ICAO ENVIRONMENT

Lower Carbon Aviation Fuels Technology Update

ICAO Committee on Aviation Environmental Protection

April 2023

Introduction

- **This presentation was developed by experts from the ICAO Committee on Aviation Environmental Protection (CAEP)**
- **It covers the following topics related to Lower Carbon Aviation Fuels (LCAF)**

1. a high-resolution approach for understanding jet fuel supply chain emission variability
2. a summary of technologies and processes that could lead to the production of LCAF
3. A description of the role of LCAF in the context of technology improvements and SAF growth

Lower Carbon Aviation Fuel (LCAF)

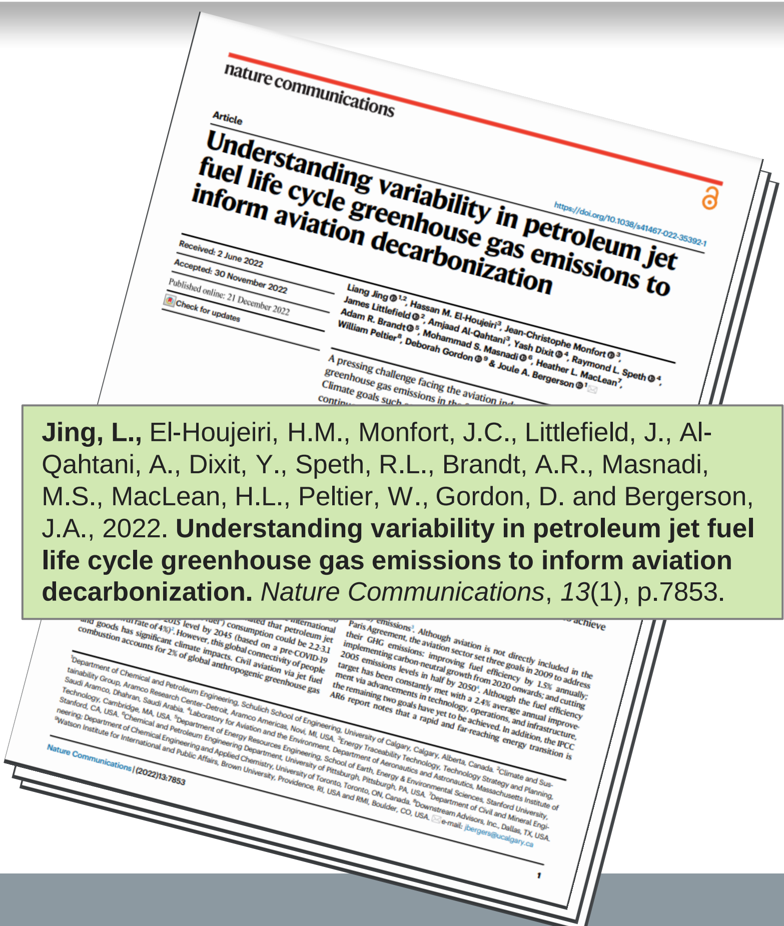
Lower Carbon Aviation Fuel (LCAF) is defined in Annex 16 Vol IV as a “A fossil-based aviation fuel that meets the CORSIA Sustainability Criteria under this Volume.”

- LCAF can serve as a complementary measure alongside SAF in helping to reduce aviation greenhouse gas (GHG) lifecycle emissions.
- An LCAF may be certified as a CORSIA eligible fuel if it meets the CORSIA Sustainability Criteria, including a 10% reduction in lifecycle emissions compared to the conventional aviation fuel baseline of 89 g CO_2/MJ.
- For example, five billion liters of LCAF at 80 gCO_2/MJ could provide the equivalent GHG emissions reduction of about one billion liters of SAF at 45 gCO_2/MJ.

Reference: ICAO, Chapter 7 - Lower Carbon Aviation Fuels: contributing to the energy transition, ICAO Environmental Report 2022

Topic 1
high-resolution approach for understanding jet fuel supply chain emission variability

recent jet fuel LCA study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Understanding variability in petroleum jet fuel life cycle greenhouse gas emissions to inform aviation decarbonization

