IATA
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MEDIA DAYS

Energy Transition

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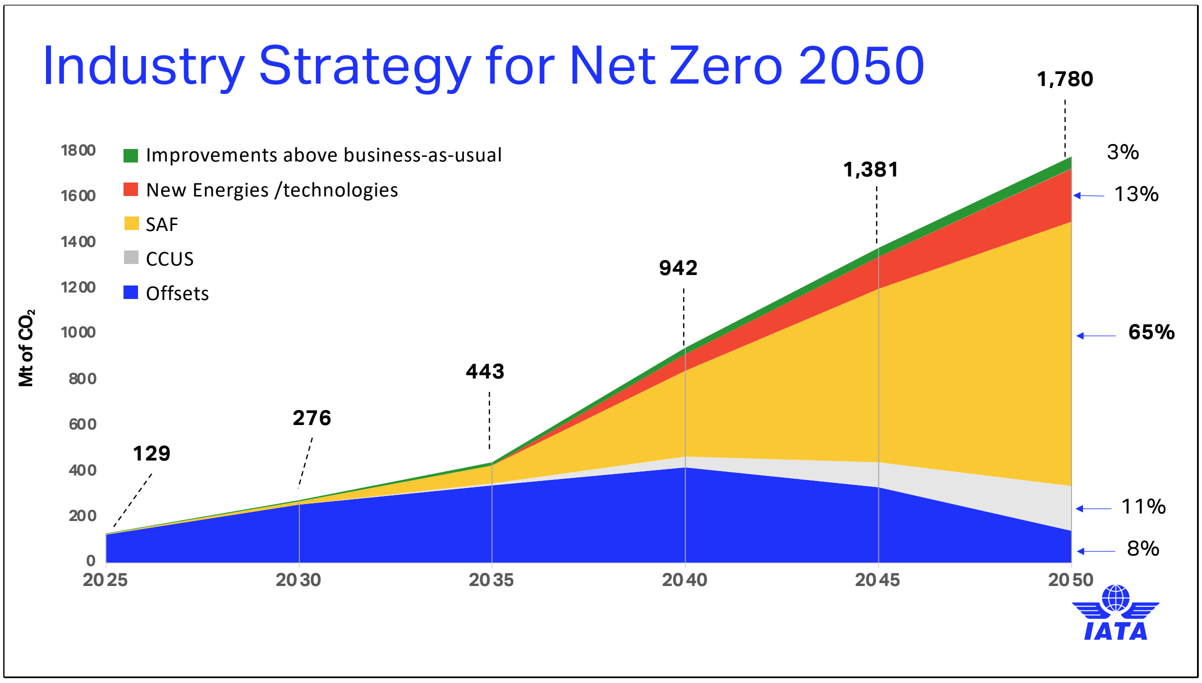
IATA



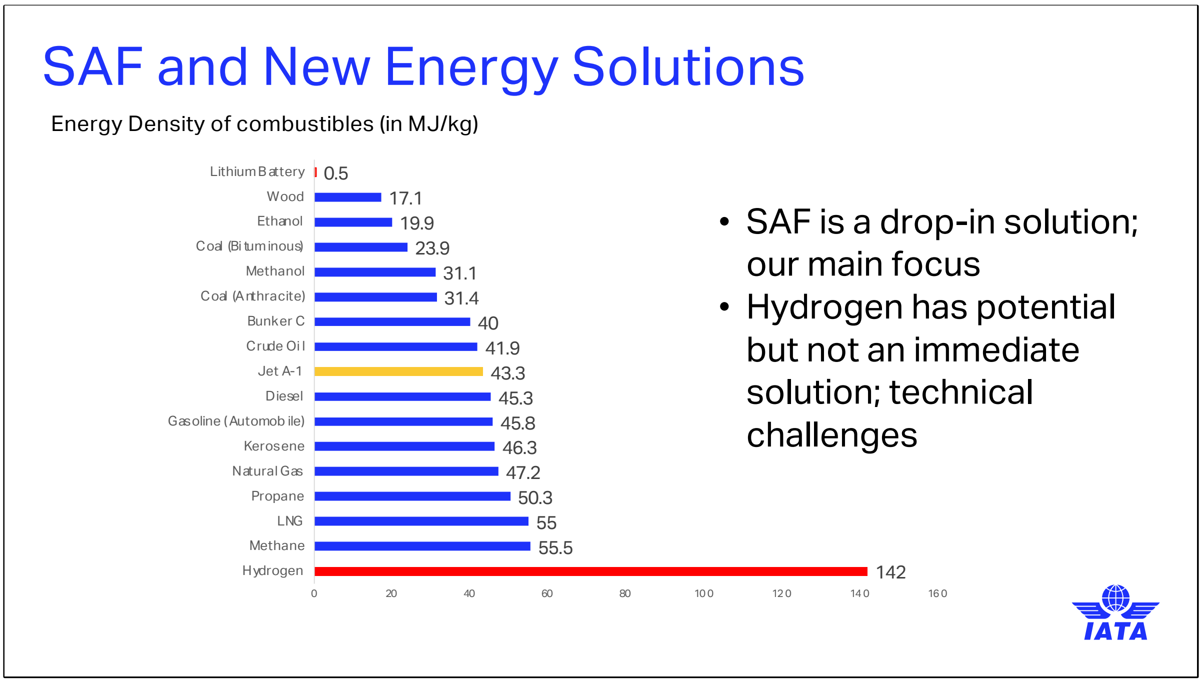
There are many examples of strategies to reach NZ 2050. These may vary across different bodies, NGOs or indeed individual airlines - that is OK because at this stage there is a tremendous amount of innovation and development ongoing and each party may have differing perspectives on how best to reach the goal.

