



DESTINATION  
2050

# A ROUTE TO NET ZERO EUROPEAN AVIATION

EXECUTIVE SUMMARY &  
INDUSTRY COMMITMENTS



## Destination 2050 – A route to net zero European aviation

### Preface

Aviation has brought enormous benefits to European society and its economy. It has allowed people to visit other cities and countries and facilitated the transport of goods in ways that previous generations could only have dreamed of. Passenger traffic has enjoyed remarkable growth over the last ten years, reaching a total of over 11.1 million movements in the 44 European countries of the ECAC area<sup>1</sup> in 2019.

Yet with this growth, the role of aviation and its environmental impact are now the subject of greater scrutiny in society, most notably in relation to carbon emissions. While climate change already had a high profile in Europe, the entry into force of the Paris Agreement undoubtedly contributed to pushing this to the top of the political agenda. Recognising this, the current College of European Commissioners (2019-2024) led by Commission President Ursula von der Leyen has said that making Europe the first climate-neutral continent will be the '*greatest challenge and opportunity of our times*' and with it, her Commission's number one priority as laid out in the European Green Deal.

It is right to expect the aviation sector to meet its responsibilities in this regard. Aviation accounts for around 2-3% of CO<sub>2</sub> emissions globally, and 4% in Europe. While the fuel efficiency of aircraft operations has been improving by an average of over 2% per year between 2009 and 2019, we acknowledge that further action is needed to bring down the absolute level, even if traffic levels increase. We must do this in an ambitious way in order to meet the EU's goal of net zero CO<sub>2</sub> emissions by 2050. We believe that this is desirable and should be achievable – not only for European society and the economy as a whole, but also for the aviation industry and future generations of travellers.

Our five associations, representing aircraft manufacturers, airlines, airports and air navigation service providers in Europe, have therefore come together to plan a route to achieve this – an initiative we have called "Destination 2050" to reflect our common end goal. Recognising that the whole European air transport ecosystem must act together decisively, our intention is to identify the measures which our members can apply to achieve this decarbonisation collectively. In some cases these may be new measures, while in others there may be existing programmes that need to be approached in a new and better way.

We asked the Netherlands Aerospace Centre (NLR) and SEO Amsterdam Economics to support us in providing a scientific basis for this project. They have identified measures across four pillars which are presented in this report:

- 1. Aircraft and engine technology**
- 2. Air traffic management and aircraft operations**
- 3. Sustainable Aviation Fuels**
- 4. Smart economic measures**

*Destination 2050* does not describe the only pathway to net zero CO<sub>2</sub> emissions. Assumptions may change and other factors and opportunities may enter into the equation, such as the role of intermodal travel. Equally, the report does not address the financing of the tremendous effort required for a socially compatible transformation that ensures European citizens' and businesses' connectivity.

The impact of the COVID-19 pandemic and its negative consequences for aviation have been a complicating factor in producing this report, but we do not see the downturn in traffic since March 2020 or the higher profile

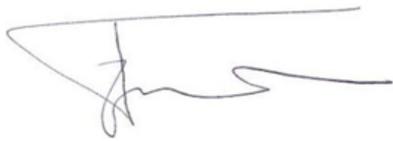
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<sup>1</sup> See <https://www.ecac-ceac.org/member-states>

of the crisis as an excuse for inaction. Once passenger traffic has returned to 2019 levels, we expect the number of flights to resume its upward trend. The time to start implementing our plan is now.

The undersigned five associations have used the conclusions of this report to develop a set of commitments, representing our contribution to the EU Pact for Sustainable Aviation, a forthcoming initiative resulting from the *Round Table Report on the Recovery of European Aviation*<sup>2</sup> (November 2020). In fact, we cannot undertake this decarbonisation journey on our own. To be successful, we will need support from European and national policy makers to create the right policy frameworks and, in some cases, to provide financial assistance to develop and apply new technologies. We take the lead but call on policy makers to play their part, as well (both at a European and worldwide level) to help our industry achieve its climate goals.

Together we are confident that we can find a route to net zero European aviation.



**Thomas Reynaert, Managing Director, Airlines for Europe (A4E)**



**Tanja Grobotek, Director Europe Affairs, CANSO (Civil Air Navigation Services Organisation)**



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**Olivier Jankovec, Director General, Airports Council International-EUROPE (ACI)**



**Jan Pie, Secretary General, Aerospace & Defence Industries Association of Europe (ASD)**

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<sup>2</sup> See: <https://canso.org/eu-aviation-maps-a-sustainable-post-crisis-future-in-round-table-report/>