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Check for updates

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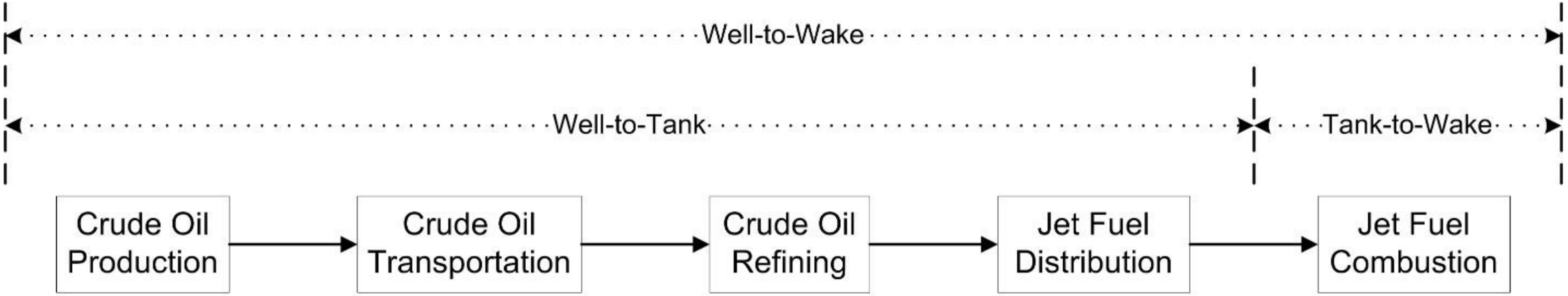
Jing, L., El-Houjeiri, H.M., Monfort, J.C., Littlefield, J., Al-Qahtani, A., Dixit, Y., Speth, R.L., Brandt, A.R., Masnadi, M.S., MacLean, H.L., Peltier, W., Gordon, D. and Bergerson, J.A., 2022. **Understanding variability in petroleum jet fuel life cycle greenhouse gas emissions to inform aviation decarbonization.** *Nature Communications*, *13*(1), p.7853.

"A high-resolution baseline against which sustainable aviation fuel and other emissions reduction opportunities can be prioritized to achieve greater emissions reductions faster."

Jet Fuel Life Cycle
Boundaries of the analysis & models used

88.7 $gCO_2e\ MJ^{-1}$ (vs. ICAO's 89.0 $g\ CO_2e\ MJ^{-1}$)



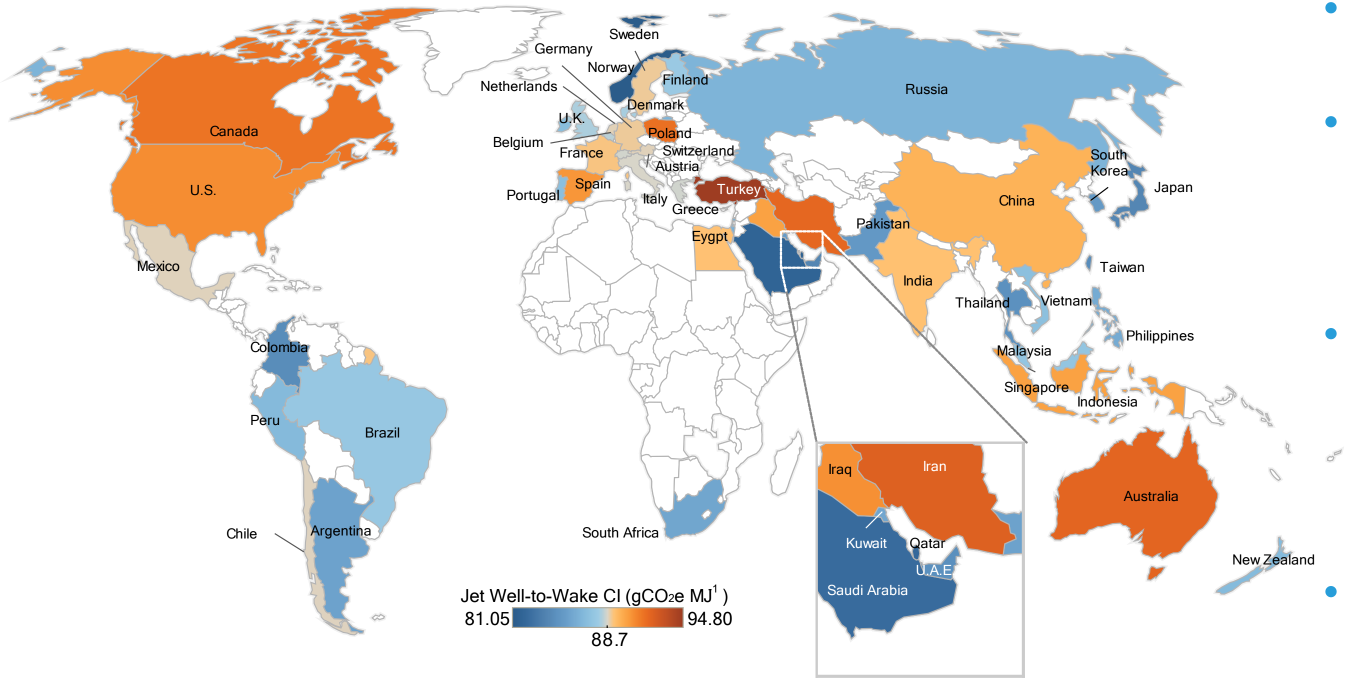
Crude Oil Production	Crude Oil Transportation	Crude Oil Refining	Jet Fuel Distribution	Jet Fuel Combustion
OPGEE v2.0 $g\ CO_2e\ MJ^{-1}$ crude	COPTEM $g\ CO_2e\ MJ^{-1}$ crude	PRELIM v1.5 $g\ CO_2e\ MJ^{-1}$ jet MJ crude MJ^{-1} jet	Average distance between refineries and airports $g\ CO_2e\ MJ^{-1}$ jet	ICAO $g\ CO_2e\ MJ^{-1}$ jet
8.6 gCO_2e/MJ jet	1 gCO_2e/MJ jet	4.5 gCO_2e/MJ jet	0.8 gCO_2e/MJ jet	73.8 gCO_2e/MJ jet

