To Achieve LTAG: Ways to Address and Minimize Residual CO_2 Emissions

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Introduction

IATA's framework for net-zero 2050 is simple: Reduce energy use (and in turn, fuel use), change the energy source from fossil fuels to renewable alternatives, and re-capture residual CO_2 emissions. IATA estimates that even in a scenario where 90% of the fossil fuel is replaced by SAF, residual CO_2 emissions could still amount to nearly 500 million tonnes in 2050. While there is no standard definition for what constitutes residual CO_2 emissions, it can be broadly explained in the net zero context as the amount of CO_2 emissions leftover after all other decarbonization levers have been applied. In the air transport context, as per the ICAO LTAG scenarios, this would mean the CO_2 emissions leftover after the emission reductions through the use of sustainable aviation fuel (SAF), energy efficiency and operation improvements, and hydrogen and battery electric aircraft. According to many decarbonization roadmaps for aviation, including IATA's Net Zero Roadmaps, the amount of residual CO_2 emissions to be addressed in 2050 represents about 20% of the total baseline emissions, a proportion higher than the emissions which are expected to be tackled from more efficient operations, or from zero-carbon energy aircraft like battery or hydrogen.[1]

IATA recognizes the important role of market-based measures to address the residual emissions as an integral part to deliver the LTAG in 2050. This has also been widely recognized already in several decarbonization roadmaps.[2] Carbon dioxide removals (CDR) are identified as one of these market-based measures (MBMs). In fact, this solution can already be used today in the form of CORSIA Eligible Emissions Units, for operators to comply with their CORSIA obligations. This article focuses on the role of CDR in addressing residual CO_2 emissions directly and the importance of maximizing the use and increasing the potential of deep emission reductions to minimize the amount of residual emissions that need to be addressed.

Leveraging Carbon Dioxide Removal to address residual emissions

According to the IPCC, "carbon dioxide removal (CDR) refers to a cluster of technologies, practices, and approaches that remove and sequester carbon dioxide from the atmosphere and durably store the carbon in geological, terrestrial, or ocean reservoirs, or in products". The International Panel on Climate Change (IPCC) acknowledges the use of CDR **as a means to counterbalance residual CO_2 and greenhouse gas (GHG) emissions from hard-to-transition sectors, which includes the aviation sector**.[3] CDR can exist in the form of many different technologies and methods, each with a unique means of capturing and storing CO_2 from the atmosphere. Using CDR, CO_2 can be stored in other parts of the Earth's sphere from the atmosphere i.e. in ocean

1 IATA (2024). *Net Zero Roadmaps*. [online] Iata.org. Available at: https://www.iata.org/en/programs/sustainability/roadmaps/.
2 IATA Net Zero Roadmaps suggest that roughly 400 to 1,300 Mt CO_2 of residual emissions must be addressed through out-of-sector measures (market-based measures and CDR). Likewise, ATAG's "Waypoint 2050", Royal Netherlands Aerospace Centre's (NLR) and SEO Amsterdam Economics' (SEO) "DESTINATION 2050 for European Aviation", and the two Mission Possible Partnership (MPP) roadmaps also consider MBMs as part of their decarbonization levers.
3 Coppola, E., John and Dunne, P. (n.d.). Coordinating Lead Authors: Lead Authors: Contributing Authors: Climate Change Information for Regional Impact and for Risk Assessment. *United States of America)*. [online] DOI: https://doi.org/10.1017/9781009157896.014.

bodies, biological sinks, and geological reservoirs. CDR is one way to directly address residual emissions that will be left over after deep emission reduction measures such as SAF, hydrogen, and battery electric aircraft are applied.