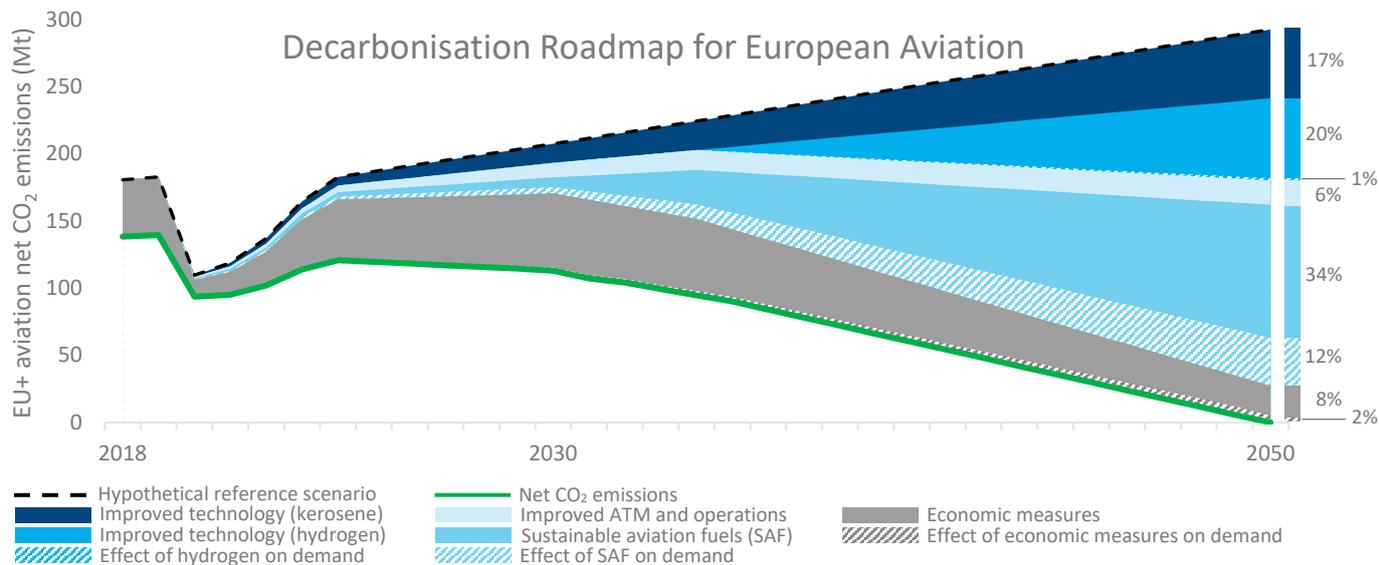
## Destination 2050

Net zero CO<sub>2</sub> emissions<sup>1</sup> from all flights within and departing from the EU<sup>2</sup> can be achieved by 2050 through joint, coordinated and decisive industry and government efforts. The European aviation industry is committed to reaching this target and contribute to the goals set in the European Green Deal and the Paris Agreement. Destination 2050 shows a possible pathway that combines new technologies, improved operations, sustainable aviation fuels and economic measures. Absolute emissions are reduced by 92%, while the remaining 8% is removed from the atmosphere through negative emissions, achieved through natural carbon sinks or dedicated technologies.

Royal Netherlands Aerospace Centre and SEO Amsterdam Economics conducted this study commissioned by the representatives of European airports, airlines, aerospace manufacturers and air navigation service providers. It assesses to what extent four groups of sustainability measures are able to reduce carbon emissions until 2050, strongly influenced by policies and actions. The effects of these measures are compared to a hypothetical reference scenario taking into account continuous demand growth and the recent COVID-19 impact. These sustainability measures result in the following net CO<sub>2</sub> emissions reductions in the year 2050:

- 111 MtCO<sub>2</sub> through improvements in aircraft and engine technology:
  - 60 MtCO<sub>2</sub> by hydrogen-powered aircraft on intra-European routes and
  - 51 MtCO<sub>2</sub> by kerosene-powered or (hybrid-)electric aircraft;
- 18 MtCO<sub>2</sub> through improvements in air traffic management (ATM) and aircraft operations;
- 99 MtCO<sub>2</sub> through using drop-in sustainable aviation fuels (SAF);
- 22 MtCO<sub>2</sub> through economic measures (carbon removal projects only).

The combined cost of these sustainability measures is modelled to impact ticket prices, resulting in a lower air travel demand. This would avoid 43 MtCO<sub>2</sub> whilst maintaining an average compound annual passenger growth rate of 1.4%.



Results are presented for all flights within and departing from the EU region<sup>2</sup>. Improving aircraft and engine technology, ATM and aircraft operations, SAF and economic measures all hold decarbonisation potential. Modelled for 2030 and 2050, the impacts are linearly interpolated. The base year for this study is 2018.

<sup>1</sup> While acknowledging that aviation is also responsible for non-CO<sub>2</sub> climate impacts, the scope of this study is limited to a quantitative assessment of CO<sub>2</sub> emissions. Further study is required to develop a roadmap to take these non-CO<sub>2</sub> emissions into account.

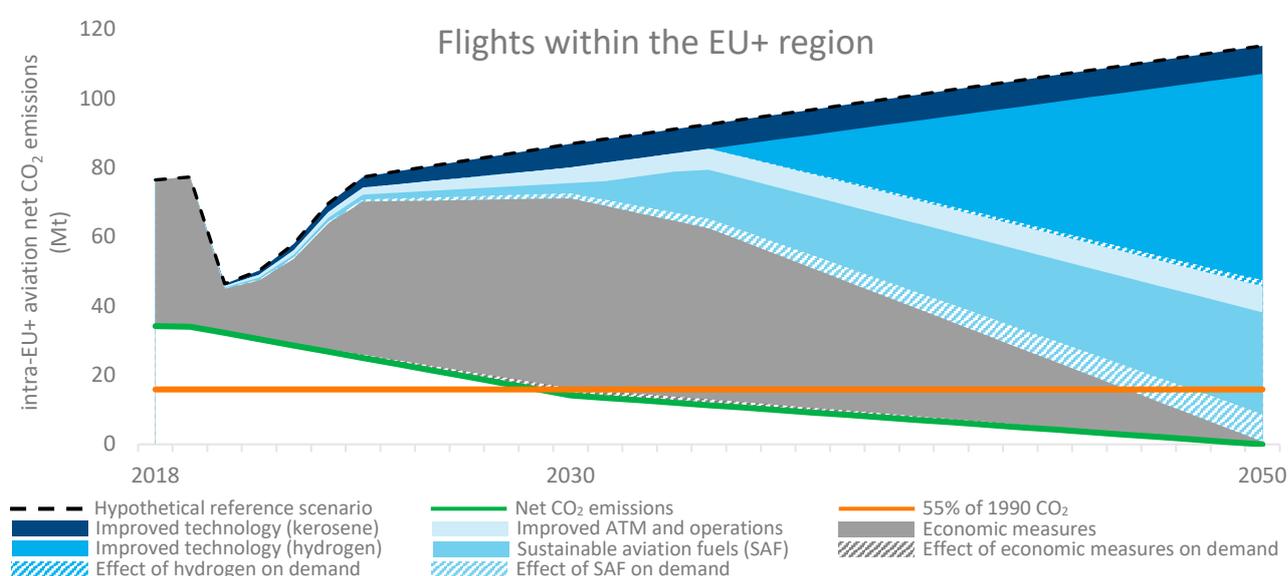
<sup>2</sup> Specifically, the European Union (EU), the United Kingdom (UK), and the European Free Trade Association (EFTA).