Stanford University

University of Calgary

Source: Jing et al., Understanding variability in petroleum jet fuel life cycle greenhouse gas emissions to inform aviation decarbonization, Nature Communications, 2022

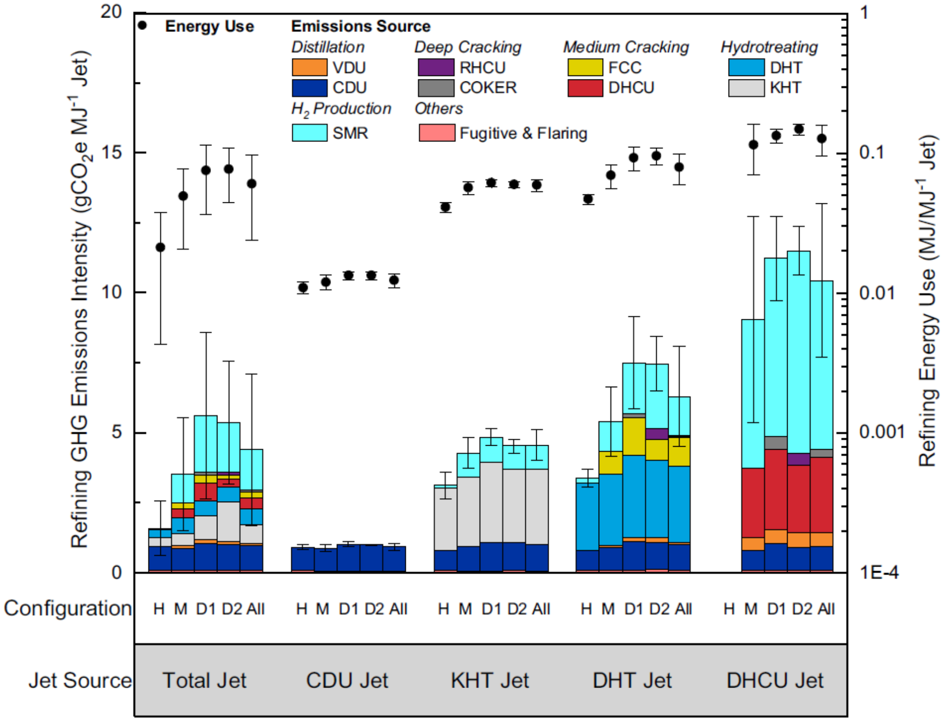
Country-level Variability



- Well-to-wake ranges from 81.1 to 94.8 g CO_2e MJ^{-1}
- Crude oil production emissions have the most variability : 2.9 to 27.6 g CO_2e/MJ
- Jet fuel distribution emissions are not as variable as other stages (but there are a couple outliers)
- A single point value is used for combustion : 73.8 g CO_2e/MJ

Source: Jing et al., Understanding variability in petroleum jet fuel life cycle greenhouse gas emissions to inform aviation decarbonization, Nature Communications, 2022

