Global Aviation Innovation Analysis

Setting the Scene for the Netherlands

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About the Authors

To70 provides research and advisory services to the global aviation community for more than 20 years. Our strength lies in our broad and international scope and in our close relation to both policy and sector developments from a strategy point of view. With its main office in The Hague, the Netherlands, and with fourteen offices globally in Asia, Australia, Americas, and across Europe, To70 has a global perspective that allows it to gather a broad range of information and data. Our experience lies in safety, environment, efficiency and capacity and promoting these performance areas to improve aviation.

Regarding sustainable aviation, To70 has many years of experience in environmental research, starting with noise reduction and developing towards into sustainability strategy and verification. Within the team, relevant experience in Collaborative Decision Making (CDM), Air Traffic Management (ATM) and safety is leveraged to contribute to sustainable aviation. Regarding sustainability strategy and innovation, To70 has experience in both aviation and airport sustainability verification and roadmaps. Research projects often look into both environmental as well as financial impacts assessments and analysis, thereby giving integrated insights that look at multiple aspects that need to be taken into account when looking into innovation and sustainability.

Unified International, located in The Hague in the Netherlands, has an extensive strategy, market and technology experience providing consultancy services.

Our expertise is aviation and defence projects ranging within five main pillars of consultancy services, being: 1. Public procurement lead and support, 2. Mergers and acquisitions, 3. Strategy development & roll out, 4. Strategic business development, and 5. Mediation and arbitration.

New areas we support are Urban Air Mobility (UAM) and Vertiports. Like the title implies it is air mobility in an urban context. But in reality, it is more than that, it is the next generation of aviation. The term UAM is becoming more popular but it underserves the phenomenal changes it will bring to our countries, cities and lives.

Unified International provides end to end consultancy services for new energy sources enabling a green and sustainable future from a market and technology perspective.

Unified International brings together experienced professionals who believe in bringing success to our clients. We are focused and driven towards delivering results that are practical and positive. Our knowledge and experience allow us to understand what our clients need and work to achieve their desired end results. As we grow, we will ensure that all of our valuable team members believe in the same philosophy – remain client-focused and bring value to your business.

SUMMARY

Civil Aviation Policy Memorandum 2020 – 2050

In November 2020, the Ministry of Infrastructure and Water Management (hereafter referred to as the Ministry) published the Civil Aviation Policy Memorandum 2020-2050. In the memorandum, innovation is identified as the key to climate-neutral aviation. New forms of transport may be introduced in the future, and new providers of mobility and online platforms will appear that offer mobility as a service. Such providers will play a major role in aviation soon. Besides making room for new types of aircraft, the sector also faces a considerable challenge in becoming cleaner, quieter and more efficient. Innovation also creates opportunities for the Dutch aviation industry. For the energy transition, also cooperation with other sectors like the automotive, the energy and charging infrastructure sector is opportune.

With this in mind, the government is drawing up a Civil Aviation Innovation Strategy. This Civil Aviation Innovation Strategy will consist of five parts:

1. A definition of scope, importance and goals for innovation (*part of this report*)
2. A baseline analysis of various relevant topics for the Netherlands in an international context (*part of this report*)
3. An analysis of the innovation capacity, main challenges and barriers facing the Dutch ecosystem to increase the innovation capacity
4. The strategy itself i.e., the proposed measures to be taken to overcome the barriers
5. A proposal for monitoring innovativeness and the impact of the proposed measures

In December 2021, the Ministry has commissioned a baseline analysis (hereafter: Global Aviation Innovation Analysis) for the Civil Aviation Innovation Strategy covering the first two parts of the Civil Aviation Innovation Strategy. The result of the Global Aviation Innovation Analysis is presented in this document.

Global Aviation Innovation Analysis

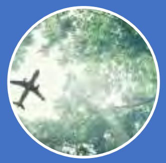
The purpose of the Global Aviation Innovation Analysis is to create an overview for the Netherlands in an international context for four innovations areas.

Aircraft Platforms | Future Fuels | Airports | Airspace Design

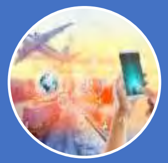
The overview covers a range of topics with a specific focus on the technology innovations needed to make aviation future-proof.

Policy

Technology roadmaps

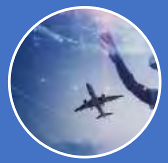


Contributions of innovations



Value chains

Stakeholders



Research & development

Resources

Monitoring activities

Scope of the Innovation Areas

AIRCRAFT PLATFORMS

Outcome 1: Aircraft are powered by sustainable energy powertrains that have a low impact on the environment, driven by:

- Transition to aircraft platforms on sustainable aviation fuel (SAF)
- (Hybrid)-electric propulsion
- Hydrogen combustion

Outcome 2: Aircraft require less energy to fly and make less noise, driven by:

- Continued classical aircraft platform optimization
- New disruptive aircraft platform development

Outcome 3: New platforms for air mobility meet safety and operational needs of the airspace, driven by:

- Certified vehicles (electric vertical take-off and landing platforms - eVTOLs - and drones)

FUTURE FUELS

Outcome 1: Sufficient green hydrogen fuel is produced and supplied to airports to facilitate hydrogen aircraft operations, driven by:

- Green Hydrogen Production and Import
- Hydrogen Infrastructure and Certification

Outcome 2: Sufficient SAF is produced and blended in line with legislative mandates, driven by:

- SAF Production through Multiple Pathways
- SAF Blending Mandates

Outcome 3: Electric infrastructure that supports novel aircraft designs and logistics is available at airports, driven by:

- Resilient Electric Charging Infrastructure

AIRPORTS

Outcome 1: Airports are becoming an energy hub for its stakeholders and surrounding community, driven by:

- Energy Hub
- Adapt for Aircraft Revolution

Outcome 2: Towards a sustainable airport, and a friendly neighbour, driven by:

- Reduce Emissions and Become Net Zero
- Accommodate for Climate Resilience
- Vertiports

Outcome 3: Digitalisation and automation are key for optimised and safe operations at airports, driven by:

- Terminal Seamless Flow
- Electric and Autonomous Airside
- Intermobility

AIRSPACE DESIGN

Outcome 1: Airspace rules, routes and flight procedures optimise flight operations and integrate aircraft seamlessly in all airspace, driven by:

- Systemized En-Route and Terminal Manoeuvring Area (TMA) Airspace
- Arrival and Departure Operational Concepts
- U-Space Airspace

Outcome 2: Air traffic management (ATM) capabilities are scalable to all airspace users and resilient to demand and supply disruption events, driven by:

- Air Traffic Service Providers
- ATM Data Service Providers
- U-Space Service Providers
- Automation in ATM Tools

Outcome 3: Surveillance and communication infrastructure is available on the ground or space to support all aircraft types, driven by:

- Optimizing Current Communication, Navigation and Surveillance (CNS) Infrastructure
- Advancement of New Surveillance and Communication Technology

Global Innovation in Aviation

Slide 9 to 16 provide an overview of the global innovations for aircraft platforms, future fuels, airports and airspace design. For each innovation area the overview comprises of:

- the **CONTRIBUTIONS OF INNOVATIONS** to safety, connections, liveability and climate. The impact ranges from small/neutral to large.

impact: small/neutral *impact: medium* *impact: large*

- the **MAJOR MILESTONES** for now, 2025 – 2030, 2030 – 2035 and 2035 and after.

- the **CURRENT RESOURCES IN THE NETHERLANDS** in terms of finances, human and infrastructure. The availability of resources ranges from insufficient to sufficient.

availability: insufficient *availability : limited* *availability : sufficient*

- the **TOP 10 TRENDS AND POSITION OF THE NETHERLANDS** and the position of the Netherlands on the global playing field ranging from innovator to follower.

- the **CURRENT STATUS ON REGULATIONS RELEVANT FOR THE NETHERLANDS**.

Global Innovation in Aircraft Platforms

CONTRIBUTIONS OF INNOVATIONS

impact: small/neutral, medium or large

- safety
- connections
- liveability
- climate

MAJOR MILESTONES

NOW

- European Union (EU) Clean Aviation launched
- (Hybrid) electric demonstrators for air taxi and commuter aircraft

2025 – 2030

- Hybrid electric commuters in service
- Hydrogen combustion demonstrators
- First (piloted) air taxi in service
- Towards 100% SAF

2030 – 2035

- Hydrogen combustion aircraft in service
- Hybrid electric regional aircraft in service
- (Unpiloted) air taxi fleet scaling up

2035 AND AFTER

- Disruptive aircraft configurations in service
- Fleet renewal with electric and hydrogen

Innovation in Aircraft Platforms in the Netherlands

CURRENT RESOURCES IN THE NETHERLANDS

availability of resources: insufficient, limited, sufficient

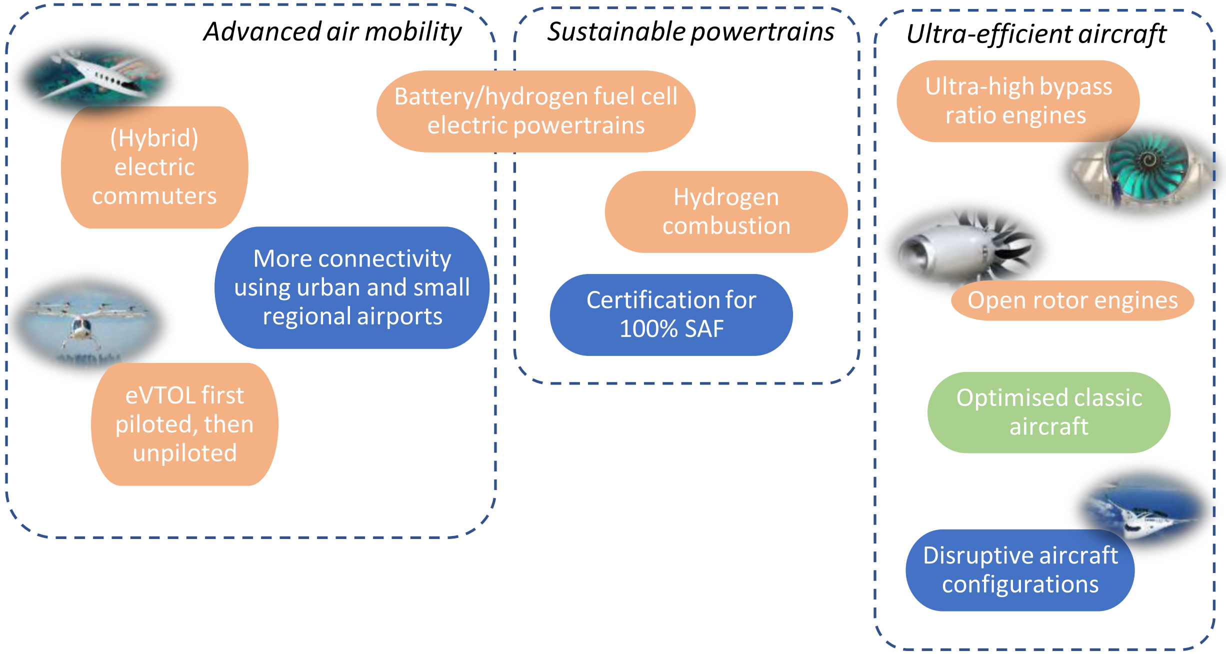
finances

human

infrastructure

TOP 10 TRENDS AND POSITION OF THE NETHERLANDS

*position on the global playing field: **innovator**, **early majority** or **follower***



CURRENT STATUS ON REGULATIONS RELEVANT FOR THE NETHERLANDS

Certification regulatory provisions are in place (EASA) for piloted eVTOLs, light Unmanned Aircraft System (UAS up to 600 kg) and small (battery) electric aircraft up to 19 passengers. Gaps in current regulations exist for hydrogen powered aircraft, unpiloted eVTOL and larger hybrid electric aircraft (20^+ pax). In the Netherlands, regulations raise a bar for flights tests since this part of the aviation law is not fully completed yet.

Global Innovation in Future Fuels

CONTRIBUTIONS OF INNOVATIONS

impact: small/neutral, medium or large

- safety
- connections
- liveability
- climate

MAJOR MILESTONES

NOW
- Research on hydrogen operations and safety
- SAF incorporated in current fuel supply
- Research on electric infrastructure requirements

2025 – 2030
- Outcomes of first hydrogen refuelling pilots
- SAF mandates push production and use
- Small electric aircraft can recharge at regional airports

2030 – 2035
- Leading/most innovative airports facilitate steady supply of green hydrogen fuel
- EU SAF use 5%, syn-SAF production starts
- Point to point electric aviation facilitated by airport charging infra

2035 AND AFTER
- Commercial hydrogen flights require supply at all airports
- EU airports able to supply multiple SAF blends
- Electric charging at all airports

Innovation in Future Fuels in the Netherlands

CURRENT RESOURCES IN THE NETHERLANDS

availability of resources: insufficient, limited, sufficient

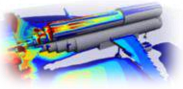
- finances
- human
- infrastructure

TOP 10 TRENDS AND POSITION OF THE NETHERLANDS

*position on the global playing field: **innovator**, **early majority** or **follower***

Hydrogen

- Green hydrogen production at sufficient scale
- Hydrogen supply and storage at airport
- Hydrogen safety



SAF

- SAF blending mandates
- Scale up of SAF production
- Business models & investment in SAF
- Feedstock availability

Electric

- Local, renewable smart grid development
- Electric systems safety

CURRENT STATUS ON REGULATIONS RELEVANT FOR THE NETHERLANDS

Future fuels use and integration into airports and with new aircraft operations requires extensive research and development on both a national and international level. Currently, organizations such as EASA, the Federal Aviation Administration (FAA), Certification Authority Authorizations (CAAs) and ICAO are responsible for these developments, and on integrating national standards with international standards. Within the Netherlands, ILT together with I&W and other public safety providers are imperative in developing regulations on a national scale.

Global Innovation in Airports

CONTRIBUTIONS OF INNOVATIONS

impact: small/neutral, medium or large

- safety
- connections
- liveability
- climate

MAJOR MILESTONES

NOW
- Emission reductions
- Intermobility
- First pilot projects of vertiport

2025 – 2030
- Climate resilience actions
- Single digitalisation system
- Electrification of the airside

2030 – 2035
- Airport net zero emissions
- Operations digitalisation
- A sustainable journey point-to-point

2035 AND AFTER
- Collaboration to net zero emissions
- Automated operations
- Multi-modal hub
- Network of vertiports
- Energy hub

Innovation in Airports in the Netherlands

CURRENT RESOURCES IN THE NETHERLANDS

availability of resources: insufficient, limited, sufficient

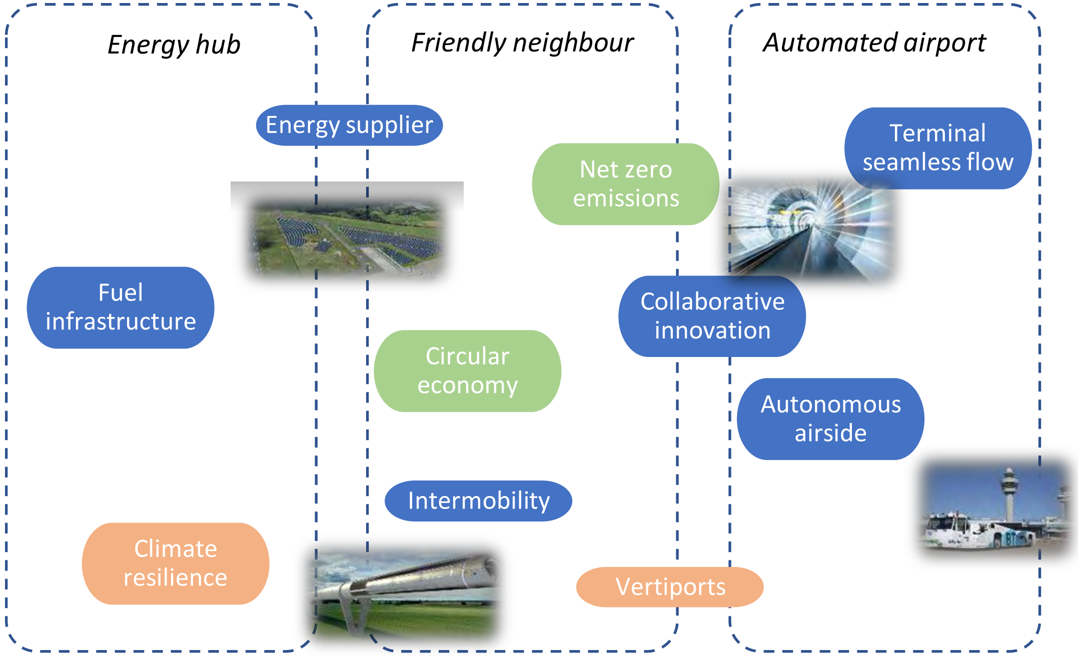
finances

human

infrastructure

TOP 10 TRENDS AND POSITION OF THE NETHERLANDS

*position on the global playing field: **innovator**, **early majority** or **follower***



CURRENT STATUS ON REGULATIONS RELEVANT FOR THE NETHERLANDS

Airports work closely with fellow regulations stakeholders such as government institutions and Air Navigation Service Providers (ANSPs). Airports are of course also a part of the larger aviation regulation ecosystem, which is often less adaptive and innovative. Therefore, airports may need to take the lead to support new regulation and certification for many types of innovation within the sector. Knowledge on safety, infrastructure, and operations regulations are already available for many other industries for certain types of innovations. For airports, the main challenge is to transfer this to the airport sector.

Global Innovation in Airspace Design

CONTRIBUTIONS OF INNOVATIONS

impact: small/neutral, medium or large

- safety
- connections
- liveability
- climate

MAJOR MILESTONES

NOW

- Optimisation of current CNS infrastructure

2025 – 2030

- Full Required Navigation Performance (RNP)
- Free-route airspace
- Collaborative and responsible automated systems

2030 – 2035

- Full PBN
- TBO deployment
- Highly-integrated automated networks
- Remote towers fully operational

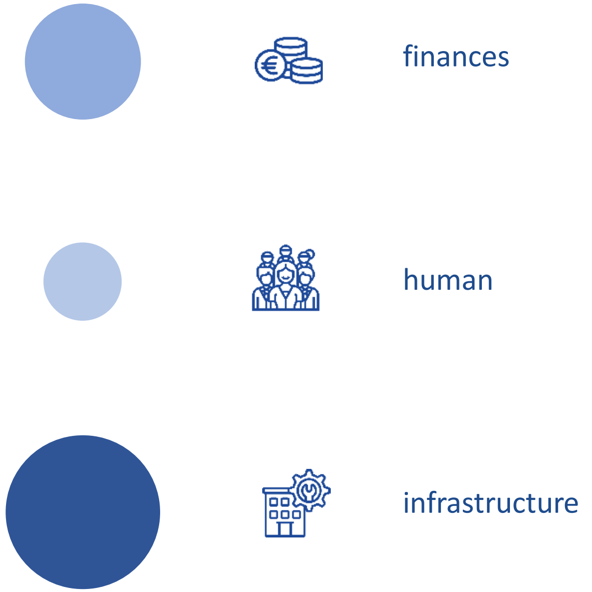
2035 AND AFTER

- U-space full services
- Virtual centers fully operational

Innovation in Airspace Design in the Netherlands

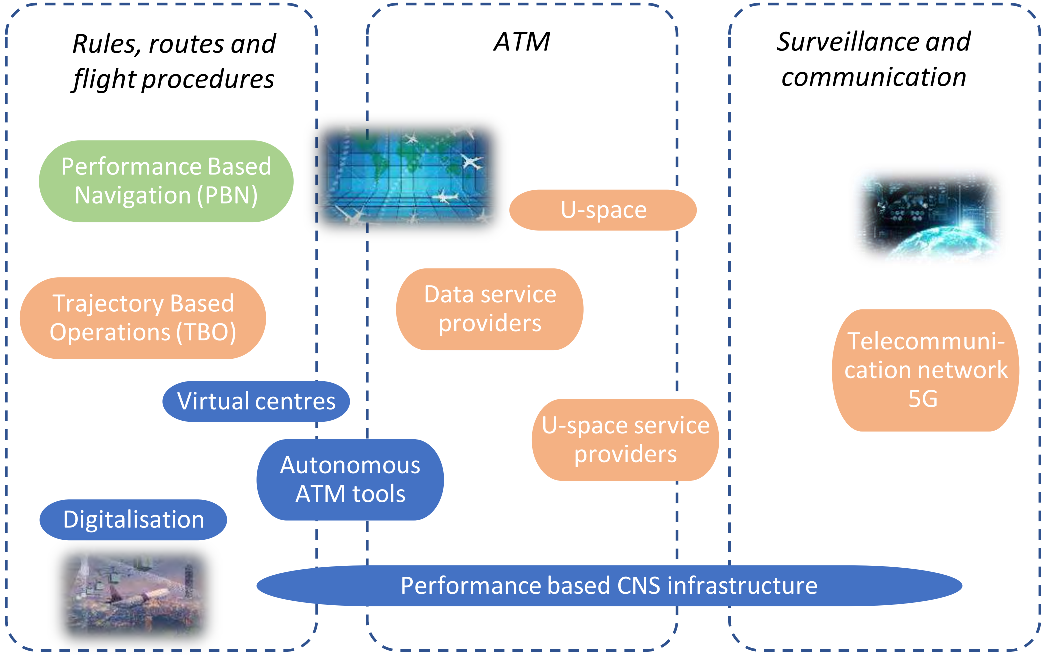
CURRENT RESOURCES IN THE NETHERLANDS

availability of resources: insufficient, limited, sufficient



TOP 10 TRENDS AND POSITION OF THE NETHERLANDS

*position on the global playing field: **innovator**, **early majority** or **follower***



CURRENT STATUS ON REGULATIONS RELEVANT FOR THE NETHERLANDS

The implementation of new regulation and infrastructure which will enable new classes of air vehicles outside controlled airspace is being managed by the traditional stakeholders, however, new service providers driven from technology innovation are also increasingly contributing. Resources are required within Europe to develop standards for U-space design and technological developments surrounding critical tools such as e-Conspicuity. However, this falls with EASA's remit. Other standards organisations such as the International Organization for Standardisation (ISO) have begun publishing standards in the field of UAS.

GLOBAL ANALYSIS

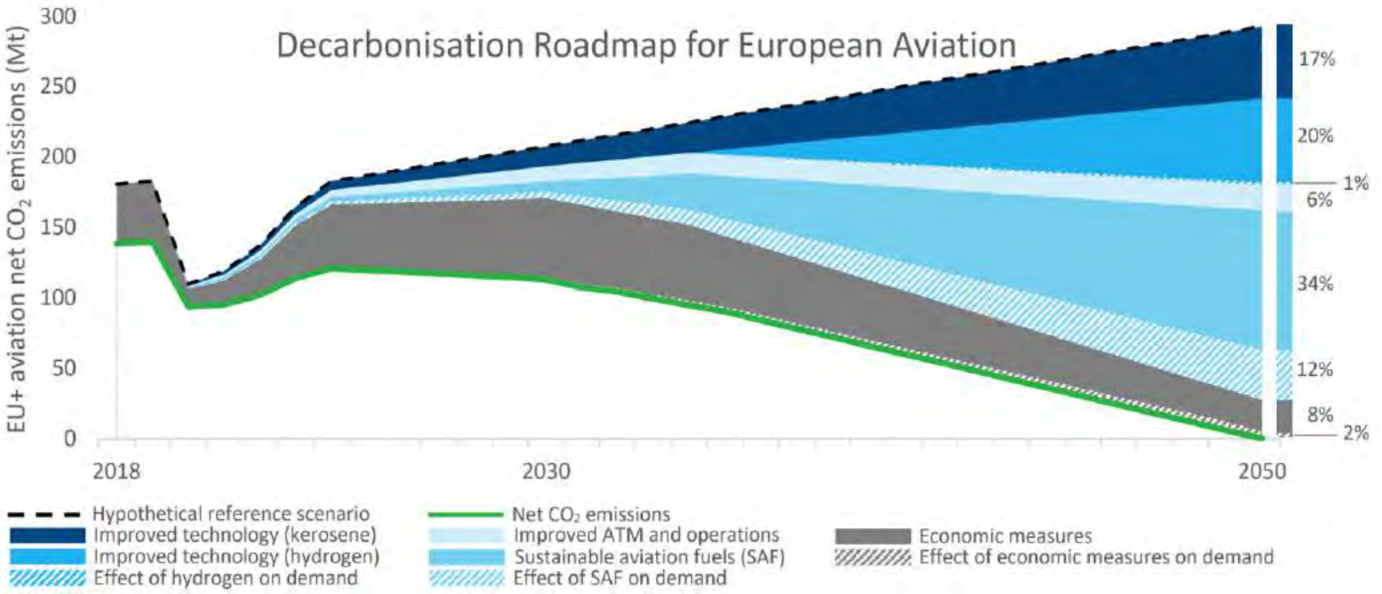
1. Policy and Market Development
2. Trends in Aviation
3. Stakeholder Landscape and Value Chains
4. Contribution of Innovation
5. Resources
6. Monitoring

1. POLICY AND MARKET DEVELOPMENTS

Policy Developments

The aviation industry is facing a once in a generation slow-down as a result of the COVID-19 pandemic. All aviation sectors have had to adapt significantly to survive in such difficult circumstances. In parallel, the societal impact of climate change is challenging the energy sector and the transport industry. The aviation industry has already taken significant steps to set out its sustainability strategy and since 2020 a range of key initiatives have been launched. The following key global, European and key national sustainability initiatives are identified by the Netherlands as influencing our future strategic direction.

Sustainability at the heart of the policies and regulation
Destination 2050 provides a decarbonization roadmap for European aviation that is quite similar to the one proposed by Waypoint 2050 (Air Transport Action Group, ATAG) at international level. This study describes in term of roadmap and policy the actions to take to decarbonize the aviation. This has been ordered by the all the European aviation community. To complete this roadmap, lots of policies and roadmaps are in place at national, European and global level.
Developed by the International Civil Aviation Organization (ICAO) and adopted in October 2016, the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) goal is to have a carbon neutral growth from 2020. CORSIA uses market-based environmental policy instruments to offset CO_2 emissions: aircraft operators have to purchase carbon credits from the carbon market.



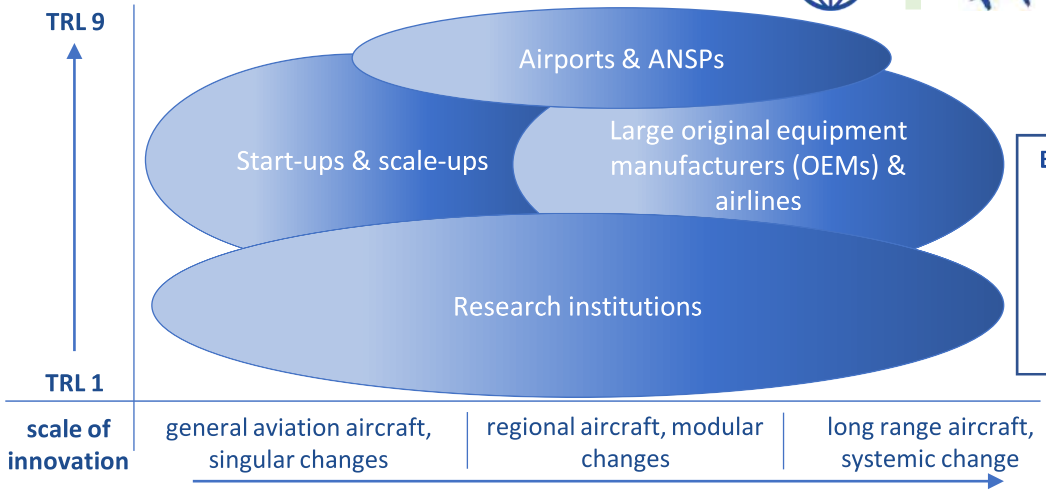
Source: *Destination 2050. A route to net zero European Aviation*

Starting in 2021, the scheme is voluntary for all countries until 2027. European Green Deal includes both general measures such as the taxonomy and EU Emission Trading System trading system, but also aviation specific subsidies and regulations, such as the green airport call, Clean Aviation (formerly Clean Sky) and blending mandates. The EU is guiding the sector towards sustainable aviation with a focus on SAF and in the longer-term hydrogen powered aviation solutions.

A global air navigation plan replicated at national level
The Global Air Navigation Plan (GANP) is a key contributor to the achievement of ICAO's strategic objectives and has an important role to play in supporting the United Nations 2030 Agenda for Sustainable Development. This is completed by the European Master Plan with a focus on the activities until 2030 and the Global Air Safety Plan (GASP) with a focus on safety to keep an acceptable level of safety for aviation.

Market Developments

Levels of innovation can best be divided over technology readiness levels (TRL). This system developed by NASA describes multiple stages of development. Four main innovating groups have been identified within the aviation market landscape. Each of these groups develops innovations at different TRL levels and at different scales of innovation. Of course, there are outliers within all groups, but this schematic aims to indicate where certain market developments are coming from. Critical within this schematic is the role of policy, which must bridge the gaps between innovating groups. Crossing the different TRL levels and connecting singular, modular and systemic innovations is required to develop radical new aircraft systems. For example, airports and ANSPs require academic conceptual research on infrastructure systems and communications technology to develop their future infrastructure.



Boundary conditions (out of market scope)

- Certification institutions
- Renewable fuel generation
- Communication technology

Start-ups and scale-ups
Radical, disruptive innovation by start-ups are leading to radical retrofit and completely new aircraft. While outliers also include hypersonic aviation, the focus remains sustainable GA, commuters and regional. Within aircraft and future fuels development there is a focus on singular and modular applications, such as fuel tank systems, power trains or refueling systems. Within SAF, which is more engrained in current systems, start-ups play less of a role. Regarding airspace, start-ups tend to develop mainly singular innovations, rather than aiming for systemic changes.

Large OEMs and airlines
Although traditionally focused on incremental change, OEMs are increasingly innovating on a large scale. They can tackle large scale problems and systemic change through their overarching capabilities and budgets. Though they do tend to move more slowly, targets set by OEMs set a standard for the industry, paving the way for other market players to innovate towards that goal, mainly in aircraft and future fuels development.

Research institutions
Research institutions form a key role within market developments in aviation innovation. Conceptual research that falls outside of the scope of start-ups and OEMs is required for many of the innovations currently being developed, both singular changes such as distributed propulsion or laminar flow research, as well as systemic research such as SAF value chain assessments and digital communications developments. There is a clear lower TRL focus, as the main goal of fundamental research is to clarify and conceptualize new ideas.

Airports and ANSPs
Not considered strong innovators, airports and ANSPs are increasingly developing innovation teams to work on high TRL implementation. This includes both singular, modular and systemic work, but mainly focuses on subjects within their own domains such as passenger journeys and integration of airspace procedures. Market developments from leading airports and ANSPs show a step towards integration of innovative aircraft and future fuels, showing increased collaboration with other stakeholders. For ANSPs, systemic innovations including Single European Sky's ATM Research (SESAR) are coming increasingly to the forefront.

Trend for entry into market (often overenthusiastic):

- Piloted electric UAM /eVTOL by ~2024
- Autonomous cargo in remote areas by ~2027
- Unpiloted pax UAM/eVTOL by ~2030
- (Hybrid) eCTOL retrofit by 2026
- New built eCTOL/eSTOL by 2027-2030
- SAF/hydrogen supersonic 2030s (uncertain)

Trend for entry into market (often far ahead):

- First hydrogen commercial by 2035
- New aircraft configurations (blended wing) 2040/2050
- Alignment with new ATM tools and functionalities
- New sustainable airlines being founded

Entry into market - not applicable
Focus into research – for an entry into market by 2050

- Blending wing bodies, New Configuration aircraft
- Innovative Power Trains and Propulsion Systems
- Full automated aviation

Trend for entry into market (often understated):

- SAF fuelling starting now, large scale up (mandates)
- Hydrogen refuelling pilots 2025
- U-space development by 2030
- Distributed aviation from small airports 2025-2030
- Wider adoption of vertiports 2025

2. TRENDS IN AVIATION

Trends of the Global Aviation Innovation Analysis

AIRCRAFT PLATFORMS

Innovation in aircraft platforms for passenger and cargo operations including those operated remotely or autonomous is changing the way we understand air mobility. Flight performance and lower cost of operation opens a new era for aviation. Importantly, new use cases are being introduced that provide significant societal benefit such as emergency response and connecting rural communities. The basis of this new type of aircraft, and a 'must' for conventional aircraft platforms, is the energy transition to sustainable fuels, green hydrogen and electric energy. This is the backbone for achieving net-zero emissions to reduce climate impact and enhance liveability around airports.

FUTURE FUELS

Future fuels are an integral part of decarbonizing aviation in both the short and longer term. It can be divided into sustainable aviation fuel (bio-fuel and synthetic fuel), hydrogen which can either be burned in a turbine engine or used to power a fuel cell which drives an electric engine, and finally electric power for battery-electric flight. For bio and synthetic fuel, rapidly increasing the technological maturity of synthetic fuels and scaling up production of bio and waste fuels is required, together with policies that connect supply and demand uptake. Though not completely emission free, SAF is vital to decarbonize aviation in the short and medium term and for long range aircraft. For hydrogen fuel, aircraft must be completely reengineered to facilitate the use of hydrogen as a fuel. Furthermore, hydrogen production, transport, safety and new refuelling operations must be developed and supported by the aviation sector. This will allow testing and pilots from 2025 onwards for short and regional flights and be a long-term solution for increasingly longer flights from the 2030s onward. Electric charging supply and facilities are required and must be developed in tandem with ground infrastructure. Battery electric flight most feasible for general and short haul aviation.

AIRPORTS

As airports are at the heart of aviation operations, they strive to align their infrastructure with the newest operations and anticipate innovation. As a key player and central actor, they also have an engaging role with all the stakeholders, becoming a leader for innovative solutions and operate in a sustainable, safe, liveable and connected environment. The airport of the future is a connected, integrated infrastructure that links passenger flows, energy levels, security and operational systems and processes across landside and airside operations. It is where passengers enjoy a safe, welcoming, seamless and memorable travel experience.

AIRSPACE DESIGN

Airspace users require a resilient and ATM system to help ensure safe, efficient, equitable and sustainable operations, whether transporting passengers or cargo, or recreational flying. The type of traffic, traffic numbers, and the airspace environment they fly in will place significant demands on the airspace design and the infrastructure. This innovation area is will see a transition from tactical air traffic control services at the local level to strategic ATM at the network level. This will involve innovation in new airspace and technology concepts that are tailored to the airspace category or type of operations including low level urban air mobility or high-level space operations. This will include new airspace routes based on PBN capabilities as well as new air-to-ground and air-to-air communication and surveillance capabilities.

As trends in cybersecurity apply to all innovation areas, an overview on these trends can be found on page 21.

Overview of Trends in Aircraft Platforms

To realize the policy targets of the European Green Deal of (net-) zero aviation in 2050, a cascade of developments is needed. Part has been ongoing for decades and part has gained much attention in recent years.

The current aviation emission are mainly generated by large long haul, short haul and regional aircraft that have the wing-tube configuration that has been around for decades. Most emissions and noise savings gained have been accomplished in engine technology, with more modest contributions from light-weight structures and aerodynamics. This evolutionary optimisation continues with new engines (e.g. ultra-high bypass ratio engine and counter rotating open rotors), introduction of large-scale thermoplastic composite structures and new aerodynamics concepts such as morphing wings. They have been at the forefront of large research & development programs such as EU funded CleanSky 1 and 2 and were set to be incorporated in the new major OEM airliner programs for a 2030^{+} market introduction.

This evolution will however never lead to net zero. The energy transition is inevitable, also for aviation. SAF is the lowest hanging fruit, yet still emits net CO_2 and other emissions. The energy density of jet fuel versus alternatives (batteries and green hydrogen) leads to a long-term transition roadmap. The innovations needed that dictate the pace of the transition comprise energy density improvements batteries, and solutions for hydrogen-electric powertrains and storage systems as well as system architecture improvements (including high voltage aspects), and development and certification of large electrical engines.

The first electric trainer (2 seater) has been certified in 2020. General aviation up to 4 seats is within easy reach. 6 Passenger retrofit prototypes have been demonstrated: full electric (short range), hybrid electric (up to 750 km), and hydrogen / battery. Small conventional take-off and landing (eCTOL) commuters (~9 pax up to 19 pax) are under development for market introduction, realistically between 2025 and 2030. This comprises retrofits and new built aircraft. Certification regulations are not yet available for larger (20^{+} pax) aircraft. Scale-up to 40 and ultimately 80 seaters will take until the 2030s and 2040s, depending on progress of certifiable energy storage with increased energy density per weight.

Another path to aid the energy transition, and save energy consumption, is presented by unconventional configurations such as blended wing body (BWB). The Electric motors provide more design freedom and enable distributed propulsion configurations, in combination with SAF engines (hybrid) supporting energy intensive take off and climb. Another propulsion concept investigated is boundary layer ingestions. These new configurations, especially the BWB, make most sense for larger airlines. Flying scale models are available, but actual aircraft are not beyond the drawing board. Market entry is not expected before 2035. The key challenge is to keep the mono-disciplinary aerodynamic fuel savings in the detailed design (structures weight, systems).

These trends can bring us close to (net)zero aviation in 2050. This requires research & development funding, adaptation and investments in airport infrastructure and procedures, and sufficient resources at aviation authorities to certify a high number of newcomers.

As part of Advanced Air Mobility (AAM), eCTOL aircraft can unlock more point to point connections from small airports (distributed aviation). To leverage smallest airports, or even 'open public spaces' also some electric short take-off and landing (eSTOL) aircraft are under development. In parallel, driven by mobility demand in congested urban areas, 200+ new air space entrants are being developed for cargo delivery, air taxi and personal air vehicles. This comprises mainly eVTOLs. Initially these will be need to be piloted (first expected market entry 2023) as certification regulations do not cover unpiloted yet. Unpiloted (first cargo later pax) will mostly like be introduced near or in the 2030s. Business models innovations beyond scheduled and milk-run flights are also considered such as on-demand and even prescription based.

AAM external success factors are infrastructure connections to other (ground) transport, (digital) ATM/airspace infrastructure (especially for eVTOL), and a network of vertiports and small airports, connected to renewable energy, with acceptable noise impact for the environment. These vertiports should be safe and secure, yet fast for the passengers to navigate for achieving travel time efficiency.