The concept of CDR durability is also a key aspect of consideration for quality assessment and is increasingly scrutinized to determine the appropriateness of different types of CDR in addressing CO_2 emissions. Durability refers to the timescale in which CO_2 is stored without being re-released to the atmosphere. Definitions of how to quantify durability can vary across scientific literature and market standards. CDR methods that use biological sinks, such as afforestation and reforestation, typically have lower durability scales spanning decades. Meanwhile, CO_2 storage utilizing deep underground reservoirs such as saline aquifers is able to store CO_2 for longer periods of time without reversal, spanning several millennia.[3] A popular thought among the scientific community is that anthropogenic CO_2 emissions, which persist in the atmosphere for centuries, must be appropriately removed by removals that store these CO_2 emissions over similar timescales, i.e., via geological storage.[4] Therefore, ambiguity still exists on the applicability of each of these measures and their appropriateness to address residual CO_2 emissions, not just from a net zero perspective, but also from an overall climate neutrality perspective.

There is also ongoing debate about the role of storage mediums that can store CO_2 at shorter timescales. Some have suggested that these types of CDR can be used to counterbalance shorter-lived greenhouse gases, such as methane emissions, compared to the greenhouse warming potential (GWP) of CO_2.[5] For many CDR methods utilizing biological sinks, more clarity is required on establishing baseline emissions before the removal activity and subsequent measurement of the net carbon uptake, as this can be challenging to monitor. Additionally, more clarity is needed on terms like net-zero, carbon neutrality, and climate neutrality, as well as what types of residual emission mitigation measures would be most appropriate to meet the LTAG.

However, CDR is **not meant to be a substitute for deep emission reductions** in a net zero emissions goal, but can rather serve as a complementary strategy to enable short to medium-term targets or to ultimately reach net zero CO_2 and GHG emissions in the longer term. Even now, there are opportunities for the sector to engage through CORSIA, as a market-based measure, with emissions units that incorporate CDR methodologies. In the context of air transport, this means that CDR should act as a **complementary** solution to the other basket of measures. CDR is also unique in that it is not a decarbonization solution that will solely be used by the air transport sector, but it will also be utilized and required in all other sectors that are trying to decarbonize, especially other hard-to-abate sectors, such as steel, cement, and shipping.

Maximizing deep emission reductions

While CDR will be an increasingly important component in addressing residual emissions from the air transport sector, the reliance on CDR, and other similar MBMs, can be reduced by maximizing deep emission reductions using "in-sector" measures (reducing energy use and changing the energy source). To do so requires encouraging innovation in key technologies and the recognition of existing emission reduction measures in emission life-cycle accounting.

Some of the measures to maximize the potential of in-sector emission reductions can be outlined as follows:

- Reducing in-flight energy: Transition to new, more efficient aircraft and encourage further innovation in developing new aircraft and engine types that can maximize emission reductions through efficiency improvements. Historically, every new aircraft generation has been 20% more efficient than the one it replaces.[1]

- Change the energy source: Increase support and faster adoption of hydrogen and battery electric aircraft for at least short-haul flights well before 2050. Based on IATA's estimations, a focus on the transition to hydrogen-powered aircraft (for regional

4 Allen, M.R., Friedlingstein, P., Girardin, C.A.J., Jenkins, S., Malhi, Y., Mitchell-Larson, E., Peters, G.P. and Rajamani, L. (2022). Net Zero: Science, Origins, and Implications. *Annual Review of Environment and Resources*, [online] 47(1), pp.849–887. DOI: https://doi.org/10.1146/annurev-environ-112320-105050.

5 https://roberthoglund.medium.com/how-much-carbon-will-we-need-to-remove-26fda7b5e19a

and narrow-body aircraft) **alone** will displace close to 37 (million tonnes) Mt of fossil jet fuel in 2050. This would reduce the respective residual CO_2 emissions from 117 Mt to 21 Mt if green hydrogen was used, or 40 Mt if blue hydrogen was used, considering life-cycle emissions.[1]