Refinery Drilldown



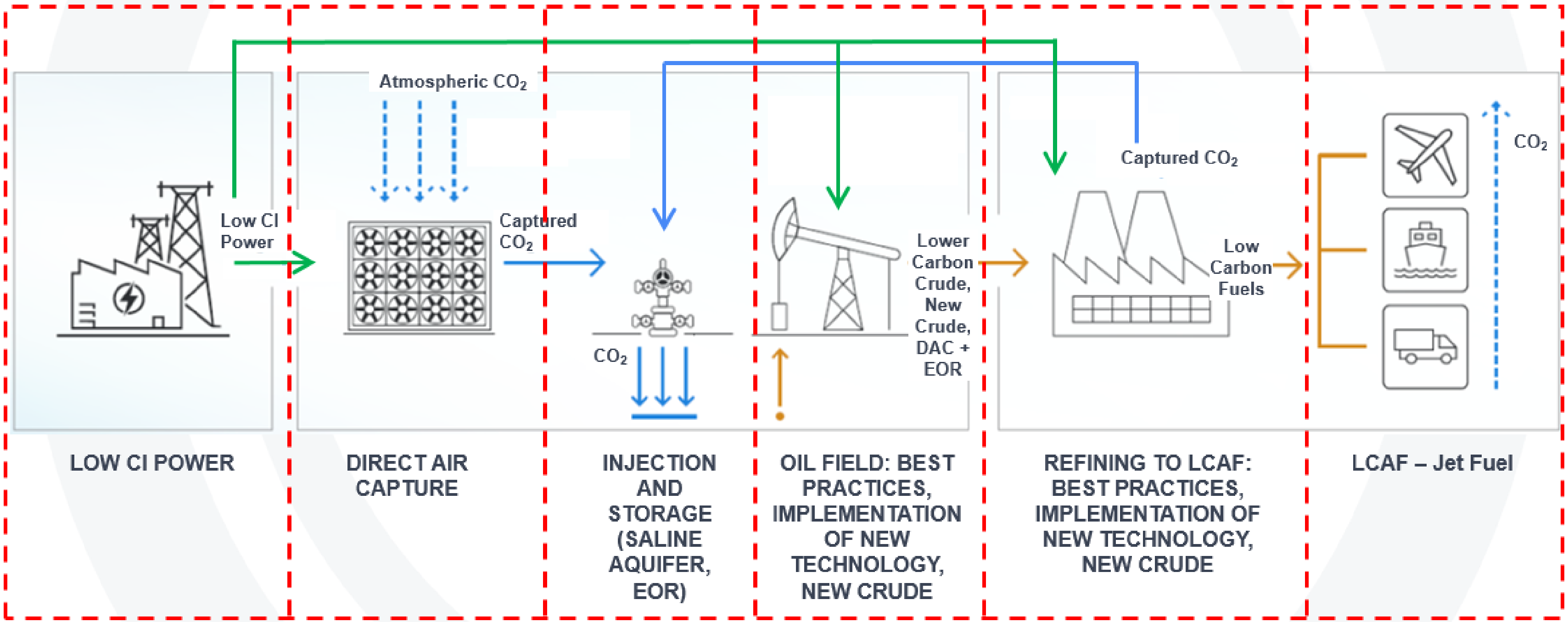
DHT Jet = prod. from diesel hydrotreater DHCU Jet = prod. from distillate hydrocracking unit

- 480 refineries
- Crude characteristics and refinery configuration are key GHG emission drivers
- Country-level variability ranges from 0.9 to 12.5 g CO_2e MJ^{-1}
- Jet fuel produced from crude distillation (CDU) and kerosene hydrotreater (KHT) has low emission intensities, but all jet fuel sources are important for product specs & blending requirements

Source: Jing et al., Understanding variability in petroleum jet fuel life cycle greenhouse gas emissions to inform aviation decarbonization, Nature Communications, 2022

Topic 2
summary of technologies and processes that could lead to the production of LCAF

Technology measures & Jet Fuel Production



Note : this is a representation of existing and future technologies that could be implemented. Not all technology measures have yet been assessed by ICAO for inclusion in CORSIA.