Overview of Trends in Future Fuels

Future fuels are an integral part of the solution to decarbonizing aviation. Future fuels can be divided into SAF (bio-fuels and synthetic fuels), electric power and hydrogen, which can either be burned in a turbine engine or used to power a fuel cell which drives electric engines. For bio and synthetic SAF fuel, rapidly increasing the technological maturity of synthetic fuels and scaling up SAF production is required, together with policies and market collaboration that connects SAF production (supply) and SAF uptake (demand). Synthetic fuel production as well as hydrogen production through electrolysis requires large amounts of renewable energy, which will become part of the aviation fuel supply chain and therefore must be scaled up. For hydrogen fuel, new aircraft powertrains and designs are required that can use hydrogen as a fuel. Furthermore, the aviation value chain will need to innovate for hydrogen transportation, storage and refuelling, as well as hydrogen safety and certification. For electric battery powered aircraft, the refuelling infrastructure must be further developed, although the knowledge from the automotive industry can be leveraged to also facilitate electric aircraft infrastructure, certification and safety.

The transition to future fuels is a requirement to reach net zero carbon aviation. Future fuels decrease or eliminate CO_2 and in some cases other emissions such as NO_x, contrails and water vapor.

Electric aviation has the advantage of operation without any type of emissions but is limited by the performance and the weight of the battery. As a result, electric propulsion is expected to only be feasible for low capacity, short-haul flights in the next 10-15 years, depending on battery improvements. Although there are many low capacity, short-haul flights in which electric aviation can make a change, the largest part of the carbon emissions is caused by medium to long-haul flights as 58% of emissions are caused by flights over 2000 km. For long-haul flights, SAFs in the short term and hydrogen in the medium to long term have the most potential to provide a carbon emissions reducing option.

It is important to note that electric, SAF and hydrogen value chains are connected regarding fuel production and availability. Hydrogen fuel requires enormous amounts of renewable electric energy generation, and synthetic SAF requires enormous amounts of green hydrogen. Current SAF production requires bio and waste materials as the main resources.

The transition pathways towards net zero carbon aviation from international organisations such as ATAG, Airports Council International (ACI), IATA and ICAO, see both SAF and hydrogen as emerging technology developments that will ensure the aviation sector is able to decarbonize by 2050. Electric aviation is also seen as a development, yet the impact is lower due to the range limitations. Although the extent to which hydrogen aviation can develop commercially is debated due to mainly to technology development and high investment issues, there is a market consensus that it will become possible in the coming 5-15 years, and commercially viable between 2030 and 2040. For SAF, bio and waste fuels are currently being produced and developed, but a large scale is needed to make an impact in aviation emissions. Regarding synthetic fuels, research is required to produce at an industrial scale and achieve the goals for 2050.

Overview of Trends in Airports

The ownership of Europe’s airports shows that over 40% of Europe's airports have at least some private shareholders - and these airports handle close to 75% of passenger traffic each year. This number is slowly increasing each year. In the US, airports are considered only as a public service while in Asia they are privately owned and therefore operated as a commercial operation. As European airports are often a combination of private and public ownership, they also combine the targets of proving a public service and generating revenue through commercial activities.

Whether public or private, many airports across the world understand the need to innovate and become sustainable and more connected to their local communities. The main concerns for airports involve their own carbon footprint and internal sustainability, local noise reduction and local emissions from aircraft. As an infrastructure provider, airports also influence the development of aviation sustainability and innovation on a wider scope, including aircraft, airspace and ground mobility. Their priority remains to ensure that airports are safe, efficient and provide the infrastructure services required for aviation.

Airports developing the future of their operation often develop target time frames between 2030 and 2050. They engage in sustainability, digitalisation and mobility as a service strategies within their own operation as well as beyond to achieve targets as set by themselves and by higher level aviation bodies such as ACI, ICAO and national policy. A number of projects, including the EU horizon 2020 green airports call, Airport Carbon Accreditation, as well as the is the 2050+ project which aimed to prepare airports for 2050 and beyond support these aims.

A first major focus is on the airport as an energy hub. Vehicles as well as heating energy are increasingly electrifying and new types of fuel also develop, including biofuels and hydrogen. The airport can take a larger role in developing these forms of energy and their operation at the airport. As an energy hub provider, airports can also push the decarbonisation of their own operation as well as their stakeholders.

A second major focus is on decreasing the airport’s own environmental footprint to become sustainable, as well as decreasing their negative impacts on the local community. Most airports have set targets to achieve positive change between 2025 and 2050. Currently, a number of Scandinavian airports are Net zero carbon, showing that it is possible to achieve. Airports are implementing innovations targeting all aspects of environmental emissions, on local and global scales. The Airport 2050+ targets go into these aspects and aim to “develop climate neutral operations and low sound pollution”. The ACI airports guidance has set an industry wide target for all airports to be net zero by 2050. These ambitions and the guidance provided to achieve this can be critical in airport innovation.

A third major focus for airports is the autonomous airport trend towards digitalization and integration of systems airside, landside and in the terminal. This is seen as a critical solution to facilitate efficiency and improvement. Targets within the 2050+ project, for example, enabling 90% of European travellers to complete their intra-European door-to-door journeys within 4 hours through increased connection and digitalisation. This also includes the integration of new modality within the airport infrastructure. Looking forward, different types and a wider range of mobility options are expected to emerge, and the airport can play a major role in becoming a central hub for all of these different types of transport. New supply chains require airports to innovate and work together more closely with their stakeholders but also with outside parties from different sectors that may be further ahead with digitalization and sustainability technology.

Overview of Trends in Airspace Design

Innovation in the delivery of ATM services within the future airspace management system will be critical to its success. This includes managing traditional aviation actors in the controlled airspace categories alongside the introduction of new vehicles in the lower airspace, referred to herein as AAM, and the upper airspace which takes into account supersonic and space vehicles. The capabilities that are required within the ATM system have been identified and the challenge within the industry is implementation at large scale to benefit the entire network.

In traditional aviation the global transformation programme is described through ICAO Framework; namely the GANP and the GASP. The GANP is the highest air navigation strategic document and details the plan to drive the evolution of the global air navigation system. It also provides the strategic and technical basis for regional and local planning. In support, the GASP establishes targeted safety objectives and initiatives while ensuring the efficient and effective coordination of complementary safety activities between all stakeholders.

At the regional level, within the USA the Next Generation Programme manages changes to the national airspace system. Within Europe, the Single European Sky (SES) programme is the leading global initiative with the Technical pillar of the SES being implemented through the SES's ATM Research (SESAR). Within Europe, at the national level the contribution to SESAR dominates the innovation strategies of most states. Outside Europe similar co-ordinated projects exist and they explore the same concepts linked by the ICAO GANP.

For AAM and other new airspace users then the trend is that innovation is being driven from the industry and is driven by high-tech industry knowledge that is unfamiliar within the traditional aviation sector. The identification of new cheaper and more environmentally friendly propulsion technology is driving innovation in aviation at a speed not seen before. In the urban environment and lower airspace then new use cases are being identified to support personal health and wellbeing, along with cargo and passenger mobility and driving innovation across aviation but also other transport sectors as we re-think our understanding of mobility. Supersonic transport and space tourism use cases, whilst at a different scale to urban mobility, provides new use cases and again challenges our understand of future mobility

The GANP and GASP has initiated development of their strategic and technical contributions relating to remotely piloted aircraft systems and other vehicles. Within Europe, the development of the U-space programme within SESAR has progressed since the Drones Helsinki Declaration in November 2017. The development of new regulation from the European Union Aviation Safety Agency (EASA) for U-space and drones along with new U-Space projects within SESAR demonstrate the speed at which Europe has responded to the call from industry users to support safe and efficient integration of users into the European airspace. The developments in vehicle technology and infrastructure concepts is advancing at a different rate to the developments in airspace rules. The momentum of the AAM industry still places pressures on the regulatory environment and change is required to ensure the predicted benefits are realized whilst ensuring the safety of all airspace users and the general public.

Overview of Trends in Cybersecurity

The aviation system will evolve significantly in the future, with the application of new operational concepts, an increased use of commercial off-the-shelf products developed using open standards, increased sharing of data and networking of systems, and the introduction of new vehicles into controlled airspace. The next generation of systems resulting from the digitalization of aviation will apply emerging technologies (e.g., artificial intelligence, data analytics and new security technologies), and may introduce new threats. These threats will be particularly pertinent in the area of cyber security, the exploitation of which could result in undesirable impacts.

Creating a cybersecure environment in aviation within Europe is based on a combination of the Network and Information Security Directive adopted in 2016 and aviation specific requirements.

In recognition of the challenge of developing cybersecure and recent amendments to ICAO Annex 17 Standards and Recommended Practices (SARPs) and associated guidelines explicitly address cybersecurity.

In Europe, in order to promote a harmonised approach to meeting Annex 17 SARPs, the current ATM-specific Implementing Rule is IR (EU) 2017/373 which, coupled with amendment 2020/469, specifies security requirements for ANSPs, the EUROCONTROL Network Manager, and Air Traffic Flow and Capacity Management (ATFCM). This regulation compels operators to adopt a broad-based, holistic approach to security, addressing people, processes, and technology, beginning with the requirement to implement a Security Management System to protect facilities, personnel, service provision, and operational data.

Besides the operational aviation system, cyber security is also essential for the design, manufacturing and maintenance repair and operations (MRO) industries, especially when transitioning to more digital cooperation environments (digital twin, industry 4.0 principles, virtual certification). Besides the increasing 'ransomware' attacks, the aviation industry is subject to espionage for industrial reasons as well as dual use or military use state of the art technology. The Cybersecurity Task Force is a cross functional group that is responsible for the development and implementation of ACI EUROPE cybersecurity policy position on issues such as the rulemaking by EASA, including the technical and strategic level of the European Strategic Coordination Platform.

3. STAKEHOLDER LANDSCAPES AND VALUE CHAINS

Stakeholder Landscape and Value Chain within Aircraft Platforms

LEGISLATION AND REGULATION	STANDARDISATION BODIES	MANUFACTURING INDUSTRY	OPERATING INDUSTRY	AFTERMARKET & SERVICE PROVIDERS
ICAO	EUROCAE	OEMs (aircraft integrators)	Airlines/ operators (scheduled & on demand)	MRO
EASA (aircraft, production, operators maintenance)	RTCA	Tier 1: Systems/ structures integrators	Aircraft lease companies	Engineering, testing and certification support
Ministry of IenW (DGB/ILT)	SAE	Tier 2: Large components & (sub)systems	Airports (real estate, ground handling Support)	End of life solutions
	ASTM	Tier 3: Parts & components		Training (crew, maintenance, etc.)
		Tier 4: Raw materials & processes		

RESEARCH & DEVELOPMENT	Research institutes, universities
EDUCATION	Universities, colleges (engineers, production staff, mechanics)
POLICY & GOVERNMENTS	EU, national, regional and local
GENERAL PUBLIC	General public (end users, acceptance)

Stakeholder Overview within Aircraft Platforms

POLICY, LEGISLATION AND REGULATION
Aviation policies are set by ICAO, The European Commission and the Netherlands Netherlands Ministry of Infrastructure and Water management.

For aircraft platforms, regulations are in place for safety and emissions. This comprises the design (type certificate), operation and maintenance. Organisations are also certified or approved for design (DOA), production (POA), maintenance (MOA/Part 145) and operations (AOC). The key stakeholders are ICAO (global), EASA (Europe) and Inspectie Leefomgeving en Transport (ILT). Aircraft that are not certified under ICAO principles, such as test and demonstration aircraft fall under the national authority for permits to fly.

STANDARDISATION BODIES
Provide standards for aviation equipment, systems and design processes. Complying with these standards facilitates certification. Key new standards under development concern adoption of 100% SAF (American Society for Testing and Materials, ASTM), charging of electric aircraft (Society of Automotive Engineers [SAE], Radio Technical Commission for Aeronautics [RTCA], EUROCAE) and detect and avoid/airspace integration of unpiloted aircraft (RTCA/EUROCAE).

OPERATING INDUSTRY
Airlines are operating the aircraft platforms, on scheduled services mainly. Smaller aircraft (business jets and commuters) are often also operated under 'on demand' models. With KLM-Air France, The Netherlands as a major airline for European and intercontinental flights. Other Dutch airlines are Transavia, TUI Fly and airlines in the Caribbean (Divi Divi, Winair). The Caribbean with 'thin-haul' routes between the islands where little alternatives exist for fast transport could be early adopters within the Netherlands. A new player could be Lucy that has the ambition to become a 100% sustainable airline. Further smaller, general aviation operators for e.g. parachute, leisure flights and training (notably e-Flight academy) could benefit from sustainable aviation. Key requirements for airlines on sustainable aircraft solutions are payload-range capacity and turn around times versus life cycle costs. Pilot human factors and workload is also key for new propulsion concepts and a drive towards single cockpit operations. Other operators that can benefit from innovations are emergency services aircraft (e.g. air ambulance in the Caribbean)

Lease Companies: lease companies play a role in the ecosystem in acquiring aircraft and providing them to airlines depending on demand. As owner of aircraft, life cycle costs of new, sustainable aircraft concepts is of high importance.

Airports need to be equipped and ready for new sustainable aircraft in terms of infrastructure and ground services (including fire fighting). Schiphol is a major European Hub (and leading the EU TULIP green airport project). Rotterdam-The Hague, Eindhoven and Groningen are exploring (hybrid) electric domestic flights under the Power-Up initiative. Teuge airport is hosting DEAC. The distributed aviation model (small aircraft operating on regional point-to-point connections from smaller airport) could provide increased connectivity for other Dutch airports, especially where city pair connections via rail and road are cumbersome.

RESEARCH AND DEVELOPMENT and EDUCATION
Under Horizon Europe, the EC funds R&D through public private partnerships of which Clean Aviation is the most prominent one. Internationally, the Association of European Research Establishments in Aeronautics EREA (e.g. DLR, ONERA) and NASA are key players. In the Netherlands Royal NLR and TU Delft are the main aerospace research organisations who are active in all innovation areas relevant to this study.

TU Eindhoven and TU Twente have knowledge on specific niches. The Universities of Applied Science active on aviation are Amsterdam (Hogeschool van Amsterdam) and InHolland. TU Delft, Hogeschool van Amsterdam and Deltion college cooperate in the Dutch Electric Aviation Centre, in addition to various student teams from Delft (Aero Delft), Eindhoven (Falcon Electric) and InHolland (DragonFly).

MANUFACTURING INDUSTRY
The key value chain for innovations in aircraft platforms is the manufacturing industry, driven mainly by OEMs and Tier 1s as they decide which innovations make it to the next aircraft program. Key OEMs is Europe for civil transport aircraft are Airbus and Leonardo. Globally Boeing is the major player. Others are Embraer, COMAC, United Aircraft Corporation (Russia), Bell, De Havilland, Mitsubishi and a variety of OEMs for commuters and general aviation.

For eSTOL and eCTOL, the OEMs are mainly start-ups. eVTOLs are start-ups and traditional OEMs, leading company examples are within Europe Volocopter and Lilium and internationally Joby. An overview of the Dutch manufacturing industry in terms of established capabilities and new developments in the aviation energy transition is included on the next slide.

AFTERMARKET AND SERVICES
Maintenance Repair and Overhaul plays a key role during the operational life to keep aircraft airworthy, safe and efficient. The MRO industry can also play a role in aircraft conversions, modifications and retrofits towards sustainable powertrains. The Netherlands has a strong position in MRO around Schiphol, Aviolanda Woensdrecht and Aerospace & Maintenance Park Tilburg and Maastricht Maintenance Boulevard, supported by SMEs for component repair and spare parts located elsewhere in the Netherlands.

Engineering, Testing and Certification Services are performed by specialized companies with knowledge, experience and facilities and approvals for ground testing, wind tunnels and flight testing. This is essential to support the development and certification of new or retrofit aircraft for Entry Into Service. From the Fokker OEM legacy, the Netherlands still has a strong position with multiple companies in its industry base and research institutes .

End of life Services (EOL), decommissioning aircraft after their operational life, will play an increasing role in the transformation to a circular economy model. The Netherlands has EOL capabilities Twente airport.

Initial and recurrent training of flight crew (pilots, flight attendants), ground crew, mechanics is essential for the production, operation and maintenance of aircraft platforms. Dedicated companies provide training services and training tools (flight simulators, mock-ups, augmented/virtual augmented reality (AR/VR) solutions, training aircraft). In the Netherlands, several companies are involved in developing and manufacturing simulators for aircrew and maintenance purpose , this varies from Desktop to full motion level D Devices.

Also several companies within the Netherlands currently provide the actual training through their ATO or PART 66 of which some already operate full electrical aircraft.

Within the Netherlands there is a perfect opportunity to play a role in the development of new simulation media like AR/VR and training course ware in order to facilitate training for the next generation aircraft (e.g. electrical, hybrid and eVTOLs).

Value Chain Position for Aircraft Platforms

POSITIONING STRENGTH OF A CLUSTER LEAD BY AN OEM/TIER 1

An OEM or Tier 1 is the driving force behind a product portfolio for a global market with development initiatives and production deriving from it. The OEM and/or tier 1 is therefore everything that determines the 'demand' to the different elements from the Eco system and the integration. In other words: If there is no targeted demand from the market and there is no integrator, it will be very difficult to maintain a healthy ecosystem. Conversely, if there is no ecosystem, it will be very difficult for an OEM nowadays to be successful.

The Netherlands currently has no longer its own demand for development and production. Also, the fact that key players at the component level in the Netherlands have come into foreign hands has impact on the balance in the ecosystem in terms of alignment with Netherlands national and regional economic interests.

The current ambition that arises in the Netherlands on sustainable aviation can re-establish a leading position in a Dutch cluster with the leverage to influence the demand side by the 'system integrator/OEM' positioning. With this step it is possible to position the Netherlands much better and to meet a worldwide demand from airlines that want/need to fly sustainably. It will lead to a very robust boost to the ecosystem and significant new business with related employment opportunities. In short, it means that the 'demand' of 'zero emission' in the Netherlands must be translated into demonstrators via development programs in order to ultimately meet this demand from international customers (airlines) via an OEM and tier 1 (system integrator) position.

DUTCH MANUFACTURING INDUSTRY

The key value chain for innovations in aircraft platforms is the manufacturing industry, driven mainly by OEMs as they decide which innovations make it to the next aircraft program. The table below presents the established capabilities (already in market) and the new developments (not yet in the market, at various levels of maturity).

The NAG is the trade association for national and international organisations established in the Netherlands and active in aerospace & airport development. The NAG has more than 100 members who together represent 95% of the Dutch aviation industry's revenue.

Tier	Current Dutch established capabilities in value chain	Additional new Dutch capabilities
OEM	-	Newbuilt (full electric) aircraft
Tier 1	Lightweight structures, EWIS (electric conversion and power distribution)	Full liquid hydrogen (LH_2) powertrain, HVDC distribution
Tier 2	Avionics, compressors, cooling/thermal management components,	LH_2 composite tanks, electric motor/inverter, fuel cell integration, e-compressor and cooling system, AR and VR simulation solutions
Tier 3	HVHP components, (in structure) sensors, Fibre Metal Laminates	Efficient low noise propeller, precision navigation solutions
Tier 4	Thermoplastics, composites, production automation, process innovation	Composites for hydrogen, automation and process innovation for sustainable production at low costs

Stakeholder landscape and Value chain within Future Fuels (1/2)

	GENERATION	TRANSPORT	STORAGE	REFUELLING INFRASTRUCTURE	SAFETY & CERTIFICATION	REGULATION

HYDROGEN TRENDS IN THE VALUE CHAIN

Within hydrogen, current energy incumbents transitioning to sustainable fuels can deliver the funding required for hydrogen production. Further into the value chain, hydrogen stakeholders must collaborate with the chemical industry who have been handling hydrogen logistics for decades. Hydrogen aircraft start-ups are often integrating the refuelling into their value proposition. Much research must still be done regarding safety and certification to transition current knowledge from other sectors to the aviation ecosystem.

SAF TRENDS IN THE VALUE CHAIN

In SAF, some incumbent energy producing firms have taken bold steps to lead in SAF production. However, collaborations and consortiums between multiple aviation stakeholders also work well to cross the value chain barriers and ensure that the uptake of SAF by airports is aligned with the production. Blending mandates will increase the integration of SAF into the value chain, although much of the handling is the same as with traditional kerosine.

ELECTRIC TRENDS IN THE VALUE CHAIN

The electric value chain will engage mostly new stakeholders, as both fuel suppliers and airports do not have much experience. It is vital that within the development, other sectors that have advanced further such as automotive can share their knowledge.

Stakeholder Landscape and Value chain within Future Fuels (2/2)

ENERGY GENERATION

Energy generation for sustainable fuels is critical to stimulate the development of sustainable aircraft. For electric aviation, the transition to renewable electricity is well underway, although the requirement from all other sectors may lead to competition for the scarce amount of renewable electricity that is available.

Green hydrogen relies heavily on renewable electricity, as current grey hydrogen production is largely produced from fossil fuels. Currently, green hydrogen production is 2 to 3 times as expensive as grey hydrogen and due to the inefficiencies of green hydrogen production, producing green hydrogen is not the most efficient use of scarce renewable energy. Green hydrogen production can be applied when renewable energy production peaks due to intense sun or high winds. However, the shortcoming in such a case is that expensive hydrogen electrolyser systems are not continuously used, leading to higher costs.

SAF production relies on waste and bio fuels initially, but as the resources for this are scarce, the industry is currently also looking into synthetic fuels. Using crops as a feedstock for fuels also brings negative land use externalities and may not lead to sustainable alternatives. Synthetic fuels are produced using green hydrogen and captured CO_2. This process, power-to-liquid is very energy intensive.

All stakeholders within the aviation value chain must invest largely for all three types of future fuels. To ensure that these investments are made, there must be a clear demand developed by policy and through market based cross-value chain collaborations

ENERGY TRANSPORT AND LOGISTICS

For the transportation of future fuels, electricity and SAF can make use of current systems and infrastructure. For electric aviation, the capacity of energy grids would need to be updated, and there are opportunities to do this in synergy with local renewable energy production and onsite storage. For SAF, blending certifications will allow SAF fuel to be integrated inti the current systems.

However, hydrogen systems present a more difficult development. Within the short term, hydrogen refuelling infrastructure can be supplied through trucking systems, which are well developed within the chemical industry by incumbents such as Linde and Air Liquide. In the long term, much research must still be done to develop the storage, handling and transportation systems to and at airports.

RESEARCH AND DEVELOPMENT

Research into sustainable fuels is focused on multiple aspects, including production, storage, safety, but also business cases and legislation. Universities are working together with market players to receive EU funding for projects such as hydrogen storage systems or integrated smart grids. These type of projects must be further developed to higher TRL levels so that businesses inside and outside of the aviation industry can develop them.

AIRPORTS

The role of airports in future fuels and their infrastructure must increase if airports want to get ahead and stimulate sustainable aviation. By providing testing and pilot facilities for the first hydrogen and electric aircraft, airports develop connections with the frontrunners of sustainable aviation, and gain knowledge and experience with the infrastructure for future fuels.

SAFETY AND CERTIFICATION

The role that safety stakeholders such as fire departments play must not be underestimated. By including them into the process of future fuels installations, the certification process is also clearer. Furthermore, it is important to take the best practices from other sectors to ensure that the knowledge that is already available is used.

TECHNOLOGY DEVELOPMENT

The development of the technology required to produce future fuels, such as renewable energy, electrolysis and carbon capture for SAF production processes, is currently well underway, although much progress still must be made. The aviation sector can connect more closely with the developers of these systems to ensure that demand from the aviation sector for these systems and this energy is applied to boost production. Getting even more involved, will also provide opportunities for stakeholders such as airports that can produce local renewable energy or blend their own SAF on-site.

Stakeholder Overview within Future Fuels

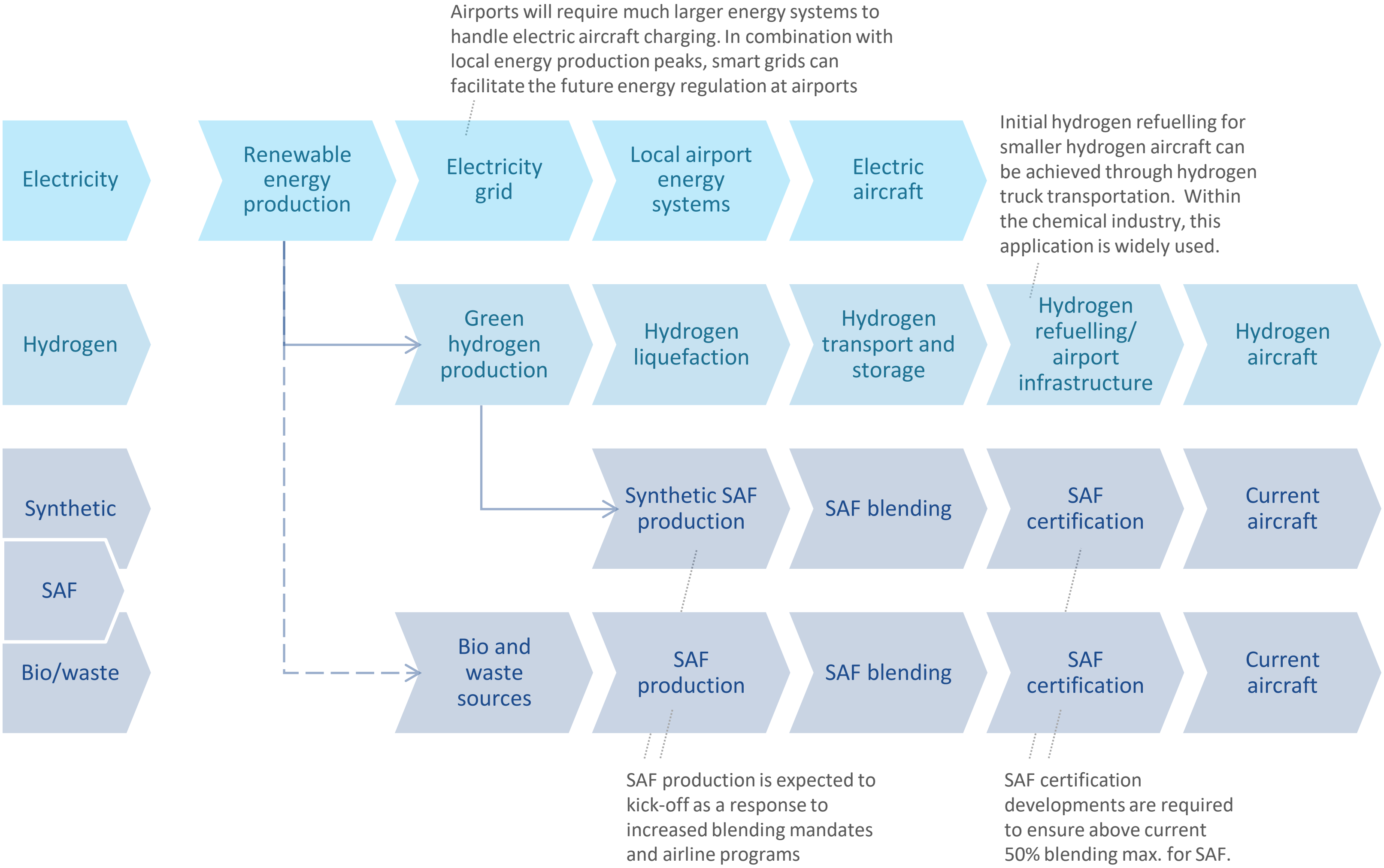
Within future fuels availability and infrastructure, the aviation sector must innovate within their own value chains, also look beyond the current stakeholders. Other sectors have years or even decades of experience in parts of the value chain that can be very complex.

By leveraging the learnings of other sectors, the aviation sector can make the switch towards future fuels at the pace that will be required to achieve sustainable aviation.

	GENERATION	TRANSPORT	STORAGE	REFUELLING INFRASTRUCTURE	SAFETY & CERTIFICATION	REGULATION & OVERARCHING TRADE BODIES	LEGISLATION
CURRENT STAKEHOLDERS	Fossil fuel energy providers	Energy grid regulators Fuel transport providers	Tank storage systems	Airport fuel service providers	Airport safety professionals	ATAG, ICAO, ACI, IATA EASA, FAA, CAAs; regulatory bodies	National and EU blending mandates, CO2 targets, EU ETS, CORSIA
CROSS SECTOR OPPORTUNITIES	Clean energy providers (solar, wind) Electrolyser initiatives	Chemical industry	Chemical industry storage Smart grids Heat storage	Automotive industry charging systems Chemical industry refuelling systems	Chemical fire safety professionals Electrical safety professionals External firefighters	Safety regulation and standards from other industries	Fit for 55, EU green deal, Horizon 2020, EU taxonomy Dutch climate accord & climate policy

Value Chain for Future Fuels

Within future fuels, there are multiple value chains for the different energy carriers. As described below, they are connected to renewable electricity as a main energy source. Within the Electricity and SAF value chains, the transport, storage and refuelling infrastructure have already been developed, while within the hydrogen value chain, this infrastructure must still be developed. As there is a strong development of electric recharging systems within the automotive industry, aviation can use this as a stepping stone. While the electric value chain is more simple to develop, electric powered aircraft are limited in pax and range. For the SAF value chain, smart integration into the current refuelling value chain presents the easiest way to integrate into aviation. However, SAF production at the beginning of the value chain presents a challenge due to the low feedstock availability for bio and waste SAF and low TRL levels and high energy costs for synthetic SAFs. For the hydrogen value chain, there are still many challenges, but hydrogen does present the opportunity to fully decarbonise aviation even for longer range flights, although the time frame is larger than for SAF due to the low TRL levels for hydrogen powertrains and aircraft.



Stakeholder Overview within Airports

	LEGISLATION AND REGULATION	TRADE & STANDARDISATION BODIES	INFRASTRUCTURE DEVELOPERS	OPERATING INDUSTRY	AIRPORT USERS & LOCAL STAKEHOLDERS
CURRENT & CONTINUOUS INNOVATION	ICAO EASA, National regulations, SESAR JU Ministry of IenW (DGB/ILT)	ACI Sustainable building standardisation (LEED, BREEAM)	IT provider Energy providers Real estate developers GSE suppliers	Airside operators (handlers, airlines, ANSPs, GA, helicopter operators) Landside operators (taxi's, train operators, rental agencies, real estate, retail)	Passengers Local communities Cargo Training (crew, maintenance, etc.)
NEW ENTRANTS & DISRUPTIVE INNOVATION	ATAG EU fit for 55	Financing standardisation (GRI, ESG)	Airside and landside system integrator (ALS, security systems) Electric & hydrogen GSE suppliers Future energy providers	Future mobility (eVTOL, eCTOL, hyperloop, point to point aviation)	Energy hub users Future mobility users

Stakeholder Overview within Airports

LEGISLATION AND REGULATION

Legislation for airports mainly comes from a national level, although EU policy has increased to develop a level playing field for all airports to operate within the EU. International bodies also play a role in Airport regulations, including standardisations by organisations such as EASA and guidelines by ICAO. Airports can also increasingly look for support from government and intergovernmental institutions. Examples of this include the fit for 55 package from Europe, but also national mobility and innovation funds.

STANDARDISATION BODIES

Airports do not require strict standardisation, although new innovation developments do demand that airports are aware of industry standards outside of the airport scope. Regarding digitalisation, there are many IT standards that can be used within aviation so that systems can be easily integrated. When connecting different modalities, this can be critical. The main airports trade body is ACI. The ACI has set up a standardisation for measuring airport sustainability to reach net zero, referred to as the Airport Carbon Accreditation. Such standards can guide and help airports to become sustainable.

INFRASTRUCTURE DEVELOPERS

Airports have the main infrastructure at the airport within their own scope of control, but a portion of it is developed by third parties. As airports innovate, integrating with their current infrastructure developers, strengthening their own infrastructure and partnering with new developers on the areas of digitalization, sustainable technology and new mobility is key. Examples are the development of vertiports, integration of passenger flow information and new types of refuelling systems.

OPERATING INDUSTRY

The infrastructure at the airport developed with he future of aviation in mind, must be operated by partners that are able to develop a more digitalized and sustainable airport. It is clear that the current partners must be included in continuously developing their operations in line with airport innovation, including new vehicles, new systems and the new human resources required to achieve this. Furthermore, new entrants that have the knowledge on future operations, sometimes coming from other sectors can also be involved to ensure the airport operations are aimed at future developments.

AIRPORT USERS

Passengers, as well as cargo users of the airport can integrate the future airport developments into their way of working together with the airport. This mainly focusses on adoption, but also clear communication. Airports can facilitate these interactions by clear communication. Other airport users include the human resources associated with the new airport operations. Personnel must be adequately trained and understand the new digital systems so that they can incorporate it into their work.

Value Chain Position for Airports

Value chain importance

Airport's operators are usually the one in charge of and leading the innovation at the airport. They are at the heart of the value chain, implementing innovative solutions:

- to follow legislation and regulations,
- improve safety, capacity, liveability and climate conditions and
- accommodate the new type of transport and services in accordance with the end-users' behaviours

Therefore, the value chain is evolving along the years according to the new business models, stakeholders needs and clients' behaviours.

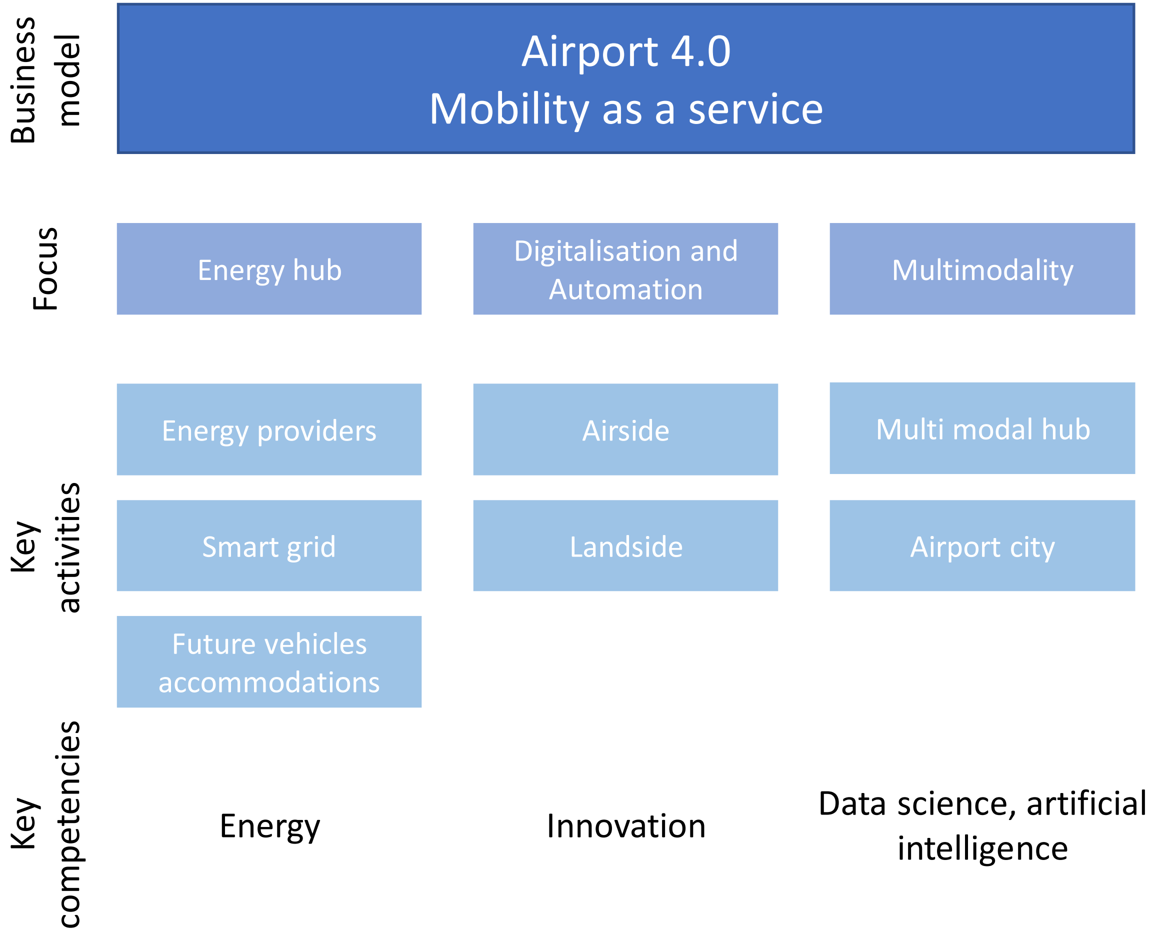
Airport proof of concepts in the Value chain

Airport often start innovations with a proof of concept, developing the solution for one specific part of the operations and performing a trial. Some airports have even created a testbed or innovation centre such as Rotterdam The Hague Innovation Airport at Rotterdam airport, Airport Lab at Paris Airport, and the innovation hub at Schiphol Airport to gather start-ups, researchers, industrial, end-users in a unique location and perform trials.

Trials often take place in collaboration with the complete airport community, as most of the innovations impact the operations of multiple stakeholders. Beyond this, an innovation carried by all stakeholders will have a greater positive impact and is especially relevant for digitalisation which often effects many different systems.

Funds are supporting these trials such as the European Green deal and national funds.

Once the proof of concept is assessed, deployment at the airport can be realised and good practices can be shared to other airports. As every airport had its own specific context within which it operates, a direct replication or common deployment is very difficult. Therefore, the innovation processes mainly start with a proof of concept even if the solution is already deployed in many other airports.



Stakeholder Landscape and Value Chain within Airspace Design

The industry landscape in airspace design and reflects the traditional stakeholders that guide aviation development and the delivery of its services.

The implementation of airspace rules and guidelines to accommodate new classes of air vehicles outside controlled airspace is being managed by the same stakeholders, however, new service providers driven from technology innovation are entering the market to provide new traffic management services.

New alliances and partnerships will be formed to prepare for the new future airspace system.