## A pathway to 2050

Implementing these measures **could make 2019 the peak year in absolute CO<sub>2</sub> emissions** from European aviation, thereby surpassing the industry target of carbon neutral growth from 2020 onwards. In the year 2030, net CO<sub>2</sub> emissions are reduced by 45% compared to the hypothetical reference scenario as a result of continued fleet renewal, improvements in ATM and aircraft operations and a substantial reliance on economic measures. Compared to the CO<sub>2</sub> emissions in the year 1990, on which European Green Deal targets are based, this however means a 36% increase of net CO<sub>2</sub> emissions from European aviation. This is due to the fact that most substantial emission reductions measures – a next generation of aircraft and substantial uptake of sustainable aviation fuel – take more time to materialise. It is nonetheless **essential that the foundations for post-2030 reductions are laid in the coming years**, to realise net zero CO<sub>2</sub> emissions in 2050 and reduce reliance on economic measures.

## A detailed look at flights within the EU

For flights within the EU<sup>2</sup>, the results highlight that net zero CO<sub>2</sub> emissions in the year 2050 can be achieved with **close to zero economic measures**. The largest contribution is made by **hydrogen-powered aircraft introduced in 2035** followed by sustainable aviation fuels. Net emissions can be limited to **13 MtCO<sub>2</sub> in the year 2030, estimated to be 55% below the emission levels in 1990** and thereby contributing to the implementation of the European Green Deal.



*Intra-EU<sup>2</sup> only. Modelled for 2030 and 2050, the impacts are linearly interpolated. The base year for this study is 2018.*

## Recommendations to industry and government

The measures leading to net zero CO<sub>2</sub> emissions from European aviation need to be realised through **collective policies and actions by governments and industry**. Both should work towards **global commitment to a net zero carbon future for aviation**, to avoid differentiated policies, carbon leakage and transfer of activity. Europe should maintain and evolve its leading position in sustainable aviation by the following policies and actions:

### Industry should

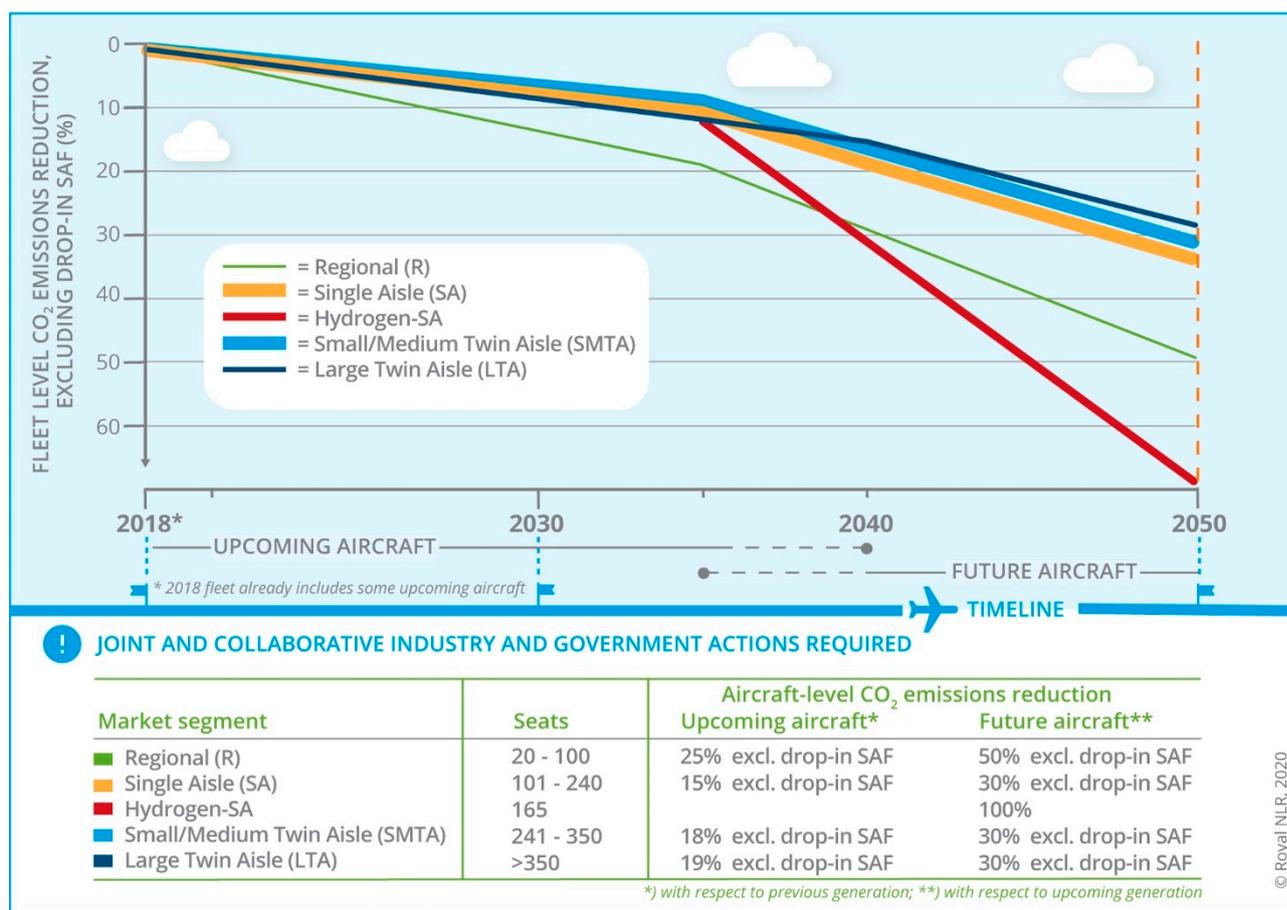
- Continue to substantially invest in decarbonisation
- Develop more fuel-efficient aircraft and bring these into operation through continued fleet renewal
- Develop hydrogen-powered and (hybrid-)electric aircraft and associated supporting (airport) infrastructure and bring these into the market
- Scale up drop-in SAF production and uptake
- Implement the latest innovations in ATM and flight planning
- Compensate remaining CO<sub>2</sub> emissions by removing carbon dioxide from the atmosphere