Energy Conservation

- Reducing the energy consumed : among the most economical methods of reducing GHG emissions
- Oil and gas companies can invest in new technologies and research to address the various energy needs such as :
  - energy efficient design of plants
  - advanced modelling of reservoirs to increase production efficiencies
  - improved technologies for monitoring the efficiency of equipment in the field…

Process Gas Management

There are several places where measures can be taken to mitigate emissions from gases associated with fuel production, such as :

- Flaring Management
- Venting control
- Fugitive Emissions Detection

Flaring management :

- Flaring can occur for many reasons[1], ranging from technical issues (e.g. initial start-up testing of a facility) to market factors (e.g. insufficient demand), and is commonly used as a safety mechanism in the event of unplanned equipment malfunctions
- Reinjection of associated gas is one particular measure to avoid flaring but may not always be technically feasible and/or economic due to the nature of the oil reservoir

Venting control :

- Atmospheric process are equipped with vents which emits process gases directly into the air
- Best control measure is to eliminate the need for discharge by altering the process operation or recycling the material
- Storage, loading & unloading of oil (offshore/onshore) can emit gas to the atmosphere
- Mitigation technologies : Vapor Recovery Units and practices like 'closed hatch' measurement and sampling

1. See the IPIECA Flaring management guidance, Section 1, pages 13-14, developed by Ipieca, IOGP and GGFR for other key reasons why gas flaring occurs

Fugitive emission detection :

- Refineries contain hundreds of thousands of piping components such as valves, connectors, flanges, pumps and compressors
- There is potential for the process gas to escape around the seal of each them, usually in very small quantity
- However, the large number of components in a refinery may make fugitive emissions the largest aggregate source of hydrocarbon emissions
- Detection done through the use of sensitive gas sampling devices to ‘sniff’ for parts-per-million (ppm) concentrations on the piping component (device to be very close to the leak site)
- New technology (optical gas imaging equipment) combined with adequate controls (e.g. improved seals, materials and metallurgy in addition to large leakers repair)

Low Carbon Intensity measures to lower the GHG emissions of the jet fuel production cycle

- Renewable electricity : through their own production with technology like solar panel arrays, or via renewable power purchase agreements
- Renewable gas
- Low carbon hydrogen :
  - Hydrogen is used in refining processes to remove undesirable elements like sulfur and is commonly produced by the steam reforming of natural gas
  - One lower carbon hydrogen option requires using renewable electricity to split water into hydrogen & oxygen
  - New technologies like auto-thermal reforming (natural gas reacting with oxygen and steam in a single reactor), methane pyrolysis or the use of biomass as a feedstock

Carbon Capture and Storage (CCS)

- Collecting & compressing CO_2 generated by fossil fuel production cycle which is then sequestered at depths beyond one kilometer below the earth's surface, within geological formations suitable for permanent storage
- Suitability of site storage depends on several factors (e.g. proximity to CO_2 sources) or reservoir-specific qualities (e.g. porosity or permeability)
- A diverse array CCS technologies category (such as Liquid Solvent, Membrane, Solid Adsorbent), with various Technology Readiness Level (TRL) scores
- Optimized utilization of carbon through Direct Air Capture of CO_2 combined with Enhanced Oil Recovery : various quantities of carbon being sequestered in the extraction process by making use of existing wells and infrastructure

Technology Measures

Emissions type	Pathway	Example levers	**Abatement potential**[1], % of Cradle-to-grave CI
Scope 1&2	**Operational decarbonization**	Decarbonizing **power supply** Reducing **venting, flaring and fugitives** Switching **fuel/feedstock to greener alternatives** (e.g., green hydrogen) CSS to abate **refinery process emissions**	10-30%[2]
Scope 1,2 & 3	**CCUS EOR**	**Direct Air** Capture + EOR **Biogenic point source** Capture + EOR	70-90%[2]

- Carbon capture[3] + EOR is a pathway that can address Scope 3 abatement of fossil fuels and achieve fossil fuel CI reduction between 70-90%

1. Theoretical maximum assuming all scope1&2 or scope 3 emissions are abated
2. Ranges due to light versus heavy crude i.e., a light crude will have a lower scope 1&2 abatement potential but a higher scope 3 abatement potential
3. Requires DAC or biogenic point source to achieve true atmospheric neutrality

Source: Carnegie Endowment Oil Climate Index

Technology Improvements
LCAF role

	Crude oil production	Crude oil transportation	Crude oil refining	Jet fuel distribution	Jet fuel combustion	Total
Conventional jet fuel	8.6	1	4.5	0.8	73.8	88.7
Conventional jet fuel w. low tech improvement	7.1	0.9	4.0	0.7	73.8	86.6
Conventional jet fuel w. high tech improvement	4.5	0.5	2.0	0.7	73.8	81.6