LEGISLATION AND REGULATION
- ICAO
- EC
- EASA
- Netherlands Ministry of Transport
- State National Aviation Authorities

STANDARDISATION BODIES
- EUROCAE
- ETSI
- RTCA

RESEARCH AND DEVELOPMENT
- SESAR
- FAA Next Gen Programme

AIRSPACE USERS AND AIRPORT OPERATORS
- Commercial, business and general aviation operators
- UAS and other future airspace users
- Airport operators
- Urban airport operators

SERVICE PROVIDERS
- Air traffic service providers
- ATM data service providers
- Network Management (ATFCM)
- CANSO and other ANSP alliances
- U-space service providers

TECHNOLOGY SUPPLIERS
- ATM software suppliers
- ANSP alliances

Stakeholder Overview within Airspace Design

LEGISLATION AND REGULATION
Air travel is a highly regulated industry, whether its environmental, security, safety or competition aspects. European governments also have an interest in ensuring that the European air industry, both users and suppliers, remains competitive in future and continues to contribute to economic growth and jobs. The key stakeholders are ICAO, the European Commission (EC), EASA and local state ministry for transport.

STANDARDISATION BODIES
The new solutions delivered will rely on the availability of industry standards to support their development and deployment such as the European Organisation for Civil Aviation Equipment (EUROCAE), the European ATM Standards Coordination Group, RTCA and ETSI.

RESEARCH AND DEVELOPMENT
Established in 2007 as a public-private partnership, the SESAR Joint Undertaking (SESAR JU) is responsible for the modernisation of the European ATM system by coordinating and concentrating all ATM relevant research and innovation efforts in the EU. SESAR JU was established under Council Regulation (EC) 219/2007 of 27 February 2007 (as modified by Council Regulation (EC) 1361 / 2008 (SJU Regulation) and last amended by the Council Regulation (EU) 721/2014). On 18 November 2021, a Framework for establishment of the SESAR 3 Joint Undertaking was adopted. This includes the development of 10 European Partnerships to progress the development of a Digital European Sky.

Link: https://www.sesarju.eu/news/framework-establishment-sesar-3-joint-undertaking-adopted

NextGen is not one technology, product, or goal. Rather, it is a series of interlinked programs, portfolios, systems, policies, and procedures. It implements advanced technologies and capabilities that dramatically improve the operation of the NAS. Relying less on ground-based systems like radar, NextGen is designed to transition the NAS from a traffic-controlled ground-based system to a traffic-managed satellite-based system. It is an evolution of ATM.

AIRSPACE USERS AND AIRPORT OPERATORS
Civilian airspace users include scheduled airlines, charter companies, cargo and air freight service providers, the business and leisure aviation sectors and all forms of non-military air travel, from hot air balloons through police helicopters to general aviation pilots. The military, in the form of the air forces of the EU's Member States, are also users with an interest in SESAR technology developments. Many of these companies and organisations are formally involved in the SESAR work programme. SESAR aims to triple the capacity of civilian airports in Europe. The ATM technology developed through the R&D programme will contribute to more direct flight paths and smoother, more rapid descents, reducing noise and other environmental impacts. Several large consortia of airport operators, such as SEAC and ENAIRE, are already SESAR members while ACI EUROPE represents an important stakeholder.

The future airspace will need to accommodate a variety of new low-level (flying typically below 500ft) as well as higher (typically above FL600) airspace users. Examples of low-level airspace users include eVTOL and drones while higher airspace users include high altitude platform systems such as balloons as well as suborbital and space aircraft.

Urban airport operators will provide the infrastructure necessary (e.g., vertiports) to service future air mobility. These urban operations hubs will provide manned and unmanned aircraft with command and control, charging/refuelling, cargo and passenger loading and other mission specific facilities.

SERVICE PROVIDERS
A service relying on digital services and automation of functions designed to support safe, secure and efficient access to U-space airspace for many unmanned aircraft systems (UASs). Unmanned traffic management providers such as Altitude Angel, ANRA, One Sky, Airmap, Unifly, Skeydrone are best placed to support this provider category either directly or in partnership with an existing ANSP.

A service consisting in the dissemination of static and dynamic data to enable provision of U-space services for the management of traffic of unmanned aircraft. Existing ANSPs or new data management experts will seek opportunity in this space.

The objective of Network Management is to ensure optimal traffic flow when demand is expected to exceed the available capacity of the ATC system. It comprises activities related to traffic organization and handling in a way that is safe, orderly, expeditious and kept within the capacity. ATC capacity reflects the ability of the system to provide service and is expressed in numbers of aircraft entering a specified portion of the airspace in each period.

The Civil Air Navigation Services Organization (CANSO) is the global voice of the ATM industry and is shaping our future skies. Their goal is to raise the bar on global ATM performance by connecting the ATM industry to share knowledge, expertise and innovation. CANSO has recently initiated a cross industry innovation forum, the CATS Global Council, for leaders across the industry to create and align on a unifying blueprint for our future skies.

Link: https://www.futureskyvision.com

There are several ANSP partnerships across Europe. The most common is the grouping of ANSPs under Functional Airspace Blocks. Others include Borealis and the A6.

TECHNOLOGY SUPPLIERS
The competitiveness of European industry depends on innovation and technological development. Innovation and technological advancement leads to increased competitiveness for European industry, especially in aerospace. Today’s R&D helps to produce tomorrow’s technical standards, increasing the potential customer base worldwide.

Several major companies from the following aviation supply industry sectors are already SESAR members, including ground and aerospace manufacturing, aircraft manufacturers, and airborne equipment manufacturers.

There are two major ANSP/supplier partnerships within Europe relating to ATM technology development. These are COOPANS and iTEC. They each have a slightly different business model for collaboration. COOPANS is a group of ANSPS who have together contracted Thales to provide technology to support their strategic goals. iTEC is a consortium of ANSPS including Indra who are the technology partner. Within iTEC there are different technology paths available to new members. Both partnerships aim to reduce cost for members, speed up development and share best practice.

Value Chain for Airspace Design

There are two main stages within the value chain for Airspace Design and Infrastructure. The first is strategic improvement of the aviation system through research and development of high-benefit capabilities. The second stage is the practical implementation of these capabilities within the local environment taking into account the existing geographical and environmental characteristics of the service providers. Historically, in the air traffic management industry there is a significant lag between the concept development and the operational realisation. Many concepts do not apply to service providers or require significant investment to realise the benefits.

Significant opportunity exists for those States that can identify opportunities and paths for implementation of new strategic concepts.

Stage 1
Industry strategic direction

Netherlands involvement in Stage 1

The Netherlands as part of Europe are within the EU Regulatory Framework. Dutch organisations are not a member of SESAR but participate in SESAR Trials and Demonstrations. The Netherlands as part of Europe are within the EU Regulatory Framework. They are able to set local policy on EU Regulation implementation.

ICAO, EASA and States provide the regulatory framework for aviation. In Europe the Basic Regulation provides the framework.

SESAR within Europe and NextGen within the USA drive research and development. In Europe SESAR leads in the development of trials and demonstrations of future Concepts.

Standardisation bodies are critical to regional improvement in the ATM System.

Regulatory framework → Vision and concepts → Research, development and trials → Regulatory requirements → Standardisation

ICAO, EASA and States alongside Industry are active in development of strategic visions and concepts. CANSO as the ANSP Industry Association promotes advances in traditional and U-Space services.

EASA provide specific implementing rules and community specifications to support implementation of the Basic Regulation.

Stage 2
Sector implementation

Netherlands involvement in Stage 2

The Netherlands have a thriving Airline, Airport and Airspace Management sectors. The Dutch Ministry are responsible for the Dutch Airspace Programme including the definition of U-Space services. All Dutch aviation sectors are involved in the development of new innovation, the derivation of new operational and technical requirements and the implementation and operation.

The State is responsible for the design of the airspace and related change programme to serve the needs of all users. Local service providers are responsible for the definition of the requirements for operational and technical delivery of services. ANSP partnerships drive interoperability across the industry.

Local service providers deliver the new services and realise the benefits of operational and technical changes.

Local operational and technical requirements → Local design and validation → Local operations

Local service providers are responsible for the design, verification, validation and transition to operations.

4. CONTRIBUTIONS OF INNOVATIONS

Public Interests

The Civil Aviation Policy Memorandum 2020-2050 sets course towards a sustainable aviation sector that will safeguard the Netherlands' strong connections with the rest of the world now and in the future. It will put all the parties involved in the sector on a solid footing and give them an agenda for the years ahead, with clear goals and a detailed approach. In this way the Netherlands is doing what it is good at: leading the way in the global changes in aviation that lie ahead. In the memorandum, the government sets out its vision of a new balance in aviation for the period until 2050 and the promotion of four public interests is central:

1. **Safety** - Keeping the Netherlands safe, in the air and on the ground, is a key aim of aviation policy. This means ensuring the safety and protection of aircraft passengers and crew, and the safety of people on the ground. Developments in aviation must not come at the expense of safety. Central government is therefore responsible for managing all aspects of aviation safety. Whenever major decisions are taken that lead to significant changes in aviation, an independent safety analysis is conducted first to highlight possible consequences for safety. This type of analysis looks at various factors, such as the number of aircraft in the air, flight routes and air-traffic rules. The Minister of Infrastructure and Water Management commissions safety analyses for civil airports. Automation offers opportunities for safe, efficient aviation, but it also creates new vulnerabilities: for cybercrime, terrorism and technical failures. Central government works with the sector to protect aviation from these risks.
2. **Connections** - The Netherlands needs to stay well connected to the world's major destinations. This calls for a modern, efficient and sustainably organised airspace. The government therefore seeks to prioritise forms of aviation that have the greatest value for the Dutch economy and employment. To this end, central government is developing a policy framework on network quality and will test existing policy instruments for their possible use in strengthening network quality. Where necessary and possible, the Dutch government will also endeavour to modify EU frameworks.
3. **Liveability** - Reducing adverse health effects is a precondition for the future growth of aviation. Central government will find ways to improve methods of, respectively, measuring and calculating aviation noise in such a way that they better reinforce each other. Efforts are also being made to gain a deeper insight into what aspects of aviation noise determine people's experience of this as noise nuisance, so as to devise policy that takes better account of these aspects. This calls for a customised approach for each airport, which will be reflected in airport decrees for civil airports. The aviation industry will also be required to help achieve the air quality goals of the Clean Air Agreement (letter to parliament, 13 January 2020) between central government and provincial and municipal authorities.
4. **Climate** - An ambitious climate approach has been formulated for the aviation sector which the government eventually aims to align with the aims of both the European Union and the National Climate Agreement (reflecting the Paris Agreement) of being practically climate-neutral in 2050. Within the EU and the ICAO, a United Nations body, the Netherlands is therefore pressing for more ambitious climate goals. Anticipating these more ambitious goals, the Netherlands is implementing the draft Sustainable Aviation Agreement which aims to reduce carbon emissions from Dutch aviation to 2005 levels by 2030, to half of 2005 levels by 2050 and to zero by 2070. If more far-reaching agreements are made at international level, the Netherlands will adjust its national goals accordingly.

Source: Civil Aviation Policy Memorandum 2020-2050

Also, the contributions of innovations to economic growth is relevant.

Contribution of Innovations in Aircraft Platforms

SAFETY

Safety is a pre-requisite to aviation. The current trends in vehicle design do not target safety increasements per se, as they aim to be certified within the same requirements.

Configuration optimisations, disruptive configurations and the energy transition need to be safety neutral at least. New electric and liquid hydrogen storage. These step changes require significant attention from regulators and industry.

Safety is also a key challenge for new airspace entrants (piloted and unpiloted eVTOLs, eSTOLs and drones). Certification (cost) is challenging for these new vehicles. Automation will be important to drive down operating costs and has potential to eliminate human pilot error but is costly in itself, and time consuming to develop and certify for complex operational traffic environments. Certification regulations for unpiloted passenger vehicles are not yet published.

CONNECTIONS

The energy transition and new configurations can bring connectivity improvements. Smaller battery electric and hydrogen fuel cell commuter aircraft have the (economic) potential to serve more point-to-point flights between 2nd and 3rd tier regional airports that are currently hardly used for scheduled flights. This 'distributed aviation' model is pushed by various experts and aircraft start-up companies. This can benefit small and regional airports in the Netherlands and the Dutch Caribbean for affordable, clean domestic and regional cross-border travel

Connectivity is the main driver for new entrants (eVTOL, eSTOL drones), being able to take-off and land from more locations. This requires a new network of helipads, vertiports and eSTOL landing sites. From urban to rural areas, new entrants could support and feed the distributed aviation model and provide first/last mile delivery. New entrants could work in scheduled milk run services or on demand business models.

LIVEABILITY

Aviation challenges for aircraft design and development in terms of liveability lie in air quality in airport areas and noise levels.

Configuration improvements of classic aircraft can reduce noise levels (ultra high bypass ratio, reduction of airframe noise). New configurations such as engines on top of blended wing bodies could shield part of the noise to the ground.

For propeller aircraft, electric motor propulsion has the potential to reduce 20+ dBA noise, through lower motor noise, optimised propellers operating at other propeller speeds, through distributed propellers with lower blade loadings and different propeller phase settings.

eVTOL noise could be a barrier for wide adoption in urban areas, so noise reduction is a key objective. Currently, public perception towards eVTOLs/air taxi's is positive (EASA study).

CLIMATE

The main current driver for commercial aircraft design is sustainability. The following contributions can be expected in CO_2 emissions reduction:

- Evolutionary optimisations 10-15% compared to 2020 aircraft entry into service (EIS)
- Revolutionary configurations up to 20-25% compared to 2020 aircraft EIS
- SAF up to 80% compared to fossil fuel
- Electric and hydrogen up to 100% compared to fossil fuel

Note that SAF and hydrogen combustion still produce NO_x and other emissions.

The sustainability impact of eVTOL/air taxi's is usually not included in aviation impact analysis since they are more competing with cars and subway, depending on existing infrastructure.

Contribution of Innovations in Future Fuels

SAFETY

Safety is one of the major concerns for future fuels as new energy carriers such as batteries and hydrogen but also synthetic kerosine behaves differently in operations and emergencies. To address these concerns, safety studies, clear certification and standardized regulation for new fuels are required.

However, safety concerns are not only a constraint. Coordinating appropriately with other sectors and current knowledge partners will lead to the development of a connected safety systems at airports. For hydrogen and SAF safety and regulation, industrial and chemical process knowledge within the Netherlands can be applied, while for electric charging there is an abundance of knowledge within the Dutch automotive industry and regulators. Finally, future fuels also provide an increase in safety for maintenance and airport ground personal, who no longer work in the unsafe conditions created by fossil fuel emissions.

CONNECTIONS

Within Future fuels, battery electric and hydrogen powered aircraft lead to shorter routes and therefore to more point-to-point connections. This means regional airports can develop their infrastructure to facilitate this and increase the connectivity of the region.

With the strong development of hydrogen and electric aviation in neighbouring countries, such as France, Germany and the UK , there is much opportunity to connect closely and become partners in the development of sustainable aviation.

Future fuels can also provide new and stronger connections regarding the supply of energy. As renewable electricity, hydrogen and biofuels develop and become feedstocks for sustainable aviation fuels, the dependency on fossil fuel import decreases. New connections can be set up with renewable energy and hydrogen producing countries, such as southern Europe and Africa.

LIVEABILITY

Electric powertrains are expected to lead to lower noise emissions, currently one of the main liveability concerns around airports. Aircraft powered by sustainable fuels will have a smaller noise footprint than current aircraft.

Regarding local employment, future fuels provide many new opportunities within a clean sector. Smaller aircraft will also provide more jobs to flight and ground personnel.

Furthermore, electric powertrains are expected to lead to lower noise emissions.

CLIMATE

The use of future fuels would lead to less emissions, up to 80% less for SAF and up to 100% for electric and hydrogen as a fuel. Within the immediate surroundings this will lead to decrease or even complete mitigation of local emissions such as NO_x and PM.

Non-CO2 emissions such as contrail formation and water vapour will also be decreased as a result of future fuels. The impact these fuels have is still being researched, but it is clear that they decrease aviation's impact on climate warming

While sustainable aircraft on electric and hydrogen may be smaller, this also means they will have a smaller noise footprint in general.

Contribution of Innovations in Airports

SAFETY

The automation of landside and airside processes significantly improves safety. The main benefits are the avoidance of human mistakes and reducing disruptions. On the other hand, the risks of cyberattacks do rise as digitalisation and connection of the airport systems increases Therefore, to ensure airport safety, the threat of cybersecurity should be taken seriously, and solutions should be developed to keep digital operations safe. Another aspect in airport innovation is resilience for climate change. By improving safety from natural disasters, disruptions can be avoided.

A final important aspect is the adoption and integration of new types of fuel for the airport such as hydrogen fuel, but also electric charging and an increase in battery storage. This brings new risks that need to be understood and mitigated through increased awareness, training campaigns as well as new equipment.

CONNECTIONS

Airport becoming a multimodal hub improves connections between the cities and region, and connects more people to travelling. This can be done by integrating other current other modalities such as the high speed trains, public transport and bikes. However, airports can also integrate new forms of mobility including urban air mobility, car sharing services and hyper loops.

Digitalization tools will improve the awareness of passengers to take multiple types of mobility. It can provide insights into the impacts of the different mobility options.

LIVEABILITY

Innovations for airports are often developed with a focus in improving liveability, especially for local communities. Airports developing sustainability targets, and implementing this at their strategy level. Sustainability starts with carbon but also includes noise and many local emissions. Local emissions include NO_x, PM2.5 and PM10 as well as ultra fine particles (UFPs), and these must be constantly monitored to understand their impact. Innovations are being developed to reduce these emissions. Noise is also a primary focus for airports, who can mitigate this by changing the procedures, creating plans for local communities and developing innovative solutions such as sound walls to decrease noise.

Awareness and communication campaign is also key in improving liveability and through the implementation of digital platforms, local community can follow and better understand the airport activity.

Airports handle more than aircraft operations. Becoming multi-modal hub as well as local renewable energy producer will be positive for the full local community and improve liveability around the airport.

CLIMATE

As said in the liveability, airports are developing sustainability strategies and part of this is becoming net zero carbon. More than 90 airports in Europe are committed to become net zero by 2050 and are developing their roadmap to reduce their emissions. By electrifying its vehicle fleet, implementing solar panels, electrifying heating and cooling systems or developing geothermal solutions airports can cut their scope 1 and 2 emissions. Airports can also create partnerships with local producers and other stakeholders that have a large impact around the airport. More than reducing just their own emissions, airports can become a leader in carbon management, engaging stakeholders in their journey for a better sustainable aviation.

By digitalising their operations, airports can also better understand their climate emissions, and develop plans on how to mitigate these. Solutions such as digital twins provide the tools to achieve this.

Contribution of Innovations in Airspace Design

SAFETY

The systemisation of airspace operations and through the introduction of PBN and other flight concepts will form the foundation of ATMs contribution to the improvement of aviation safety.

Within U-space new airborne and ground infrastructure will ensure electronic conspicuity and the basis of the rules of the air relating to see and avoid (or detect and avoid in the case of UAS). New unmanned air traffic management (UTM) services within the U-Space drive towards a target of achieving a safety performance equivalent to what we understand in current airspace operations.

The success of automated solutions in current ATM Services and in new U-space will contribute significantly to aviation safety.

Note: In U-space the frequency of flights in urban environments will change the way we understand safety risk and we are unsure what the outcome is on the contribution to safety performance.

CONNECTIONS

The aviation industry will continue to enable physical connectivity in our communities within international, regional and national settings. New airport infrastructure or 'vertiports' within the urban and rural environment or the development of existing general aviation airports creates new opportunity for air mobility for the general public. The design of the airspace to seamlessly integrate with other mobility solutions is a key success factor.

Innovation in U-space opens the airspace to new use cases that support the mobility of people and cargo. The only limitation will be the affordability of the mobility options.

LIVEABILITY

The design of the future airspace environment and the technical contributions in all classes of airspace will reduce the environmental impact on aviation.
The impact of noise, privacy and security on the public in the urban and rural environment as a result of drones and other air vehicles is not yet understood. A combination of the location of flights (over flying new communities) and the number of predicted flights has the potential to impact the public. Strategies to avoid, control or mitigate these impacts must be employed.

CLIMATE

The aviation industries drive to sustainable operations from an environmental perspective is the introduction of new aircraft vehicles with net-zero propulsion technology. Primarily, the contribution of new airspace and technology innovation will ensure that the new air vehicles can integrate seamlessly into the airspace and ensure the safety of the flying passengers. New airspace concepts in traditional aviation will drive more direct routing for aircraft.

New performance based navigation technology in the air traffic environment will bring about significant environmental impact through more efficient routing.

From a financial perspective, the provision of ATM services is a significant cost to airspace users. The transition to a service orientated architecture for service provision will provide the scalability needed to ensure demand for air traffic services can be supplied flexibly. This will rely significant on virtualisation of services and the ability to conduct these activities cross-borders.

Contributions of Innovations to Economic Growth

The contribution of aviation to the Dutch economy (gross domestic product) increased by 15.3% in five years to more than € 10 billion in 2018. Schiphol's direct economic contribution corresponds to approximately 0.8 to 0.9% of GDP. There is a relationship between economic development and aviation.

The growth of the economy stimulates aviation and vice versa. Regions with good international connections are growing faster than others. Large airports in particular have a positive effect on the economy. The knowledge-intensive service industry and logistics, two sectors of great importance to the Netherlands, appear to benefit the most from an airport.

The Netherlands is a small country with an open economy and accessibility is of great importance for its international competitive position. The Netherlands earns a third of our wealth abroad. Access to (new) markets, international entrepreneurship, mission-driven innovation policy and economic diplomacy requires a good and broad connection with the rest of the world. More cross-border activity also benefits our productivity and capacity for innovation. The application of Dutch knowledge and expertise in the field of global tasks related to agriculture, energy and health as well as new technology are an important aspect of our future earning capacity.

Airline, airports and operations industry: With (Air France) KLM, the Netherlands has a flagship airline, with Schiphol as main hub (No 2 airport in Europe). Sustainability (CO_2, noise and air quality) are essential for their longer-term strategy, where Lelystad airport expansion could help offload traffic from Schiphol. Regional airports Rotterdam, Groningen and Eindhoven have ambitions to provide sustainable domestic flights (Power-up initiative). Airports, also in the Netherlands Caribbean islands, can benefit from more point to point sustainable hybrid electric aircraft flights and as such serve as incubators for sustainable aviation as battery and hydrogen technology matures. The Netherlands could play a leading role as early adapter of sustainable aviation. Airport design will require changes which offers potential for the relevant Dutch players.

Manufacturing industry: The Netherlands has well-respected aircraft manufacturing supply chain companies, in particular on (composites) structures, and aircraft systems. This is complemented by engineering, certification and testing (ground, windtunnel, flight) facilities and expertise. This is a 100 year legacy of having Fokker as an OEM, and later Fokker/GKN as a tier 1 supplier and as such the Dutch industry cluster can contribute to new aircraft and eVTOLs. The current industry landscape in the Netherlands is quite fragmented except for the (vertically integrated) lightweight structures and materials cluster.

The key revolution for aviation in the coming 50 years lies in the **energy transition and digitization**. To keep playing a truly leading industry role in this transition, in line with the Dutch government expressed ambitions, and ensure sustainable economic growth would require a strong OEM or at least tier 1 position in the new “true zero emission” powertrain technology, with clustered and vertically integrated players similar to the current position on lightweight structures. Additionally, industry 4.0 principles, digital twin and virtual certification will become key technologies for the aviation sector, with cyber security as an essential part for the vehicles as well as design and manufacturing environments. The National Growth Fund ‘Luchtvaart in transitie’ would allow major steps to be taken to continued economic growth in this sector.

Services and maintenance repair and overhaul industry: With many aircraft platforms under development, new Airbus/Boeing in the 2030s but especially eVTOLs and 9 to 19 pax commuters in shorter term, this offers potential for consultancy (certification, new ‘on demand’ business models with a highly digital customer experience) and the aftermarket MRO. KLM E&M, Maintenance Valley (Woensdrecht, Tilburg) and Maastricht Maintenance Boulevard are established players.

5. RESOURCES

Resources for Aircraft Platforms

FINANCES

Aerospace innovation, especially on aircraft level requires large financial resources. Especially maturing products to high TRL (flight test) and certification is costly.

Key innovation grants and subsidies: Globally no innovation subsidies are available. The European Union Horizon Europe provides the main instruments for the next 7 to 10 years, namely Clean Aviation (4.1 B€ | 1.7 B€ grant) and Clean Hydrogen (4.1 B€ | 1.7 B€ grant), the latter for all industries and not just aviation. Bi-yearly work programs are published under Cluster 5: Climate, Energy, Mobility, with typically 5-10 M€ available per project. The content of the calls can be influenced by EU member states. For SMEs specifically the European Innovation Council Accelerator can provide grants and equity to bridge the gap to the market. On national level, major aerospace countries (UK ATI and UKRI, Germany LuFo, France, USA via NASA) provide hundreds of millions for aerospace innovation. Regional funding is available for both innovation and facility development. Recently, the National Growth Fund awarded 383 M€ for the proposal 'Aviation in transition'.

Private sector funding: The aerospace sector is CAPEX intensive, with high financial requirements and risks to reach the market (mainly proof of concept and certification) and longer ROIs than other industry sectors. A 'valley of death' exists between angel investors in early stage until VC and banking sector funding becomes available after certification risks. Investments are mainly done by aviation sector stakeholders. The Netherlands has the 'innovation credit' instrument to de-risk this phase, but with modest project amounts compared to aircraft level funding needs. Several international start-ups have secured tens to hundreds of millions in funding rounds (e.g. Eviation, ZeroAvia, Universal Hydrogen, Volocopter, Lilium). Although some companies are expected to be successful, the majority of the new aircraft platforms will however run into a dead end for funding reasons (which could be driven by poor technical performance and poor business case).

HUMAN

Human resources are instrumental in innovation. For the following areas, resources should be available.

Regulations and certification: With current market activities, a large batch of eVTOLs and hybrid electric aircraft will apply for certification within the next 5 years. Each project (especially new aircraft) requires specialists at the aviation authorities for aerodynamics, flight performance, structures and in particular propulsion and systems, where many new electric architectures and components are introduced. With the ramp up in projects, also a ramp up in experts is needed to handle all these projects in a timely manner. Typically, new aircraft certification takes 5-9 years and retrofits (Supplemental Type Certificate) takes 2 to 5 years. On a national level, also sufficient expertise is needed to judge 'permit to fly' applications during the development phase.

Production and MRO: Once aircraft are certified, licensed mechanics will be needed for the manufacturing and MRO. The educations of such mechanics are usually approved reviewed by aviation authorities. The curricula need to be adapter especially to hydrogen and hybrid electric storage systems and (high voltage) powertrains. To support EIS by 2025, current mechanics skill sets need to be adapted and new mechanics need to be trained.

Pilots: With the introduction of initially piloted passenger and cargo eVTOLs and hybrid electric commuters, more routes can be serviced. This requires also sufficient licensed pilots. Since pilots need to be type rated, this can only start once aircraft platforms are sufficiently mature and near market ready.

INFRASTRUCTURE

In addition to a regulatory framework, also locations for flight tests and demonstrators should be available to safely execute flight tests.

Flight testing locations and facilities: Larger aircraft require larger airports and airspace areas. The higher the maturity level, the more (mission) realistic the test or demonstration environment should be. Norway has expressed explicit ambition to become a (flight) test location for sustainable aviation. In the Netherlands, finding test locations can be cumbersome especially for early-stage tests. The temporary reserved areas (TRA) on the North sea provide a 'low risk to population' environment but may be hard to reach for vehicles with limited range. For mature demonstrations past this stage, several airports have expressed interest. With testing, there's an inherent risk of accidents and incidents (e.g. ZeroAvia mishap in the UK) which may affect public acceptance for testing and for market adoption. A balance is needed between allowing aircraft modifications to test innovations and public and crew safety.

NOTES ON REGULATIONS

The development of aircraft innovations requires regulations and standards to be in place.

Regulations for certification: Certification regulatory provisions are in place (EASA) for piloted eVTOLs, light UAS (up to 600 kg) and small (battery) electric aircraft up to 19 passengers. Gaps in current regulations exist for 1) hydrogen powered aircraft, 2) unpiloted eVTOL and 3) larger hybrid electric aircraft (20+ pax).

Regulations for flight testing: Since non-certified aircraft do not adhere to ICAO standards, permission to fly is granted at national level. In the Netherlands, regulations raise a bar for such tests since this part of the aviation law is not fully completed yet. Other countries have put in place provisions to lower the bar, such as e-conditions in the UK for platforms up to 2000 kg.

Resources for Future Fuels

FINANCES

Developing future fuels and infrastructure requires large investments, including outside of the aviation sector's direct scope of influence. Regarding infrastructure at airports to accommodate future fuels, much research must still be done to develop the required systems and safety. The continued development and adaptation of aircraft to future fuels presents airports with significant financial risks.

Key innovation grants and subsidies: At the European Union level "Horizon Europe" provides the main instruments for the next 7 to 10 years, namely "Clean Aviation" (4.1 B€ | 1.7 B€ grant) and "Clean Hydrogen" (4.1 B€ | 1.7 B€ grant), the latter for all industries and not just aviation. Biyearly work programs are published under "Cluster 5: Climate, Energy, Mobility", with typically 5-10 M€ available per project. The content of the calls can be influenced by EU member states. For infrastructure specifically, the recent green airports call funded research at multiple EU airports for the coming 5 years. On national levels, major aerospace countries (UK ATI and UKRI, Germany DLR, France, USA via NASA) provide funding for infrastructure innovation.

Private sector funding: The aerospace sector is CAPEX intensive, with high financial requirements and risks. For future fuels availability, many large oil and gas incumbent firms are investing in renewable energy, Sustainable fuels and hydrogen as a demand increase is expected from multiple sectors. To decrease risk in this transition, collaborative investment between supply and demand is being developed on a private scale. Furthermore, airports must invest in infrastructure regarding future fuels. With uncertainties in future fuels development, airports can partner with market leaders to assess what infrastructure developments are required. This includes airlines, aircraft OEMs, start-ups and research institutes. Private sector funding in other countries is often carried by large aviation stakeholders, such as Lufthansa in collaboration with DLR in Germany, Safran together with Airbus in France, NASA together with Boeing and DARPA in the USA and Rolls-Royce and BP together with Heathrow in the UK. Within the Netherlands, funding can come from partnerships between Shell and KLM and Schiphol for example, as is currently being developed within SkyNRG.

HUMAN

Human resources are instrumental in innovation. The human resources required to increase the supply of future fuels and to develop the infrastructure must not be underestimated.

Future fuels infrastructure: The systems required to achieve electric recharging , SAF blending and hydrogen refuelling are in the initial stages of development. Airports must develop the human resources together with their stakeholders that can develop the new systems that are required. This can be achieved by including experts from other sectors who have experience in future fuels infrastructure but can also include the education of new professionals. Key in these developments is connecting with the other sectors so that the knowledge can be spread and investing in education so that new generations have the required skills.

Different energy systems: As there is no silver bullet within future fuels, multiple developments will need to be addressed at the airport at the same time. This will require more resources at one airport, and better coordination between the different departments. Outcomes of this will be that airports might need to take a larger level of ownership in the fuel supply for aircraft, as it is more closely connected with their core business.

Human resource scarcity: As the aviation sector develops towards sustainability, it is still largely defined by its polluting image. This may form a barrier to attracting human resources that have the capabilities to transform the sector. To ensure sufficient and capable human resources are available, airports but to a larger extent the entire sector will need to embrace the transition to sustainable and socially positive aviation.

INFRASTRUCTURE

The aviation sector has strict regulations on fuel safety, which has implications for SAF and green hydrogen production and infrastructure. On airports, the development of refuelling infrastructure must be developed in alignment with future aircraft. Leadership from airports as well as the responsible government bodies is required for pilots and test infrastructure. Throughout development of infrastructure, regulation must be included in the process. As SAF blending, and electric and hydrogen refuelling/recharging are new processes, infrastructure can be developed based on research but also experience from other sectors. While the airport infrastructure requirements for SAF remain low, this will be higher for electric and even more for Hydrogen.

NOTES ON REGULATIONS

Regarding future fuel regulation, this must still be developed, but there are opportunities to achieve this through collaborations with other sectors such as the chemical industry and fire safety institutions.

Renewable electricity generation and infrastructure requires some initial regulation, regarding safety and operations on airside. Increased SAF blending will require clear regulations on a global level on the short and medium term. For SAF regulations are already set internationally, and OEMS together with fuel suppliers have developed these regulations and compliance. Green hydrogen fuel for aviation will require more stringent regulation to ensure quality and thereby ensure safety. Green hydrogen, especially in cryogenic form will need to be well regulated to ensure safety in new aircraft. Research from both the academic as well as the private sector will need to be funded to ensure these regulations are in place on national and global levels.

Organizations such as EASA, the Federal Aviation Administration (FAA), Certification Authority Authorizations (CAAs) and many other national groups are responsible for these developments. Within the Netherlands, ILT together with other government safety institutions are imperative in developing regulations on a national scale.

Resources for Airports

FINANCES

Through EU grants and national subsidy initiatives, airports are increasingly able to receive funding to develop innovations at the airport, both for their scope 1 and 2 emissions, as well as scope 3. Several projects focusing on sustainable aviation also include airports to ensure that they can provide the required infrastructure.

However the main financial contribution for airport innovation is expected to come from airports themselves. Within many leading airports, they are aware of this and are willing to invest in future developments. However, this does make the innovative developments dependent on the wider economic success of the airport, that could lead to a decrease in financial resilience.

A number of airports are also seeing new business model opportunities within the innovations and adaptations required to become more sustainable and future proof. These include mobility as a service, as well as becoming a more central mobility hub to facilitate all modalities. Airports developing renewable energy are also seeing financial opportunities in generating, storing and delivering renewable energy in the function of an energy hub.

HUMAN

Airport adaptations and innovations require sufficient human capital. As many of the innovations include new types of technology and digital systems, there will be a higher demand for a more diverse group of resources. This includes data analysts, artificial intelligence specialists, safety engineers, chemical engineers and technicians, but also increasing overlaps with other sectors. There is sufficient knowledge available, but this must be connected to the airport.

As Airports are becoming a new energy supplier, diverse knowledge in energy and renewable activities is also required. This regards the refuelling systems, but also safety and operations.

INFRASTRUCTURE

Airports must be willing to adapt their infrastructure to allow for digitalization, new fuels, autonomous systems and new types of aircraft. They also nee to adapt their infrastructure to decrease their impacts on climate and liveability, while keeping the same standard of safety. However, airports, as they have full control and ownership of their infrastructure, can manage this well and have the capacity to develop the required infrastructure.

Many leading airports are launching plans to facilitate and provide the infrastructure for multi-modality, new type of operations and new entrants: electric aircraft, hydrogen, vertiport. They are increasingly applying knowledge from other sectors to achieve this.

NOTES ON REGULATIONS

Airports generally have strong ownership and control of their airport operations, which allows them to contribute in developing new and more innovative regulations for innovations. Airports work closely with fellow regulations stakeholders such as government institutions and ANSPs.

Knowledge on safety, infrastructure, and operations regulations are already available for many other industries for certain types of innovations. For example, electric autonomous vehicles, or future fuels are used in other sectors. For airports, the main challenge is to transfer this to the airport sector and increase their human resource readiness and stakeholder perception.

Airports are of course also a part of the larger aviation regulation ecosystem, which is often less adaptive and innovative. Therefore, airports may need to take the lead to support new regulation and certification for many types of innovation within the sector.

Resources for Airspace Design

FINANCES

At the start of SESAR, the aviation industry employs around 1.4 million people and supports between 4.8 and 5.5 million jobs. The aviation contributes an overall impact of €110 billion to the EU's GDP.

Aviation, supported by ATM, is a key driver of EU economic growth, jobs and trade, and essential for the life and mobility of its citizens. However, the current ATM system is highly fragmented and reliant on ageing technology, leading to inefficiencies of €4 billion annually. The role of SESAR is to define, develop and deploy what is needed and build a more connected greener, safer ATM system for Europe in aviation and air transport.

An example of the public/private investment in AAM is the UKs Future Flight Challenge. This challenge is investing up to £125 million to develop greener ways to fly, such as all-electric aircraft and deliveries by drones, by advancing electric and autonomous flight technologies. This investment is matched by £175 million from industry.

In the case of Free Route Airspace, EUROCONTROL predict that once implemented across the European Network then 3,000 tonnes of fuel could be saved per day which amounts to 10,000 fewer tonnes of CO_2 per day and a fuel costs saving of €3 million per day.

Other public / private programmes contributing to global sustainability targets are also being develop through the Connected Places Catapult and Aerospace Technology Institute.

HUMAN

The aviation industry suffered from a significant shortage of aviation professionals. Airspace congestion reached undesirable levels in 2019. Shortages of Air Traffic Controllers was mitigated by a shortage of Pilots. A significant level of resource will continue to leave the industry in short-term due to high-average age of staff and that they will reach retirement age over next 5 to 10 years.

In traditional aviation, challenge of recruiting new air traffic controllers and support staff continues to be an issue and there is a significant lead time (up to 4 years to become operational). Training and competence of staff is a long-term strategic activity but often managed tactically by organisations because of the tension between supply and demand.

The current demand side shock created by the Covid pandemic has resulted in significant cuts in staff which has short-term benefit but for the long-term investment is required to ensure shortages do not create capacity issues seen in 2019. A staff shortage among air traffic controllers and engineers may also arise due to the currently high age profile of these professions and no viable strategy to mitigate staff shortages when current engineers and ATCOs retire.

The Next Generation of Aviation Professionals Programme has been initiated to ensure that enough qualified and competent aviation professionals are available to operate, manage and maintain the future international air transport system.

INFRASTRUCTURE

Infrastructure present in the Netherlands is ready for innovations in Airspace Design. The diversity of the type of operations also allows to explore the different part of airspace, both civil and military.

NOTES ON REGULATIONS

In terms of regulation and infrastructure, the resources required for innovation are being provided by traditional aviation stakeholders who guide aviation development and the delivery of its services.

The implementation of new regulation and infrastructure which will enable new classes of air vehicles outside controlled airspace is being managed by the same stakeholders, however, new service providers driven from technology innovation are also increasingly contributing.

Resources are required within Europe to develop standards for U-Space design and technological developments surrounding critical tools such as e-Conspicuity. However, this falls with EASA's remit.

Other standards organisations such as ISO have begun publishing standards in the field of UAS including, but not limited to, classification, design, manufacture, operation (including maintenance) and safety management of UAS operations. ISO have published seven standards so far and have another 24 in development.