- Encouraging an economy-wide shift to renewables will increase the access and reduce the price of renewable energies for aviation. This will improve the availability and lower the life cycle emissions of aviation fuels, including Power-to-Liquid (PtL) SAF for conventional aircraft and green hydrogen for hydrogen-powered aircraft, both of which use green electricity as inputs. Based on the IATA Net Zero Roadmap baseline scenario, residual CO_2 emissions if only fossil jet were used in 2050 would amount to about 1,940 Mt (baseline scenario, zero SAF or hydrogen use, and no further improvements in aircraft technology beyond 2018-level technology). Implementing only efficiency measures brings this down to 1,820 Mt. Residual emissions could be lowered to 1,120 Mt based on the F2 scenario for SAF deployment in the IATA Net Zero Roadmaps (or the LTAG report), if the emission reduction factor (ERF) of all SAF over its life cycle averaged 60% below the fossil-based jet fuel baseline. This could be further reduced to 546 Mt CO_2 if the ERF of SAF used averaged 90%. It is even lower with the respective type of SAF implemented together with efficiency measures. With the incorporation of hydrogen aircraft and SAF averaging 90% ERF, this is brought even further down to about 330 Mt of CO_2 in 2050 (Figure 1).[1]

Adopt and enable greater recognition of emissions reductions in the lifecycle of aviation fuels through new technologies such as carbon capture and storage (CCS).[6] One study suggested that for a specific alcohol-to-jet (AtJ) facility design, implementing and maximizing deep emission reductions such as using renewable electricity, green hydrogen, and renewable heat can yield CI reductions of the SAF over its life cycle. Particularly, the application of CCS and sustainable farming practices can contribute to large CI reductions that can potentially yield more than 100% emission reductions over a life-cycle basis.[7]

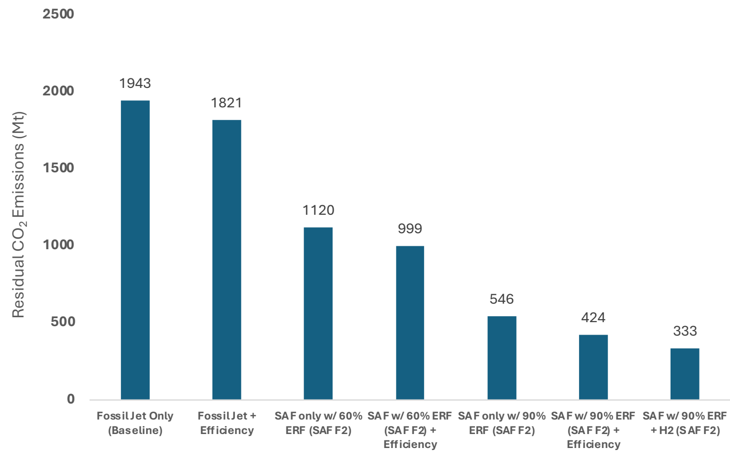

FIGURE 1: Residual CO_2 emissions in 2050, depending on the mitigation strategy used.

In 2050, All the remaining fuel used by aviation from fossil origin should be LCAF.[8]

Future work

Many of the aspects mentioned in this article are core to the work and mission of the ICAO CAEP. Its Working Group 5, Fuels, constantly evaluates SAF pathways and better methodologies to account for their life cycle emissions. CAEP Working Group 3, Emissions Technical, has developed the first-ever CO_2 standard and recently recommended, along with Working Group 1, Noise Technical, a dual stringency standard that should continue to encourage more efficient aircraft entering the fleet. All these groups aim to maximize and improve emission reductions, which will reduce the residual emissions toward 2050. To address the remaining residual emissions that will inevitably be there even after maximizing the potential deep emission reductions to 2050 will be a continued discussion both in the context of CORSIA, in Working Group 4, and the Long-Term Aspirational Work Monitoring and Reporting Task Group (LMR-TG), where progress towards the LTAG will be constantly monitored.

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6 Carbon capture and storage (CCS) refers to, in this case, carbon captured and stored from a particular emitting point source.

7 Yoo, E., Lee, U. and Wang, M. (2022). Life-Cycle Greenhouse Gas Emissions of Sustainable Aviation Fuel through a Net-Zero Carbon Biofuel Plant Design. *ACS Sustainable Chemistry & Engineering*, 10(27), pp.8725–8732. DOI: https://doi.org/10.1021/acssuschemeng.2c00977.

8 LCAF is defined as fossil-based jet fuel that meets at least 10% emissions reductions over its life-cycle (defined as $89gCO_{2e}/MJ$ in ICAO) through measures taken across the oil supply chain such as using renewable electricity and using CCS during refinery operations