This slide shows the strategy which was used to gain the commitment across IATA members.

- We see Offsets as an energy transition tool. Given the challenges in abating CO2 in aviation, offsets provide a steppingstone until solutions to reduce the carbon impact and decarbonize aviation mature and are scaled up across the globe.
- CUSS (Carbon Capture Utilization and Storage) offers increasing potential and contribution and is probably underestimated here.
- Sustainable Aviation Fuel (SAF) is where we see the most significant contribution to reach Net Zero. By 20250 we are projecting around 65% of carbon abatement though the use of SAF.
- The use of new energies and technologies also provide an increasing share. Although in the near term we are very much focused on the ramp up of SAF, new energies such has hydrogen are likely to play an increasing role from 2035.
- Finally. we have a smaller contribution from improvements beyond business as usual - ie developments we have not foreseen and therefore not modeled in yet.

Two points important to understand:

1) The strategy already has adjustment made for expected improvements in airframe and engine design which will reduce fuel burn. In the same way the strategy also has adjustment made for the possible, long overdue, improvements in Air Traffic Management. Every stakeholder has to play their part.
2) The strategy does not foresee the need for demand management - reaching Net Zero is possible without restrictive policies if all stakeholders work together.



Energy density is really important when looking at energy transition.

Here you can see the relative energy density of combustibles (in MJ/kg).

Conventional fossil based fuel - Jet A1 produces 43.3 MJ/kg. We need that level of energy density to provide a solution for global air transport as we know it. To accelerate the widebody aircraft of 300 tonnes to over 200 km/h over 3 kms.

The great thing about SAF is it is drop in solution - it has the same combustion properties but provides life cycle benefits compared to fossil fossils. We can blend with conventional fuel and still use the exiting fuel distribution infrastructure on the ground as well as existing aircraft systems and engines. It is our key lever to reach net zero and we discuss the ramp up of SAF production in the coming slides

Battery produces far less energy. Even if technological advancements allow a tripling of current capability, battery solutions will still have limited use for aviation and supporting Net Zero.

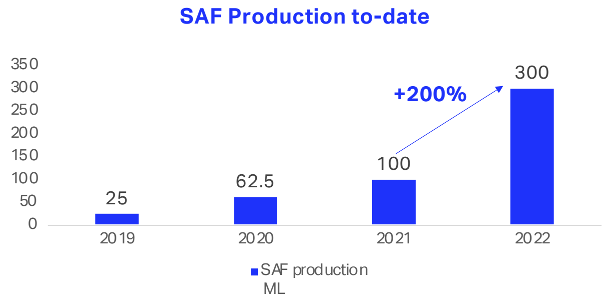
Hydrogen offers a very different solution - it has 3 times the energy density offered by Jet A1 but it does requires 4.5 times as much volume for storage and that's for storage in liquid form which has to be below 250 degrees centigrade. So it present new challenges and opportunities for the decarbonization of aviation. This will also be explored further later in this presentation.

(To convert to kW/hr you divide by 3.6)

Sustainable Aviation Fuel Capacity & Ramp-Up

Insights: 2020-2030

SAF production to-date



SAF Production To-Date

Year	2019	2020	2021	2022e
Estimated SAF Output (Million Liters)	25m L	62.5m L	100m L	**300m-450m L**
Global Jet Fuel Output (Billion Liters)	360	196	227	**317**
SAF % of Global Jet Fuel	<0.01%	0.03%	0.04%	**0.1%-0.15%**

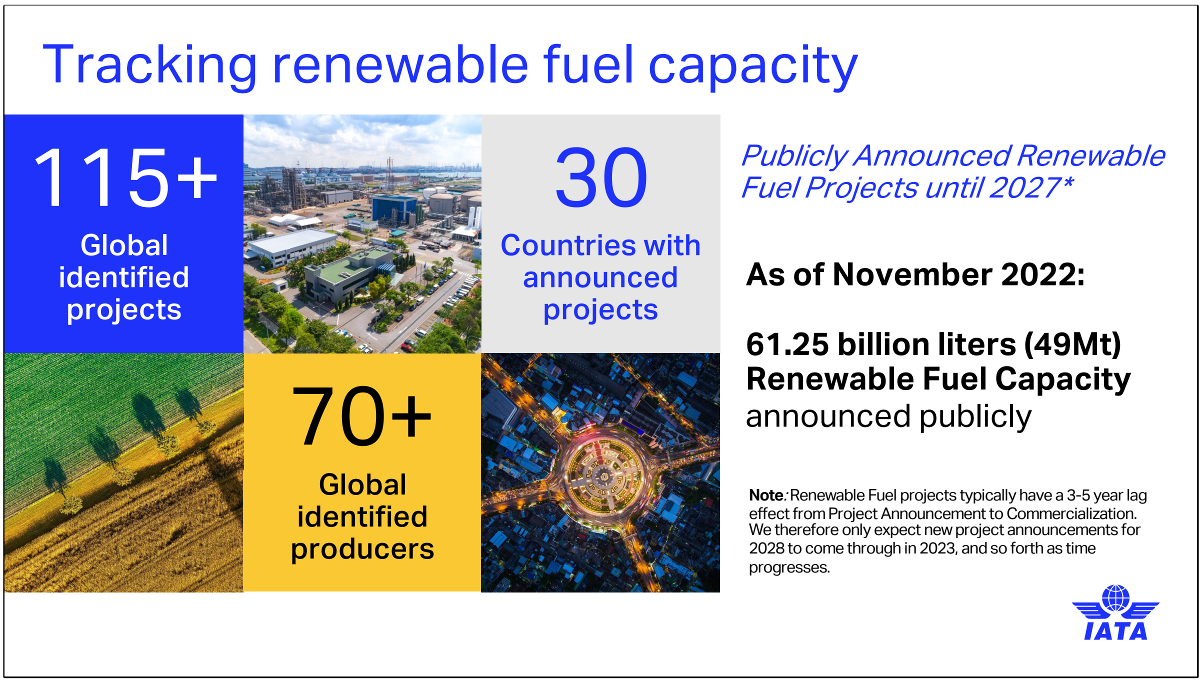
Firstly we are starting from very baseline for the use of SAF. And this is due the limited production capacity we have today.