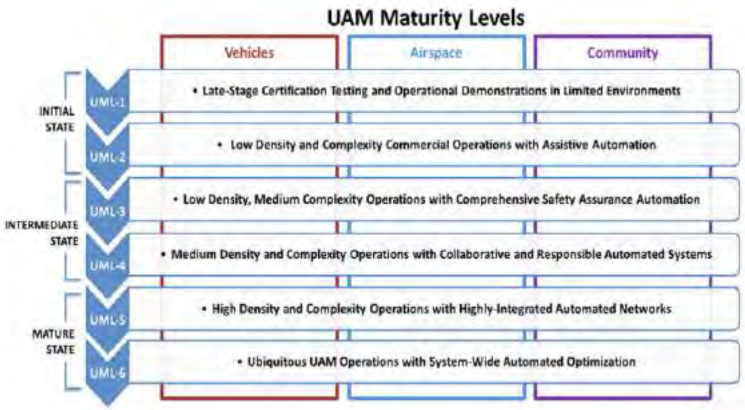
6. MONITORING ACTIVITIES

Monitoring Activities on Aircraft Platforms

The following monitoring instruments are available to track progress in aircraft platform development.

- Technology Readiness Levels: NASA has developed TRLs as a generic instrument to measure the progress from concept (TRL1) to market ready (TRL9). There is no centralized or institutionalized monitoring of TRL levels (yet) for sustainable aircraft platforms. This scale could be used to track the maturity of market front runners and national projects of interest regarding powertrain (subsystems) and aircraft. A key difference to look out for with hybrid electric aircraft is the step from TRL5-6 to TRL7. Where TRL5/6 prove the technology ('yes we can fly'), TRL7 bridges the step to an economically viable product in a flying demonstrator ('yes we can demonstrate airline/airport/operator requirements').
- CleanSky/CleanAviation Technology Evaluator: A Technology Evaluator is part of the European CleanSky projects, which tracks the progress against the program's initial objectives. Clean Aviation requests impact monitoring as part of its projects. This, together with the TRL levels that are also used by the European Commission, provides very useful insight in all the work done on optimization of classical configurations, radical new configurations, conventional engine technology and new sustainable powertrains.
- Urban Air Mobility Levels: NASA also developed a UAM maturity level scale. This can be used to track the progress of specific eVTOL/UAM concepts against vehicle readiness, airspace readiness and community readiness (public acceptance). There is no centralized body in Europe that tracks the eVTOL/UAM market on a structural basis in the public domain.
- The European Platform on Sustainable Urban Mobility Plans tracks and coordinates progress on UAM.

Source: TBD



Source: TBD

Monitoring Activities on Future Fuels

Current monitoring systems for future fuels are limited to none, due to the limited development. On a global level, ICAO has developed a tracker tool that tracks developments in technology, operations, sustainable aviation fuels and aviation net zero plans, although focused on market developments. Many of the European subsidies such as clean aviation (previously Clean Sky 1&2) and clean hydrogen publish periodic developments that have a monitoring function. A short description is given per type of future fuel regarding future monitoring opportunities.

Electric charging: Electric charging infrastructure is currently being developed by the same firms developing electric aircrafts, to enable the connection between. This market focused innovation makes clear monitoring difficult, although indicators can be identified to better understand the development.

Hydrogen refuelling: Green hydrogen availability and infrastructure monitoring is currently tracked within the ICAO tracker tool, as well as within continues reports from national and intergovernmental institutions such as the ATI in the UK, the DLR in Germany, the WEF, and Clean Sky. For more information, see the document repository which includes many of these reports.

SAF Blending and refuelling: Monitoring of SAF is more developed within the ICAO tracker tool. It includes a clear map of SAF production facilities and partnerships that increase SAF uptake. However, the developments within SAF, especially as SAF blending and uptake pick up increase, are difficult to monitor at a global level. At a national level, legislation on blending mandates gives a first monitoring opportunity, although the production side is still largely unmonitored. There is an opportunity to apply monitoring tools to better connect supply and demand within SAF developments.

Source: ICAO technology tracker

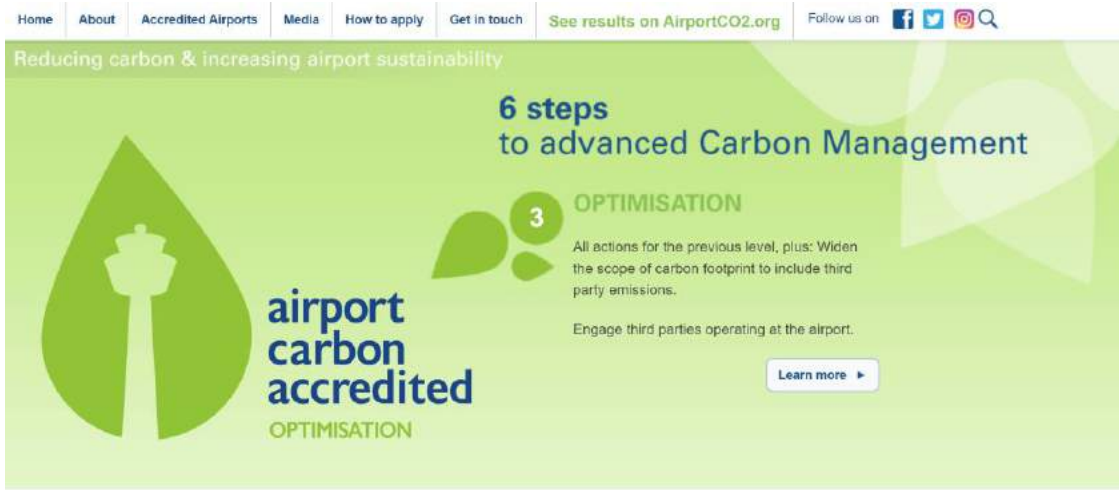
Source: ICAO SAF tracker

Monitoring Activities on Airports

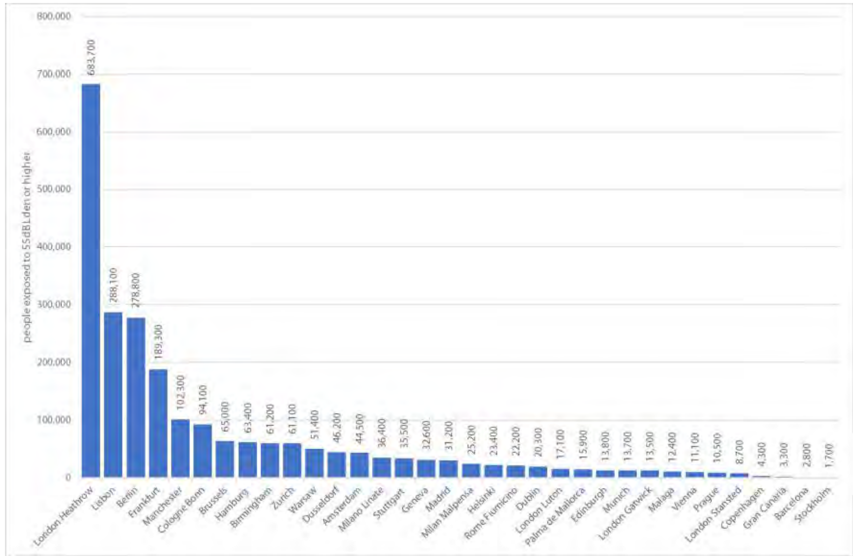
Airport innovation monitoring is not centrally developed, yet there are tools and organisations that provide insights into current developments. First, all EU funded projects require a clear description of achieved targets and the developments reached. Within SESAR and its monitoring platform, the different topics where airports are concerned are detailed and can be followed

ACI is reporting on airport CO_2 management through the ACA platform and ACI Europe has recently launched a repository for airport roadmaps.

Within Europe and part of regulations such as the Directive 2002/49/EC regarding noise, the European Environmental Agency keep track of the different environmental indicators and publish them periodically. On noise, for example, the number of inhabitants exposed to Lden 55 dB(A) or above are reported in the Environmental report every 5 years.



Source: Airport Carbon Accreditation website



Source: European Environment Agency, 2017 data
** Data excludes French and Greek airports*

Monitoring Activities on Airspace Design

The European ATM Master Plan is the main planning tool for the modernisation of ATM. The monitoring view of the European ATM Master Plan, directly linked with SESAR, shows the implementation status of the Level 3 of the European ATM Master Plan - Implementation Plan. The Implementation Plan is translated in Local Single Sky ImPlementation plans (LSSIP) per ECAC country. Results of the LSSIP implementation can be visualised through the LSSIP Map Tool and form the basis for Master Plan Level 3 - Implementation Report. Monitoring takes place in an annual cycle.

Source: TBD

APPENDIX: DETAILED ANALYSIS

1. Aircraft Platforms
2. Future Fuels
3. Airports
4. Airspace Design

1. INNOVATIONS IN AIRCRAFT PLATFORMS

Introduction and Scope

Innovations in aircraft platform technology are currently dominated by reduction of noise and gas emissions (which saves fuel costs and lowers environmental impact) and by mobility demands, particularly in remote rural and urban congested environments. With the policies aiming for zero emission aviation to help fight the human effects climate change, the energy transition is no longer an option, bur a necessity. Key challenges are certification of new aviation platforms, maintaining mono-disciplinary benefits of new concepts in actual multi-disciplinary design trade-offs of an actual aircraft program, and public perception.

Outcome AC1: Aircraft are powered by sustainable energy powertrains that have a low impact on the environment

As the aircraft industry has already made staggering evolutionary improvements in the past 70 years of the jet age in fuel efficiency and noise reduction, a more radical step is needed to realize the 2050 net zero goals. Aircraft need to switch to sustainable sources of energy. The three main options are: 1) Sustainable Aviation Fuels for which increased blend levels and engines need to be tested and certified. 2) (Hybrid-)electrical power (battery or hydrogen fuel cell) is currently being pioneered on general aviation and commuters. It has the most promising reductions in reductions of carbon and other emissions (NOx),but needs to scale up in energy density to make then viable for large aircraft. 3) Hydrogen combustion promises great carbon reduction, while still emitting NOx.

Drivers: AC1.1 Transition to aircraft platforms on SAF | AC1.2 (Hybrid)-electric propulsion | AC1.3 Hydrogen combustion

Rolls Royce Ultrafan

Outcome AC2: Aircraft require less energy to fly and make less noise

This outcome is a continuation of the evolutionary changes in engine improvement and aircraft weight and drag reductions. In view of scarcity of sustainable energy and fuels (see Future Fuels) it is essential to make more progress even if only modest savings are to be expected for classic wing-tube aircraft. Additionally, more disruptive aircraft configurations could bring bigger gains in fuel and noise reductions. Blended Wing Body and new wing concepts are explored as well as distributed propulsion and new engine aircraft integration that could lead to lower energy needed and less noise emission to the ground.

Drivers: AC2.1 Continued classical aircraft platform optimization | AC2.2 New disruptive aircraft platform development

Airbus Zero-e

Outcome AC3: New platforms for air mobility meet safety and operational needs of the airspace

Driven by improved mobility and facilitated by the advent of electric motors and electric propulsion with lower costs than complex combustion engines, new airspace entrants are being developed: AAM. This study will focus on transport of passengers and cargo by piloted vehicles and unpiloted vehicles ('drones'). These vehicles can be eCTOLs, eSTOLs and eVTOLs. The key challenge is to develop economically viable concepts that are certifiable. A second challenge, particularly air taxis and delivery drones in urban environments, is to ensure they can operate safely in complex environments with ground obstacles and lots of other air traffic, if these vehicles are widely adopted.

Drivers: AC3.1 Certified vehicles (eVTOLs and drones)

Volocopter

AC1.1 Transition to Aircraft Platforms on SAF

INNOVATION READINESS LEVEL: **HIGH**

As long as true zero emission fuels are not yet viable for larger aircraft, sustainable aviation fuels are the only alternative to reduce CO_2 emissions, especially for the existing fleet. Transition to aircraft platforms on 100 % sustainable aviation fuels enables relatively quick reduction of net CO_2 emissions without large and costly changes of the aircraft platform. It basically relies on issuing a new standard of jet fuel fully comprised of synthesized hydrocarbons. Development and approval of such a new standard requires involvement of airframe and engine stakeholders, amongst others such as producers of SAF.

REGULATORY AND MARKET DEVELOPMENTS

According to the ATAG more than 350,000 commercial flights operated using SAF since 2011. The fuels get certified to work with existing engines for a certain blend level. To accommodate and approve the transition to 100% SAF, ASTM has formed a taskforce in 2021 on 'Standardization of Jet Fuel Fully Comprised of Synthesized Hydrocarbons', to modify ASTM D7566 drop-in standard.

ANALYSIS

Aircraft modifications: No major aircraft modifications are needed to accommodate safe, which makes SAF for the short-term the most viable option for regional aircraft, Short haul, medium haul and long haul. Aircraft platforms can already operate on 50% SAF, when the blend is certified along standard ASTM-D7566. Aircraft platforms on 50% SAF blend are feasible.

Transition to 100% SAF: A new 'Standard of Jet Fuel Fully Comprised of Synthesized Hydrocarbons' needs to be written and approved first. Standardisation is a necessary but slow process, requiring test-programs with involvement of airframe and engine stakeholders. 100% SAF experiments are ongoing and flights have been performed. Examples are a FedEx Express Boeing 777 flight using 100% SAF in 2018, and the 2021 ECLIF3 study involving Airbus, Rolls-Royce, DLR and Neste used 100% SAF simultaneously on both engines of an Airbus A350 with Rolls-Royce Trent XWB engines.

Aircraft platforms on 100 % SAF will become feasible after standardisation.

TIMELINE

2011	2025	2030
Transition to aircraft platforms on 50 % SAF blend	Standardisation & test programs for 100% SAF	Transition to aircraft platforms on 100 % SAF

OPPORTUNITIES

R&D: pilot projects (ground tests and flight tests) towards 100% SAF are already ongoing and offer R&D opportunities for the (Dutch) airline community and SAF stakeholders.

Standards: to accelerate uptake of 100% SAF (or higher blends initially), standards should be adapted (ASTM).

Energy and Airline industry: the demand, availability, supply, pricing can be accelerated through government financial (subsidy) and non-financial incentives (legislation).

MRO: No negative impact is expected on engine MRO from using SAF that adheres to standards, and potentially even positive impacts.

AC1.2 (Hybrid)-Electric Propulsion – Battery-Electric

INNOVATION READINESS LEVEL: **MEDIUM – HIGH**

Electrical powertrains with battery-based energy storage systems make the most direct use of renewable energy, as all renewable energy starts with electricity (i.e. production of green hydrogen). As such it is very efficient with less losses in conversion from source to propeller. This driver can leverage economies of scale advantages from the automotive industry. Battery electric aviation does not have any in-flight emissions (also no water vapour), and noise can be reduced by leveraging propeller noise optimisations.

Lower energy costs (electricity) and lower maintenance costs (electric motors) can change economy to allow (sub)regional in a distributed aviation model (as part of AAM). eSTOLs can be operated from (short) runways.

REGULATORY AND MARKET DEVELOPMENTS

Regulations: Pipistrel trainer aircraft EASA certified in 2020 (Light Sports Aircraft - LSA). Regulations up to 19 pax (CS23) are ready for battery electric certification, not yet for larger aircraft (CS25). For electric propulsion systems certification, EASA has released a special condition. Also (multi-engine) eSTOLs could most likely be certified under existing EASA regulations (perhaps a larger number of engines would need to be accommodated). In the USA, FAA has also issued a special condition for electric propulsion in October 2021. Experimental Type Certification is available in the USA which makes experimenting and R&D easier.

Market: The 9 - 19 seater market is targeted first by start-ups. Satisfying airline operations is key, including reserves for airport diversion, short turn-around times at airports, lower life cycle costs. Innovation readiness should be assessed against operational market requirements. Public acceptance for short distance flying is negative, and people tend to favour the train. However, train networks are not as flexible as aviation and are underdeveloped for cross border travel. When flying can be done 'zero emissions' public perception can be regained. Safety perception is essential. Infrastructure and procedures at airports needed (see relevant driver).

ANALYSIS

Timelines to Market: Electric flight trainers are a reality. Commercial aircraft companies tend to be optimistic in touting entry into service dates (see industry roadmaps on next slide). Certification time is often underestimated. Pipistrel certification took 3 years in the more basic LSA category. FAA mentions typical certification times for commercial aircraft to be 3-5 year for a retrofit (type amendment) and 5 - 9 years for a new aircraft. This depends on aircraft complexity, novelty and resources at aviation authorities. A realistic expected time to market is probably 2027 for retrofits and near or past 2030 for new builds in the 9 - 19 seater segment. To speed this up, governments need to ensure sufficient human resources at EASA and national CAAs are available, as well as (flight) testing provisions for demonstration projects.

Battery energy density and engine capacity: Currently the highest energy density at (certifiable) pack level lies at 150 – 170 Wh/kg, usually using Li-ion cells (see the UK funded ACCEL project at 165 Wh/kg). To reach densities of 400 or 500 Wh/kg would require new chemistries beyond Li-ion. Key challenges lie in protecting the pack against uncontrolled thermal runaway. Electric motors are currently being scaled up from about 300 kW to 500/600 kW to MW level (e.g. MagniX, Rolls Royce). Hybrid electric power trains are being explored by e.g. Safran (ENGINeUS).

Retrofit versus new builds: New built aircraft take significantly more time and investment to develop and certify but can be optimized for electric propulsion. Retrofit certification can be faster, for example at time engine replacement is needed, but are most likely less optimized.

Technical challenges lie in High Voltage power trains (including HVDC distribution), thermal management (for batteries and for handing LH_2 and fuel cell cooling) and certifiable software. Engine noise will decrease with electric motors, which is vital for public acceptance.

TIMELINE

2020+	2025+	2030+	2035+
Trainers and GA market ready **Commuters** Demonstrators 9-19 pax	**Commuters** retrofit market entries **Regional** Scale up R&D	**Commuters** newbuild market entries **Regional** Scale up R&D	**Hybrid electric regionals** market entry

OPPORTUNITIES

R&D: A key EU level project to drive this forward is EC funded Clean Aviation.

Regulations and standards: Develop regulations for larger (EASA CS25) aircraft and develop. Globally harmonized charging standards: SAE AE-7D Aircraft Energy Storage and Charging Committee, SAE E-40 committee on Electrified Propulsion, EUROCAE WG-113 'Hybrid Electric Propulsion', ASTM F3239-19 Standard Specification for Aircraft Electric Propulsion Systems.

Door-to-door network change: The distributed aviation model (many point-to-point connections between small airports) can improve affordable connectivity, especially for rural areas and islands (e.g. Dutch Caribbean, which IenW is assessing in a Master Plan Hybrid Electric flight). eSTOL aircraft can use very small airports with short runways.

The train is an alternative to flying at shorter regional distances provided rail tracks already exist. For city pairs without rail infrastructure, electric aviation could provide a more cost effective and more flexible (demand/routing), especially for regional cross border links. Historically, railway network development is very nationally organized. Zero emission aircraft should allow for public choice to use either the train or aircraft for the travel preference over the short < 500km journeys.

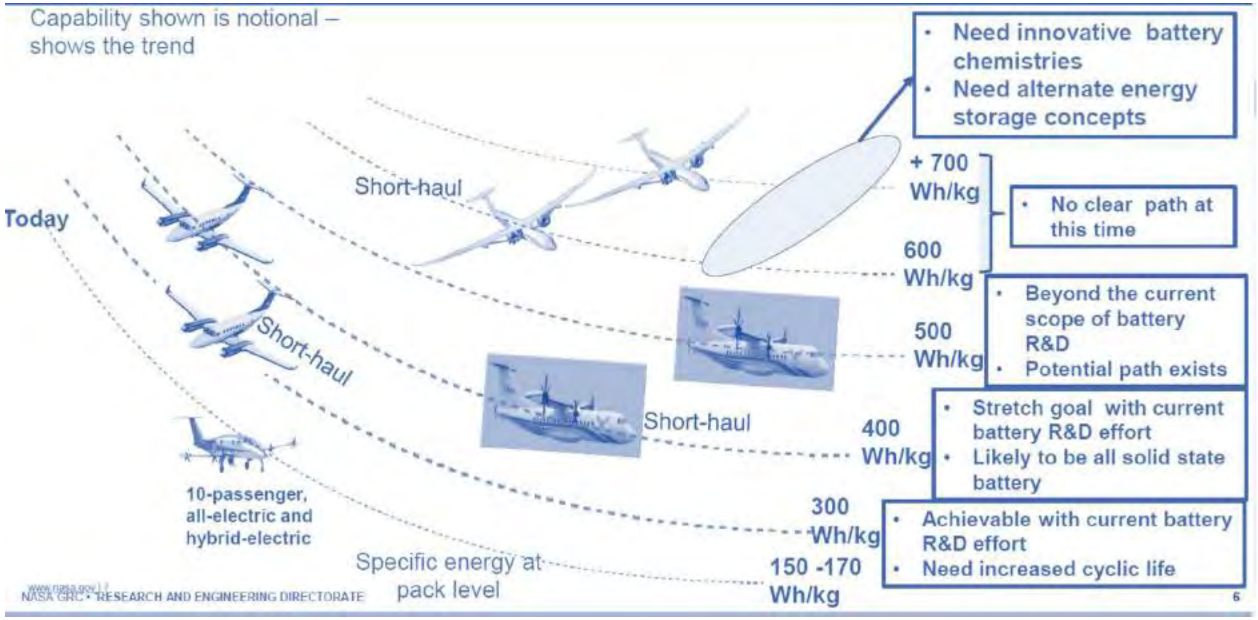
Market pull: The Dutch initiative Power-Up (3 Dutch airports, supported by Schiphol and NLR) creates a market pull. On Bonaire investigations are ongoing for a (hybrid)electric air ambulance between the ABC islands. E-flight academy has started a flight school in the Netherlands. Airlines (like KLM) are increasingly looking to decarbonize their short regional flights.

Manufacturing and MRO industry opportunities: The market is currently dominated by innovative start-ups. This offers industry opportunities (e.g. GKN will develop wings and empennage for Eviation). If large numbers of aircraft will be produced in this segment, this also offers potential for after market MRO services in which the Netherlands is well positioned. Start-up Saluqi offers electric motors, while Venturi aero expresses OEM ambitions (and would need significant financial backing to catch up with frontrunners).

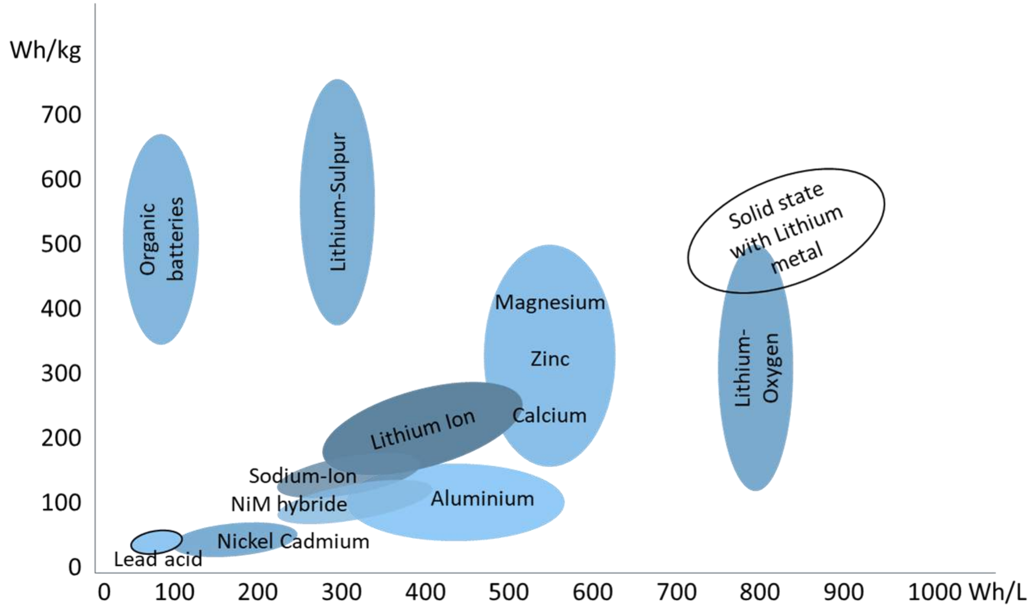
AC1.2 (Hybrid)-Electric Propulsion – Battery-Electric

MORE DETAILS ON: PROGRESSION OF BATTERY TECHNOLOGY FOR ELECTRIFIED AIRCRAFT

The growth in energy density of Li-ion batteries is levelling off. Full electric aircraft beyond regional will be hard to achieve, without new battery chemistries. Note that the energy density is stated at cell level. At pack level, safety protection measures against losing the entire pack in a thermal runaway will lead to lower densities. The currently highest energy density that has been flight tested (and approved by the aviation authorities for test flight) is at 165 kW at pack level in the Rolls Royce UK ATI funded ACCEL project.



Source: Dr. Arjay Misra, NASA Glenn Research Center, More Electric Aircraft 2019, Seattle



Source: EU Battery 2030+ roadmap – Inventing the Sustainable Batteries of the Future

Current commercial batteries and targeted performance of future possible chemistries. The post lithium batteries chemistries are given as names indicating all kinds of metal-type batteries in respective category. There is a large uncertainty of their respective position in the graph. NiM hydride refers to nickel metal hydride

AC1.2 (Hybrid)-Electric Propulsion – Hydrogen Fuel Cell

INNOVATION READINESS LEVEL: **MEDIUM**

Fuel cell-based powertrain and storage systems designs will enable the outcome that future aircraft require minimum sustainable energy to fly and make less noise and fly with zero emissions. This driver relies on bringing new technologies prevalent form industries such as automotive, marine and space combined with well-established craftsmanship in aerospace engineering, and classical aircraft platform and powertrain optimization.

Hydrogen fuel cell electric aircraft could also be deployed in the distributed aviation model as part of AAM, if the economics work out for the green hydrogen production costs and availability.

REGULATORY AND MARKET DEVELOPMENTS

Regulations: Do not yet support LH_2 and fuel cell certification. This needs to be (urgently) addressed to realize this market. No certification precedent exists, besides 'permits to fly' for ZeroAvia demonstration flights, and smaller demonstrators.

Market: Gas hydrogen fed fuel cells could serve small aircraft up to 9-19 seaters. LH_2 solutions could serve a market up to larger, regional aircraft. For economic viability, high volume production of components is needed to lower fuel cell costs. Trend towards hydrogen large cars/trucks will support this. Public acceptance for short distance flying is negative, and people tend to favour the train. However, train networks are not as flexible as aviation and are underdeveloped for cross border travel. When flying can be done 'zero emissions' public perception can be regained. Safety perception of LH_2 is however critical. Hydrogen cars can positively influence this. Infrastructure changes are needed at airports (see relevant driver).

ANALYSIS

Time to market: As for battery electric aircraft, hydrogen electric aircraft touted EIS dates are optimistic, especially in view of lacking certification regulations. Depending on the pace at which regulators adopt this, certification may be faster. An Energy Supply Advice Committee recommended to FAA to replace articles on battery systems with more generic energy carriers. As for electric aircraft, in view of multiple applications, aviation authorities should increase their resources. Accelerated adoption via demonstrators and retrofit programs to enable first step changes in the operation and support of zero emission flying using Hydrogen. As in all aircraft design processes compromises will be required for optimization this will be even more so for the retrofit approach.

Energy density: Fuel cell energy density for the integrated fuel cell system module is about 2kW/kg. Technology enhancement towards > 4kW/kg for fuel cell system is needed for scaling up in the longer term to larger regional aircraft. LH_2 is required as opposed to gas due to volumetric energy density.

Technology challenges: thermal management solutions are required for the LH_2 storage, distribution and heat transfer from fuel cells. High voltage power distribution is needed to transfer power to electric motors. Transfer non-aviation technologies for fuel cells to aviation and set out plans to improve the power to weight ratio as well as cost effectiveness of Fuel Cell stacks within the fuel cell system. Fuel cell development in Europe is focused within the Fuel Cells & Hydrogen Joint Undertaking.

TIMELINE

2020+	2022+	2025+	2030+
More attention for LH_2 solutions Increasing number of start-ups	EASA creates regulations for LH_2 Industry develops certify-able fuel cell and LH_2 storage	Flight demonstration and certification EASA resources aligned to enable industrial change	EIS of retrofits, with spin off to larger aircraft New turboprop regional aircraft

OPPORTUNITIES

R&D: EC funded Clean Aviation is a key to advance this driver. EC Clean Hydrogen addressed hydrogen in the wider sense, with spin-off into aviation or spill-over from aviation.

Regulations: To accelerate the adoption of hydrogen as a fuel in aviation, governments and aviation authorities should develop regulations.

Network change: Like battery powered aircraft, hydrogen electric aircraft could contribute to a network change towards more point-to-point flights between smaller airports, increasing connectivity or rural areas and smaller islands in a clean and affordable manner. Zero emission aircraft should allow for Public choice to use either the train or aircraft for the travel preference over the short <500km journeys.

Market Pull from airlines: As hydrogen powered aircraft currently have better potential than battery electric for (sub) regional and even short haul aircraft operations, they could create larger CO_2 reduction impact of current aviation. Leading airlines recognize this, e.g. British Aerospace investment in ZeroAvia, which could accelerate market adoption.

Energy Supply: To accelerate adoption of hydrogen powertrains and vehicles, some system providers (Universal Hydrogen and ZeroAvia) also position themselves as energy/infrastructure suppliers.

Manufacturing and MRO industry: Currently the market is dominated by start-ups (e.g. ZeroAvia and Universal Hydrogen) that target retrofits. For LH_2 new built aircraft, no companies with significant financial backing exist that have made tangible development steps. Lack of regulations slows down the market, which on the upside creates opportunities for new entrants to enter with still early market entry perspective. The Netherland's industry has shown ambition (Toray composite LH_2 tank, HAPSS consortium ambition for Tier 1 position).

AC1.2 (Hybrid)-Electric Propulsion

MORE DETAILS ON: R&D AND INDUSTRY PRODUCT ROADMAPS – SELECTED FRONTRUNNERS AND DUTCH PROJECTS

New built aircraft


Pipistrel VelixE
2 pax / 2020
Full-e battery


Bye eFlyer2
2 pax / 2022-23
Full-e battery


Eviation Alice
9 pax / 2024
Full-e battery


VoltAero Cassio330
4 pax / 2024
Hybrid-e battery


Heart Aerosp. ES19
19 pax / 2025
Full-e battery


Ampaire Tailwind
9 pax / 2030
Full-e battery


Venturi Echelon 1
40 pax / 2030
Full-e battery

Retrofit products


Ampaire eCaravan
9 pax / 2024
Hybrid-e battery


ZeroAvia Do228
19 pax / 2024
Full-e H2 Fuel Cell


Tecnam PVolt
9 pax / 2026
Full-e battery


Ampaire eco Otter
19 pax / 2026
Hybrid-e battery


Wright BAe146
100 pax / 2027(?)
Full-e H2 Fuel Cell

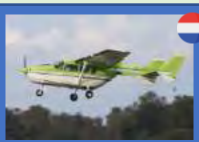
Demonstrators


Ampaire C337
6 pax / 2019
Hybrid-e battery


MagniX eBeaver
6 pax / 2019
Full-e battery


ZeroAvia Piper M
6 pax / 2020
Full-e H2 Fuel Cell


Project Fresson
9 pax / 2022
Full-e H2 Fuel Cell


DEAC C337
6 pax / 2023
Hybrid-e battery


DLR/MTU Do-228
19 pax / 2026
Full-e H2 Fuel Cell

(Scalable) powertrains


Universal Hydrogen
~40-60 pax / 2025
Full-e H2 Fuel Cell


GE NASA EPFD
Demo 2025 /
Product 2035
Hybrid Electric


GKN H2GEAR
~40 pax / 2026
Full-e H2 Fuel Cell


HAPSS
~40 pax / 2028
Full-e H2 Fuel Cell

AC1.3 Hydrogen Combustion

INNOVATION READINESS LEVEL: LOW

Hydrogen combustion engine and storage systems designs will enable the outcome that future turbofan aircraft require minimum sustainable energy to fly, make less noise and fly with zero carbon emissions. This driver relies on bringing new technologies prevalent form industries such as automotive, marine and space in terms of LH_2 cryogenics, new coating solutions within engines combined with well-established craftsmanship in aerospace engineering, and classical aircraft platform and engine optimization.

REGULATORY AND MARKET DEVELOPMENTS

Regulations: No EASA regulations for hydrogen (combustion) in place. To be developed in parallel with aircraft systems. No precedent for hydrogen yet. Fuels would need to certified with engines, much like today's fuels. Certification procedures need to urgently be accelerated in terms of resources and infrastructure to align with the demands for 2050.

Market: (L)H_2 combustion is mostly considered for large(r) aircraft for which fuel cell systems are not (yet) a solution. Outside of SAF this is the best option to decarbonize medium range and long-range aircraft (100 seats and above). Mostly classical configurations are considered, equipped with engines that can use hydrogen. The most known flagship plan for a product is the Airbus ZEROe project. Public perception is mostly positive, provided safety is guaranteed.

ANALYSIS

Time to market: Hydrogen combustion has already been demonstrated in the TU-155 (1988). The energy density and handling of hydrogen prevented this from becoming a serial product so far. No new builds are currently under development, although Airbus has announced the ZEROe project with three possible configurations. Demonstrators being planned or in progress by R&D institutes (e.g. DLR H2Amo) and some OEMs (airframe e.g. Airbus and engine e.g. GKN H2JET).

Technology challenges: non aviation technologies will be transferred to aerospace in cryogenics and hydrogen use, these challenges are part the same for LH_2 for fuel cells. A key challenge for combustion is to counter degradation in the engine, to overcome fusion and to determine the economic viability in terms of engine maintenance, overhaul and replacement. Smart engine components are needed and aircraft systems integration architectures to ensure safe operation with hydrogen.

Retrofit versus new build: New aircraft can be tailored to LH_2 storage in terms of volume and weight and balance. The viability for a retrofit approach due to the significant amount of fuel required for the long range will need to be decided upon for turbofan aircraft.

Infrastructure: New fuel (LH_2) storage (creation) and handling solutions are needed for airports aligned with the introduction of LH_2 fuelled aircraft.

Contribution to sustainability: Hydrogen combustion does not emit CO_2 but does emit water vapour and NO_x. The impact of hydrogen contrails (as opposed to kerosine contrails) is under investigation.

TIMELINE

2020+	2022+	2025+	2030+
More attention for LH_2 OEMs need to understand engine life, reliability and safety	EASA creates regulations for LH_2 Combustion engine develop-ment, ground testing, econo-mic viability	Flight demonstration EASA resources aligned to enable industrial change	EIS of single isle aircraft, with turbofans (if viable) and new engines

OPPORTUNITIES

R&D activities: The EC funded European partnership for Clean Aviation is a major opportunity to advance hydrogen as a fuel for aviation, including combustion. Additionally, the European partnership for Clean Hydrogen assesses hydrogen in the wider sense, which may lead to spin-off into aviation or spill-over from aviation.

Regulations: To accelerate the adoption of hydrogen as a fuel in aviation, governments and aviation authorities should develop regulations.

Manufacturing Industry and MRO: traditional engine manufacturers are assessing the impact of hydrogen combustion on their engines, and the need for new H_2 engines. The MRO schedule may be different. The Netherlands MRO industry is well positioned for current engine MRO (e.g. F-35) and could play a role for H_2 combustion engines. The Dutch manufacturing industry can contribute with the same technologies as for conventional aircraft programs (HTSM top sector).

AC1.2 (Hybrid)-Electric Propulsion & AC1.3 (Hydrogen Combustion)

MORE DETAILS ON: KEY RESEARCH & DEVELOPMENT PROJECTS (MOSTLY PUBLIC/PRIVATE FUNDED)

General Electric NASA EPFD (179 M$ | 2021-2026 | Hybrid-elect)
MagniX NASA EPFD (74 M$ | 2021-2026 | Electric powertrain)
Raytheon Project 804 (| 2019- ?| Hybrid electric powertrain)

Future Flight Challenge (130 M£ | 2020-2024 | H_2 and electric)
FlyZero (15 M£ | 2020-2021 | Zero emission aircraft)
GKN H2GEAR (27 M£ grant | 2021-2024 | LH_2 powertrain)
Cranfield FRESSON (9 M£ grant | 2019-2022 | LH_2)
ZeroAvia HyFlyer II (12.3 M£ grant |2021-2024 |LH_2 aircraft)
Rolls Royce ACCEL (3.3 M£ grant | 2019-2021| Electric aircraft)

Clean Aviation (4.1 Bn€ / 1.7 Bn€ grant | 2021-2030)
Clean Hydrogen (2 Bn€ / 1 Bn€ grant | 2021-2030)
IMOTHEP (2 M€ | 2020-2022 | Electric aircraft)

GKN H2JET (2 M£ | 2021-2023 | H2 combustion)

Growth Fund (383 M€ | 2022-2026 | Wide range of topics)
Mobility Fund (50 M€ | 2021-2024 | LH_2 tank, structures, etc.)
HTSM TKI (? M€ | 2020-2022 | Structures / systems)

BMWi LUFO VI (~500 M€ | 2020-2025 | Wide range of topics)
DLR /MTU Do 228 (? M€ | 2020-2026 | H_2 fuel cell aircraft)
SynergIE (? M€ | 2018-2021 | Distributed hybrid electric aircraft)

PROSIB (? M € | 2018-2012 | Hybrid-electric regional aircraft)

AC2.1 Continued Classical Aircraft Platform Optimisation

INNOVATION READINESS LEVEL: **HIGH**

Continue classical aircraft platform optimization will enable the outcome that future aircraft require minimum sustainable energy to fly and make less noise. This driver relies on well-established craftsmanship in aerospace engineering, and classical aircraft platform optimization. A multi-disciplinary trade-off in the aircraft design space has to be proven after a classical mono-disciplinary trade-off has been found.

REGULATORY AND MARKET DEVELOPMENTS

Continuation of historic industry market push and (airline) market pull for more fuel efficient aircraft that create less source noise. Clean Aviation (and CleanSky 1, CleanSky 2 before) is the major EU funded innovation activity for this driver. This fits well within the current regulatory framework, so no major changes are needed. New technologies on structures and aerodynamics are introduced in the market with new platforms, as they cannot be retrofitted. The major market leaders Airbus and Boeing are not planning to introduce new platforms until 2035+. COMAC is working on C919 (single isle) and C929 (wide body), but is training in innovation level. Smaller new builds planned by newcomers in the 9-19 seater segment may already benefit before 2035. Economic viability can well assessed and is positive. Public acceptance is high. No infrastructure changes are needed.

