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Zero Emission – The New Credo in Civil Aviation

EASA, EEA, and EUROCONTROL published the "European Aviation Environmental Report" (2019) on 2019-05-13. The report does not set a zero emission target, but is noteworthy in this respect.
https://www.easa.europa.eu/eaer
https://doi.org/10.2822/309946

CS3PG Stakeholder Group is the commission's strategic planning group to deliver in a timely, open and transparent manner an aligned position from the European aviation stakeholders related to "Clean Aviation". For a 2050 horizon the goal is climate neutral aviation. A draft report "Clean Aviation" was published on 2020-06-25.
https://www.clean-aviation.eu
https://ec.europa.eu/info/sites/info/files/research_and_innovation/funding/documents/ec_rtd_he-partnerships-clean-aviation.pdf

Airbus announced on 2020-09-21 a new "Zero-Emission" hybrid-hydrogen passenger aircraft with estimated entry into service by 2035. Essentially, the idea is to burn liquid hydrogen in jet engines. This will avoid long-living CO2 emission, but will produce more water in the exhaust. Airbus has not produced a report, but provides much information to the media.
https://www.airbus.com/innovation/zero-emission.html

DLR and BDLI in Germany delivered on 2020-10-14 the report "Zero Emission Aviation – Emissionsfreie Luftfahrt: White Paper der deutschen Luftfahrtforschung" (2020).
https://www.dlr.de/content/de/artikel/news/2020/04/20201014_deutschland-auf-kurs-zum-klimaneutralen-fliegen,
https://www.bdli.de/meldungen/deutschland-auf-kurs-zum-klimaneutralen-fliegen-dlr-und-bdli-uebergeben-white-paper-zero

Research institutions from 13 countries have joined forces on 2020-11-24 to form the **'Zero Emission Aviation' (ZEMA) Group**. A four-page document includes this statement: "As researchers, we aim for an aviation system which is free of negative impacts. We will do our utmost to protect our planet and communicate this to the public in order to achieve not only acceptance but strong support for aviation."
https://www.dlr.de/content/en/articles/news/2020/04/20201124_research-initiative-pioneers-sustainable-flight.html
https://www.dlr.de/content/en/downloads/2020/statement-zero-emission-aviation.pdf

Europe's airlines, airports, aerospace manufacturers and air navigation service providers (A4E, ACI Europe, ASD, CANSO, ERA) have laid out a joint long-term vision of reaching net zero CO2 emissions. The report is called "Destination 2050 – A Route to Net Zero European Aviation" (2021).
https://www.destination2050.eu

Based on some of the above documents, **Zero Emission can be achieved** by one or a combination of these principles:
1. applying new technologies to increase efficiency,
2. applying new fuels and new means of propulsion with no or less emissions,
3. applying the carbon cycle with biofuels,
4. compensating remaining emissions.

The **problems with Zero Emission measures** are:

1. It is a mathematical fact that putting measures with improved efficiency on top of each other does not lead to zero emissions. If you take an aircraft that burns only 50% of the fuel on a magic ATM system that reduces the distance by 50% you do not get zero emission, but 25% emission of the reference. Above that the rebound effect teaches us that in the long run increased efficiency leads to a lower price, which leads to more demand, which leads to more emissions.
2. It is not so easy. Electricity does not just come from the socket. The energy production needs to be considered with a Life Cycle Analyses (LCA). Hydrogen combustion does not produce CO2, but has non-CO2 effects. Initial details on that below.
3. A biofuel carbon cycle is not 100% efficient. It reduces CO2 by about 50%.
4. Compensating emissions is problematic. A new forest that is cut after 30 years is not a long term carbon sink. Compensation comes with philosophical questions. In addition, no one likes to pay for compensation.

Hydrogen aircraft emissions

Hydrogen combustion has 2.58 times more water emissions. This means, hydrogen combustion leads to contrails forming already at lower altitudes and hence more often. The method from Schwartz 2009 (Figure 1) was applied and adapted. With the mentioned primary effects, aviation-induced cloudiness (AIC) with its line-shaped contrails and cirrus clouds leads to an equivalent CO2 mass 50% higher than for kerosene. Hydrogen flame temperature is higher (without applying special technologies) and as such NOx emissions would be higher. It is assumed here that NOx are the same as for kerosene. Results are calculated with an Excel table: https://doi.org/10.7910/DVN/DLJUUK (Figure 2).