Last year we have a production of 100 million liters of SAF (80 000 tonnes). This was only 0.04% of total jet fuel uplift.

This year we estimate the production will increase to at least 300 million liters (240 thousand tonnes) which would be 0.1% of total uplift. More optimistic figures predict 450 million liters.

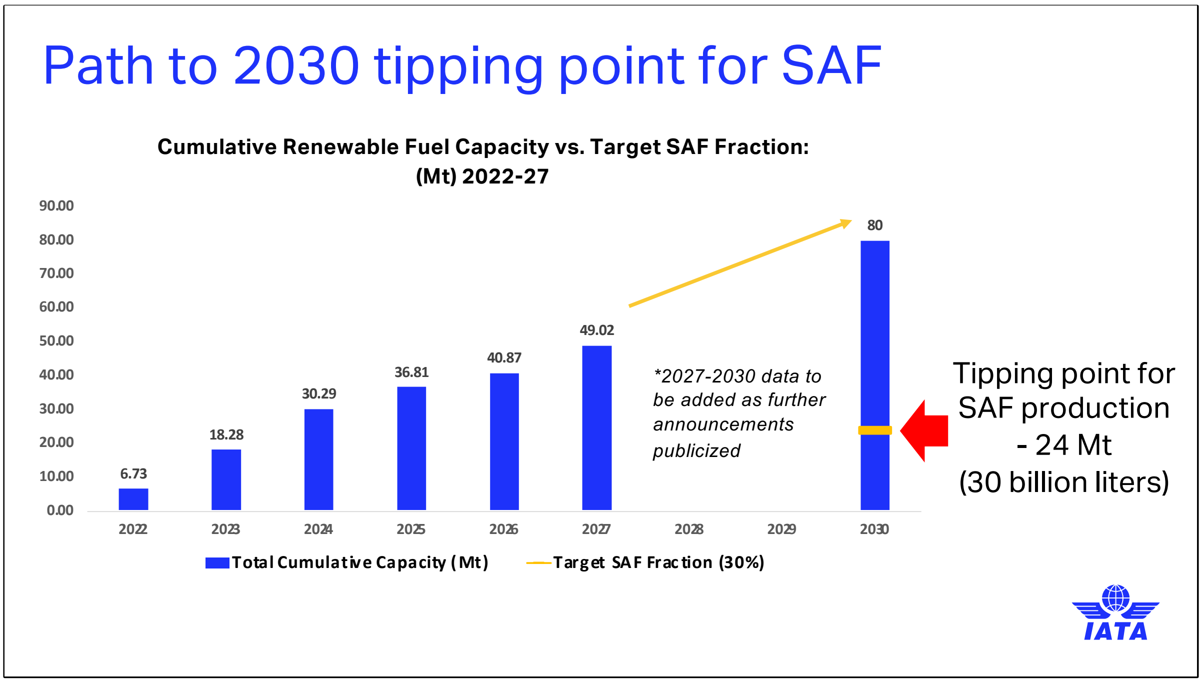
The good news is this represents a minimum 200% increase compared to last year. But of course 0.1 % of uplift means we still have a long way to go.

Airlines used every last drop of available SAF, even at very high prices so what we need urgently is continued production ramp-up



To forecast production development or SAF we need to look at the capacity development for renewable fuels overall. This is because SAF will be cut of the output of a renewal fuel refining process - alongside other renewable fuels such as biodiesel.

According to our research we have been able to identify well over 100 projects around the world – covering 30 countries and over 70 individual producers.