ANALYSIS

Propulsion: The highest past efficiency improvements originate in engines. New developments are the introduction of Ultra High Bypass Ratio and geared turbofan.

Airframe: Weight reduction through light weight materials and larger integrated structures, where the advent of composites in primary structure such as wings and fuselages has contributed to substantial improvements. Introducing load alleviation, leads to lighter aircraft platforms. Improved aerodynamics and morphing structures, such as for instance the B-777 aerodynamically optimized wing tip that folds on the platform.

Aircraft Systems: More Electric Aircraft is a trend to eliminate hydraulic and pneumatic powered systems and replace them with electrical systems. This reduces the weight (pumps, hydraulic channels etc) and maintenance costs while improving dispatch reliability. Electric taxiing and elimination of ground Auxiliary Power Unit power can be deployed to reduce the CO_2 impact of ground operations.

Multi-disciplinary design and IT: Traditionally, design disciplines worked stove piped. Advances in computing power drive increased possibilities for multi-objective, multi disciplinary design optimisation at aircraft platform level. Digital twins are increasingly used.

Contribution towards sustainability: It is not easy to quantify exactly the contributions towards energy and noise reduction, since this depends on the platform and the multi-disciplinary design choices, but the typical order of magnitude to be expected is 10% to 20% of CO_2 reduction for the next generation of aircraft compared to aircraft EIS 2000, of which the engine contribution is traditionally the greatest contributor, with at least two-thirds of the expected saving.

TIMELINE

2022+	2035+	2050+
Continued optimization existing classical aircraft platform designs	Clean sheet designs of classical aircraft platforms introduced by the market leaders	Renewed fleet of classical aircraft platforms

OPPORTUNITIES

R&D: CleanAviation (and maturing the past achievements in CleanSky 1 and CleanSky2) are the main R&D vehicle in Europe to advance the maturity of innovations. Additionally, programs are available on a national level (e.g. LuFo in Germany, HTSM in the Netherlands).

Market pull: Governments can influence market pull by providing financial and non-financial (legislative) incentives to reduce emissions and noise. These should be implemented such (at global level preferably) that they don't affect the level playing field.

Manufacturing and MRO industry: Most innovations are introduced in re-engine programs or new aircraft, the delivery of which is not expected until 2030-2035 for Airbus or Boeing. This is the right moment however for the (Dutch) supply chain partners to be down selected into such programs. The new companies in the (hybrid-)electric 9-19 seater segment could provide shorter term opportunities to introduce configuration optimisations and (Dutch) supplier positions. As larger numbers of these aircraft are projected to be sold, this also provides opportunities for the MRO and after market.

AC2.2 New Disruptive Aircraft Platform Development

INNOVATION READINESS LEVEL: **MEDIUM**

New disruptive aircraft platform development can enable the outcome that future aircraft require minimum sustainable energy to fly and make less noise. This driver relies on well-established craftsmanship in aerospace engineering, and disruptive aircraft platform concepts. A multi-disciplinary trade-off in the aircraft design space has to be proven, after a disruptive mono-disciplinary trade-off has been found.

REGULATORY AND MARKET DEVELOPMENTS

Disruptive configurations have reached TRL 4-5, with scale model flights being performed showing promising technical feasibility. Clean Aviation will be a major EU funded innovation activity for this driver. New configurations in general fit well within the current regulatory framework, so no major changes are needed. Existing means of compliance may need to be revised which makes the certification of new configurations more time consuming and costly. Ensuring economic viability is part of the design process. Public acceptance is high in general, but embracement of disruptive aircraft platforms by the general public might take time., especially for windowless concepts. Infrastructure at airports may need to change for embarking / disembarking of passengers.

ANALYSIS

Propulsion: Counter rotating open rotor propulsion are most feasible in the future, with large CO_2 reduction potential and stage 5 noise characteristics (the current FAA noise standard for jet and large turboprop aircraft). Boundary layer ingestion propulsion have benefits on drag reduction at the cost of engine inlet flow distortion challenges. Distributed (electric) propulsion offer the possibility to generate thrust at the location where drag is occurring, such that structural components to transfer those loads are not needed. For more than three propulsion units per wing this rather unexplored territory of the design space. The lower maintenance costs of electric motors allows a reverse of the current trend where four engine aircraft platforms are leaving service in favour of two-engine aircraft platforms.

Airframe: Disruptive aircraft platforms with alternative wing or fuselage configurations such as Box-wing, Prandtl wing and double bubble fuselages feature clear mono-disciplinary benefits (aerodynamic performance). Disruptive aircraft platforms with wing-body integration such as BWB, hybrid wing body, Flying V feature even more clear mono-disciplinary benefits. A key challenge is to keep these mono disciplinary benefits when realizing the actual multidisciplinary aircraft design (structures, weight). BWB research has been ongoing for decades, without this resulting in a commercial product yet.

After retirement of Concord, new initiatives for a SAF/Hydrogen supersonic passenger aircraft have been launched. Key challenges are emissions in the stratosphere and sonic book reduction (supersonic flight is currently not allowed over land by FAA and EASA)

Contribution towards sustainability: New disruptive aircraft platform development alone is insufficient to reach the 2050 climate targets, but is required to deal with SAF, hydrogen and electricity scarcity and related cost increase. With disruptive configurations the order of magnitude targeted in emissions reduction is ~20 - 25% (NASA BWB, AHEAD EU project).

TIMELINE

2022+	2035+	2050+
Continued R&TD of aircraft platforms with disruptive propulsion and wing–body integration	Development of disruptive aircraft platforms	EIS of disruptive aircraft platforms

OPPORTUNITIES

R&D: Clean Aviation is the major vehicle in Europe to advance the maturity of innovations on new configurations. A key objective should be to demonstrate that aerodynamic gains can be kept when multi-disciplinary designs are detailed with structures (weight) and systems.

Market pull: Governments can influence market pull by providing financial and non-financial (legislative) incentives to reduce emissions and noise. These should be implemented such (at global level preferably) that they do not affect the level playing field.

Manufacturing and MRO industry: First advanced disruptive configurations (e.g. BWB) are not expected to reach the market well after 2035, except perhaps distributed propulsion on classical wing-tube configurations. Initially they require more R&D and multi-objective optimizations. The supply chain should cooperate to accelerate this within industry 4.0 principles, striving for horizontal and vertical digital integration and virtual certification.

AP3.1 Certified Vehicles (eVTOLs and drones)

INNOVATION READINESS LEVEL: **MEDIUM – HIGH**

Naturally, the availability of certified vehicles is the key enabler for developing these new modes of air mobility. The step from a flying prototype (TRL 6) to an industrialized, economically viable and certified vehicle is large in terms of maturity needed and funding required. This is even more so for eVTOLs with high levels of automation or even unpiloted.

Note that some eSTOL concepts are aiming for ultra short take-off in competition with eVTOL in urban uses cases (e.g. Electra, Airflow)

REGULATORY AND MARKET DEVELOPMENTS

Regulations: EASA is a front runner in regulations and has developed a 'Special Condition for small-category VTOL aircraft' with Acceptable Means of Compliance, for piloted eVTOLs. For unpiloted eVTOLs (e.g. eHang) with passengers no regulations and means of compliance exist yet. Unpiloted cargo solutions (< 600 kg) can be accommodated under EASA Special Condition for light UAS.

Market: the main market driver pushing these new entrants is mobility in large congested urban areas, although intraregional flights are also considered at ranges of 50 – 100 km. An increasing number of cities and countries (e.g. Japan) have UAM or AAM roadmaps. In Europe also many projects have been initiated as city centric use cases. Airport shuttle and urban to region transports are also increasingly considered in the market. The vehicle development is dominated by starts-ups (Volocopter, Lilium, Joby) while large aerospace players joined later are now also rapidly developing vehicles (Airbus, Boeing, Embraer, Bell).

ANALYSIS

Development and testing: Many companies have reached first flight. On the next slide a non exhaustive overview of industry roadmaps is provided taken from the EASA UAM report.

Time to market: EASA regulations are available for piloted eVTOLs, Volocopter has the first Design Organisation Approval, which is a major step. They are closest to certification (expected 2022/2023). For autonomous vehicles (like eHang) the lack of regulations and acceptable means of compliance means a lack of a road to commercial exploitation in Europe for the moment. A logical next step for passenger transport is automatic piloted eVTOLs with a safety pilot first, before allowing fully autonomous vehicles. Unpiloted cargo applications with maximum weight < 600 kg may be earlier (not over built up areas) under EASA's light-UAS special condition.

Business models and economic viability: Services considered are emergency/medical, air taxi on scheduled and on demand services. Drone delivery will be serviced by smaller drones. Economic viability will also depend on aftermarket MRO costs and spare part logistics. Electric motors make maintenance cheaper than helicopters. Removing the pilot is another cost saving opportunity, once certified.

Public acceptance: EASA has performed a survey on UAM in 6 EU cities, with in general positive outcome. Noise and safety were by far the two most important societal acceptance factors with privacy and benefits as secondary factors.

Infrastructure: In order for large numbers of eVTOLs to operate in (dense) airspace, U-Space functionality is needed (see Airspace section). This requires the vehicles to have devices onboard for e-Conspicuity such as ADS-B out (mode S transponder), (Power)FLARM, Sky Echo 2. A detect and avoid system may also be required.

TIMELINE

2020+	2023+	2027+	2030+
Many flight demo vehicles First certification projects ongoing	First EIS of certified piloted eVTOL Regulations for unpiloted available	Projection: unpiloted eVTOLs with (remote) safety pilot allowed	Projection: unpiloted eVTOL certified

OPPORTUNITIES

R&D: The Horizon Europe Cluster 5 for climate, energy and mobility may provide R&D opportunities. Additionally, the UK Future Flight Challenge aims for integrated demonstrations in 2023/2024. Paris aims to have pilots before the 2024 Olympics as part of the 'Re.Invent Air Mobility' initiative.

Regulations: To accelerate the uptake of eVTOLs, certification requirements for unpiloted eVTOLs need to be developed. A potential stepping stone is operating with a safety pilot to collect safety data of the autonomous systems. Test/demo flights in the Netherlands should become possible from regulatory side.

Market pull initiatives: Several EU and global cities are or have announced experimenting with eVTOLs (Hamburg, Toulouse, Singapore, Paris). eVTOL services should be considered by (Dutch) cities and local governments in their strategic mobility planning (not in isolation). The German aera Nordrhein Westfalen is funding a study in eVTOL public transport between Aachen and some cities in Netherlands and Belgium.

Manufacturing and MRO industry: First market entrants will have a good position to capture a large market share and drive the infrastructure development. Later entrants will need to have more unique capabilities to gain market share. The Dutch manufacturing industry can supply light weight structures, precision navigation, certification and testing expertise. The MRO and aftermarket support offers great potential for smart logistics and support concepts.

In the Netherlands, PAL-V is nearing certification for air and road with a car/gyrocopter concept. In Europe and globally a handful of other flying car concepts is (flight/road) testing

AC3.1 Certified Vehicles (eVTOLs and drones)

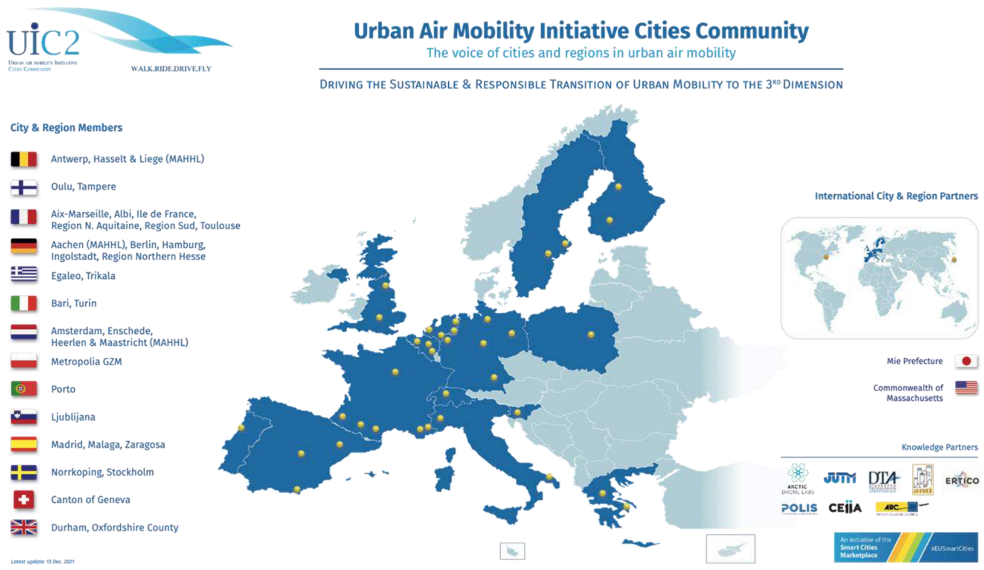
MORE DETAILS ON: EVTOL MARKET READINESS

MARKET READINESS

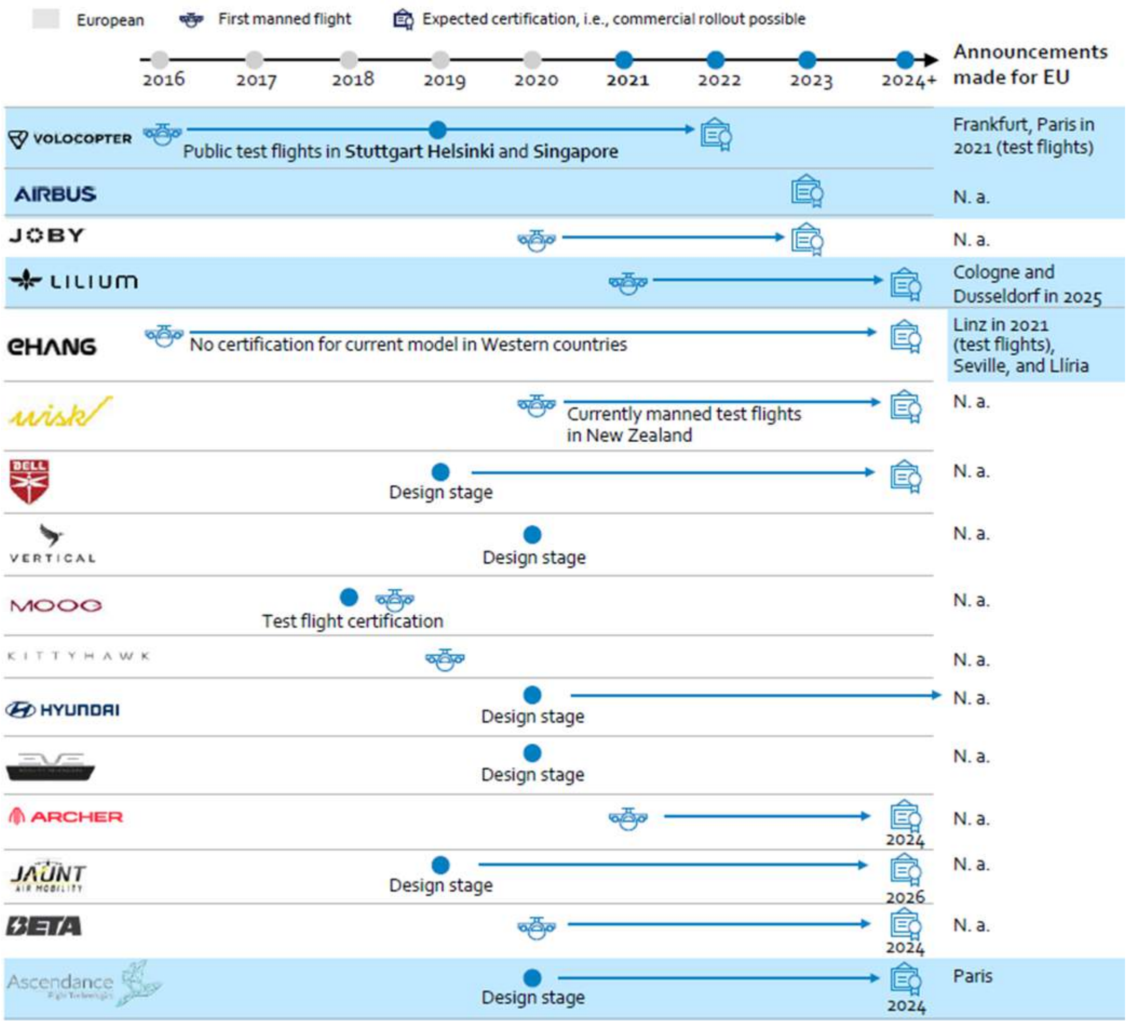
Certification & products: The schedule on the right, shows key milestones (first flight, certification in Europe) for selected OEMs towards commercial exploitation. The certification concerns piloted eVTOLs. No requirements have yet been established for unpiloted eVTOLs. EHang has started certification for their autonomous EH216 vehicle in China with the Civil Aviation Administration of China in April 2021.

MARKET PULL

The UIC2 (below) unites European cities that are exploring UAM. Cities should consider the role of UAM in their strategic overall mobility planning.



Source: https://smart-cities-marketplace.ec.europa.eu/action-clusters-and-initiatives/action-clusters/sustainable-urban-mobility/urban-air-mobility-uam



Source: EASA UAM report, May 2021

AC3.1 Certified Vehicles (eVTOLs and drones)

MORE DETAILS ON: R&D PROJECTS EVTOL AND UAM

Project name / Acronym	Global	European	National	Timeline	Finances	Organisation (lead in case of consortium)	Scope
Future Flight			X	2020-2024	130 M£	Innovate UK	Various UAM demo's
Re-Invent Air Mobility			X	2021-2024	-	RATP/DGA France + 30 partner/projects	Use cases, airspace, public acceptance, demonstration
ASSURE UAM		X		2021-2023	1.5 M€ EC H2020	ILOT Poland + 6 partners	Policy, safety, integration
AMU-LED		X		2021-2022	4.8 M€ EC H2020	NTT DATA Spain	Use cases, CONOPS
Uspace for UAM		X		2021-2022	5.2 M€ EC H2020	Honewell Czech	Airspace integration
AiRMOUR		X		2021-2023	5.6 M€ EC H2020	VTT Finland	Safety, security, noise, public acceptance
TINDAiR		X		2021-2022	4M€ EC H2020	INNOV'ATM	Airspace integration
CORUS X-UAM		X		2021-2022	EC H2020	EUROCONTROL Belgium	Airspace integration and demonstration
NASA AAM National Campaign	X			2021-2022	-	Various industries	Airspace integration and demonstration

2. INNOVATIONS IN FUTURE FUELS

Introduction and Scope

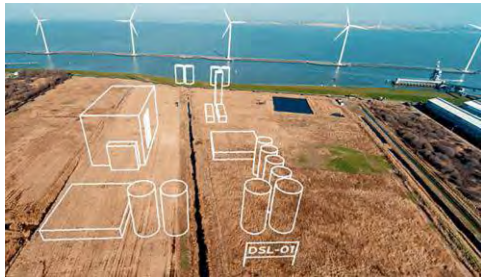
Future fuels are deemed the main way to decarbonize aviation in the long run according to multiple reports from ACI, IATA, ATAG and the EU (Destination 2050). Future fuels can be divided into electric, hydrogen and SAF propulsion, and each requires the development of new fuels and infrastructure, all based on the adequate generation of renewable energy.

The transition towards future fuels availability and infrastructure requires the development of all three energy types. It is important to realise there is not a single silver bullet, and that each energy pathway has its own timeline and use cases but must be developed.

Outcome FF1: Sufficient green hydrogen fuel is produced and supplied to airports to facilitate hydrogen aircraft operations

Hydrogen aviation is in the earliest stages of development but is seen as an opportunity to truly decarbonize aviation in the long term. Green hydrogen availability is very low, though an increase in demand from sectors outside of aviation in combination with focussed policy is expected to lead to an increase in the next decades. Challenges include low TRL levels of hydrogen infrastructure development and safety, alignment of infrastructure with aircraft and investment risks for hydrogen infrastructure.

Drivers: FF1.1 Green Hydrogen Production and Import | FF1.2 Hydrogen Infrastructure and Certification



Outcome FF2: Sufficient Sustainable Aviation Fuels are produced and blended in line with legislative mandates

SAF is currently being produced and used within aircraft, although in minimal amounts. Both through corporate purchasing agreements and blending mandates for airlines, SAF use is expected to increase. Producing SAF can be done through multiple pathways, with different TRL levels, climate impacts and feedstock requirements for each. Challenges include limited feedstock availability (both for waste/biofuels as well as synthetic fuels), higher cost for SAF relative to Jet A1 and the limitations of national or regional policy for global developments

Drivers: FF2.1 SAF Production through Multiple Pathways | FF2.2 SAF Blending Mandates

Outcome FF3: Electric infrastructure that supports novel aircraft designs and logistics is available at airports

Electricity as a fuel: Electric aviation is developing rapidly through normal aircraft platforms, but also within eVTOLs. The availability of renewable electricity is high but developing the charging infrastructure for aircraft must still be developed. Challenges include alignment with electric aircraft manufacturers, high peak demands as a result of short turnaround times and investment risks

Drivers: FF3.1 Resilient Electric Charging Infrastructure

Climate impact of Future Fuels

Emissions relative to Jet A1 fuel

		Direct CO2	Direct local emissions (PM & NOx)	Non-CO2 (Contrails, NOx, water vapour, etc)	Overall climate impact
Electricity	Electric engine	0%	0%	~0%	++
Hydrogen	Hydrogen through fuel cell electric engine	0%	0%	0%-100%*	
Hydrogen	Hydrogen in jet engines	0%	~50%	50%-150%*	
SAF (synthetic, bio waste)	100% SAF	0%	50%-100%	50%-80%	
SAF (synthetic, bio waste)	50% blend Jet A1 (current max)	50%	75%-100%	50%-80%	
SAF (synthetic, bio waste)	2% blend Jet A1 (EU 2025 target)	98%	~95%	~95%	-

*Research is being done on hydrogen aviation induced contrail formation, but specific values remain unclear

Analysis based on Internal data & Clean Sky 2: Hydrogen powered aviation.

FF1.1 Green Hydrogen Production and Import

INNOVATION READINESS LEVEL: **MEDIUM**

Green Hydrogen production is a critical development in the hydrogen aviation value chain. The initial stage in the value chain, hydrogen aircraft manufactures, airlines and airport infrastructure stakeholders must interact and engage with hydrogen production to ensure there is sufficient hydrogen available to achieve hydrogen aviation.

REGULATORY AND MARKET DEVELOPMENTS

In July 2020, the EU presented a detailed hydrogen strategy positioning hydrogen as a future fuel and energy storage tool connecting to the large scale up of renewable energy. Within the EU hydrogen strategy, production, distribution and end use are connected. The aim is to produce 40GW of hydrogen and import 40GW by 2030. Further development of the strategy can be found within the Clean Hydrogen Partnership, Hydrogen Europe and in European hydrogen valleys.

Within the Netherlands, hydrogen policy is being developed by the ministry of economic affairs and climate, through the TKI new Gas program, as well as through the National hydrogen program and H_2 platform. Large amounts of funding are expected to be given through the National Growth Fund initiative Groenvermogen. Hydrogen valley HEAVENN, NorthH2, Mission H2 and hydrogen clusters around the port of Amsterdam Rotterdam and Ems Harbour are some Dutch hydrogen programs.

ANALYSIS

Green hydrogen production & import relies on collaboration and high-level vision from government institutions & EU.

- **Value chain collaboration:** To stimulate hydrogen production, there must be a clear demand from the market. Potential producers must connect with potential users on uptake and pricing to ensure the value chain develops.
- **Renewable energy production at scale:** As green Hydrogen is produced through electrolysis this must be scaled up. Initial investment in production is high and must therefore be supported through policy and subsidies.
- **Green Hydrogen import:** Import of green hydrogen could be a solution to renewable energy scarcity within the EU. Many other regions have the potential to produce large amounts or green hydrogen, which can then be shipped in through Dutch ports, providing a new opportunity as fossil fuel import decreases.
- **Collaboration with other sectors:** Hydrogen is not just seen as a solution for aviation, but also heating, industry and other forms of transport. This presents synergies in enabling sufficient production. However, connecting green hydrogen demand and production is still a critical barrier.
- **EU programs and funding:** The EU is developing a framework that cross-cuts the value chain, so that hydrogen production, distribution and end uses are connected. This will provide the incentives for all parts of the value chain to develop hydrogen as a future fuel.
- **Price decrease of hydrogen:** The price of hydrogen is expected to drop through scale up of production to become competitive with fossil fuels, especially considering Increasing EU ETS tax on fossil fuels. Recent developments in electrolyser scale up show hydrogen prices are expected to decrease to between one and three euros per kilo.

TIMELINE

2020 – Hydrogen acceptance in policy	**2025** – First at scale hydrogen production	**2030** – Hydrogen is integrated into fuel system	**2035** – Hydrogen import and storage fully developed
EU Hydrogen strategy in Green deal Hydrogen Valleys set up all around Europe Hydrogen integrated into Dutch policy through TKI new Gas	Regional projects start delivering hydrogen First imports arrive through ports Incumbent energy stakeholders offer hydrogen	H_2 Knowledge from the chemical industry is integrated in energy systems Green H_2 can be delivered easily to all use cases Safety of H_2 is on par with fossil fuels	H_2 subsidies are no longer required H_2 is used to store renewable energy during peak supply H_2 import is fully developed

OPPORTUNITIES

There are several opportunities within hydrogen production and import that would benefit the Dutch aviation sector and act as a basis for clean hydrogen aircraft:

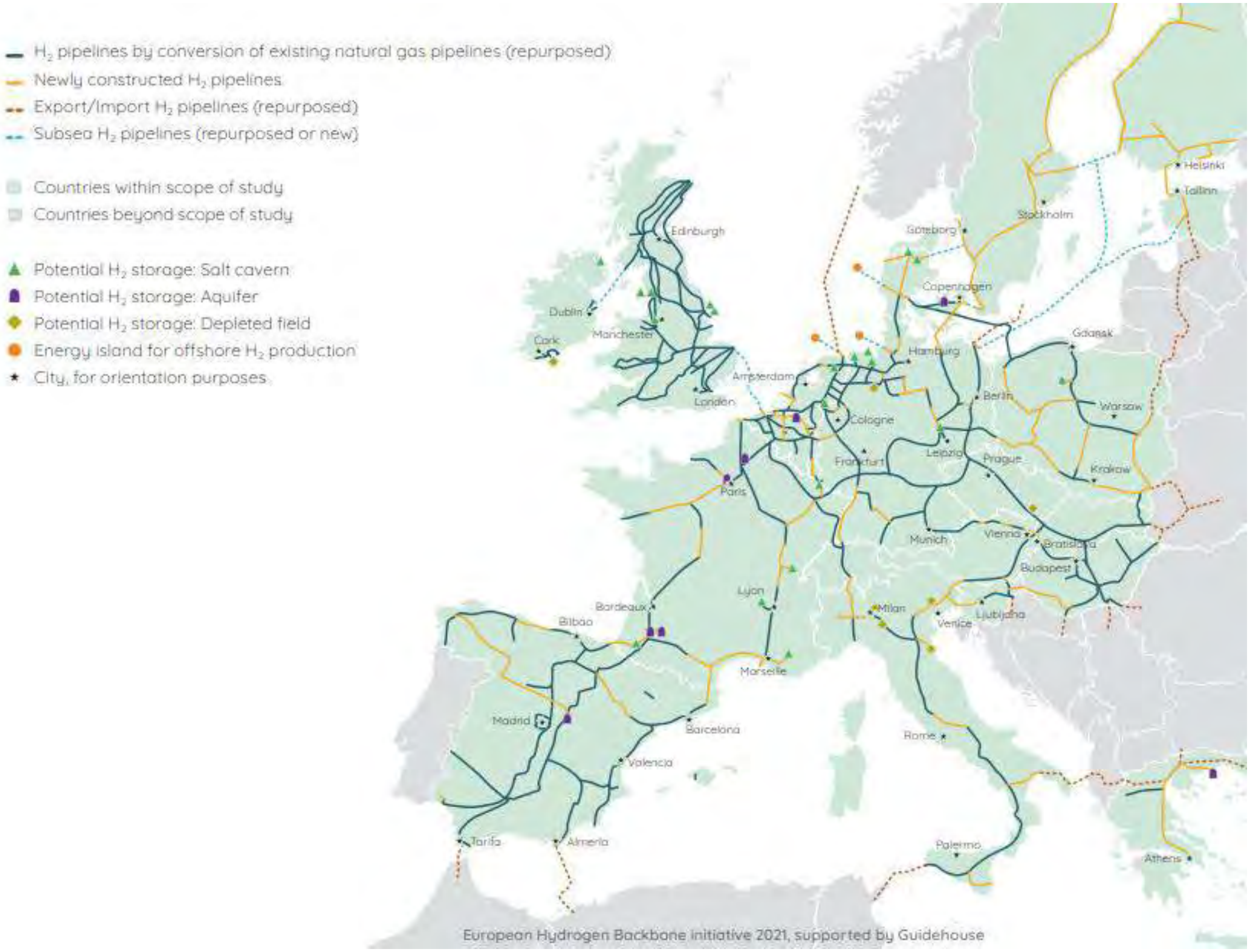
1. Scale up of green hydrogen production
2. Import from high potential hydrogen regions
3. Leveraging current gas infrastructure for hydrogen
4. Leveraging current chemical industry storage & transport knowledge and safety protocols

EU AND DUTCH INITIATIVES

Both the port of Rotterdam and Amsterdam, as well as Ems harbour are developing hydrogen strategies. These port developments include connections with Hydrogen valleys, and also with synthetic SAF production developments such as Synkero (AMS) and Zenid (ROT).

Clean Hydrogen Partnership · NWP Nationaal Waterstof Programma · Hydrogen Europe · NortH2 · TKI NIEUW GAS Topsector Energie · HEAVENN

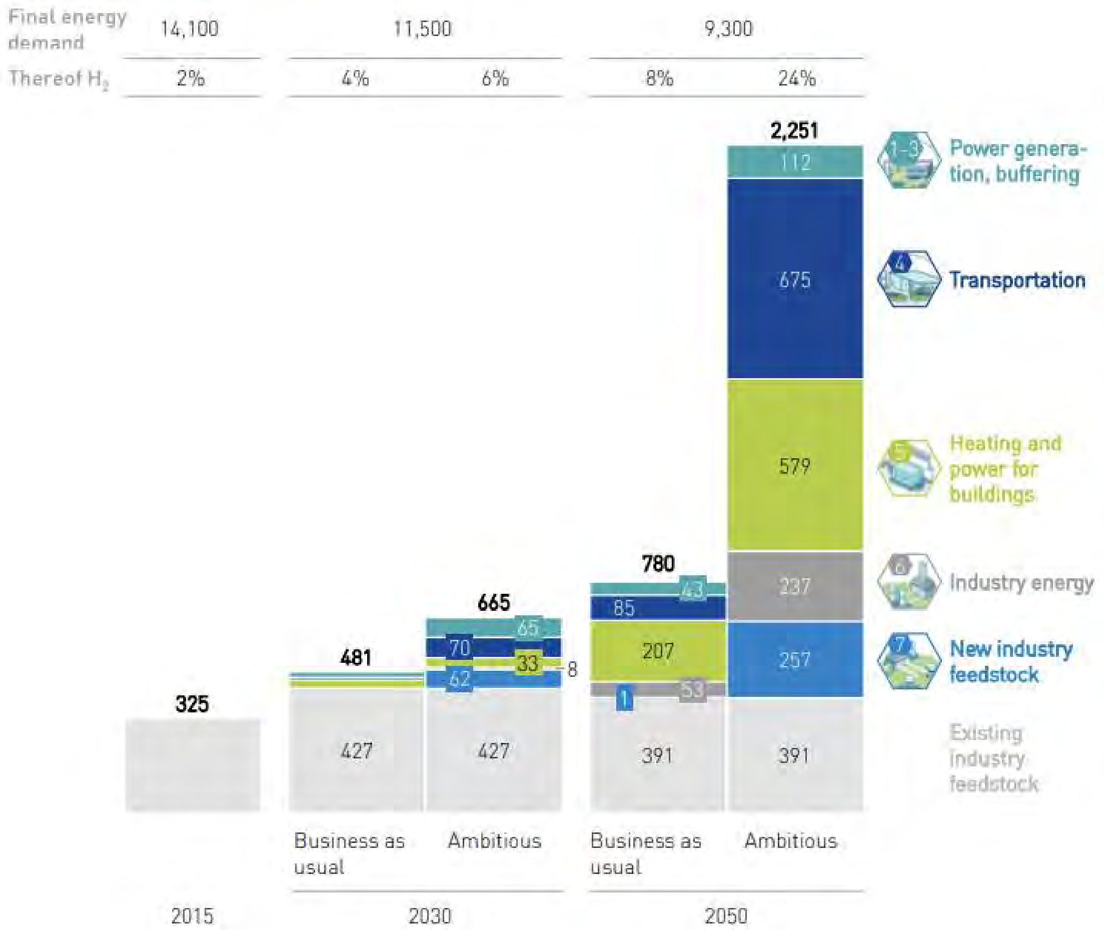
FF1.1 Green Hydrogen Production and Import



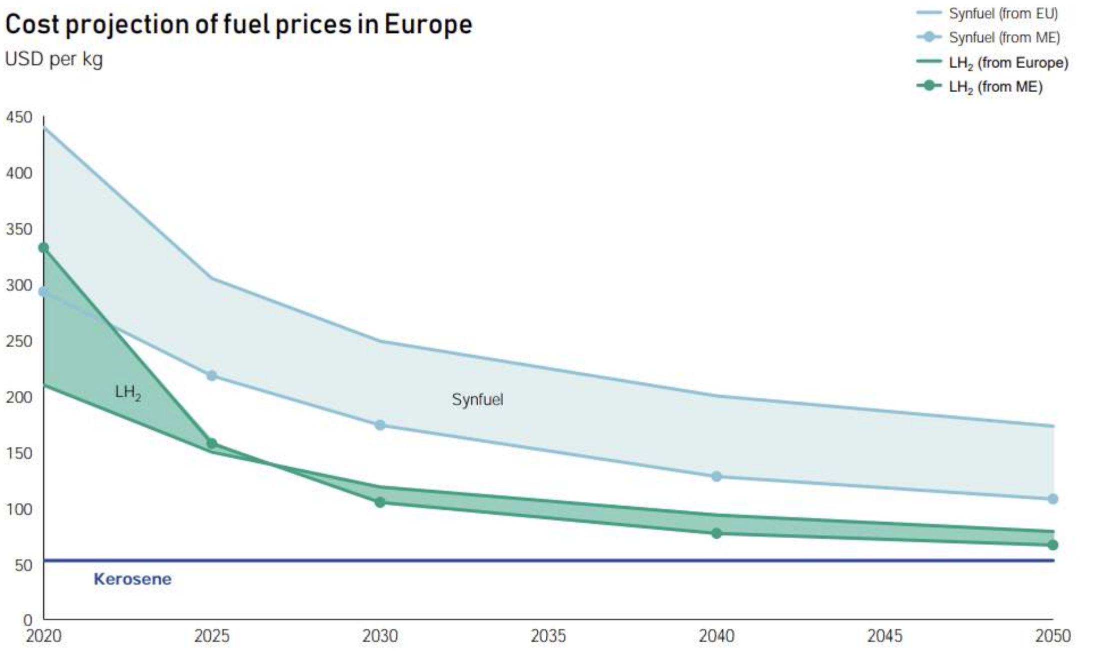
Source: EU hydrogen strategy

FF1.1 Green Hydrogen Production and Import

EXHIBIT 2: HYDROGEN COULD PROVIDE UP TO 24% OF TOTAL ENERGY DEMAND, OR UP TO ~2,250 TWH OF ENERGY IN THE EU BY 2050



Source: Hydrogen Europe Roadmap (2019)



Source: Hydrogen powered aviation, Clean Sky 2

Table 11: Renewable liquid hydrogen minimum selling prices based on multiple sources in 2030 and 2050

Year	Source	Scope	Production cost of renewable LH_2 (€/kg)
2030	Trinomics (2020)	EU	5.5
2030	McKinsey & Company (2020)	EU	3.1
2030	McKinsey & Company (2020)	import	2.8
2030	Van Wijk & Chatzimarkakis (2020)	EU + import	2.2
2050	McKinsey & Company (2020)	EU	2.0
2050	McKinsey & Company (2020)	import	1.8
2050	Van Wijk & Chatzimarkakis (2020)	EU + import	1.8
2050	International Energy Agency (2020)	Global	2.7

Source: Destination 2050 (2021)

FF1.2 Hydrogen Infrastructure and Certification

INNOVATION READINESS LEVEL: MEDIUM

To ensure airports can supply future aircraft with hydrogen as a fuel, there must be safe, certified and sufficient hydrogen infrastructure available at the airport. The required knowledge for green hydrogen infrastructure is often already available within other industries where hydrogen is transported and stored. However, an added difficulty is the requirement for liquified hydrogen for aircraft.

REGULATORY AND MARKET DEVELOPMENTS

Hydrogen infrastructure at airports is still very much in the early stages of development. Policy on it recently has focused mainly on subsidized projects through which airports can start to develop pilot projects and generate first experiences. Within the EU Horizon 2020 funding call for green airports, three EU projects have been set up which will develop the sustainability within airports, including hydrogen systems. Throughout Europe and in the Netherlands, airports are developing hydrogen strategies and first test sites so that they can develop the knowledge on hydrogen infrastructure and safety.

ANALYSIS

The main challenges for hydrogen infrastructure are the low TRL levels of hydrogen aircraft operations and refuelling infrastructure, the lack of global certification, regulation and safety standards for this infrastructure and the uncertainty in green hydrogen supply and hydrogen aircraft. However, there are many routes through which hydrogen infrastructure and certification can be connected to increase the development.

- First, through connection with ground mobility, as both airside and landside, heavy ground mobility such as busses and cargo may transition to hydrogen. By connecting hydrogen powered vehicles with hydrogen powered aircraft infrastructure, airports can get ahead in their own development for hydrogen aviation.
- Secondly, through connection with hydrogen valley initiatives. Multiple local areas are developing hydrogen valleys that work to cross the value chain and connect production, distribution and end use.
- Finally, many hydrogen aircraft developers (see aircraft platforms section) are currently developing refuelling infrastructure as a part of their value proposition. Connecting with these developers will allow airports to become leading in hydrogen infrastructure and certification.

