles determine the effects that contrails have on radiation, especially the so-called Radiative Forcing as defined and used by IPCC, the (Intergovernmental Panel on Climate Change, Welt-Klimarat).

Less impact on climate change, less burden on the aviation industry

- **Less aircraft emissions will lead in the end to an appropriate reduced multiplier for airborne CO_2 emissions, much smaller than 'three'!**
- **Less payments due to CORSIA or other ETS-Systems (e.g. EU). Less taxes??????**

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‘It always seems impossible until it's done.’

Nelson Mandela