### Governments should

- Support industry investments by direct stimuli or by reducing investment risk through a consistent and long-term policy framework
- Stimulate further development and deployment of innovations by funding research programmes and promoting carbon removal technologies
- Work with the energy sector to ensure sufficient availability of renewable energy at affordable cost
- Support the development of the SAF industry
- Contribute to optimising ATM, in particular by fully implementing the Single European Sky

## Improvements in aircraft and engine technology

By 2050, improvements in aircraft and engine technology and subsequent **fleet replacement** hold the largest promise for decarbonising European aviation. This includes the **introduction of a hydrogen-powered single-aisle aircraft on intra-European routes in 2035**. The generation of commercial passenger aircraft to be developed in the next 10 years has potential to realise a **step-change in energy efficiency**. Introduced from 2035 onwards, these aircraft types are forecast to reduce fuel burn by 30% or more per flight compared to predecessors. Range and capacity optimised **hybrid-electric** regional aircraft are anticipated to bring down CO<sub>2</sub> emissions by 50% per flight in that market segment. Future small aircraft and rotorcraft, introduced from 2030, may become drivers for larger aircraft development.



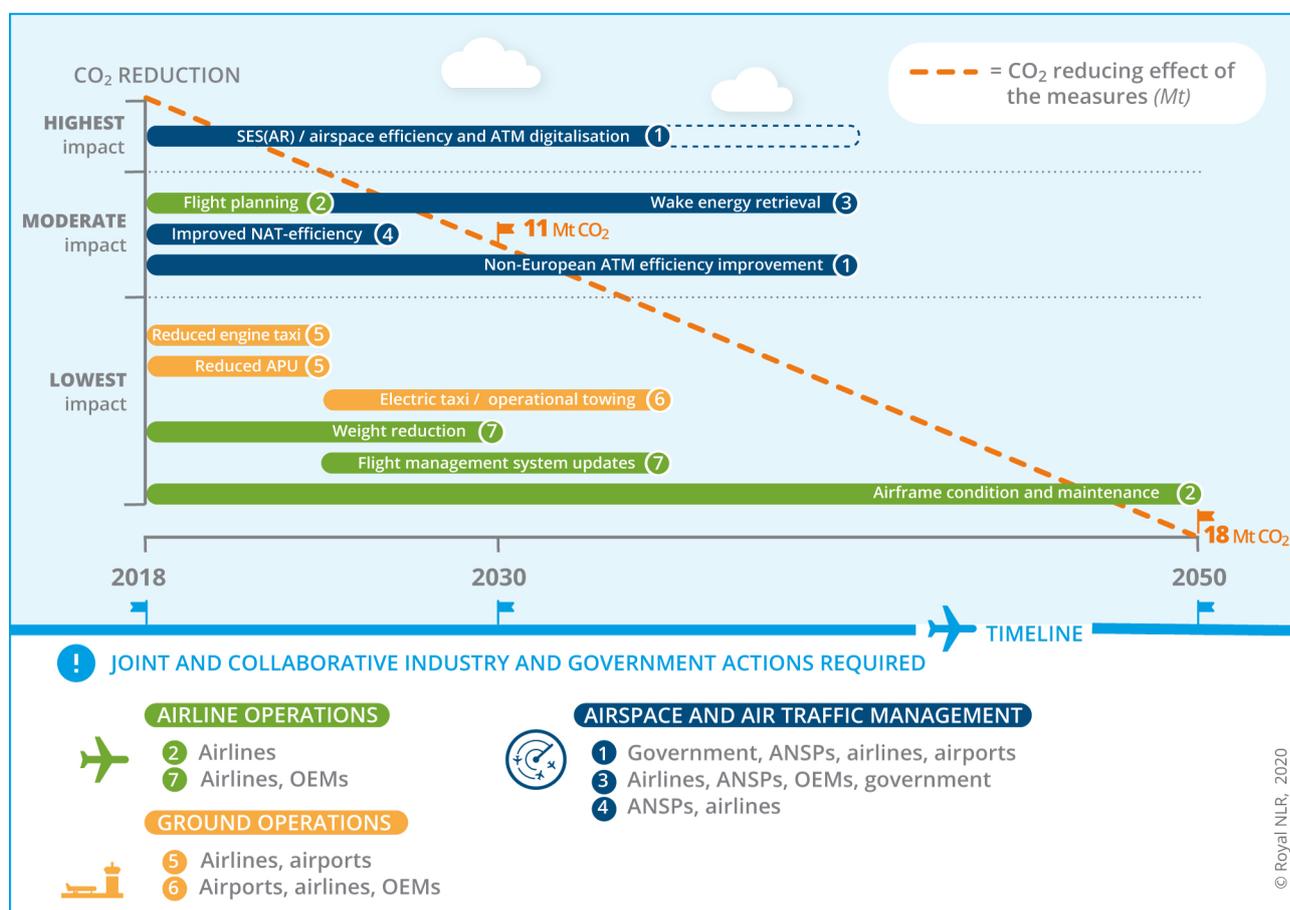
Continued replacement of current aircraft with upcoming models would reduce emissions until 2040. Next-generation future aircraft would yield aircraft-level CO<sub>2</sub> emissions reduction of 30 to 50% compared to upcoming aircraft types. Specifically for the intra-European market, a hydrogen-powered aircraft would enable zero-CO<sub>2</sub> flight. At fleet level the CO<sub>2</sub> emissions reduction by upcoming and future aircraft reaches levels of 28 to 67% in 2050.