TIMELINE

2020	2025	2030	2035
2020 – First hydrogen roadmaps at airports H_2 infrastructure introduced in EU airport subsidies H_2 infrastructure is included in visions of future airports	**2025** – Hydrogen pilots, testing and research at airports H_2 pilots at regional research connected airports (RTHA, Cranfield, Toulouse) First refuelling is conducted at an airport with trucking H_2	**2030** – Hydrogen refuelling for first scheduled aircraft H_2 storage on site is developed H_2 infrastructure regulation is developed, to ensure safety First H_2 aircraft fly specifically to leading airports	**2035** – Hydrogen infrastructure and safety is standardised First H_2 liquification systems are installed on-site Hydrogen safety becomes a key skill for ground staff

OPPORTUNITIES

Infrastructure development in synergy with aircraft development. Incumbents developing hydrogen aviation (Airbus, Embraer, etc.) can collaborate with their airport partners to prepare for hydrogen aviation. Also, new entrants can develop the refuelling infrastructure required for their aircraft simultaneously and bring their new development to market with the refuelling infrastructure included.

Infrastructure developments in synergy with other sectors: a) Airports can connect with other sectors that have years of experience with hydrogen to develop aviation specific transport, storage and refuelling infrastructure, and b) Airport safety and certification stakeholders can connect with current hydrogen certification and safety from other sectors.

EU AND DUTCH INITIATIVES

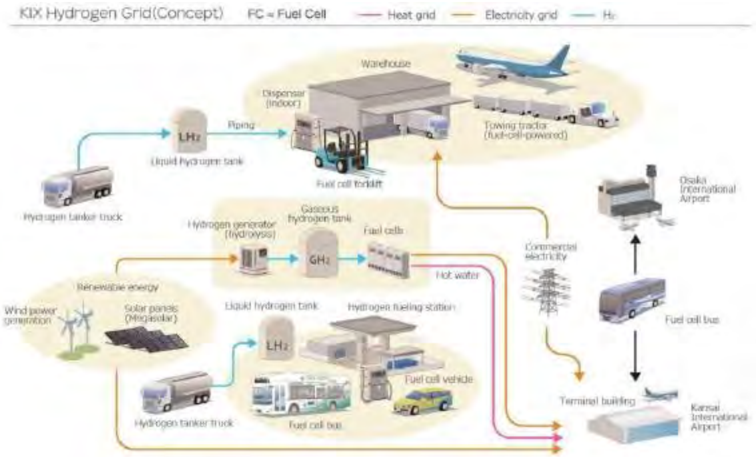
Within the EU many countries are setting up hydrogen R&D facilities at airports. This includes the NLR at Rotterdam The Hague Airport (RTHA), the German DLR in collaboration with Lufthansa at Hamburg airport, ParisRegion in collaboration with ADP and Airbus and Safran together at Toulouse airport, to name a few.

FF1.2 Hydrogen Infrastructure and Certification

HYDROGEN ROADMAPS FOR AIRPORTS

Source: Liege airport

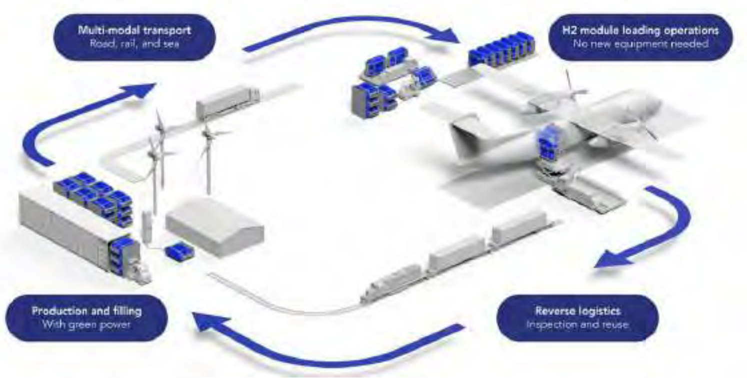
Source: Vinci airports



Source: Kansai Airport

Source: Airbus

Source: Lufthansa, Hamburg airport & Airbus



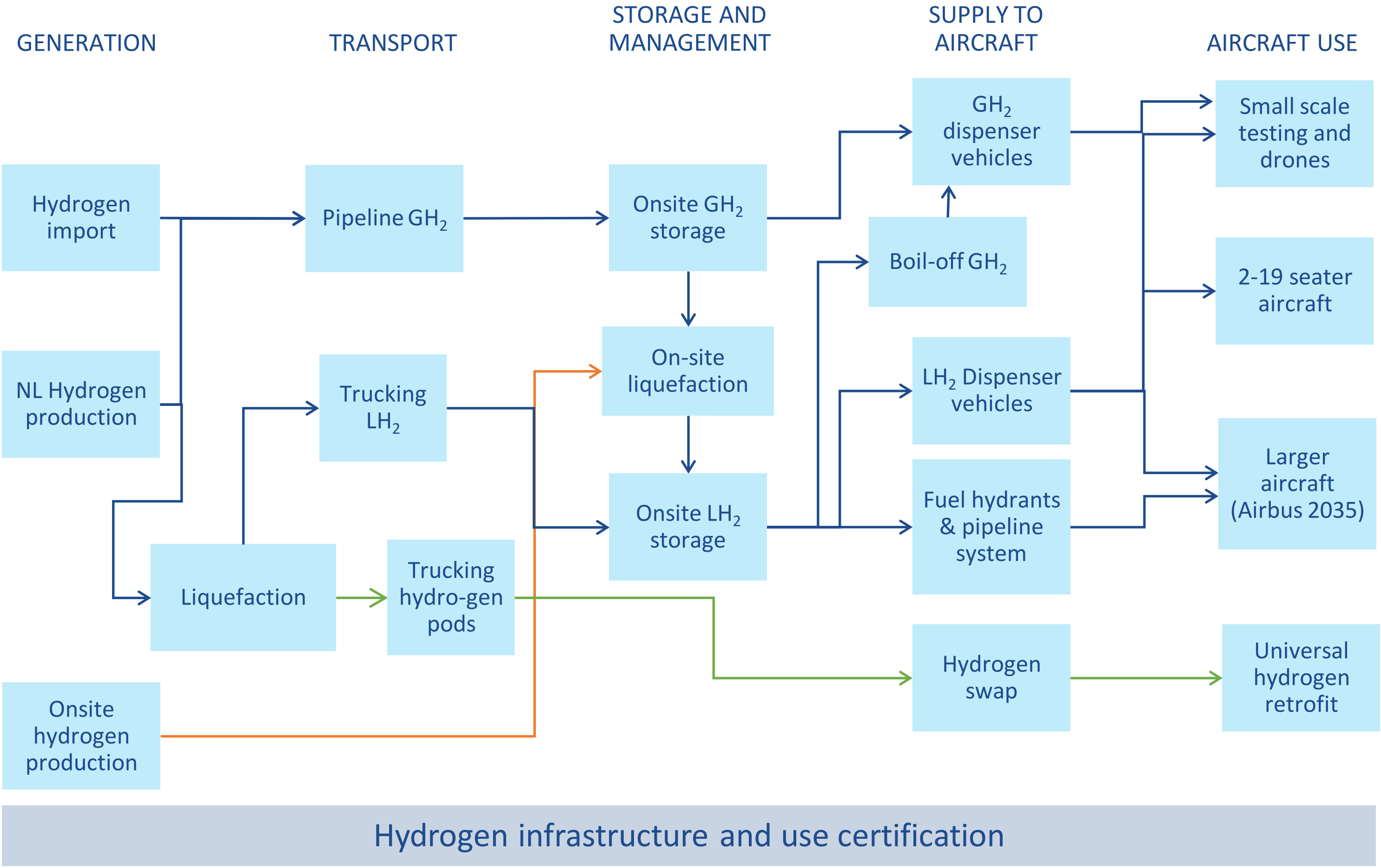
Source: Universal Hydrogen

FF1.2 Hydrogen Infrastructure and Certification

POTENTIAL HYDROGEN INFRASTRUCTURE SUPPLY CHAINS

1. Modular refuelling: if the aircraft refuels through a modular pod system, the airport will only need to facilitate the swap.
2. Trucking LH_2/GH_2: Currently, LH_2 trucks can deliver as much as 50,000L of hydrogen at a time, which is enough to refuel at least 6 19-seater H_2 powered aircraft. The airport may need to invest in small scale LH_2 storage.
3. Pipeline GH_2 refuelling: Airports could receive hydrogen through a pipeline as gas grids convert to transport hydrogen. This would require an energy intensive on-site liquefaction facility and local storage.
4. On-site hydrogen production: This would require large scale investment but could work well in combination with local renewable energy production at the airport.

Source: Liquid Hydrogen Storage: Status and Future Perspectives



FF2.1 SAF Production through Multiple Pathways

INNOVATION READINESS LEVEL: **MEDIUM**

SAFs are produced through multiple methods and with multiple feedstocks. Up to 9 different production methods are currently certified to be used as jet fuel. Within SAF production, there are three main challenges namely (1) feedstock availability, (2) production facilities and (3) uptake by airlines.

REGULATORY AND MARKET DEVELOPMENTS

SAF policy has been largely focussed on creating demand for SAF uptake, as production would pick up based on market demand. The working group sustainable aviation fuels report published by the Dutch government also analyses ways to scale up production. By diversifying feedstocks and developing multiple SAF development pathways, production can be increased, and feedstock bottlenecks can be avoided. However, bio-fuels produced using crops from arable land can be detrimental to other developments or create unintended side-effects, while synthetic fuels may cost large amounts of renewable energy, as the production pathway is currently inefficient.

SAF production is currently largely in hands of a main supplier, namely NESTE. Further development is largely being done by incumbent fuel producers. The vast industrial and chemical knowledge required is available within these firms. Outside of incumbents, new, upcoming SAF firms such as SkyNRG and Lanzatech are also developing projects and sharing knowledge.

SAF production is expected to continue developing up to 2050 as technological breakthroughs lead to the increase of different fuel pathways. The EU blending mandate includes a clear percentage of SAF that must be produced synthetically (0,7% in 2030 and 28% in 2050).

ANALYSIS

To produce SAF, a major aspect is the availability of feedstocks. Within waste fuels, this requires mainly used cooking oils but also gasification of municipal waste. It is also possible to grow crops to be used for bio-fuels, although this requires large areas of land. Finally, hydrogen and captured carbon are required for synthetic fuel. The second challenge is developing and building production facilities on a large scale. This requires research and POCs before it can be scaled up and takes time. Finally, the third challenge relates to the use of SAF. Airlines need to buy it, even though the price is often 2-5 times higher than normal kerosine which has large implications for ticket prices. Corporate SAF buying programs as well as blending mandates are a tool to ensure there is uptake.

SAF production development is highly dependant on the demand and diversification of feedstock and scale up of production. Key developments are highlighted:

1. Blending mandates must focus not only on SAF uptake but also the type of feedstock. Crop-based bio-fuels may have a lower climate effect due to production emissions.
2. Production must also focus on developing the technological pathways for synthetic SAF fuels. This will ensure sufficient SAF can be produced in the future.
3. SAF production value chains can include multiple stakeholders, to ensure that the investment costs are shared.
4. Analysis by ICF shows that the SAF production capabilities are not in line with the first SAF users. Solutions such as book and claim systems exist but must be supported by policy.

TIMELINE

2020 – SAF pilots first production plants	**2025** – SAF fast scale up	**2030** – SAF development peak	**2035** – SAF production matures
Mainly HEFA fuel, as feedstock is available	Due to EU mandates, SAF production picks op at fast pace.	With next EU mandate, SAF production peaks	As SAF develops in the EU, global developments follow.
Connection between production and supply is still weak	SAF feedstocks become limited.	SAF producers must compete heavily with other energy sectors	All pathways are mature, but differences remain in price and availability.
First pilots other SAF pathways being developed through government support or consortia.	SAF development in other pathways fully supported by all stakeholders to ensure production is on par with demand.	New pathways reach maturity, but price is still higher. "premium SAF develops".	

OPPORTUNITIES

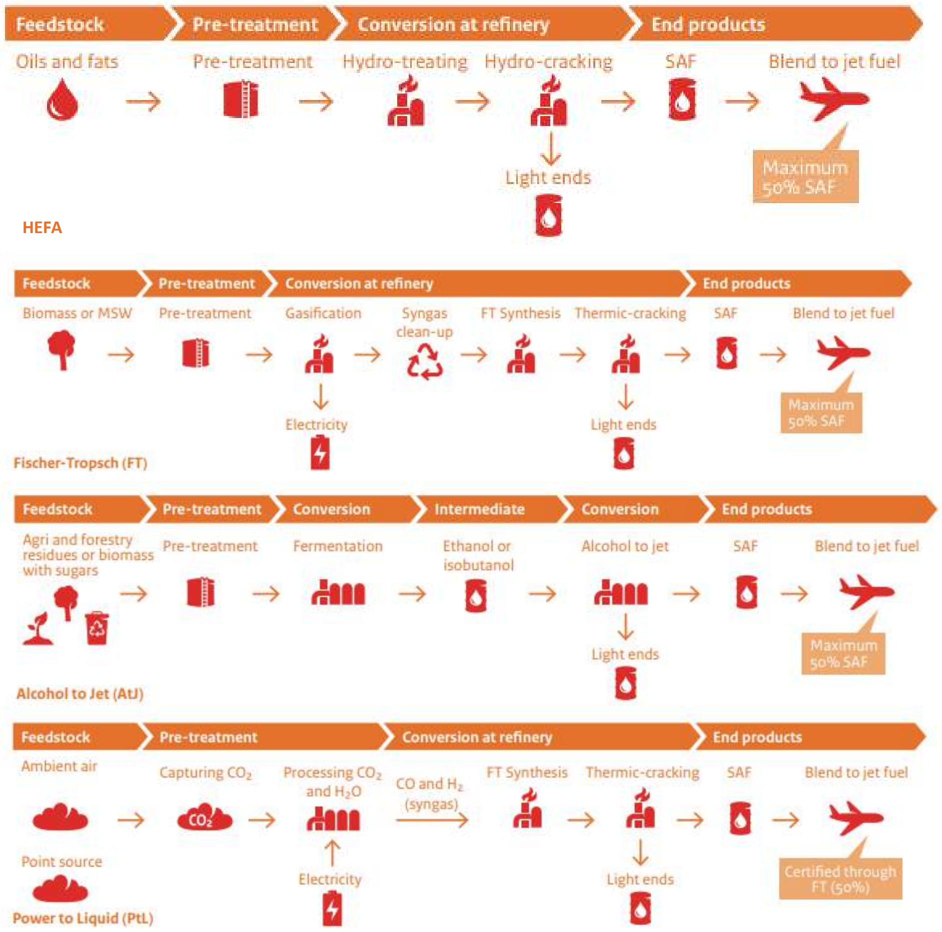
Due to the SAF blending mandates within the EU there is a high expected demand for SAF producers. Ensuring sufficient feedstocks and knowledge and technology to process SAF will require large investments over multiple years. Some interesting opportunities within SAF:

1. Increasing the amount of current fuel suppliers that can produce SAF, using different production pathways to increase the resilience of the supply.
2. Book and claim systems to connect production with use without physical supply chains. SAF does not need to be delivered to a specific airport or airline, as long as it is blended into fuel that is used by any aircraft worldwide.
3. Aligning production and use so that regions where more SAF feedstocks are available such as waste oils or hydrogen can produce SAF and still receive the funding for it.
4. SAF production and investment through cross sectoral consortia: Including multiple stakeholders within the value chain will allow for shared investment. Customers such as sustainable corporates also present opportunities to share within the investment.

EU AND DUTCH INITIATIVES

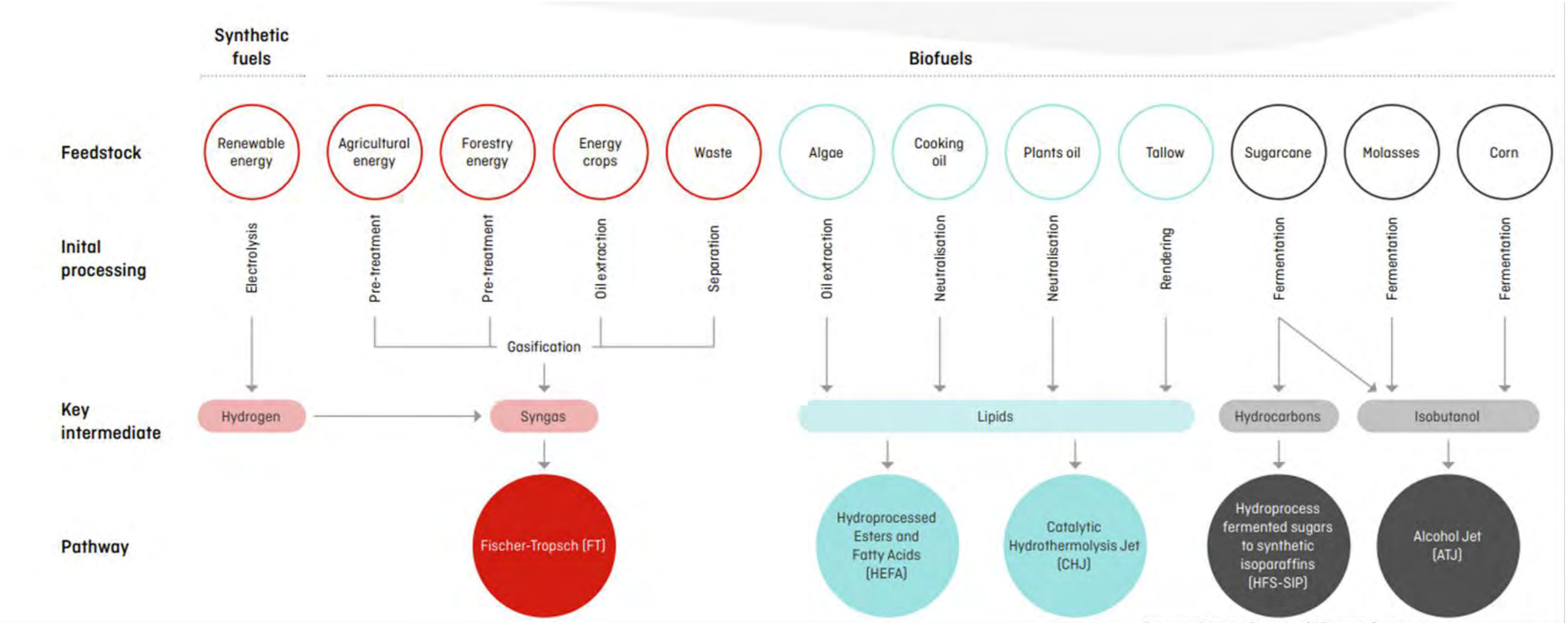
SkyNRG · Synkero · LanzaTech · NESTE MY Sustainable Aviation Fuel · zenid · JETEX

FF2.1 SAF Production through Multiple Pathways



Source: WDB Action Programme

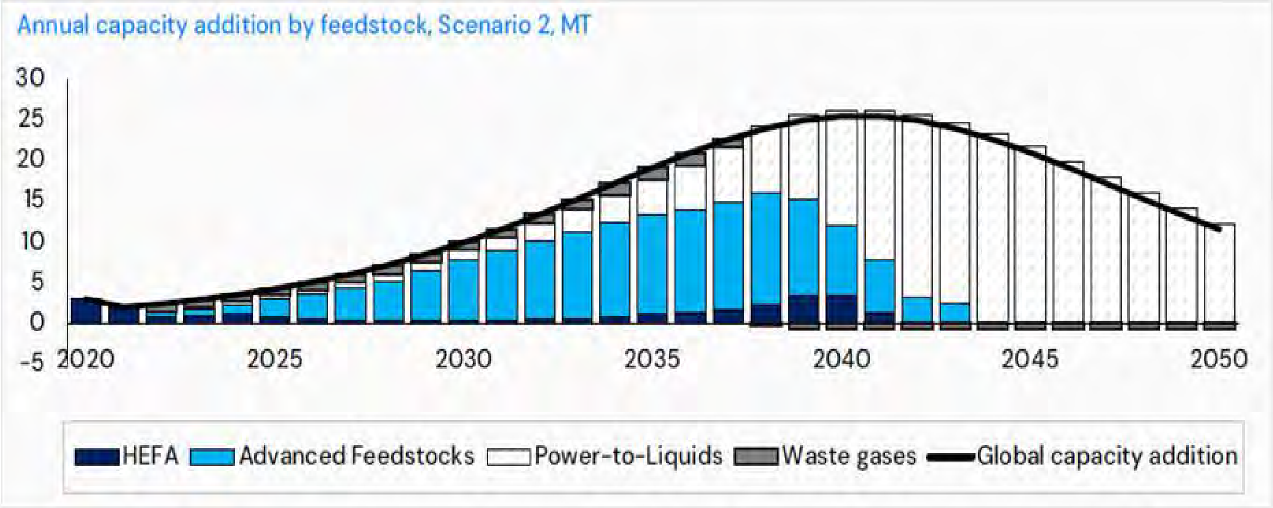
FF2.1 SAF Production through Multiple Pathways



Source: Qantas Sustainability roadmap (https://www.qantas.com/content/dam/qantas/pdfs/about-us/environment/qantas-group-climate-action-plan.pdf)

FF2.1 SAF Production through Multiple Pathways

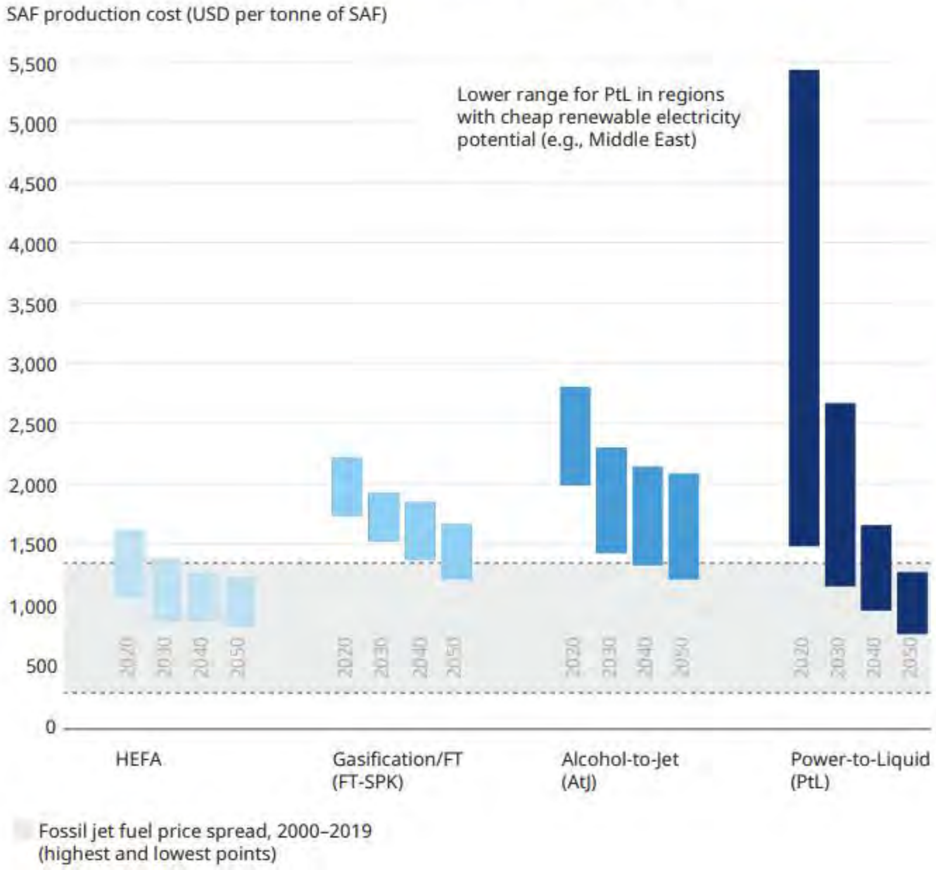
EXPECTED SAF PATHWAYS DEVELOPMENT AND PRICE DEVELOPMENTS



Source: ICF analysis

*Advanced Feedstocks include gasification and Alcohol to Jet

Exhibit 9: Cost profile of SAF pathways between 2020 and 2050



Source: Oliver Wyman & IBEC research: Sustainable aviation Our Future

FF2.2 SAF Blending Mandates

INNOVATION READINESS LEVEL: **MEDIUM**

SAF blending mandates are currently the main driver of SAF within the EU. Both on an EU and national level, mandates are ensuring that the suppliers of Jet fuel deliver a minimal amount of SAF blended into their fuel mix. The mandates must be strictly enforced to ensure they are followed and the SAF development targets are reached. Mandates must be developed carefully to mitigate negative unintended consequences.

REGULATORY AND MARKET DEVELOPMENTS

The goal of SAF mandates policy ensures that the burden of development and costs of SAF are shared within the market. This ensures action will be taken by all stakeholders that are involved.

Much research has been done on policy development for SAF demand increases, including from the World economic forum clean skies initiative, but also Transport & Environment and by the EU. Policy can be divided into three main categories. Mandatory mechanisms such as blending mandates, market based mechanisms such as price reduction for SAF or price increase of conventional jet fuel and finally voluntary mechanisms such as SAF in public procurement.

SAF blending with Jet A1 fuel requires clear policy and regulation on technical blending facilities and operations to ensure safety. All SAF fuels must be tested before use in aircraft engines. Developments such as blending to higher percentages (current max is 50%) or blending multiple production pathway SAFs will still require research supported by clear policy.

ANALYSIS

SAF blending is a key part of achieving sustainability within the short term for all aircraft and in the long term for long range aircraft. Although blending is achievable, it must be further developed by current market players and within research. Key developments are highlighted:

1. Blending mandates must be developed with the entire value chain included. This requires a clear understanding of the production pathways, to ensure that there are no negative externalities when SAF is produced, or that SAF subsidies undercut other sectors such as food production.
2. Compliance must be ensured by the entire value chain, within the EU regulation this is done by enforcing the mandate with fuel suppliers, ensuring that all fuel delivered in Europe is blended.
3. SAF policy must also enable connections within the value chain. Supply and demand must be connected so that blending requirements can be achieved but also that production is sold at value that legitimizes investment is SAF.
4. SAF blending must continue to be researched even as large scales of specific blends up to 50% are rolled out. It must be deemed safe at all airports, and blends of over 50% must also be tested.
5. Tankering at other airports outside of the EU is often seen as a barrier. This development can be mitigated through clear policy on fuel taxes when crossing borders, or regulations that include a minimal uptake obligation.

TIMELINE

2022 – First country mandates and internal airline targets	**2025** – First EU mandate and awareness increase	**2030** - fast scale up of blending mandates in EU and the Netherlands	**2035** – Global Blending mandates and 100% SAF engines
2022 France 1% blending mandate	EU blending mandate of 2% comes into effect for all EU flights.	EU blending mandate 10%	SAF demand on a global scale
Air France KLM 0.5% blending mandate	Leading corporates and airlines will provide premium SAF flights for sustainable traveller.	Dutch blending mandate 14%	increased public procurement for SAF
EU SAF blending mandates are being ratified.		Consumers can include SAF for all flights	Taxation to mitigate tankering
		SAF in high demand	

OPPORTUNITIES

Within SAF blending, there are many opportunities to further develop both the production and uptake of SAF.

1. Inclusion of SAF in public procurement will ensure that airlines and private charter firms must procure SAF for their flights. This pushes leaders within the market, after which others will follow.
2. An international system to regulate and share SAF claims would allow for a clearer book and claim system, and ensure that SAF is produced sustainably and there is no greenwashing by airlines or airports.
3. Increased connections between suppliers of SAF and potential buyers such as large corporations would ensure that the chicken and egg problem is further decreased. When there are enough buyers, a market will form from which producers can gather investment.
4. Increased blending mandates on a worldwide scale would level the playing field for European airlines and airports.

EU AND DUTCH INITIATIVES

Clean Skies for Tomorrow

COMPENSAID powered by Lufthansa

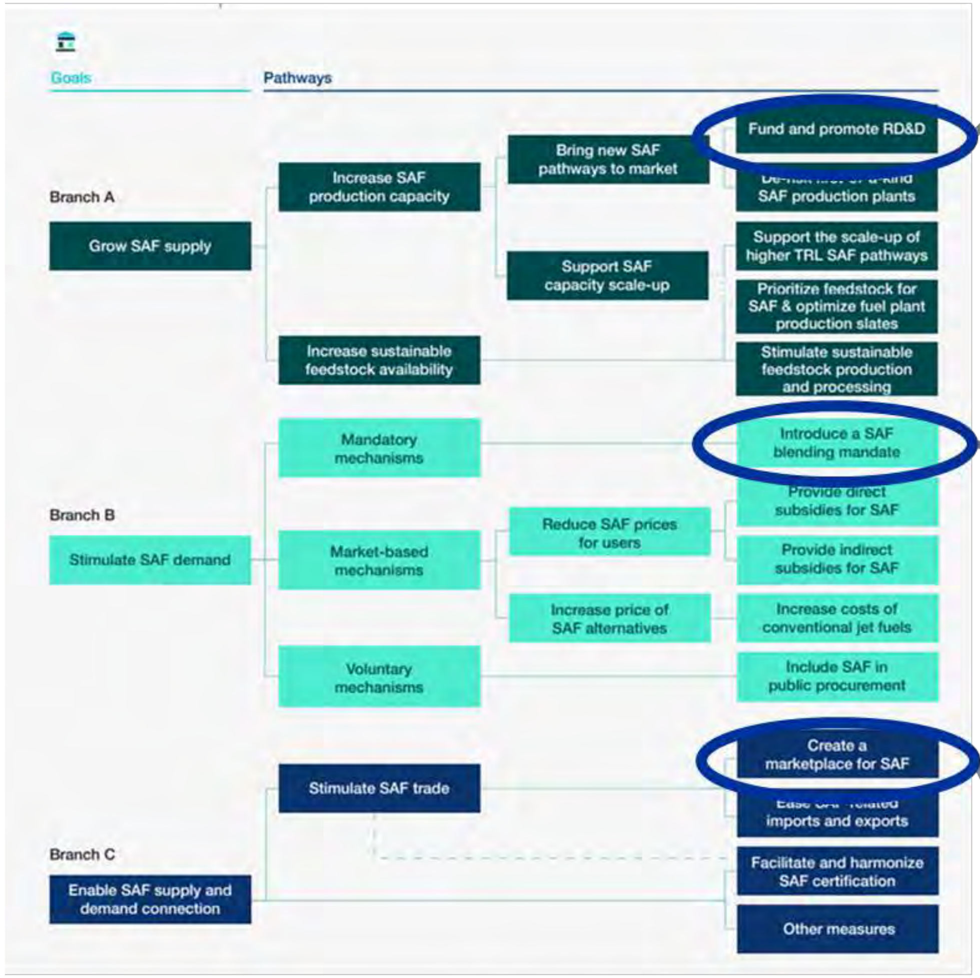
BOARD NOW coalition for sustainable living

MISSION POSSIBLE PARTNERSHIP

European Green Deal

Fly Green Fund

FF2.2 SAF Blending and Mandates



Source: WEF research on SAF policy framework

Research funding

Blending Mandates

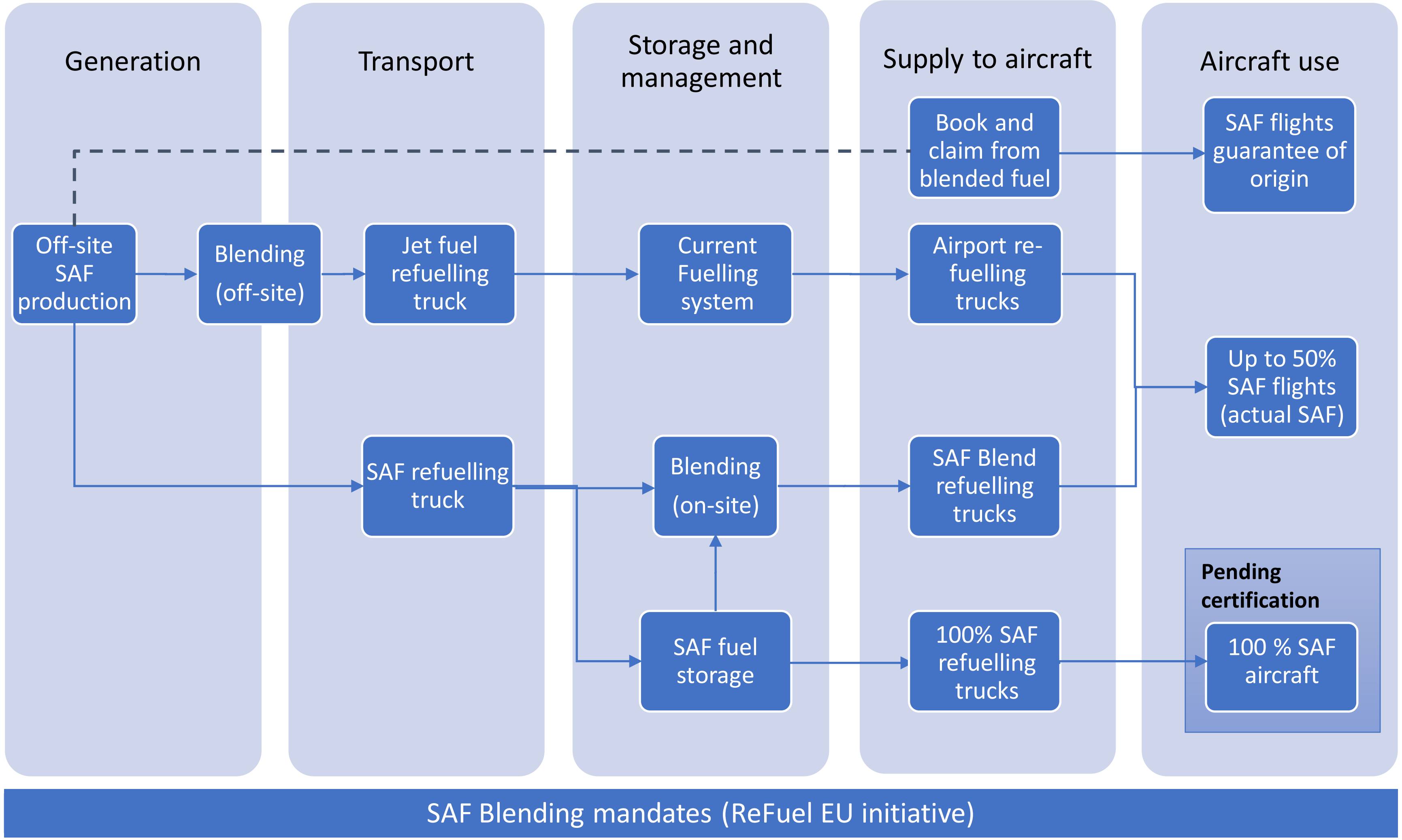
Year	IATA Global SAF blending goals*	EU SAF blending mandate	EU Synthetic SAF blending mandate	NL SAF blending mandate	Sweden Blending mandates
2022	-	-	-	0.5% (KLM only)	1%
2025	-	2%	-	-	5%
2030	5%	5%	0.7%	14%	30%
2050	65%	63%	28%	100%	100%

*** Not a mandate**

Marketplace development

Fitfor55 - Book & Claim: Until 2035, fuel suppliers will not be required to supply the minimum amounts of SAF to airports physically.

FF2.2 SAF Blending and Mandates



Source: To70 Analysis

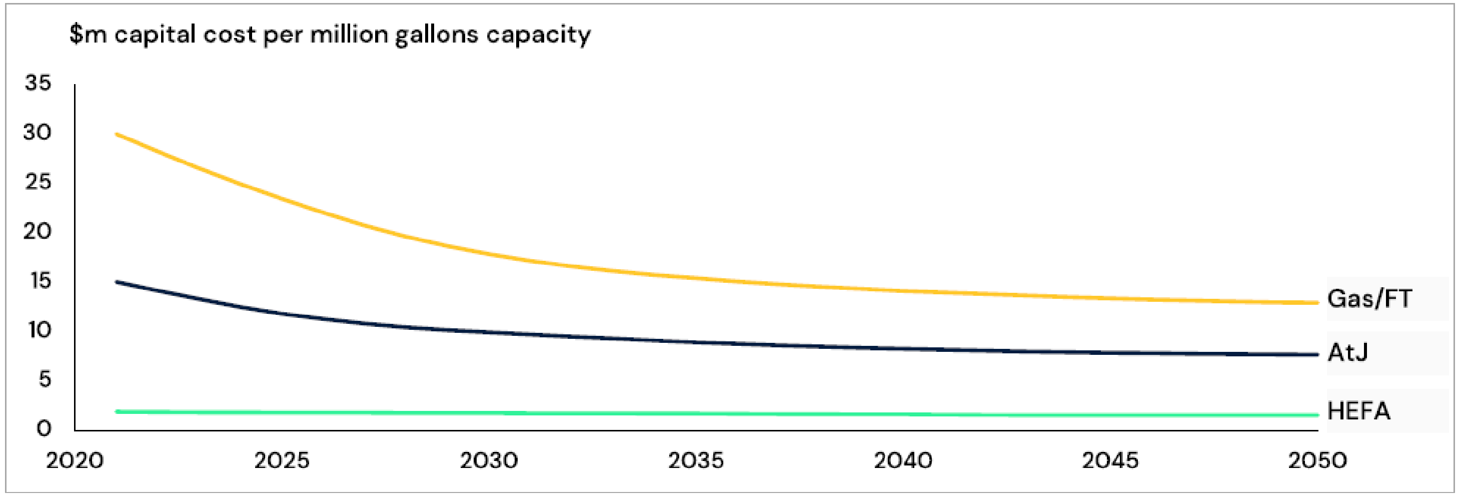
FF2.2 SAF Blending and Mandates

ECONOMIC IMPACT OF BLENDING MANDATES

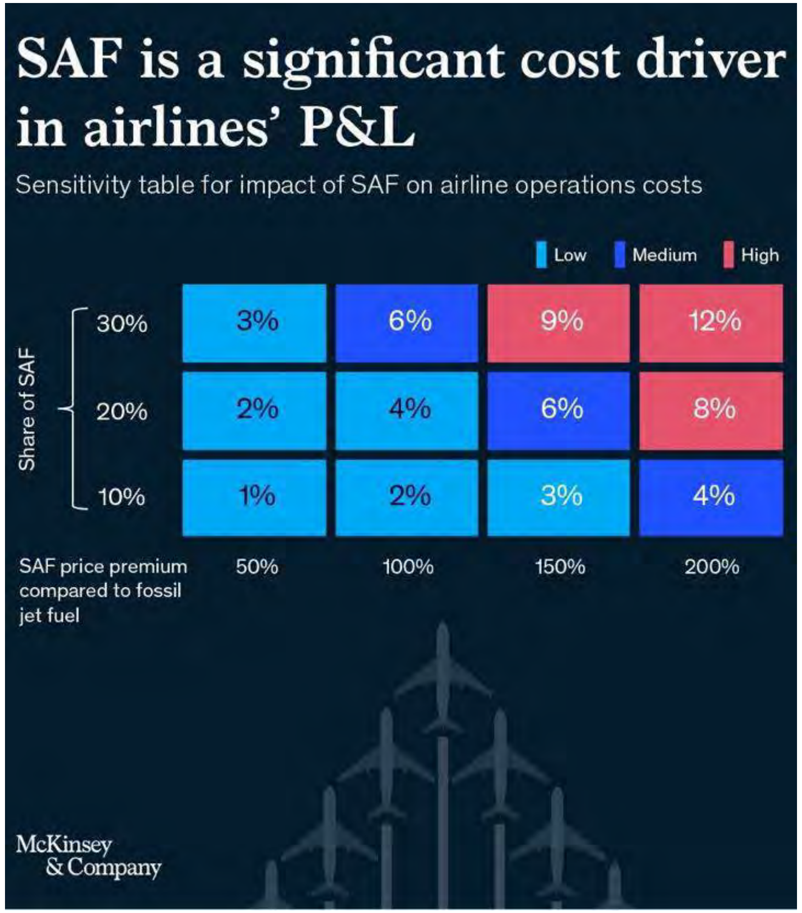
Blending mandates will lead to a price increase for fuel which will translate into ticket costs, as well to the requirement of large amounts of feedstocks, both for bio/waste SAF and Synthetic SAF.