Here we show the overall production capacity development for those projects for renewable fuel

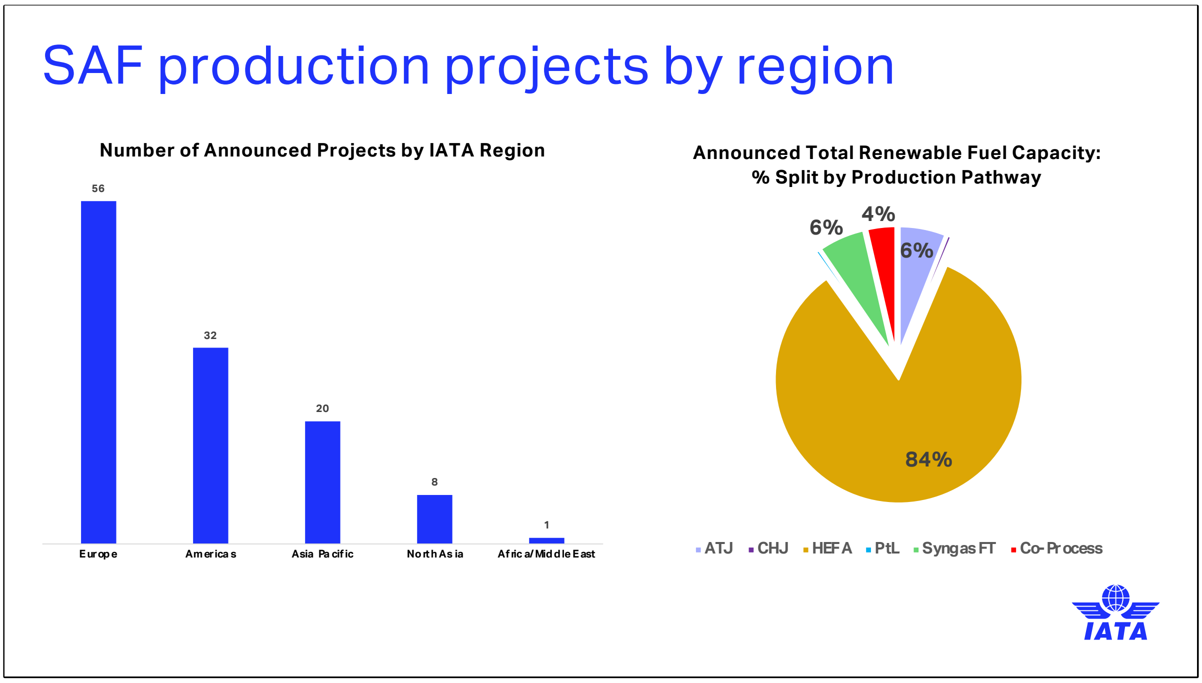
As mentioned, we are looking at a ramp up in capacity development to around 49 million tonnes by 2027.

The good news is when we project that out to 2030, it looks like we are on the right path to be able to generate enough SAF to reach the tipping point we defined at the last AGM in Doha - by 2030 the aviation industry needs to be able to use 24 million tonnes of SAF (30 billion liters).

The %age of SAF shown on the bar for 2030 represents 30% for the overall output from the biofuel refineries and this would be an optimum cut for the refining progress.

All this means the production capacity for renewable fuel and the potential for SAF production in output is forecast to progress well and in alignment with aviation needs.

However, there are some challenges which will need to be addressed.



Firstly, we need to ensure continued the development of the renewable fuel production facilities continue and that there is improved geographic spread.

(capacity forecasts for each project are available)

Secondly, we also need diversification of production pathways. As can be seen from the pie chart, over 80% of the renewable fuel outputs and therefore SAF also will be based on the HEFA (Hydroprocessed Esters and Fatty Acids) which includes for example used cooking oil.

We are looking forward to continued progress on the development other pathways to includes the use of municipal wastes, forestry residues and more solutions for Alcohol to Jet (ATJ).

By 2030 we would expect to see the pie chart much more balanced.

Promising trend for renewable fuel & SAF

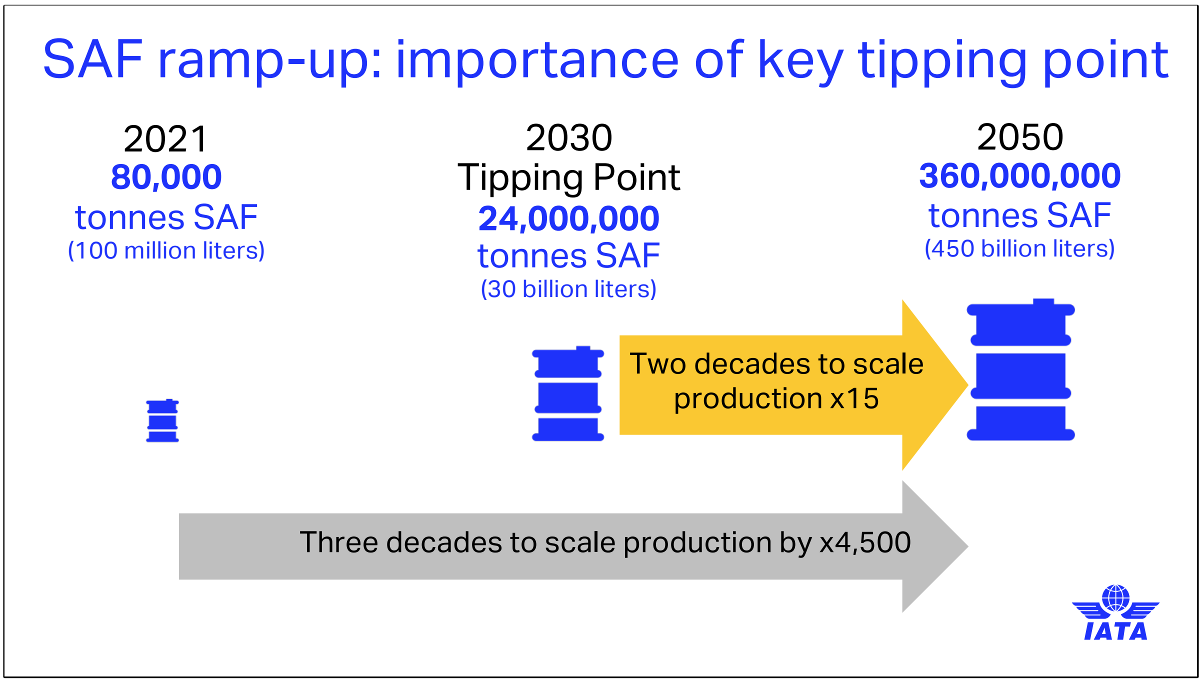
- Between 2022 and 2025, Renewable Fuel Capacity set to grow by over **400%.**
- 80Mt (100 billion liters) Renewable Fuel capacity in 2030
- SAF needs to be 30% of that output - 24 Mt (30 billion liters) in 2030 to reach tipping point