**Future aircraft availability by 2035 requires technology readiness by 2027 to 2030.** The proposed Partnership for Clean Aviation provides a well-structured stimulus framework to realise this. A **collaborative research programme should also address more disruptive technologies modelled in this study**, such as hydrogen-powered or other zero-CO<sub>2</sub> emission aircraft. Collaboration and cross-pollination with other European and national R&D programmes and instruments should be ensured. New technologies should be swiftly incorporated in commercial products, helped by **efficient new certification for disruptive technologies**. Additional improvements should be delivered by accelerating previous R&D results for market uptake, through new product offerings or upgrades to in-production aircraft. Expedited replacement of older aircraft by state-of-the-art models may realise CO<sub>2</sub> emission reductions even earlier.

Besides substantially reducing fuel consumption and fostering green technologies by design, the policies and actions recommended in this roadmap would more firmly **establish the European aviation sector as leading the way towards sustainable aviation**. With environmental concerns intensifying around the world, this offers Europe an important first-mover advantage.

## Improvements in air traffic management and aircraft operations

Improvements in ATM and aircraft operations are estimated to be a **crucial opportunity to reducing CO<sub>2</sub> emissions in the short to medium term**. Ensuring full and complete implementation of most measures by 2035 at the latest would, furthermore, allow such benefits to continue yielding impacts between 2035 and 2050.



An array of improvements in ATM and aircraft operations yields a 5 to 6% system-level CO<sub>2</sub> emissions reduction in 2030 and 2050 compared to the reference scenario. Requiring actions from all industry actors and governments, most of these improvements could be realised by 2035. Within each of the three groups (highest / moderate / lowest impact), the measures have not been sorted according to impact.

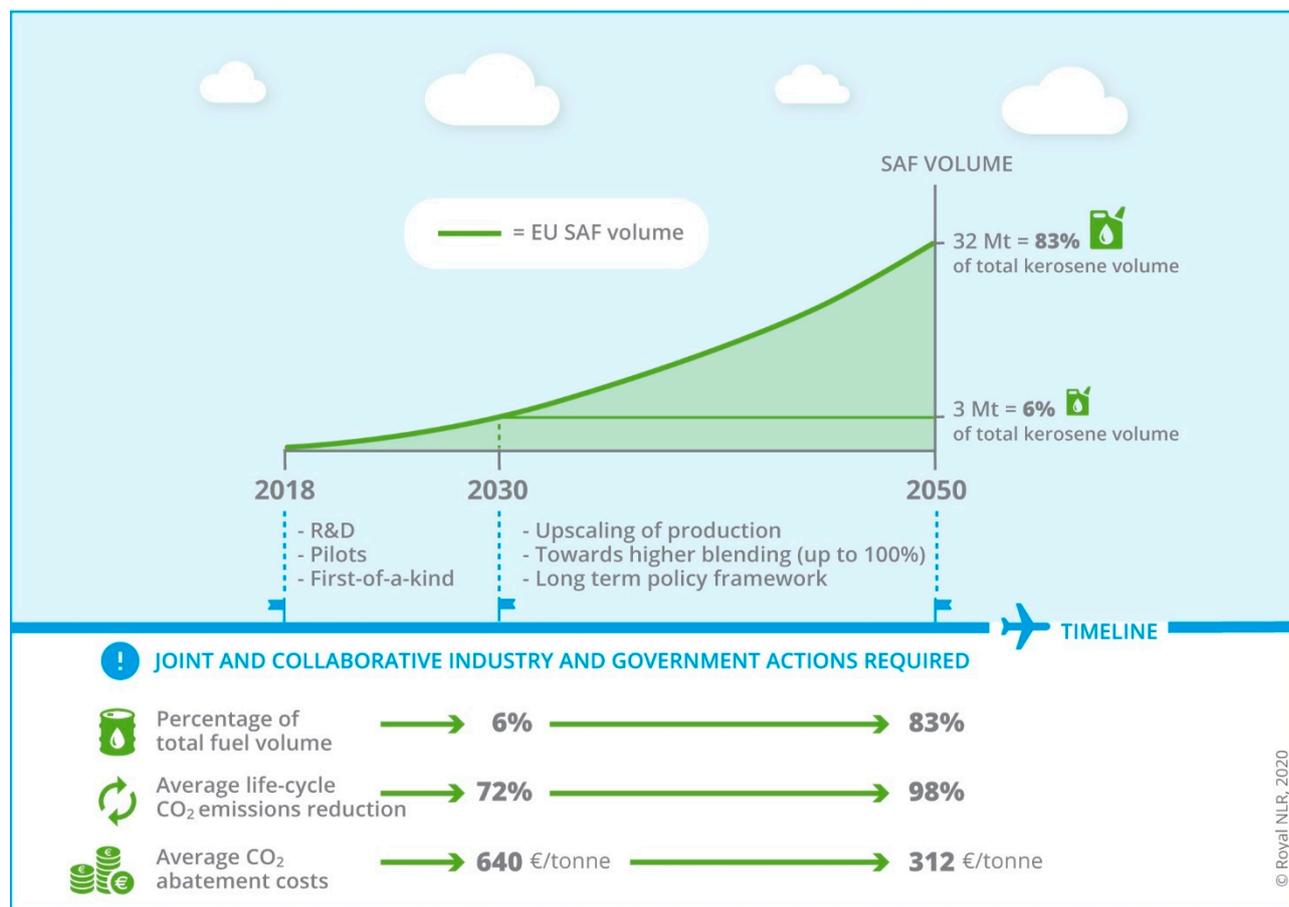
For Europe's residents and visitors to enjoy the full benefits of the Single European Sky, it is **imperative to move more towards a network-centric and digital ATM system and requires political willingness to implement many of the SESAR solutions**. Regulation and R&D efforts must optimally support that goal. First and foremost, such a system would include a renewed set of KPIs with clearly defined accountabilities; a seamless upper airspace; and an R&D policy ensuring steady progress of new technology development and deployment. Better quantifying **the anticipated benefits following from fuel and CO<sub>2</sub> optimized routing** are near-term priorities.