Although HEFA remains relatively method to produce SAF, the feedstock availability is limited. Extensive ICF and McKinsey research on the topic of SAF production and cost shows that the price will be calculated towards the customer who buys the ticket. However, this remains dependent on feedstock availability which may decrease supply while mandates drive demand.

Reduction in capital costs as SAF production scales



Source: ICF Analysis



Source: Mckinsey analysis

FF3.1 Resilient Electric Charging Infrastructure

Charging electric aircraft to ensure sustainable aviation can be achieved requires sufficient renewable energy supplied to the airport. Charging can be run on the grid or on local battery storage. Locally produced renewable electricity can support the decarbonization of aviation and provides a positive use of airport space.

Hybrid electric aircraft are also being developed, some of which would need to recharge and require electric power supply at airports. Finally, hydrogen fuel cell electric aircraft are expected to have a reserve battery on board that may need to be recharged at airports.

REGULATORY AND MARKET DEVELOPMENTS

The policy development for charging infrastructure is much less developed compared to electric road mobility, as electric aircraft themselves are still in early stages of development. Policy on electronic infrastructure could decrease the investment risk and introduce more electric aircraft to airports. Policy that introduces pilots and test beds for electric aviation could help to create the required ecosystem. Initially, mobile battery storage systems would be sufficient to recharge aircraft. However, as peak demands develop, electric distribution on the apron will be critical in ensuring electric charging infrastructure is in place.

Policy that connect airside and landside mobility would also provide a positive impulse into the development of electric aviation infrastructure, as the use cases can be combined. This would enable learning and knowledge sharing opportunities.

ANALYSIS

Several critical points have been identified to ensure that electric charging infrastructure can be developed at airports.

- Battery infrastructure would facilitate for first flights but charging power is lower, which would create problems for turnaround times at airports. It would be sufficient in the first stages of development.
- Grid charging would require a strong connection to ensure the required voltage for fast aircraft recharging. This requires sufficient time for an airport to develop and must therefore be planned into airport systems beforehand.
- Connecting local energy production to charging would require significant planning and fail safes in case there is limited renewable energy production. However, it is an opportunity for airports to connect their energy production with aircraft fuel. Locally produced electricity could also be stored in batteries, or heat or hydrogen storage systems.
- Cable network upgrades would be required to achieve the required demand of the charging infrastructure
- Supply to aircraft must be developed in line with safety authorities and aim towards standardization of charging infrastructure and cables.
- A method to decrease turnaround time for electric aircraft would be the development of swappable battery systems, although this presents new problems within the powertrain, and therefore has not yet been developed on a larger scale.

TIMELINE

2020 – Electric pilots and mobile charging stations	**2025** – First electric charging points	**2030** –Systems standardisation electric charging	**2035** – All airport electric systems connected
Mobile chargers built by aircraft producers for small aircraft	Electric charging stations at leading airports	Collaboration between airports and aircraft trade bodies on charging infra.	Electric charging stations standard at all airports
Electric systems developed as pilots	Connection made with landside charging	Airports connecting production capacity with charging capacity	Fully developed smart grids
Research on smart grid opportunities	Local energy production used to charge.		

OPPORTUNITIES

Developments from within the market provide opportunities for electrification of aviation and include the development at airports.

- PowerUp: An initiative by Dutch Airports that connects the Dutch airspace through electric flight and does market research on electric aviation.
- KLM flight academy & E-flight: A connection so that flight lessons can become more sustainable using the Pipistrel Velis electro aircraft.
- Providing charging stations at airports will ensure they are ahead of the aircraft development and therefore push other stakeholders. It is critical that charging does not become the bottleneck for sustainable electric aviation.

EU AND DUTCH INITIATIVES

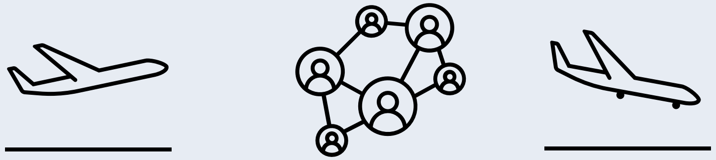
FF3.1 Resilient Electric Charging Infrastructure

Source: Eaton

Source: Pipistrel

Source: Electro.aero

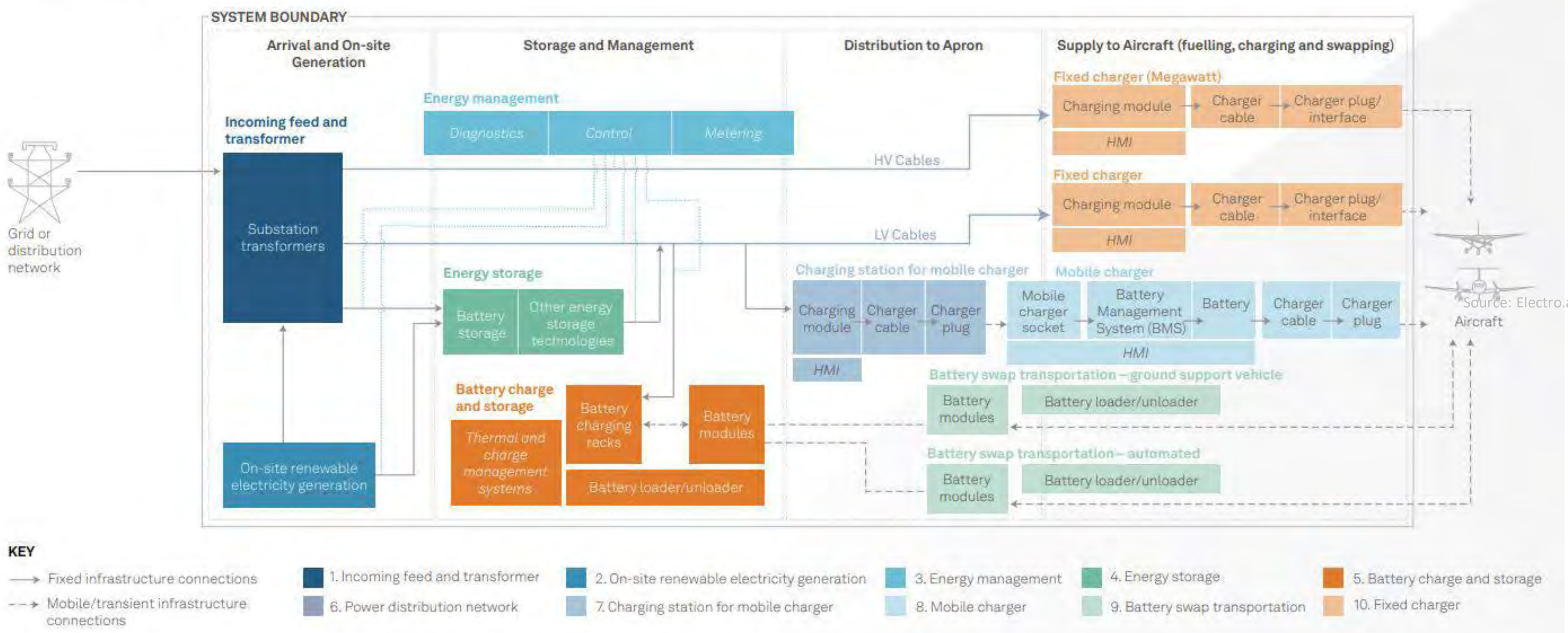
Electric regional flights, generating more point to point transport. This would require local high voltage charging points at many regional airports.



The development of Smart Grids can regulate electricity production and demand.

FF3.1 Resilient Electric Charging Infrastructure

Figure 6: Electric system architecture



Source: Catapult Connected Places: Blueprint for Zero Emission flight infrastructure

3. INNOVATIONS IN AIRPORTS

Introduction and Scope

The ownership of Europe’s Airports shows that over 40% of Europe's airports have at least some private shareholders - these airports handle close to 75% of passenger traffic yearly. This number is slowly increasing each year. These airports must innovate and develop sustainable aviation solutions in line with the sector to legitimize their position as a service provider. Most of the research and development at airports is made with a time horizon between 2030 and 2050. One of them is the 2050+ project which aims to prepare airports for 2050 and beyond by creating a concept development methodology to ultimately enable 90% of European travellers to complete their intra-European door-to-door journeys within 4 hours, promote cost effectiveness through low operating costs and optimal revenue, develop climate neutral operations and low sound pollution. Within the EU, the green airports call has also facilitated innovation development across at least 12 large European airports. On national and airport specific levels, innovation development is also taking place to ensure airports decarbonize their own emissions, decrease their local noise and fine particle emissions, and support the decarbonization of the larger aviation sector. The outcomes foreseen in this innovation area are:

Outcome AP1: Airports are becoming an energy hub for its stakeholders and surrounding community

Airports must adapt to cater for energy demands coming from new types of aircraft, the electrification of vehicle fleets both airside and landside, and digitalization. This will result in an increase in electricity demand and possibly other sustainable fuels and storage opportunities. To develop this, airports are looking at local and independent solutions into energy supply and storage. At most airports, the large amounts of space and ownership over their own energy networks allows them to install renewable energy facilities and storage. They can thereby become energy hubs or providers for the surrounding businesses and communities.

Drivers: AP1.1 Energy Hub | AP1.2 Adapt for Aircraft Revolution

Outcome AP2: Towards a sustainable airport, and a friendly neighbour

Climate action is one of the key priorities on the airport agendas, and they have the largest impact within their own operation. To safeguard the viability of the airport industry, airports must adapt to mitigate their own CO2 emissions impact, as well as connect with local stakeholders to decrease their noise emissions, air quality, waste, and other non-CO2 emissions. Airports are central to operations and engage with many stakeholders that have similar goals. Airports should take the opportunity to create a collaborative environment, leading towards sustainable and liveable activities, and being resilient towards climate change. Ground infrastructure is essential for successful operations with new airspace users. This section focuses on this infrastructure (vertiports) needed for piloted and unpiloted vehicles for transport of people and cargo.

Drivers: AP2.1 Reduce Emissions and Become Net Zero | AP2.2 Accommodate for Climate Resilience | AP2.3 Vertiports

Outcome AP3: Digitalisation and automation are key for optimised and safe operations at airports

Over the past years, significant innovations have been fast tracked within the airport sector, especially within digitalisation of operations. The focus on digital transformation, automation and efficiency will remain and grow stronger as airports aim to improve efficiency, safety security and environmental performance. Solutions that have been implemented include optimisation of the passenger flow process, and ensuring a seamless, customised and personalised journey. Increasingly, shuttles at the airport have become electric and automated while airside automation also continues with ground support equipment (GSE) and airport vehicles. Digitalization is expected to continue increasing as the connection and integration of systems is required to achieve a connected airport.

Drivers: AP3.1 Terminal Seamless Flow | AP3.2 Electric and Autonomous Airside | AP3.3 Intermobility

AP1.1 Energy Hub

INNOVATION READINESS LEVEL: **MEDIUM**

Airports have the opportunity to develop into energy hubs that generate, manage and distribute renewable energy across the airport and between all stakeholders. As infrastructure owners, Airports can engage with their users to match renewable energy generation and demand, and apply smart energy storage solutions to mitigate energy peaks. Other energy storage solutions, such as batteries, heat storage or hydrogen storage can be developed to form synergies with current developments in sustainable aviation, as was described within Aircraft Platforms and Future Fuels.

REGULATORY AND MARKET DEVELOPMENTS

Airports are increasingly investing in sustainable generation, both off-site and onsite. Landside as well as airside, the increased demand from electric vehicles and infrastructure, requires airports to upgrade their energy grids and networks. Regulations regarding energy hubs are limited, and so is policy support to develop these systems. However, as the modular systems required to enable these energy hubs and smart grids reach higher TRL levels, they become accessible for an increasing number of airports to invest in. This includes battery development, grid regulation software and many other innovations to connect energy generation, storage and use.

ANALYSIS

Airport Energy hubs require a systemic view, that includes all types of energy requirements at an airport, but also energy generation and the way this develops over time. Several critical aspects have been identified below.

- Airports must develop their energy hub beyond their current energy value chain. Providing energy can be a way to further develop the ways airports create profits in a sustainable way.
- Airports take more ownership of energy systems, so that they can influence generation, storage and demand and regulate these systems more effectively
- As energy requirements diversify towards electric hydrogen and bio/synthetic fuels both airside and landside, airports must develop strategies for each.
- Developing long term plans for expected energy requirements and ensuring that renewable generation and storage stays aligned with energy use. Tools such as digital twins can be used to develop this.

TIMELINE

2022	2025	2030	2035
Local energy production scale up Airport solar panels and geothermal energy are developing Airport energy grid ownership increases	Local energy storage scales up Airports develop decentralized battery systems Energy use is regulated to ease supply and demand	Development of Smart grids Connection of all airport energy generation, storage and use systems Smart energy Software initiated	Energy hub that can power independently Independent charging ad storage systems Still connected to the grid to support energy needs of local stakeholders

OPPORTUNITIES

Airports that succeed in the development of an energy hub within their airports have several strategic advantages, as described below.

- The airport becomes more resilient, and less impacted by external fuel prices and availability.
- The airport develops a new business case in the form of energy supply .
- The airport engages with local stakeholders in energy production, improving the connection and liveability of local stakeholders.
- The airport is able to become carbon Neutral or possibly Net zero much faster than planned by largely decreasing its carbon emissions footprint.
- The airport is less reliant on external stakeholders to decarbonize and become sustainable.

EU AND DUTCH INITIATIVES

Stargate within EU Green Deal

OLGA hOListic Green Airport

ACI Europe Airports Council International 2050 NET ZERO

TULIPS

AP1.1 Energy Hub

Energy generation

Energy storage

Energy use

On site energy production

On site energy storage

Airside, landside and heating energy use

Energy hub and smart grid development

AP1.2 Adapt for Aircraft Revolution

INNOVATION READINESS LEVEL: **LOW**

Alongside the development of an energy hub, Airports must also look outwards to the innovation in aircraft platforms and future fuels. This requires an investment in the charging infrastructure, as well as the specific operations aspects of future aircraft types. This includes, but is not limited to adapted turn around times, updated safety protocols, different space requirements for new aircraft and adaptations for ATM stakeholders.

Secondly, airports will also need to transition to different MRO requirements as new aircraft require new knowledge and expertise. By providing this, airports can ensure that the adoption of future aircraft is improved.

REGULATORY AND MARKET DEVELOPMENTS

As aircraft innovations develop and future fuels are expected to power aircraft, airports must adapt. Beyond adapting, airports can also lead in the transition. Policy is being developed to support the market to take such a leading role. This includes legislation to push airports to incentivise more sustainable aircraft, such as the CO2 ceiling in the Netherlands and blending mandates in the EU and multiple EU countries. Financial incentives to support airports in making the transition to provide sustainable fuel to aircraft are currently still limited. Airports that want to lead by providing refuelling infrastructure must be supported in making investments. This support can also come from other stakeholders in the value chain, as airbus is currently supporting hydrogen refuelling projects at airports and multiple future aircraft concept companies are also developing refuelling systems for their specific aircraft.

ANALYSIS

Airports can start to prepare for the required adaptation that must take place as aircraft and future fuels develop. A number of critical aspects have been described below.

- For airports the development of knowledge on future aircraft is relevant for all parts of the organisation and for all stakeholders at the airport including ANSPs, MRO organisations, GSE, etc.
- Visualisation of future refuelling and charging infrastructure can be a guide to other stakeholders as well as users on what is being developed and how this will effect operations. Visualising future fuel systems also shows the investments that will be required from the airports.
- Risk assessments must be conducted to understand how the different aspects of future fuel refuelling will impact the airport.
- Business cases to tailor the requirements of aviation developments to local use case requirements. This includes looking into point to point aviation versus hub and spoke, but also passenger numbers, flight school use cases, inter-island use cases and
- Connecting future fuel availability to the local context. If there are large amounts of SAF or hydrogen available locally, or there is s strong electric grid connection to renewable energy, this can be more interesting for an airport.

TIMELINE

2022	2025	2030	2035
Feasibility studies & first agreements. Airport capacity studies for electric and Hydrogen refuelling SAF refuelling contracts	First hydrogen refuelling, scale up for SAF and electric Hydrogen pilots Electric charging standardisation SAF supply scale up	Airport future fuel infrastructure ready Specific airports may focus on electric charging for point to point use cases Airports near hydrogen production or import focus on H2 All airports can supply SAF	Airports are ready to supply all fuel types Different fuels will require more space and dedicated investment Different fuels will require airports to diversify their energy systems & partner stakeholders

OPPORTUNITIES

Airports have the opportunity to facilitate early adoption of future aircraft, thereby supporting the entire aviation sector and also decreasing their scope 3 emissions.

- Future aircraft often also have lower local emissions, creating a safer work environment of ground personnel.
- Future aircraft are expected to have slightly lower noise emissions, improving the connection with local communities.
- Airport infrastructure adaptation would give airports a head start in how future aircraft will impact airports, giving them a competitive advantage.

EU AND DUTCH INITIATIVES

RHIA

H2ub Airport

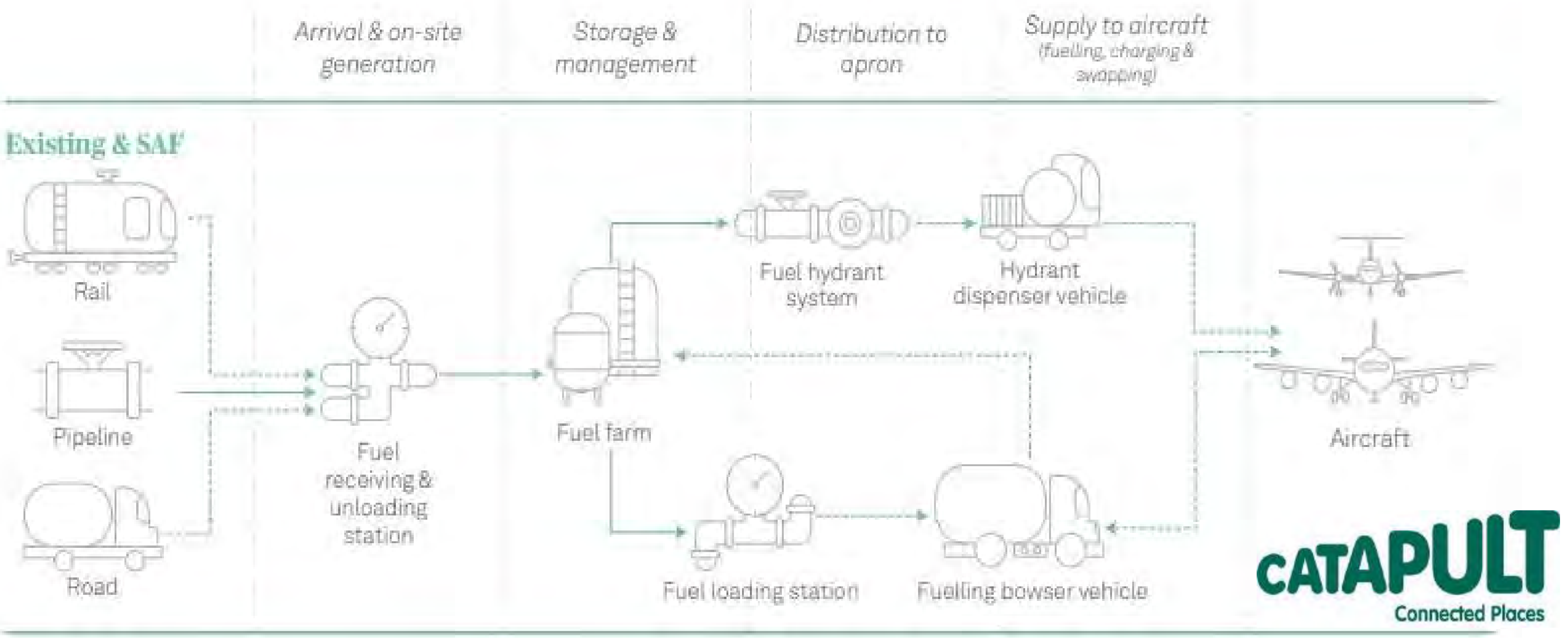
Swedavia Airports

HAMBURG AVIATION

AP1.2 Adapt for Aircraft Revolution

MORE DETAILS ON: AIRPORT ADAPTATIONS FOR SUSTAINABLE AIRCRAFT

Airports must understand their role and the role of their stakeholders in the entire supply chain of future fuels for revolutionary aircraft. Below are described the key aspects for SAF supply chains at the airport, courtesy of research by UK innovation institute Catapult connected places.



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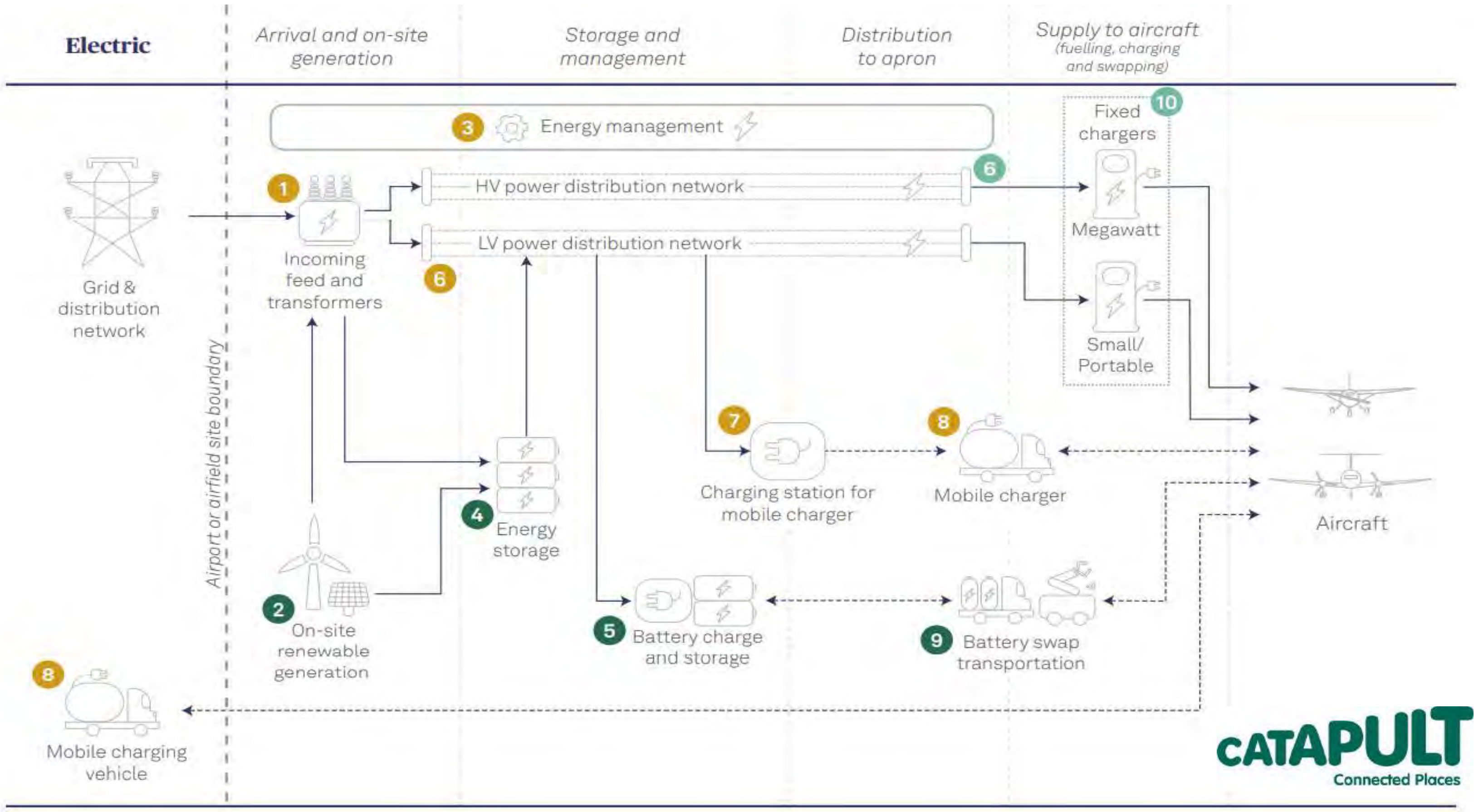

AP1.2 Adapt for Aircraft Revolution

MORE DETAILS ON: AIRPORT ADAPTATIONS FOR SUSTAINABLE AIRCRAFT

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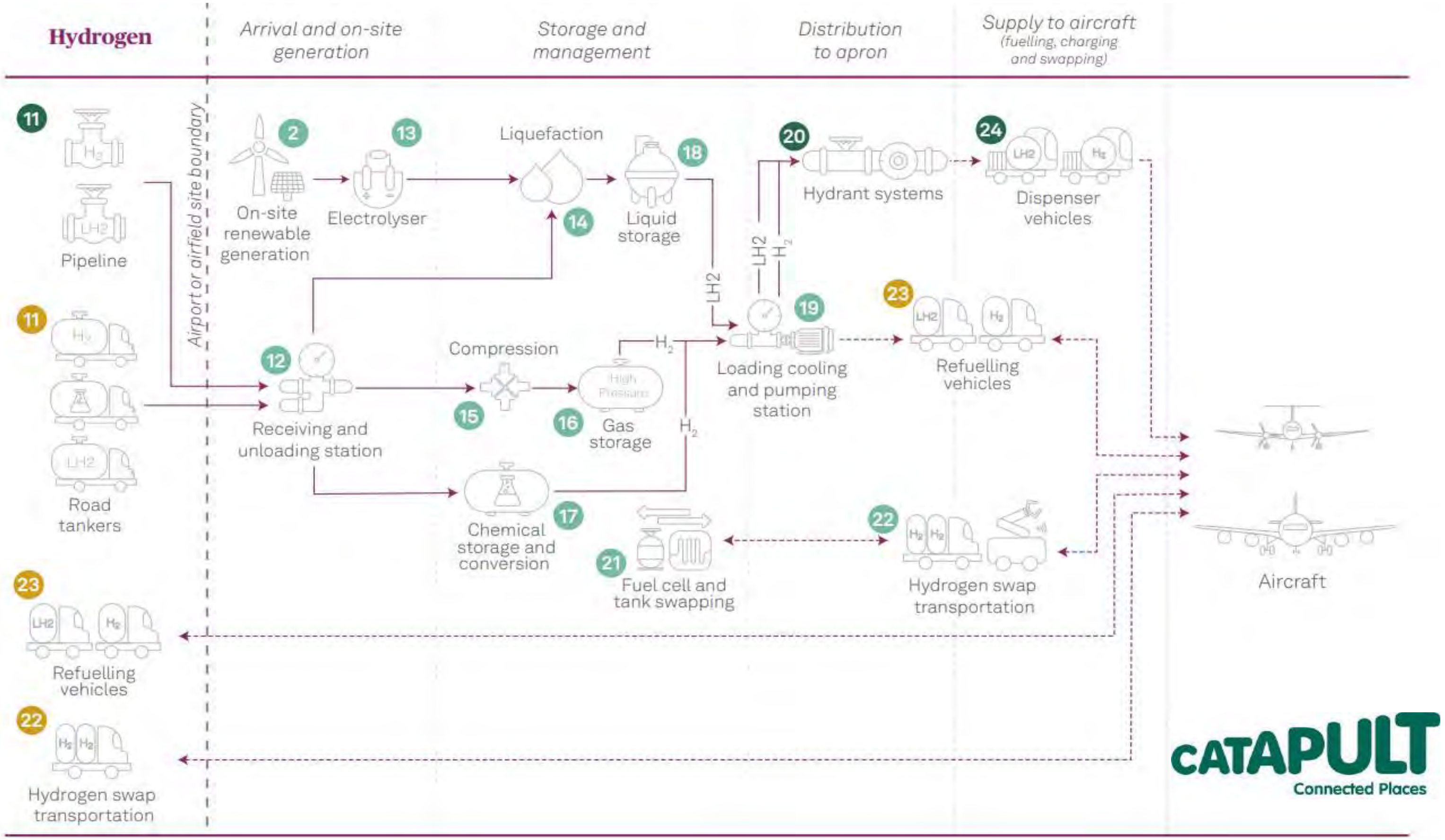
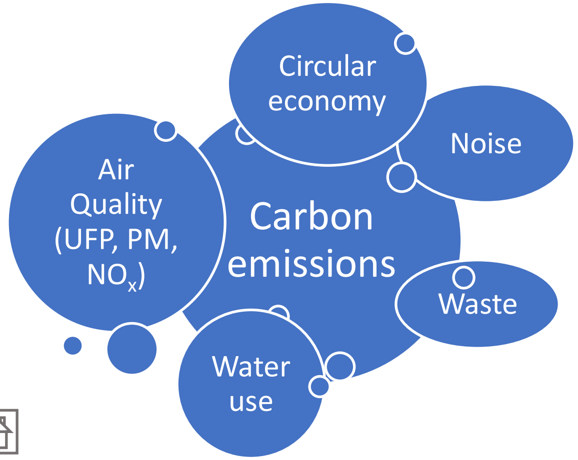


AP2.1 Reduce Emissions and Becoming Net Zero

INNOVATION READINESS LEVEL: **HIGH**

Climate action is one of the key priorities on the airport agendas. Airports have been working to reduce their carbon emissions, supported by the Airport Carbon Accreditation programme from ACI. Many airports have committed to being net zero by 2050, and several by 2030. A small number of airports are currently already net zero airports.

Besides CO_2, airports are also working to mitigate noise emissions, Air Quality – (Ultra-fine and fine) Particulate matters emission and NO_x emissions. Airports are also developing plans for circularity and for sustainable waste streams.



REGULATORY AND MARKET DEVELOPMENTS

Airports must legitimize their continued operation and lead in decarbonisation by reducing their emissions to net zero. A majority of the airports has realized this and started on the path towards sustainability. The ACI as well as the Science based targets initiative does give guidelines on how to develop a pathway to net zero carbon. By sharing best practices, airports can support each other in finding the right methodologies and solutions to do this. Decarbonisation of the airport starts with efficiency improvements, followed by a change in energy source to renewables, preferably on-site, and then to engagement of all stakeholders to also tackle scope three emissions.

Policy support for airports to achieve this is limited, although many airports are supported by governments as their main stakeholders. Airports can also follow policy support outside of their sector, including renewable energy incentives, electric vehicle leasing support and other tax incentives. The EU green airports call has provided airports with funding opportunities to develop the innovations required to decarbonise, including digital twin tools to measure efficiency and energy use, sustainable GSE's and other improvements at the airport.

ANALYSIS

- Airport operators are located at the heart of the aviation value chain, and therefore have an active role to play in collaboration with stakeholders to ensure that their scope 3 emissions at the airport are also tackled.
- ACI EUROPE launched a Sustainability Strategy for Airports, the first-ever systematic approach to sustainability at airports and practical guidance on how to achieve it. European airports can commit to achieve Net Zero Carbon emissions for operations under their control by 2050 at the latest.
- More detailed models and analysis of the emissions including climate change (CO2 with Digital Twin, Ultra Fine Particles, NOx with ATM4E) main sources of emissions can be highlighted, and action plans can be developed accordingly
- Emission reduction will be done mainly through technology improvements such as electrification of the fleet (incl. de-icing trucks & safety vehicles), water injection for engine run-ups (reduce UFP), rainwater recharge ups (to become water independent.
- Circular economy and waste management are also critical aspects for airports that affect other emission reduction targets, namely material & resource use. Airports must continue to develop plans on these targets as well.

TIMELINE

2022	2025	2030	2035
Emissions reduction at airports and first collaboration with other stakeholders Airport set individual targets and goals to reach net zero Airports develop sustainability plans and roadmaps that cover people, planet and prosperity	Innovation in airport energy systems that will allow them to achieve net zero Partnerships are developed to ensure scope 3 emissions also decrease Waste, circularity, air quality, noise and NOx emission targets are also set	First net zero targets are reached All airports must become net zero Standardised targets are set so that all airports can align Targets are set for all airport scope 3 emissions, increase in airport responsibility	Airports and its stakeholders are fully engaged in liveability and climate improvement Airports develop carbon capture practices to mitigate all emissions that are hard to abate

OPPORTUNITIES

Airports can benefit from a dedicated and fast transition to sustainability and net zero.

- Sustainable airports often have less dependency on fuel prices and availability.
- Net Zero targets give airports a clear path to work towards with the actions they take. It sets a clear timeframe and responsibility
- Circular economy benefits airports, as they require less materials to be used.
- Supporting stakeholders at the airport can improve relations, forming positive connections for the airport to learn.
- Airports can make use of cross sectoral policies that support decarbonisation practices. These can be utilized by airports.

EU AND DUTCH INITIATIVES

CO2 ceiling policy initiative

ACI EUROPE AIRPORTS COUNCIL INTERNATIONAL

2050 NET ZERO

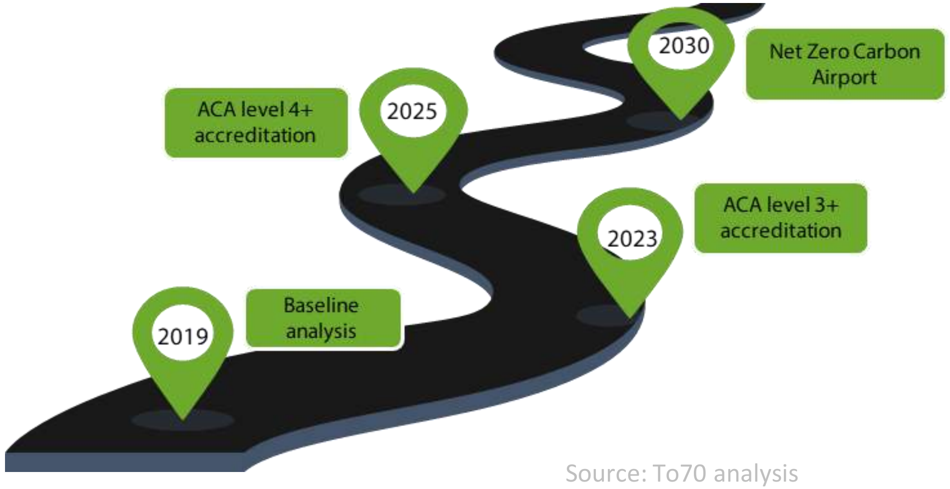
SCIENCE BASED TARGETS

AP2.1 Reduce Emissions and Becoming Net Zero

MORE DETAILS ON: ACI AIRPORT CARBON ACCREDITATION

Source: Airport carbon accreditation, [Airport Carbon Accreditation - How to apply]

Source: Developing an Airport Net Zero Carbon Roadmap To70 & ACI



Source: To70 analysis

AP2.1 Reduce Emissions and Becoming Net Zero

MORE DETAILS ON: AIRPORT DECARBONIZATION

A number of airports are also looking beyond ACI carbon accreditation. SBTI (Science based Targets Initiative) provides a cross sectoral approach and is based on achieving maximum 1.5 degrees warming through science based targets. A growing number of airports are applying to achieve SBTI accreditation. The main benefit is the scientific basis as well as the cross-sectoral application. SBTI guidelines for airports specifically are currently still being developed.

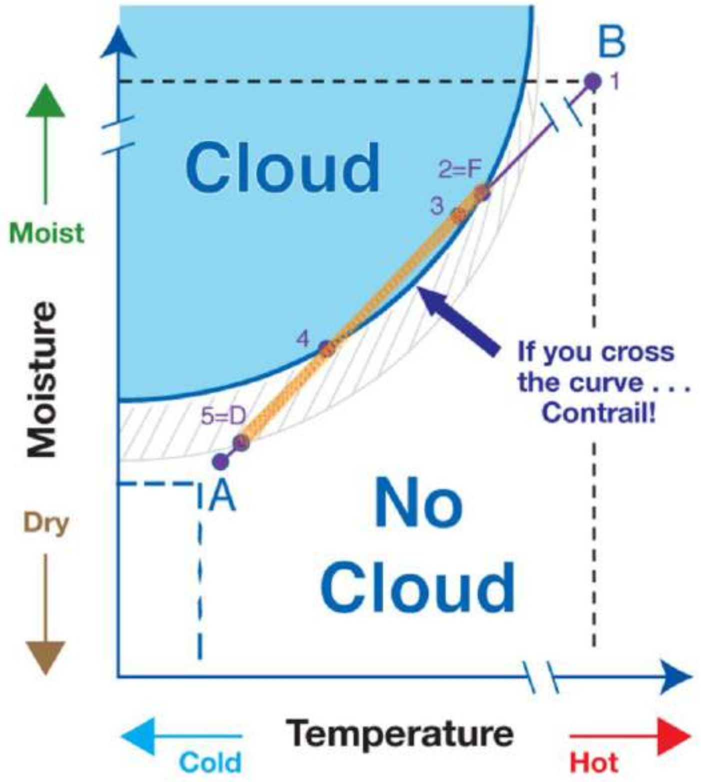
There are a number of other sustainability reporting methodologies airports can connect to, including Lean and Green, GRI reporting and a number of ESG reporting initiatives. Methodologies can be supporting, although some are more detailed than others. When setting targets it is important to go beyond ticking boxes.