Policy Needs:

- SAF's biggest challenge over the next decade: ensuring that enough SAF will be derived from RF capacity.
- Opportunity cost of producing SAF, relative to renewable diesel, needs to decrease - can be achieved through supply-side, incentive-based policies that support SAF production.

It is essential for aviation to secure its supply of SAF from this growing capacity in renewable fuel. As biodiesel benefits from significant government incentives (even though automobiles have mature electric alternative solutions available),), similar incentive-based supply-side policy measures are needed for SAF.

The needs for aviation should not be ignored and they should make sure there are balanced incentives - or ensure incentives for other renewable fuels do not adversely limit the production of SAF.



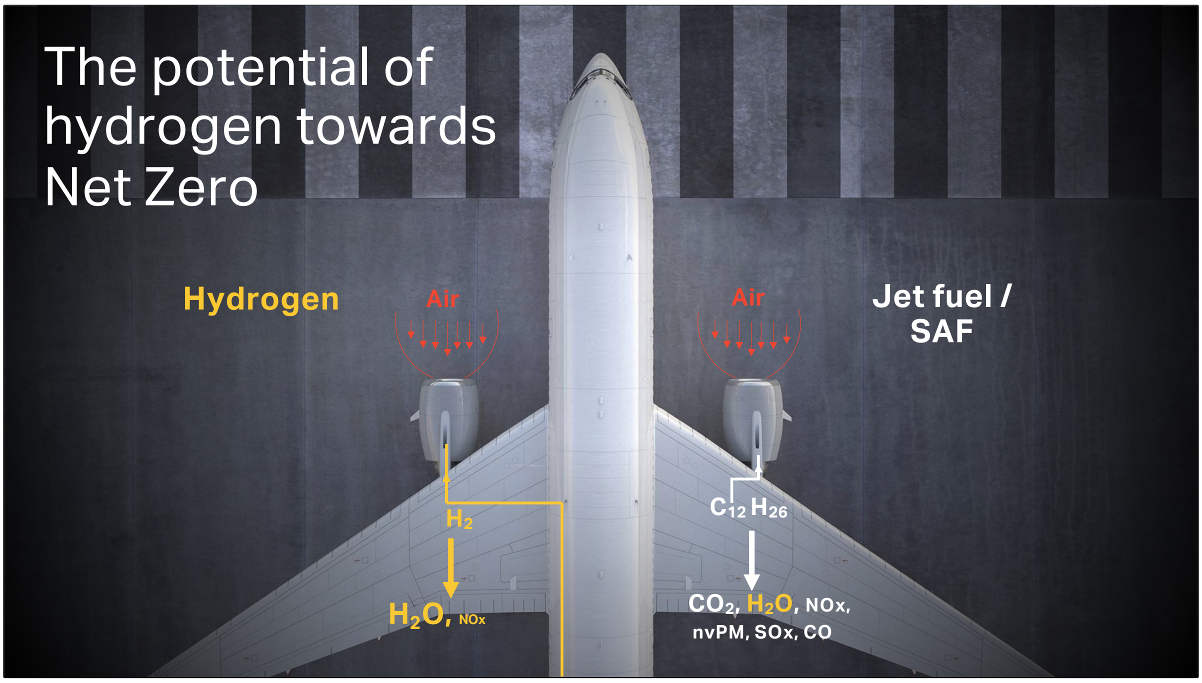
To summarize, we are on the right path reaching the tipping point for SAF in 2030.

This scale up of SAF is essential for our road to Net Zero – and it will mean we will reach a critical volume of SAF by 2030 - 24 Mt or (30 billion liters)

Starting with what we have today (in 2021) we would have to scale up by 4,500 times to reach our 2050 ambition - that is because we are starting from a very low baseline - the numbers seen unsurmountable.

If we reach our 2030 tipping point 24 Mt (30 billion litres) that gives us two decades to scale up 15 fold. Much more reasonable and manageable

We need producers and governments to take action to ramp up renewable fuel production and ensure a sufficient cut of SAF in the output between now and 2030.



We have just covered SAF. SAF is a fuel which when combusted does emit CO2 but it is near carbon neutral over its life cycle due to the feedstock benefits. It is a drop in solution that is ready to be used for aviation today. That is why it is a great net zero solution.

Hydrogen (and we will talk about the use of liquid hydrogen for fuel in this presentation) offers a different solution. But it is clear that SAF will represent the majority share of the decarbonization mix as it is a proven solution that needs to be scaled up.