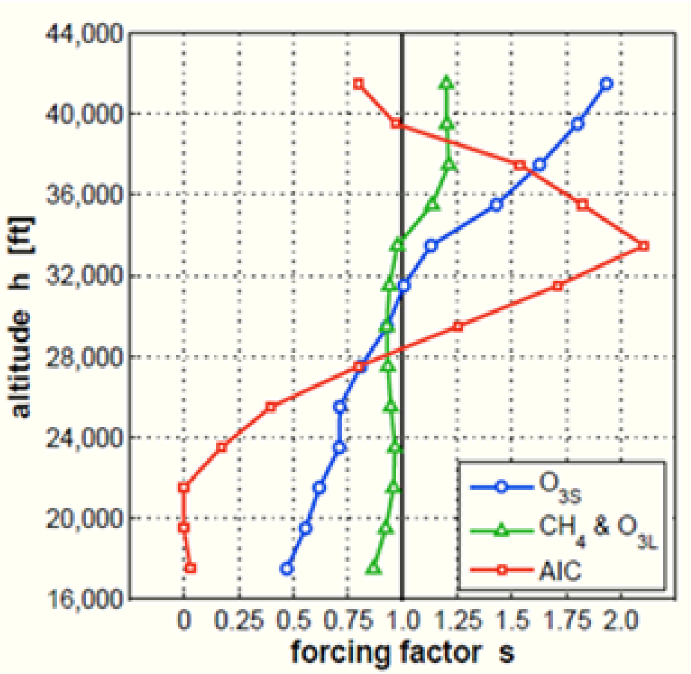

Figure 1: Forcing factors according to Schwartz 2009 and 2011.

Altitude [ft]	rel. to kero
18000	-1%
24000	59%
30000	144%
33548	163%
36000	149%
41000	112%