Innovation in communication, navigation and surveillance equipment and processes should also be encouraged, such that these can be swiftly put into practice. Beyond SES and SESAR, European governments and industry should **globally stimulate regions and States to improve ATM efficiency**.

Finally, regulations and incentives should **enable and encourage the rapid decarbonisation of ground operations**. Electric operational towing or taxiing solutions should be developed for all common aircraft and, when parked, aircraft should use renewable energy. Along with possibly stimulating or supporting companies to make such investments, European governments have a crucial role to ensure the supply of renewable energy can match its increased demand.

## Sustainable aviation fuel

SAFs deliver a **major contribution** to achieving net zero carbon emissions in 2050. The supply of SAF may increase from 3 Mt in 2030 to 32 Mt in 2050, equal to **83% of the total kerosene consumption**. The SAF contribution is directly linked to the development of industrial production capacity and strongly influenced by a supporting long-term policy framework. SAF contribution in 2030 may be increased if a strong political support is given to SAF development. Over time, life-cycle CO<sub>2</sub> reduction increases to nearly 100% while production costs decrease.



Over time, SAF production volumes and life-cycle CO<sub>2</sub> reductions increase while production costs decrease.

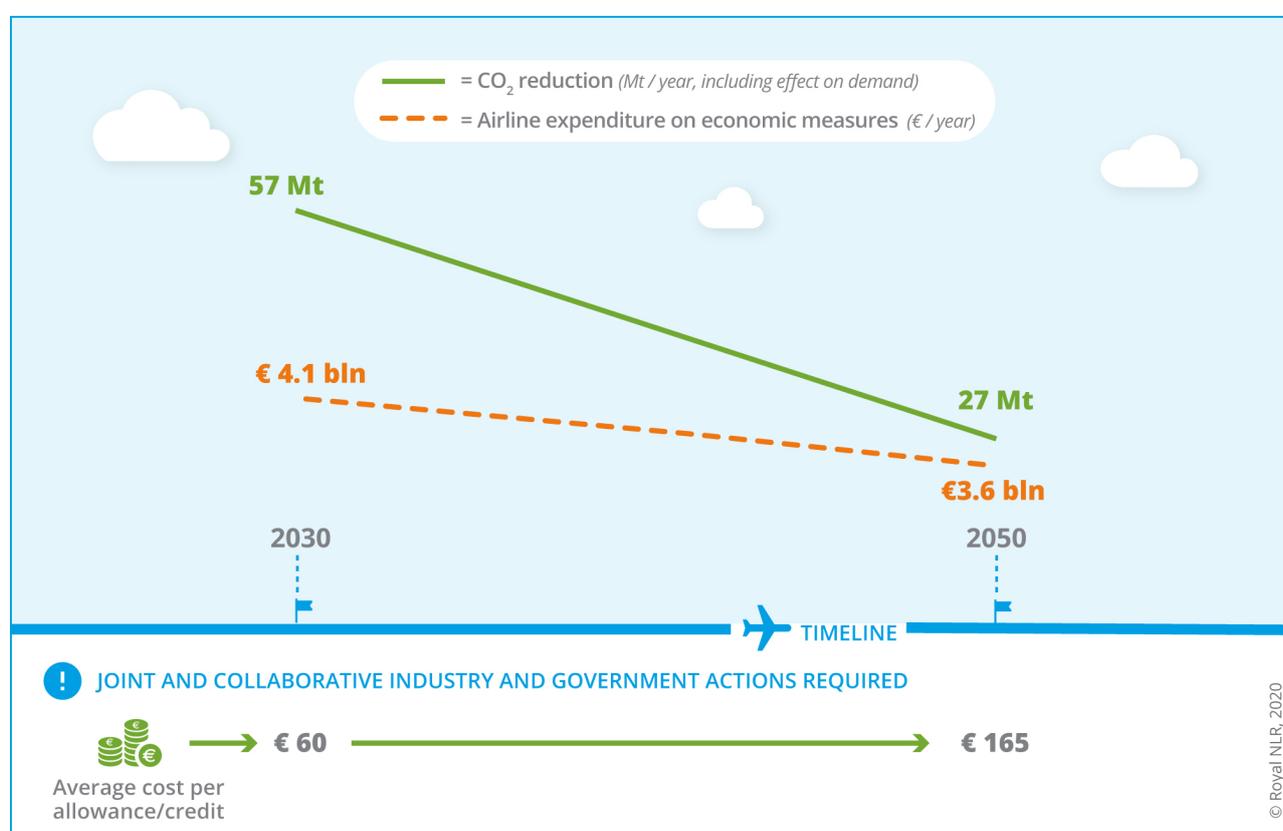
Crucial steps must be taken to **scale up and commercialise SAF deployment**. While making **robust and transparent sustainability criteria** the foundation of a long-term policy framework, a **diversified and sustainable feedstock base** should be established. This would combine biofuels from wastes, residues and non-food (lignocellulosic) crops as well as e-fuels from renewable electricity and CO<sub>2</sub> sourced from direct air capture. Multiple production pathways should be tested in pilot and first-of-a-kind facilities. This increases technological learning, reduces risk and decreases production costs. If the price gap with fossil fuels is overcome, SAFs could fulfil the entire kerosene demand from intra-European flights, necessitating increasing the blending ratio allowed by **ASTM certification from 50% currently to 100%**.