Hydrogen requirements in context

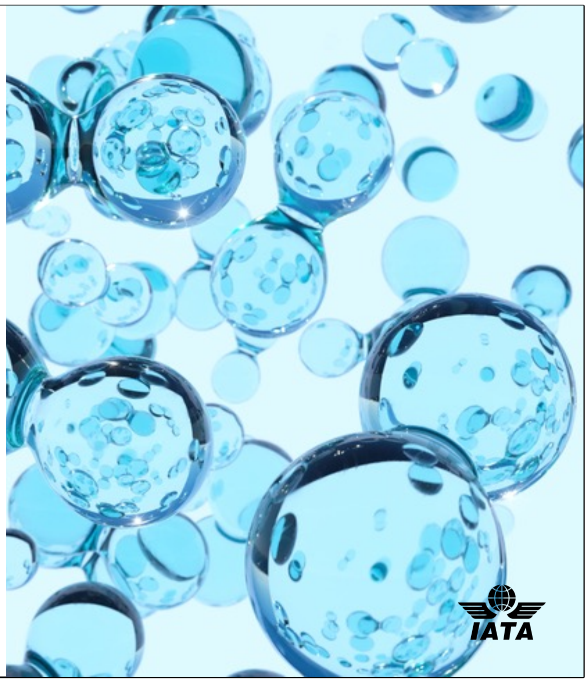
Hydrogen required for SAF (all production pathways) by 2050 **~100+ Mt**

Hydrogen required for hydrogen aircraft by 2050 **~ 20 Mt**

World hydrogen use in 2021**~100 Mt**

IRENA: 2050 hydrogen supply world-wide **~ 600 Mt**

Availability of green hydrogen will be key



So how much hydrogen could aviation use by 2050?

IATA in-line with other recent studies predicts a hydrogen requirement for aviation in excess of 100 million tonnes. This is independent of whether hydrogen aircraft ever exist, as most of this hydrogen (about 100 Mt) will in fact be required to make SAF.

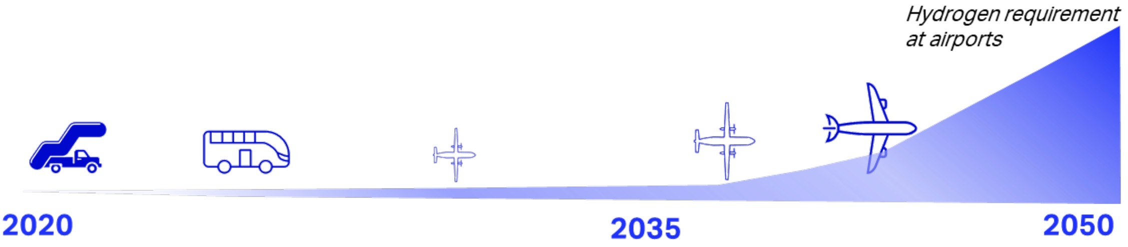
If hydrogen aircraft start entering service in 2030-35, by 2050 these airplanes could require about 20 Mt of H2.

In context, in 2021 there was about 100 Mt of H2 in circulation mainly for oil refining and fertilizers.

By 2050, the world could use about 600 Mt of hydrogen, meaning aviation could use 15-20% of the world's hydrogen production by 2050 but 3 % of that would be for use of H2 as a direct energy source for aircraft propulsion.

Where could hydrogen fit?

- **Today: non-aeronautical applications (GSE**, buses, cars, terminal use)
- **2030:** Ramp-up for small (19-50 pax) **retrofitted aircraft** - paving the way
- **2035+** Scale-up for larger **clean-sheet (100 pax) aircraft**