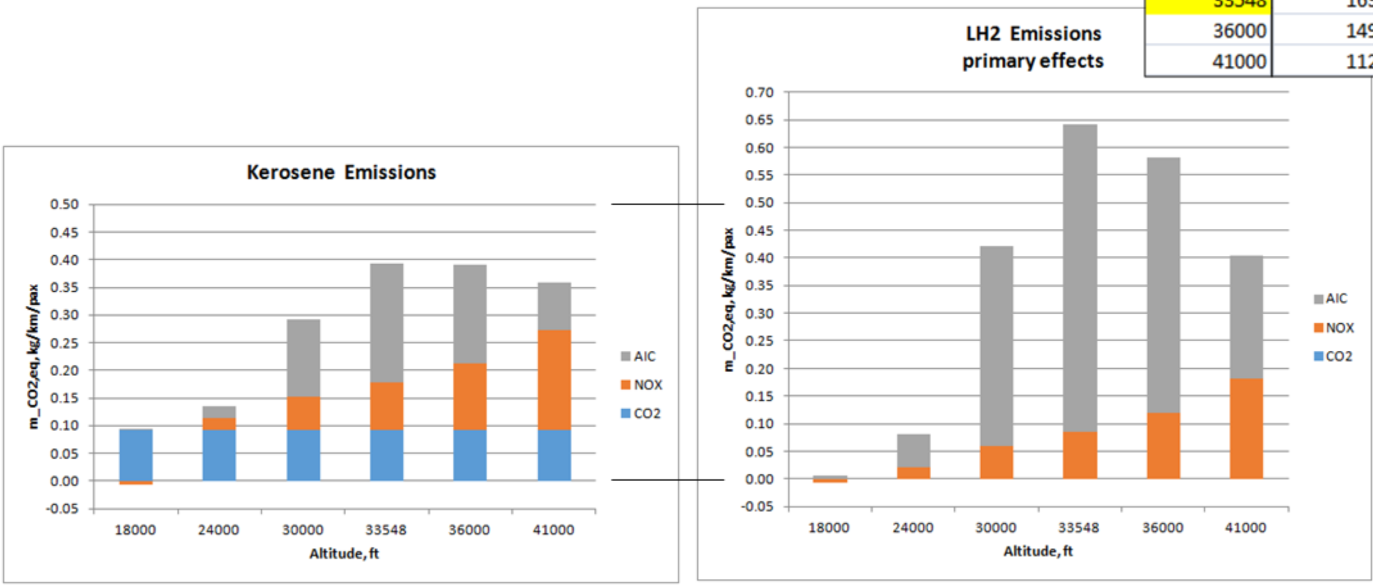

Figure 2: Equivalent CO2 mass calculated from a simple climate model adapted to hydrogen combustion. Only primary effects are considered. Hydrogen emissions are about 50% higher than kerosene emissions in normal cruise altitude and medium latitude.

Now beneficial secondary effects are applied on top of the primary effect for contrails due to larger ice crystals (factor 0.77) and for visible contrails (factor 0.77 assumed) leading all together to a reduction factor of $0.77^2 = 0.6$. The same factor is assumed for cirrus clouds. For NOx a factor of 0.35 is assumed due to lean combustion and low flame temperature. With these assumptions equivalent CO2 mass is now in the order of that for kerosene propulsion. (Figure 3)

Altitude [ft]	rel. to kero
18000	1%
24000	32%
30000	81%
33548	93%
36000	82%
41000	55%

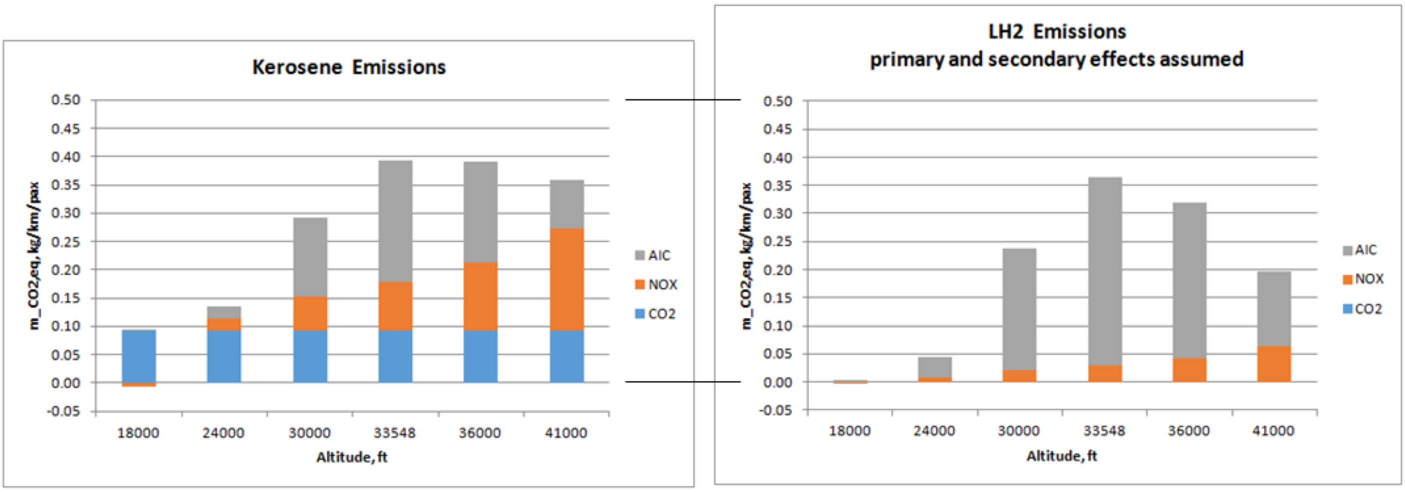

Figure 3: Equivalent CO2 mass calculated from a simple climate model adapted to hydrogen combustion. Beneficial secondary effects are considered. Hydrogen emissions may be a bit lower, but are in the order of kerosene emissions in normal cruise altitude and medium latitude.

References

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