To effectively address the price difference with fossil fuel throughout the value chain and thereby make SAF more affordable, policies need to include measures to de-risk investments and boost production and off-take. These measures could include financial incentives (e.g. carbon pricing, subsidies, auctioning mechanisms and capital grants) and regulatory measures such as the implementation of an **EU wide blending obligation**. The timing and conditions for implementing these measures are currently being investigated in ReFuelEU Aviation. To further reduce cost and increase emissions reductions, a transparent **monitoring and accounting framework** should be implemented, similar to the framework for renewable electricity. This would give airlines the possibility to claim the use of SAF in the most economically efficient way across the fleet, regardless of where SAF has been physically uplifted.

## Economic measures

In the short term, smart economic measures are central in the reduction of carbon emissions from aviation. Such measures assign a price to CO<sub>2</sub> emissions ensuring that airlines take climate costs explicitly into account in their business decisions. **To ensure cost-effectiveness, economic measures must be market-based.** The European Emission Trading Scheme (EU ETS) is the mechanism that is implemented in Europe and which is complemented by the ICAO CORSIA scheme for international flights. They trigger the acceleration towards the energy transition and **bridge the gap until breakthrough technologies and SAFs become widely available.** By 2030, economic measures are expected to reduce net CO<sub>2</sub> emissions by 27% compared to the reference scenario.

Over time, breakthrough technologies and the use of SAF reduce the role of economic measures. The price of allowances and carbon credits will increase as they become increasingly scarce. This will eventually lead to a price whereby carbon removal projects become economically attractive to investors. In 2050, any remaining emissions can therefore be balanced by **carbon removal projects**, which are assumed to lead to the issuance of additional emissions allowances and carbon credits. A global approach is critical to prevent market distortion and carbon leakage.



Smart economic measures are a key mechanism to reducing carbon emissions, especially in the short term when radical breakthrough technologies and SAFs are not yet widely available. The compliance costs to European airlines would add up to around 3.6 billion euros by 2050 – € 165 per tonne CO<sub>2</sub> – as allowances and carbon credits become increasingly scarce.

**Guaranteeing the quality of carbon credits** through both industry action and policy intervention is key to realising these necessary reductions in CO<sub>2</sub>. Implementing the global economic measure CORSIA is crucial to keeping international aviation on track to reduce emissions and contribute to the net zero ambition globally. Earmarking of revenues ensures the economic measures fully contribute to the development of aviation decarbonisation solutions. **Direct Air Capture** is seen as important enabling technology for deployment in the short to medium term in order to create high quality carbon allowance and credits.

## **Destination 2050: The European Aviation Sector's Climate Mission**

The Destination 2050 initiative and roadmap developed by NLR and SEO at the request of A4E, ACI EUROPE, ASD, CANSO and ERA show an ambitious decarbonisation pathway for European aviation:

- 1) In line with the *Aviation Round Table Report on the Recovery of European Aviation*<sup>1</sup> and on the basis of the Destination 2050 roadmap<sup>2</sup>, A4E, ACI EUROPE, ASD, CANSO and ERA commit to work together with all stakeholders and policy-makers to achieve the following climate objectives:
  - Reaching net zero CO<sub>2</sub> emissions by 2050 from all flights within and departing from the EU.<sup>3</sup> This means that by 2050, emissions from these flights will be reduced as much as possible, with any residual emissions being removed from the atmosphere through negative emissions, achieved through natural carbon sinks (e.g., forests) or dedicated technologies (carbon capture and storage). For intra-EU flights, net zero in 2050 might be achieved with close to no market-based measures.
  - Reducing net CO<sub>2</sub> emissions from all flights within and departing from the EU by 45% by 2030 compared to the baseline.<sup>4</sup> In 2030, net CO<sub>2</sub> emissions from intra-EU flights would be reduced by 55% compared to 1990 levels.
  - Assessing the feasibility of making 2019 the peak year for absolute CO<sub>2</sub> emissions from flights within and departing from the EU.
- 2) With the Destination 2050 roadmap and through these commitments, the European aviation sector contributes to the Paris Agreement, recognising the urgency of pursuing the goal of limiting global warming to 1.5°C. By doing so, the aviation sector is also effectively contributing to the European Green Deal and EU's climate neutrality objective.
- 3) Putting into action our determination to Build Back Better from COVID-19, we invite European and national policy-makers to be strong partners in this endeavour, strengthening the pillars described in the Destination 2050 roadmap and taking into account the Air Transport Action Group's (ATAG) Waypoint 2050 report, presenting decarbonisation pathways for the global aviation sector. Indeed, the above-mentioned commitments are subject to securing the required supporting policy and financing framework at EU and national level.

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<sup>1</sup> Aviation Round Table Report on the Recovery of European Aviation, November 2022.

<sup>2</sup> <https://www.destination2050.eu/report>

<sup>3</sup> Destination 2050 encompasses all flights within and departing from the EU+, i.e. the European Economic Area, Switzerland + UK. For the sake of simplicity, "EU" is used to address this region throughout the document.

<sup>4</sup> The baseline is a hypothetical 'no-action' scenario whereby CO<sub>2</sub> emissions are estimated based on the assumption that aircraft deployed until 2050 have the same fuel efficiency as in 2018. Such a scenario is purely hypothetical, because even without additional sustainability measures, fuel efficiency is likely to improve due to already implemented climate policies and industry action.

- 4) We therefore urge national governments and the EU to establish a policy framework that effectively enables industry to decarbonise and provides the necessary clarity and stability. The European Green Deal offers a great opportunity for this. All actors of our sector should be able to recover the costs of decarbonisation through access to private capital and relevant public funding. As such, it is critical that decarbonisation initiatives of all stakeholders in the air transport ecosystem are included in the EU taxonomy for sustainable investments as well as the EIB lending policies.
- 5) Working towards these objectives will also require joint efforts from all actors in the European air transport ecosystem - including airlines, airports, Air Navigation Service Providers (ANSPs), manufacturers, ground handlers and fuel producers together with all policymakers. Taking this leadership position, the European aviation sector is also sending a strong message to the rest of the industry globally and will use its influence to encourage wider adoption of its objectives and related actions, including the long-term global aspirational goal for international aviation (LTAG) to be agreed at ICAO in 2022.
- 6) Policies must be designed in a way which avoids distortion of competition between European and non-European aviation stakeholders and within the single aviation market. In a similar vein, we call on jurisdictions outside the EU to further support and accelerate aviation decarbonisation, in particular by working under the mantle of ICAO. A level playing field is indispensable to enable aviation to decarbonise without compromising its ability to continue delivering social and economic benefits globally.
- 7) Industry action and policies are required across four main pillars:
  - Aircraft and engine technology
  - Air Traffic Management (ATM) and aircraft operations
  - Sustainable Aviation Fuels
  - Smart economic measures
- 8) These measures directly address reductions in net emissions. Based on the Destination 2050 roadmap, the additional costs of these efforts may have an effect on demand. As a result, affordable air connectivity could potentially be impacted along with other sectors that rely on it.
- 9) Air transport growth and the revenues it generates will enable the aviation ecosystem to invest into its successful green transformation. Based on the Destination 2050 roadmap, European air passenger numbers are still projected to grow by an average of approximately 1.4% per year until 2050, without compromising the sector's ability to reach net zero CO<sub>2</sub> emissions in 2050. Destination 2050 thus shows that European air transport can grow in a sustainable manner.

10) The modelling in Destination 2050 identified a range of emissions reductions stemming from the above mentioned four pillars (point 7)) which taken together can deliver net zero CO<sub>2</sub> emissions for flights within and departing from the EU by 2050.

11) To fulfil the CO<sub>2</sub> reduction potential of the four pillars analysed in the roadmap:

- **Industry will:**

- Continue to substantially invest in decarbonisation
- Develop more energy-efficient aircraft and bring these into operation through continued fleet renewal
- Develop hydrogen-powered and (hybrid-)electric aircraft and supporting (airport and heliport) infrastructure and bring it to the market
- Scale up drop-in SAF production and uptake
- Implement the latest innovations in ATM and flight planning
- Compensate remaining CO<sub>2</sub> emissions by removing CO<sub>2</sub> from the atmosphere

- **Governments should:**

- Support industry investments through incentives or by reducing risk through a consistent and stable policy framework
- Stimulate further development and deployment of innovations by funding research programmes and promoting carbon removal technologies (Clean Aviation, SESAR partnerships, etc.)
- Work with the energy sector to ensure sufficient availability of renewable energy at affordable cost
- Support the development of the SAF industry
- Contribute to optimising ATM, in particular by fully implementing the Single European Sky

12) Through these commitments, the European aviation sector is also making a significant contribution to its proposed EU Pact for Sustainable Aviation, set forth in the *Round Table Report on the Recovery of European Aviation*. This Pact would allow the formalisation and enactment of the required partnership between industry and European & national policy makers ensuring agreement on joint sustainability targets and alignment between the related industry contribution and roadmap on the one hand and the enabling regulatory and financial framework on the other.

We are counting on the European institutions and Member States to actively embrace and drive our proposed EU Pact forward.