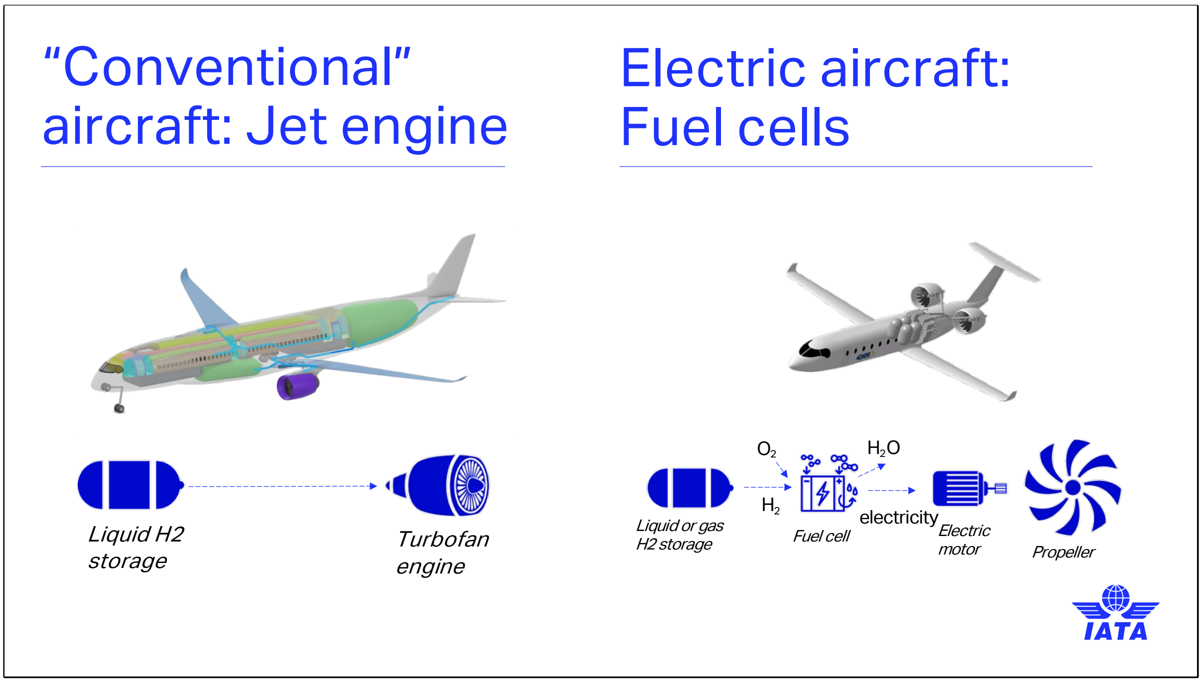


Use of hydrogen is increasing for aviation.

It will not be a switch where suddenly everything goes to hydrogen, we are seeing airports (Kansai, Memphis, Edmonton) already starting to use H2 for non-aeronautical applications.

Retrofitted aircraft with small hydrogen requirements could enter service before 2030, this will be a good learning curve for broader applications

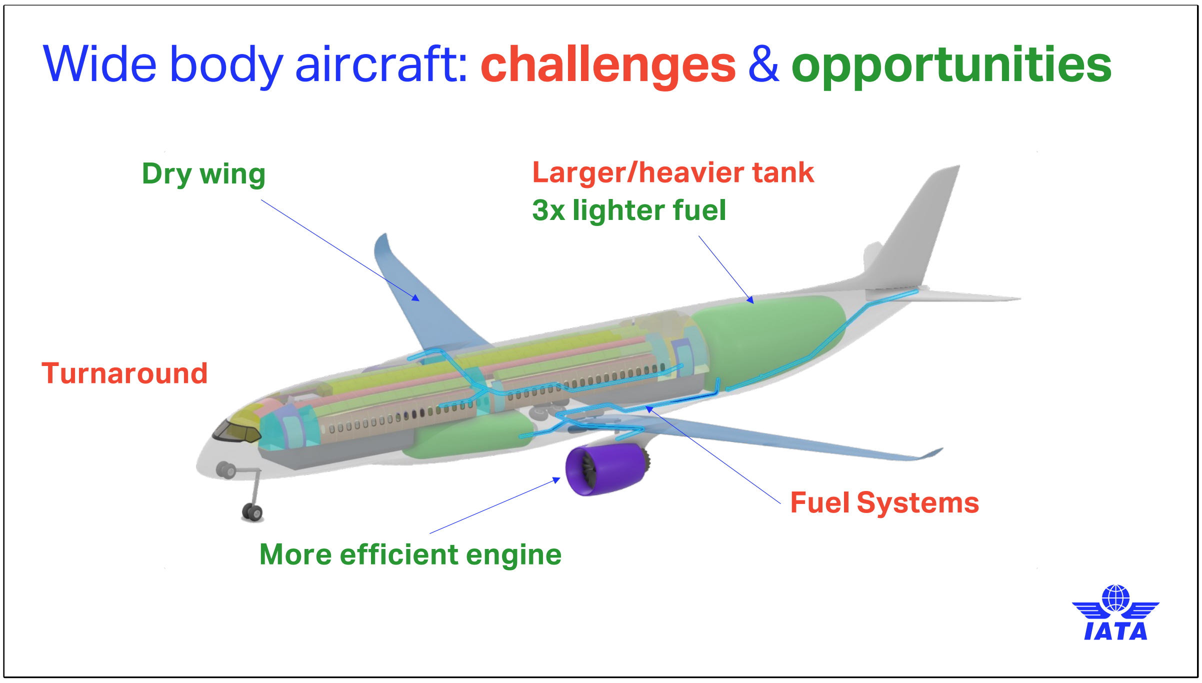
Post 2035, Airbus plans to bring clean-sheet aircraft which could start scaling-up the H2 requirements.



Two ways to use hydrogen to propel an aircraft:

1- similar way to how we use jet fuel today. We can burn it in a jet engine. When we burn it we are able to use existing jet engine technology and propel the aircraft. Rolls Royce just tested an aero-engine running on 100% H2 for the first time (last week).

2- Through a device called a fuel cell. A Fuel cell uses hydrogen and oxygen as an input and produces electricity as an output. This electrical energy can be used to power an electric aircraft, in a similar way the use of batteries (but without the energy / weight limitation). ZeroAvia, Universal Hydrogen, Airbus, and GKN are examples of companies exploring this route today. Last week Airbus revealed its concept for a fuel-cell electric powered aircraft.



From an aircraft design perspective H2 presents challenges and opportunities.

Most challenges have to do with the handling of the hydrogen, this is because it occupies a larger volume but also because it will be stored at very cold temperatures below -250 degrees Celsius.

For this reason, refilling the aircraft will be challenging and very different to how we refuel conventional aircraft.

On the other hand, since the fuel won't be stored in the wings as it is done currently, the wings could be thinner and lighter, providing aerodynamic improvements. The fuel will be about 3 times lighter, since hydrogen contains about 3 times more energy than kerosene.