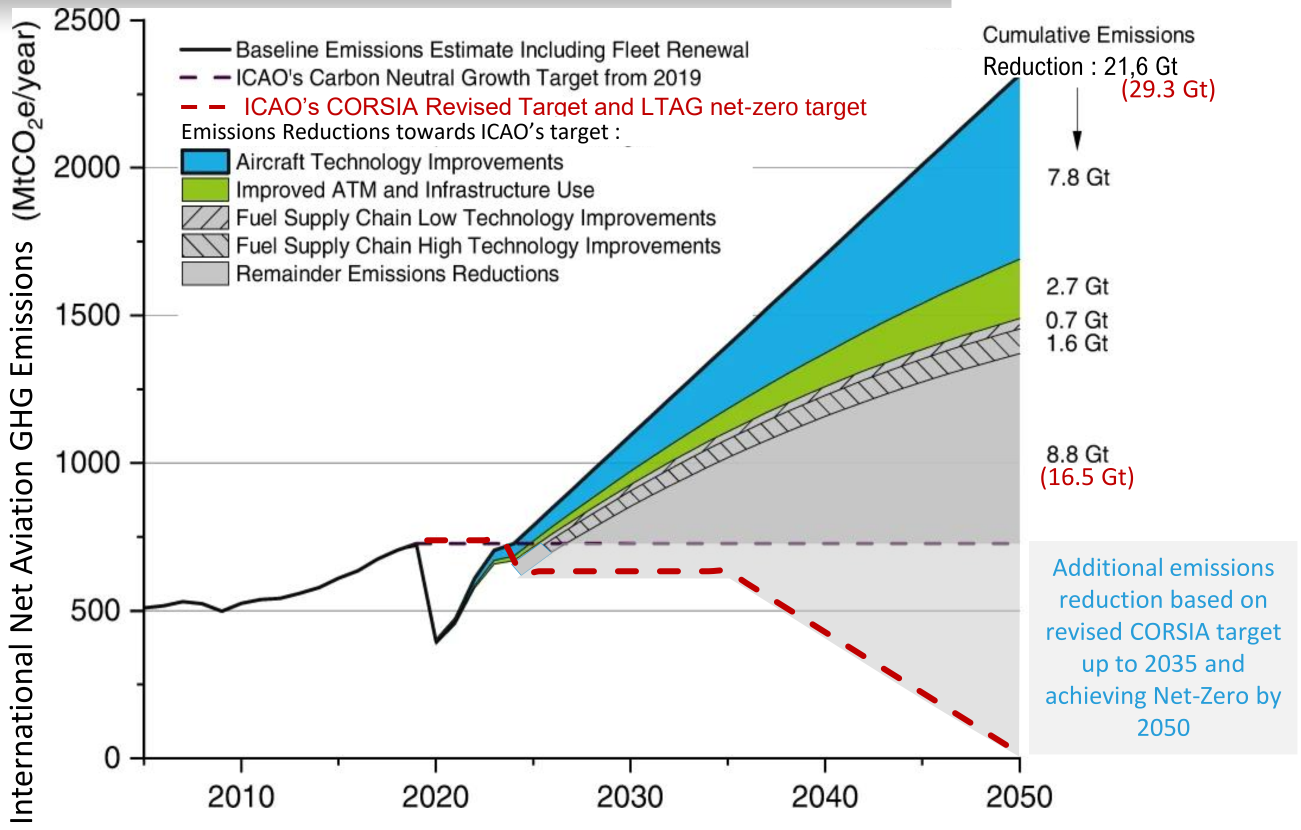
Assumptions : minimal routine flaring, carbon capture from the fluid catalytic cracker & SMR for hydrogen production (low tech improvement)

Assumptions : no routine flaring, carbon capture from all refinery process units & low-carbon steam/low carbon electricity for refinery operations (high tech improvement)

Source: Jing et al., Understanding variability in petroleum jet fuel life cycle greenhouse gas emissions to inform aviation decarbonization, Nature Communications, 2022

Topic 3
Description of the role of LCAF in the context of technology improvements and SAF growth

Emission Reduction Potential



- This represents international aviation only
- 29,3 Gt in CO_2e emission reductions are necessary to achieve Net-Zero by 2050
- A combination of emission reduction measures will be required
- LCAF and aircraft efficiency improvements can partly enable carbon-neutral growth and ease the transition to SAF

Notes :
- For simplicity, CORSIA target assumes a voluntary participation of all ICAO Member States in CORSIA offsetting for the period of 2021-2035
- GHG emissions are based on combustion emissions only

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THANK YOU