As mentioned before the fuel contains no carbon so no CO2.

Who is working on hydrogen?

OEMs

$4.5 billion of investment for:

- Technology demonstrators Infrastructure
- Feasibility studies

For **research and development**

15 Airlines

With:

- MoUs
- Investments
- Pre-purchase agreements

For **hydrogen aircraft**

15 Airports

With

- MoUs
- Investments
- Feasibility studies

For **hydrogen infrastructure** on-site

Despite of these challenges, we are seeing all parties involved in trying to solve them.

Notable is the combined investment world-wide from all parties of around $4.5 billion. A lot of this is focused on key critical milestones to be developed. For example, airport feasibility studies, key technology demonstrators (tanks, engines, fuel cells,). Every single large OEM has technology development programs or tests in place to evaluate the use of hydrogen for aircraft.

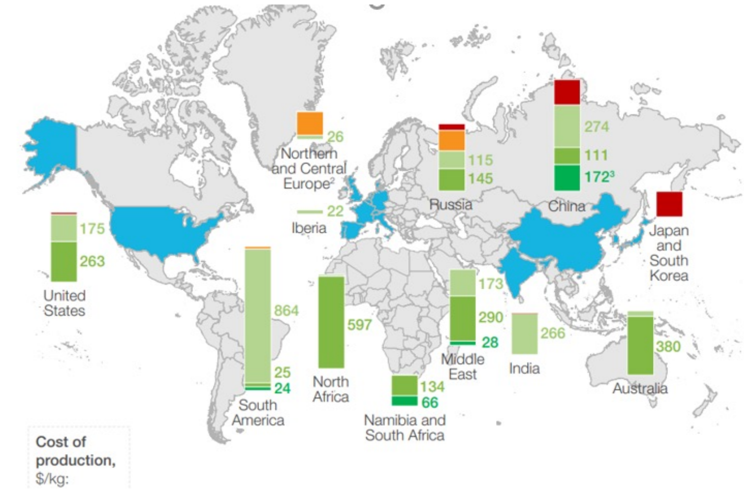
We identified 15 airlines that have expressed interest in hydrogen, either by investing on technology companies, or by signing MoUs with the developers or even trying to solve some challenges. For example, Lufthansa and KLM-Air France have projects in place to solve maintenance and turnaround challenges related to hydrogen aircraft, in partnership with aircraft OEMs.

On the infrastructure side, we tracked 15 airports which are in different stages of development. Some are already using hydrogen for non-aircraft applications, some have made feasibility studies, and some are making hydrogen deployment plans with hydrogen providers and aircraft OEMs.

(15 Airlines: IAG, Alaska, United, Delta, American Airlines, Icelandair, ASL, AvMax, RAVN Alaska, EasyJet, Wizz, Connect, DAT, Air France KLM, Lufthansa)

(15 Airports: Vinci, Edmonton, Schiphol, Rotterdam, Groniegen, Hamburg, Incheon, Changi, Venice, Milan, Toulouse, Bristol, Memphis, London City, Christchurch)

Economics of hydrogen



Hydrogen price expected to go down:

- maturity & scaling up of green hydrogen facilities
- drop in renewable energy prices

However, the cost of hydrogen will depend on the region where it is made:

- lower cost of renewables = lower cost of green hydrogen

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What about the cost of hydrogen?

We forecast a sharp reduction in hydrogen production cost due to the maturity and scaling up of green hydrogen facilities (electrolysers), and the drop in renewable energy which forms more than 85% of the final delivered cost of liquid hydrogen to the aircraft.

The cost of hydrogen will depend on the region where it is made. As the graph shows a region with lower cost of renewables will be more beneficial for hydrogen. The hydrogen council predicts a difference of 2.5 between the cheapest and the most expensive hydrogen, and this again is driven by the conditions of each region to deploy renewables for H2 production.

Hydrogen Summary

Progress but there are significant technical challenges:

- Maturation of critical technologies
- Certification times and requirements
- Scale-up of production meeting aviation hydrogen requirements
- World-wide availability
- Cost of production

Policy Needs:

- Government policies / national strategies for H2 need to integrate aviation needs

As mentioned before many of the technologies to enable hydrogen aircraft don't exist today, or don't exist for aviation applications- all these need to be designed, validated, tested and certified. This will take some years of work and necessary financial resources.

Scale-up of hydrogen and to address aviation requirements will be necessary but when we consider the use of hydrogen for aircraft propulsion only, it is only 3% of the forecast global supply by 2050

World-wide availability of hydrogen. Today 100 Mt of hydrogen is used but not traded, mostly used on-site.

We can expect a sharp reduction in hydrogen cost

Government policies and hydrogen strategies will certainly be a strong enabler for all this. Aviation must be considered in different country plans for hydrogen and renewables scale-up

Summary

Good progress but continued action required across all stakeholders:

- Energy Transition for aviation requires continued action on all fronts:
  - SAF, New energy, Carbon Capture, Credible Offsets, also ATM, airport, aircraft/engine efficiency improvement
- SAF Ramp-up projections are promising to 2030
  - Can reach 30 billion liter (24 Mt) tipping point with supplier / government policy support. Diversification in pathways is important.
- Interest in propulsion solutions using hydrogen is growing
  - Could present operational benefits from 2030 to support aviation decarbonization and needs to be considered in national strategies

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Thank you

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