AP2.1 Reduce Emissions and Becoming Net Zero

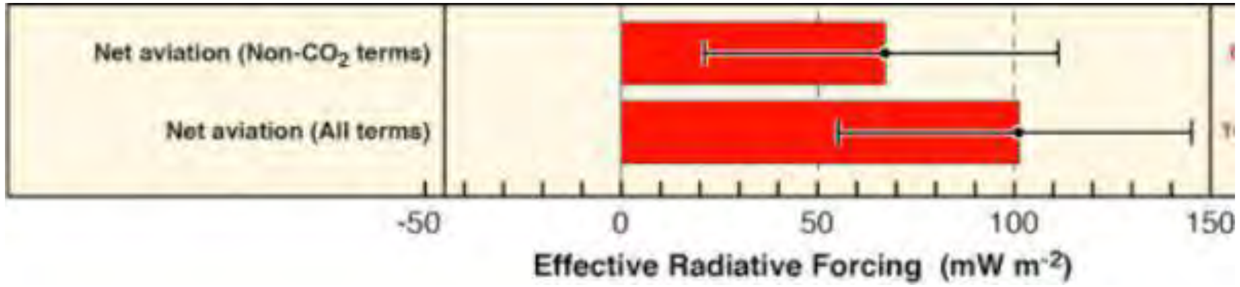
MORE DETAILS ON: NON-CO2 CONTRAIL EMISSIONS AND EFFECTS

Non-CO_2 emissions in the form of contrails form when soot particles from jet engines attach to water vapour in the air and water vapour released from the jet engine. These contrails, or clouds, keep heat trapped inside the atmosphere and therefor have a warming effect on the planet.

Other particles are also emitted from the combustion engine at altitude, including NO_x, water vapour, and aerosols (UFP, PM). Of all non-CO_2 emissions, contrails have the largest effect on warming of the earth, but there are solutions to mitigate their effect.



The effect of contrails and other non-CO_2 emissions creates a radiative warming effect on the earth, that is likely equal or larger than the warming effect of CO_2. As research is still being conducted it is yet unclear what the full impacts are of non-CO_2 emissions, mainly due to contrails.



Contrail mitigation

Figure 44 – Schematic representation of navigational contrail avoidance

AP2.1 Reduce Emissions and Becoming Net Zero

MORE DETAILS ON: NOISE

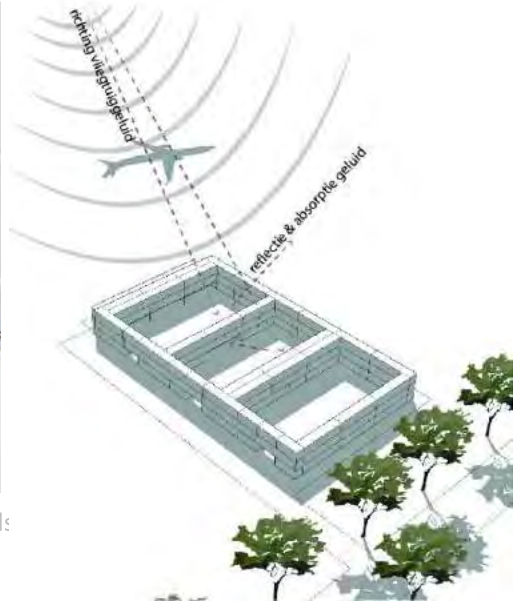
Improved ATM and increased collaboration with ANSP stakeholders will allow airports to decrease their noise impact on local communities. New operations such as continuous descent approaches can achieve noise decrease for local communities. To implement, monitor and improve such operations, collaboration is key and Airport Collaborative Decision Making and Collaborative Environmental Management are concepts the airport can develop. Finally, airports are taking measures to decrease evening and night flights and setting stricter regulations for airlines.

NOISE MITIGATION IN LOCAL COMMUNITIES

Airports can also work more closely with their local communities. Airports are involved in the development of sound proofing for local inhabitants and can collaborate with new building developments to ensure that homes are noise proofed. The outcomes of this are considered when insulating or heatproofing homes so that noise effects can be decreased. Furthermore, the Fieldlab “Geluidsadaptief bouwen” has been developed by a municipality close Schiphol airport. This field lab provides a space to experiment with new ways of spatial planning to decrease the resounding effects of noise cause by aircraft. It is supported by the ministry of Infrastructure, the TU Delft and the AMS institute, as well as “stichting leefomgeving Schiphol”.

Source: Aviation benefits beyond borders: Continuous descent approaches : Aviation: Benefits Beyond Borders (aviationbenefits.org)

Source: Schiphol Research into soundproof walls



Source: Stichting leefomgeving Schiphol

Source: Eurocontrol - Airport CDM analysis

AP2.1 Reduce Emissions and Becoming Net Zero

MORE DETAILS ON: LOCAL AIR QUALITY

Airports must work together with their stakeholders to reduce the local emissions at the airport. This includes GSE providers that can electrify their vehicles, or switch to cleaner fuels. Airlines can take measures to decrease local emissions, such as taxiing on one engine, turning off APU's and decreasing their fuel use on the apron as much as possible.
Airports must play a role in all these developments, including the installation of electric connections and air condition systems at gates, eGPUs, charging stations for electric GSE equipment and efficient turnaround and taxi times. Airports can work together to provide the infrastructure that will allow other stakeholders to decarbonize.

Some airports are experimenting with taxi-bots - or other electrical taxiing systems, like wheeltugs - to decrease the local emissions from taxing, although much research is required to reach the envisioned benefits. Another innovative solution currently being researched are moisture screens that can catch UFPs with water and decrease the amount of emissions.
The benefits of improving local air quality can ensure local communities are able to live in a healthier environment. Airport employees working on the apron also benefit greatly, as they no longer work in working environments with high emissions densities that can be dangerous for their health.

TaxiBot® is deployed in India
Oct 29, 2018

Source: New Delhi Airport

Source: Schiphol Airport

Source: Oakland Airport

AP2.1 Reduce Emissions and Becoming Net Zero

MORE DETAILS ON: SCHIPHOL AIRPORT EXAMPLE

Schiphol Airport has developed a clear roadmap that covers all aspects of sustainability for them as an airport. It looks at the own airport operations (Circular economy & Energy positive) as well as outside of their operations at the community and at sustainable aviation.

Sustainable aviation
Supporting the aviation sector by providing support for SAF and other sustainable aviation alternatives is how Schiphol's reduction goes towards scope 3 emissions as well.

Circular economy & going beyond waste

CHAPTER EIGHT

Circular Economy at Amsterdam Airport Schiphol

By Ms. Denise Pronk, Head of Sustainability, Amsterdam Schiphol Airport

INTRODUCTION

Royal Schiphol Group (RSG) is a Dutch airport company with an important socioeconomic function. Airports in the Group create value for society and for the economy. Its mission is to connect the Netherlands to the rest of the world as effectively as possible. By doing so, RSG contributes to prosperity and well-being in the Netherlands and elsewhere. It facilitates leading-edge multi-modal connectivity for the benefit of national and regional development, trade, and well-being.

The RSG vision is to safely and seamlessly operate the world's most sustainable hub and regional airports.

Sustainability and safety are fundamental principles governing the actions and activities of all aviation and non-aviation activities across the Group. They are also key indicators against which the Group's success and performance are measured.

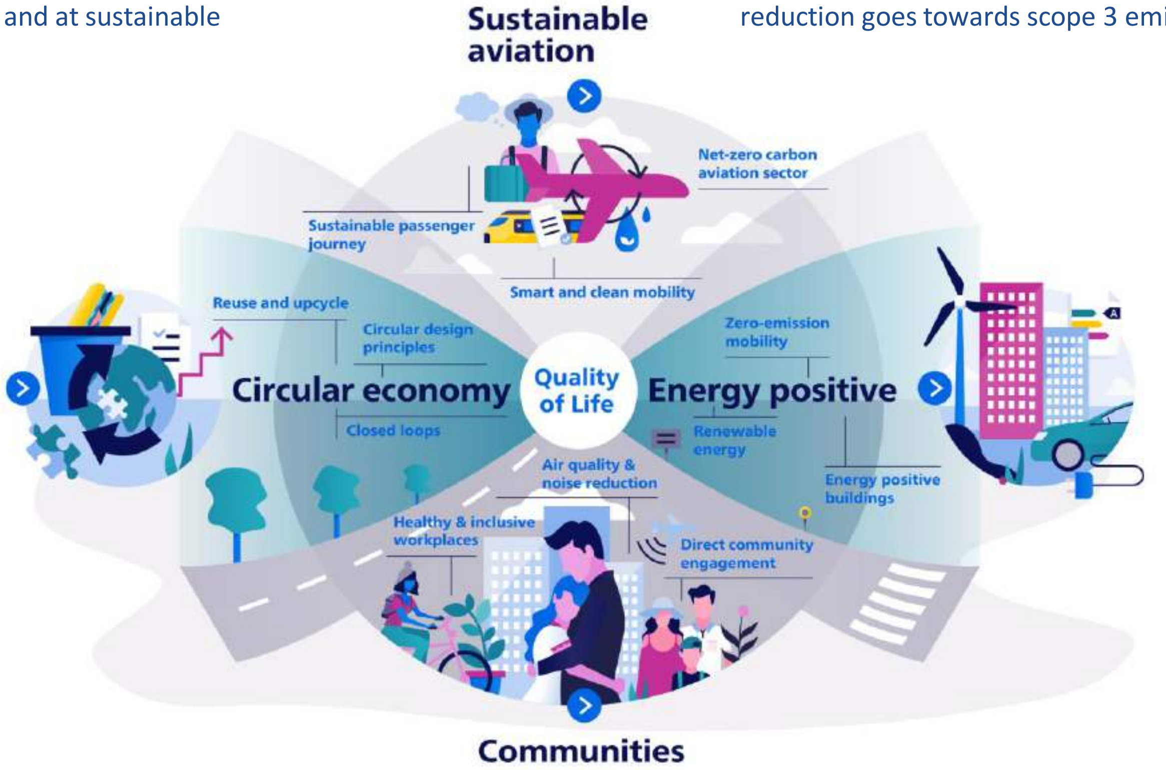
OPERATOR OF THE MOST SUSTAINABLE AIRPORTS IN THE WORLD

generations. New and existing employees find it important that Royal Schiphol Group is socially responsible. By caring about its employees and surrounding communities, it attracts talented people who add value to the company and to society as a whole and value RSG as a responsible employer. The Group wants to contribute to healthy living and working environments, including to restoring nature. The goal is to go beyond 'zero' and create value, which can be given back to the environment and communities in the Netherlands.

CIRCULAR ECONOMY

Our current world is based on the linear economy: natural resources are mined, produce goods, transport and use them and finally throw them away. By doing so, lots of valuable materials and natural resources are thrown away. At the same time, the rise in world population and the increase of prosperity levels will lead to a higher demand in natural resources. However, the natural resources that the earth can supply are limited.

Therefore humankind needs to shift from a linear economy to a circular economy. Once circular economy would have been achieved, it will be possible to preserve and increase



Becoming energy positive
Through electrification, geothermal heating and heat pumps, Schiphol is developing clear strategies to decarbonize its own operation.

airport carbon accredited NEUTRALITY

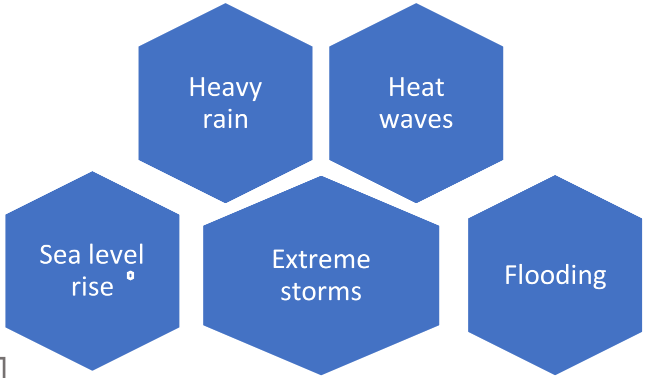
Communities
Schiphol aims to interact closely with its community so that they can become involved in a meaningful way.

AP2.2 Accommodate for Climate Resilience

INNOVATION READINESS LEVEL: **MEDIUM**

Airports must not only adapt to decrease their impact on the environment, but also understand how environmental changes may impact them. The impact of sea level rise, increases in severe weather and natural disasters must be understood and mitigated so that the airport becomes resilient to climate change. Airports can learn about the effects and share the steps they are taking to mitigate the risks.

Finally, awareness of the impact of climate change may also be positive in fully understanding the implications of emissions, thereby increasing the drive to decarbonize operations at the airport.



REGULATORY AND MARKET DEVELOPMENTS

Climate resilience is tackled at European level with the adoption of a new, more ambitious EU strategy on adaptation to climate change with ambition that the EU become a climate-resilient society by 2050, promoting nature-based solutions. Airports themselves are already promoting some solutions to become more resilient, such as improved sewage systems to decrease flooding risks and alternative roof colours to decrease heat absorption. They are increasingly engaging with governments to understand how national climate mitigation policy can ensure their continued safe operation.

ANALYSIS

Several steps can be taken by airports and supporting the stakeholders to decrease impact of climate change and increase resilience.

- Airports must understand their geo-specific risks regarding climate change to take the right measures. Within the Netherlands, Flooding and sea level rise play an important role, while airports located towards the equator may experience heat waves and possibly forest fires.
- Airports can work together to better understand the steps they can take. The ACI Resolution 3/2018 on resilience and adaptation to climate change was adopted in Brussels in June 2018.
- Policy, knowledge, Use-Cases, Tools are shared all around the world through ACI Policy brief on climate resilience and Climate ADAPT with EU.

TIMELINE

2022	2025	2030	2035
Impact Analysis, Policy and Collaboration tool Policies within Europe and at national levels are being implemented. Tools are developed to share experiences and toolbox	Airports develop and publish climate resilience plans. Shared practices are used across multiple airports	Climate impacts are felt increasingly by airports, who are enacting many of the measures within their climate resilience plans.	A climate resilient society by making adaptation smarter, more systemic, swifter, and by stepping up international action

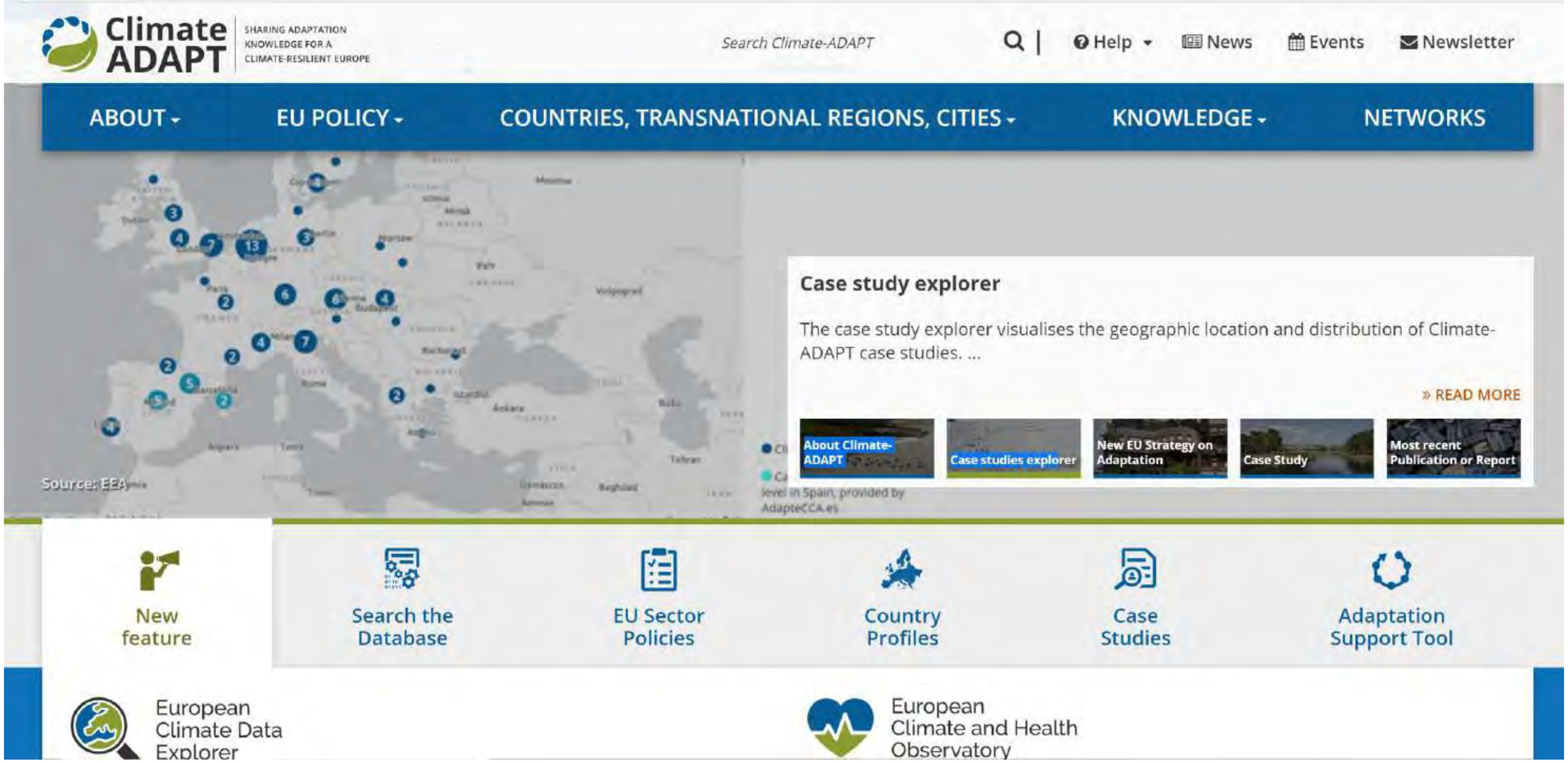
OPPORTUNITIES

Faced with climate change, Airports must adapt to become resilient. In thein process, there are many opportunities for airports.

1. Airports leading the change can develop technologies and measures that can be applied to airports worldwide. By becoming a leader, the airport is able to set itself apart.
2. Climate adaptation allows airports to reconnect with nature. Natural systems can provide solutions to become more resilient, including flooding systems and heat prevention through biomimicry.
3. Many climate resilience measures connect with local communities. Airports can further connect by engaging closely and thereby also improve these relationships.

AP2.2 Accommodate for Climate Resilience

MORE DETAILS ON: CLIMATE ADAPT PROVIDES SOLUTIONS TO BECOME MORE RESILIENT TO CLIMATE CHANGE INDUCED RISKS

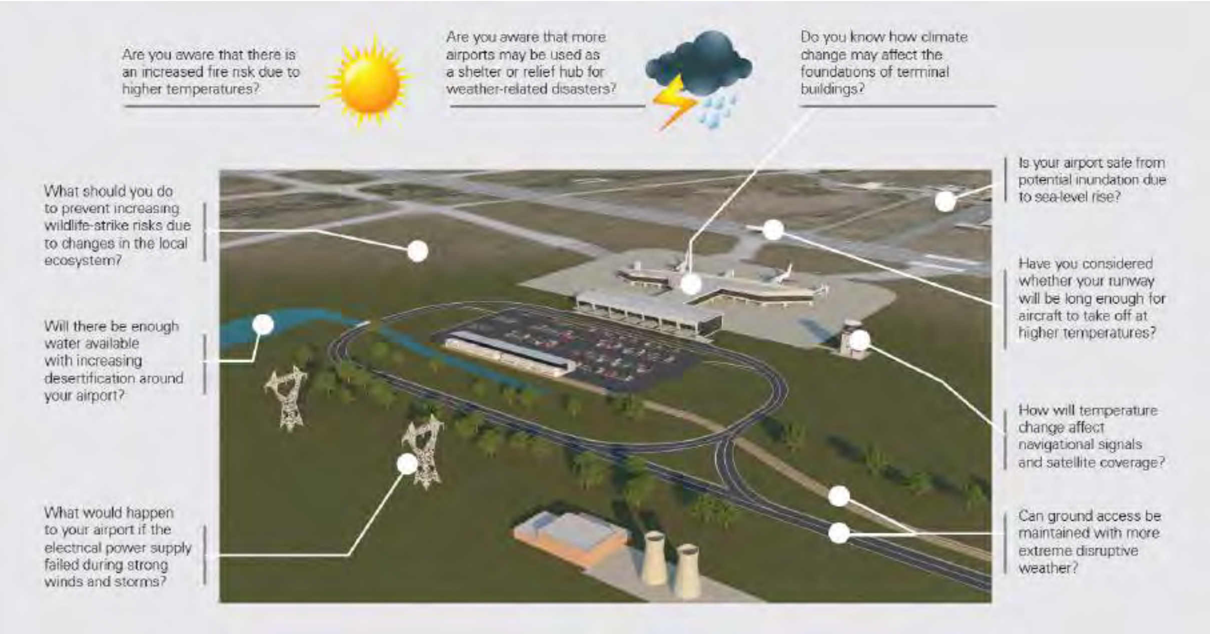


Source: https://climate-adapt.eea.europa.eu/

AP2.2 Accommodate for Climate Resilience

MORE DETAILS ON: ACI POLICY BRIEF - AIRPORTS’ RESILIENCE AND ADAPTATION TO CHANGING CLIMATE

Step 1 – What are the concern for airports?



Step 2 – What are the impacts associated?

Potential Impacts and Climate Stressors

INFRASTRUCTURE	Sea-Level Rise	Increased Intensity of Storm	Temperature Change	Changing Precipitation	Changing Icing Conditions	Changing Wind	Desertification
Airfield (including Runways, Taxiways and Aprons)							
Damage to and deterioration of pavement structure	■			■	■		■
Deterioration of pavement surface (and breakup into Foreign Object Debris (FOD))	■	■	■	■	■		■
Increased contamination of pavement surfaces (snow, ice, water)	■	■	■	■	■		
Drainage and run-off systems capability	■	■		■	■		
Electrical systems (including lighting and signage)	■	■	■	■	■	■	■
Terminals and Landside Infrastructure							
Impeded ground access, circulation, loading and parking	■	■		■	■		

Step 3 – How are airports dealing with it?

REGION	STATE	AIRPORT	TYPE	DESCRIPTION
Europe	Denmark	Copenhagen	Assessment	• Conducted vulnerability assessment and developed first emergency plan for extreme rainfall events
	Ireland		Assessment	• Conducted vulnerability assessment
	Norway	Avinor	Assessment Guideline Integration into master planning	• Conducted risk analysis • Airport design handbook includes specific requirement for future climate factors • Standards for buildings including climate adaptation • Integrated adaptation planning into airport master plan
	Spain		Assessment	• Conducted vulnerability assessment for transport infrastructure in Spain
	UK	Birmingham Gatwick Glasgow Heathrow Manchester Stansted	Assessment Progress review	• UK's key infrastructure providers are required to submit adaptation plans and progress reports under the Climate Change Act 2008

Source: ACI policy Brief

AP2.3 Vertiports

INNOVATION READINESS LEVEL: MEDIUM

Globally, about 200+ projects are ongoing to develop and manufacture eVTOLs, aiming for transport up to 50 - 100 km in urban and urban/rural routes. Some new OEMs have closed large funding rounds (e.g. Lilium and Volocopter).

Most investments have been made into eVTOL development however, which means infrastructure investments and development are lagging. The trend is that vehicle developers are actively teaming with operators and vertiport owners to accelerate this.

Key challenges are developing vertiports that can seamlessly handle passenger flows between airside and landside, accommodate many types of vehicles and which locations are favourable in terms of connections to other transport modes, to renewable energy and with low negative impact on the direct environment in terms of noise and safety.

REGULATORY AND MARKET DEVELOPMENTS

In March 2022, EASA published the world's first guidance for the design of vertiports. The 'Prototype Technical Design Specifications for Vertiports' offers guidance to urban planners and local decision-makers as well as industry to enable the safe design of vertiports that will serve eVTOLs, which are already at an advanced stage of development.

Pilot projects with vertiports are being started, such as Paris as part of the Re Invent Air Mobility challenge aiming for service around 2024 Olympics. In the UK, a vertiport has opened in Coventry, and more demonstrations are planned in the Future Flight Challenge. The EU has also commissioned various projects, such as the ultra-compact 'off grid Air One' concept opening first vertiport May 2022 in Coventry. Also, airports in Rome, Venice, Bologna, and France's Cote d'Azur have joined forces to create Urban Blue, a company for the international development of infrastructure supporting UAM.

ANALYSIS

Regulations: Current regulatory policies for heliports (ICAO's Annex 14 Volume II Heliports, the FAA's AC 150/5390-2C and EASA CS-HPT-DSN) provide a solid basis for vertiports. However, these need to be adapted to accommodate specific operations such as electric charging, automated/autonomous operations for take-off and landing, handling battery fires and accommodate passenger flows seamlessly, fast yet secure. Also, acceptable standards and reporting for noise need to be established, especially for urban environments. Finally, safety and security are – and will – be evolving.

Public acceptance: An EASA study performed in 2021 showed that public acceptance/perception is currently positive towards this new mode of transport. Acceptable noise and safety are key boundary conditions for accepting vertiports, and increased access to mobility is the main benefit for local communities. This advocates that nearby residents gain access to affordable transport (not just the happy few).

Market: To accelerate market uptake of their vehicles, eVTOL OEMs are taking the initiative to develop vertiports (such as Volocopter with Voloport). Lilium has partnered with Ferrovial. Other players aim to develop vertiports, such as Skyports.

Energy infrastructure: Access to renewable electricity is needed to be sustainable. Some vertiport concepts include solar panels, but it is highly questionable that these would suffice. Battery swap systems (e.g. Volocopter) are considered to shorten turn around times and prolong battery life. This requires storage and charging and raises challenges when multiple types of batteries for multiple vehicle types need to be stored and charged.

TIMELINE

2022+	2025+	2030+
First pilot projects for vertiports	Start of market scale up in vertiports as more piloted eVTOLs become available.	Network of vertiports in frontrunner cities for wider scheduled operations

OPPORTUNITIES

The key value proposition of vertiports is saving time and adding value to the integrated mobility solution, while meeting public acceptance (such as noise levels and privacy) and safety regulations. Other opportunities include improved connectivity for intra- and intercity connections and new economic activity in developing and operating vertiports.

R&D: The Horizon Europe Cluster 5 for climate, energy and mobility may provide R&D opportunities. In the USA NASA, FAA and universities are investigating noise levels under NASA's Advanced Air Mobility National Campaign.

Market pull: The 'EU Smart Cities Marketplace' has an action cluster on sustainable urban mobility which includes UAM (Urban-Air-Mobility Initiative Cities Community - UIC2), which includes Dutch cities of Amsterdam, Maastricht and Heerlen, the latter two as part of the MAHHL region.

Aviation operations industry: The vertiports creates new economic activity, and new market players such as Skyports. Companies aiming to integrate drones in society (e.g. Airhub, Altitude Angel, Unifly) have potential to accommodate eVTOL scheduled and on demand air taxi and emergency services. (Dutch) airports could consider eVTOL operations to offer fast and clean connectivity to nearby cities and region. Also, the transfer from current heliports to future vertiports are an interesting opportunity for heliports owners and airports. Especially from an integrated mobility solution perspective.

AP2.3 Vertiports

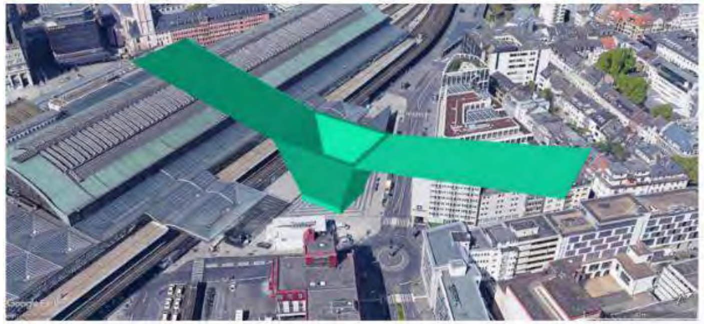
MORE DETAILS ON: PROTOTYPE TECHNICAL DESIGN SPECIFICATIONS FOR VERTIPORTS

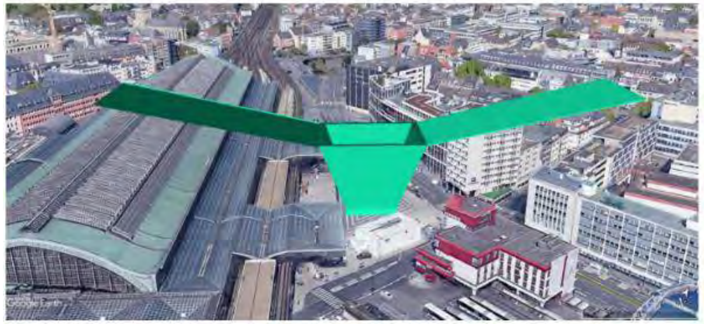
Full report title: Vertiports - Prototype Technical Specifications for the Design of VFR Vertiports for Operation with Manned VTOL-Capable Aircraft Certified in the Enhanced Category.

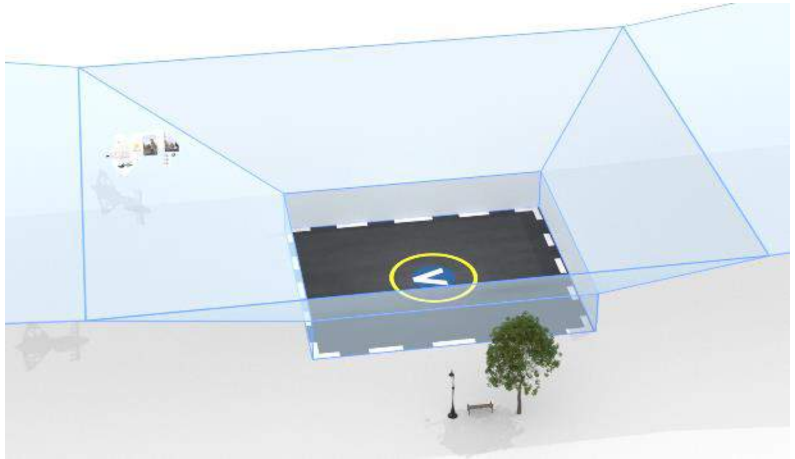
With the ‘Prototype Technical Design Specifications for Vertiports’ , EASA is publishing the world’s first detailed prototype technical specifications for the design of vertiports in the form of guidance. The prototype specifications describe in detail the physical characteristics of a vertiport, the required obstacle environment, visual aids, lights and markings, as well as concepts for en-route alternate vertiports for continued safe flight and landing. The guidance in the document has been developed under the leadership of EASA, working in cooperation with the world’s leading vertiport companies and VTOL manufacturers, and with the support of experts from EU States. In a second step, EASA will develop a full regulatory framework for vertiport design and certification, operations, and oversight of vertiport operators in the context of a rulemaking task (RMT.230).

One notable innovation is the concept of a funnel-shaped area above the vertiport, designated as an ‘obstacle free volume’. This concept is tailored to the operational capabilities of the new VTOL aircraft, which can perform landing and take-off with a significant vertical segment. Depending on the urban environment and on the performance of certain VTOL-capable aircraft, omnidirectional trajectories to vertiports will be also possible. Such approaches can more easily take account of environmental and noise restrictions and are more suitable for an urban environment than conventional heliport operations, which are constrained in the approaches that can be safely applied.

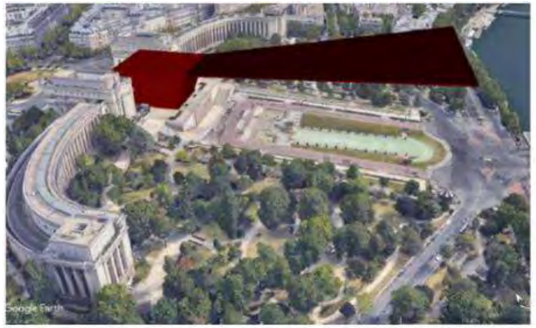
The concept of the ‘obstacle free volume’ and examples of the potential vertiports established in congested urban areas are displayed below.







Source of all figures: EASA



AP3.1 Terminal Seamless Flow

INNOVATION READINESS LEVEL: **MEDIUM**

Terminal digitalization aims to provide a seamless, customized and personalized passenger journey. This is done through the implementation of new technologies such as biometrics for control points, self-service for parking access, automated vehicles for PRM, virtual queuing, and service robots. Furthermore, to achieve automation, these different systems must also be integrated.

This is enabled with the implementation of improved telecommunications and technologies such as 5G, VR robotics, artificial intelligence as well as a monitoring of operations and infrastructure (airport BIM, digital twins) in a command control centre (APOC).

As these developments go on, and airports continue to innovate, it is possible that passengers will be able to come to the airport for more than just catching a flight, but also to get new (personalized) experiences with museum tours, VR travel experiences and attraction parks.

REGULATORY AND MARKET DEVELOPMENTS

As digitalization opportunities increase and the technology readiness improves, airport infrastructure must not remain conservative with adoption but embrace the opportunities that arise airside, landside and within the terminal. Increased adoption can be improved by increasing human resource readiness, but will also require a change in perception in the process and culture.

As these are new developments, the regulation regarding digitalisation is also conservative, slowing down some of the market developments. On the other hand, both the EU and national governments have supported some concepts to improve digitalisation, including SESAR work especially by including multiple stakeholders and stakeholder frameworks such as A-CDM, APOC, TAM.

ACI has published key manuals in the past years designed to help airports to better grasp the opportunities by digital aviation and create a digital roadmap. Moreover, every year, ACI, in partnership with SESAR awards airports in digitalisation. In 2021,the winner was Aeroporti di Roma S.p.A., the operator of Rome Fiumicino and Ciampino airports for their new Airport Operation Center.

ANALYSIS

- Increasing number of concepts are arising, developed by airports to improve collaboration and the use of digital tools such as Airport Collaborative Decision Making (A-CDM), Total Airport Management (TAM), Airport Operation Centre (APOC). In that sense, digital based airport investments are growing and are now counting for almost 50% of the investment. Cyberattack is therefore a risk increasing and that need to be tackled.
- A shift in the business model of the airports are being made. From B2B to B2C, and later Airport 4.0, airports are providing more and more services to their clients, gathering different options for a similar objectives, through digitalization.
- The increase in digitalization and new process in the terminal involves a need in organizational changes. Airports need to bring new resources in the team, especially in IT, business data analysis and network understanding.
- Multiple airport develop their own lab in the terminal to test innovative solutions for future airport concepts such as Munich with its Testlab, Rotterdam, Paris-Charles de Gaulle and Schiphol.

TIMELINE

2020 – Feasibility studies & first agreements.	2030 – A Digital Journey	2040 – A new and seamless journey
Initial trials are implemented for one part of the journey	All the steps are digitalised and through new technologies optimised for a shorter airport journey	Process at airport is no longer visible, security process is hidden for example

OPPORTUNITIES

- All these innovations are based on digitalisation and automation. Cyber security will be at the aim of the operations and a strong focus on this topic is arising. Airports can lead in understanding the effect of this on their operation.
- System providers have a key role to play in developing the innovative solutions for airports, and airports must collaborate closely.
- More than the systems, the type of activities and services is also shifting, requiring new type of resources in the airport industry with special skills in IT components for example.
- Airports providing new digitalized services can take a unique spot in providing safety and efficiency to customers.
- Through digitalisation, new business models van provide airports with new revenue streams.

AP3.1 Terminal Seamless Flow

MORE DETAILS ON: AIRPORT 4.0

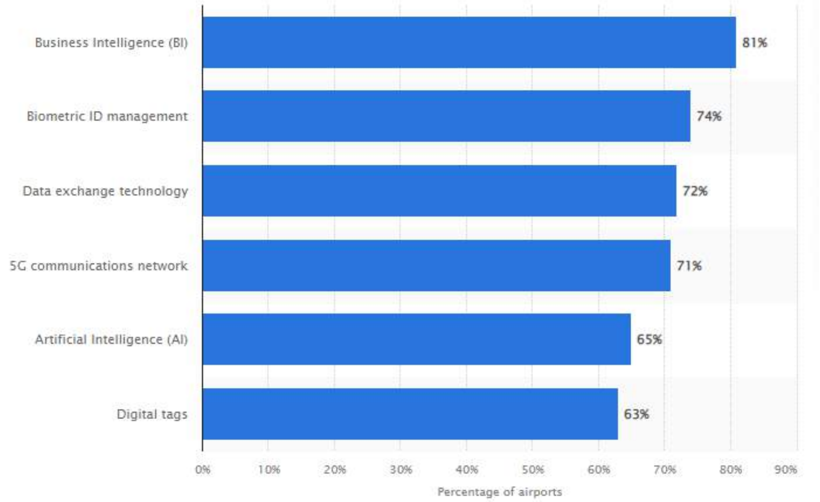
Airport 4.0 is the air transport hub of the future. Using the latest advancement in wireless and wireline connectivity, automation, artificial intelligence (AI), robotics and digital twins, this wave of digitalization is set to take operational and situational awareness to a whole new level, reduce costs and generate diverse forms of non-aeronautical revenues.

Airports are currently mature to implement 2.0 digital solutions but should look forward for the next 10-15 years in order to implement an Airports 4.0 model

Airport models	
Airport 1.0	▪ All about manual and analogic processes ▪ Long lag-time between resource solicitation and the airport answer
Airport 2.0	▪ Implementation of self-service thanks to the automation of some key flow processing tasks (bag-drop, passport check)
Airport 3.0	▪ Several focused initiatives to leverage digitalization so that to optimize flow monitoring and processing
Airport 4.0	▪ Full-connected with all stake-holders ▪ Superior proactivty and reactivity to adapt to the real-time solicitation of the airport (operational needs, customer requests etc…)

Little - 2015

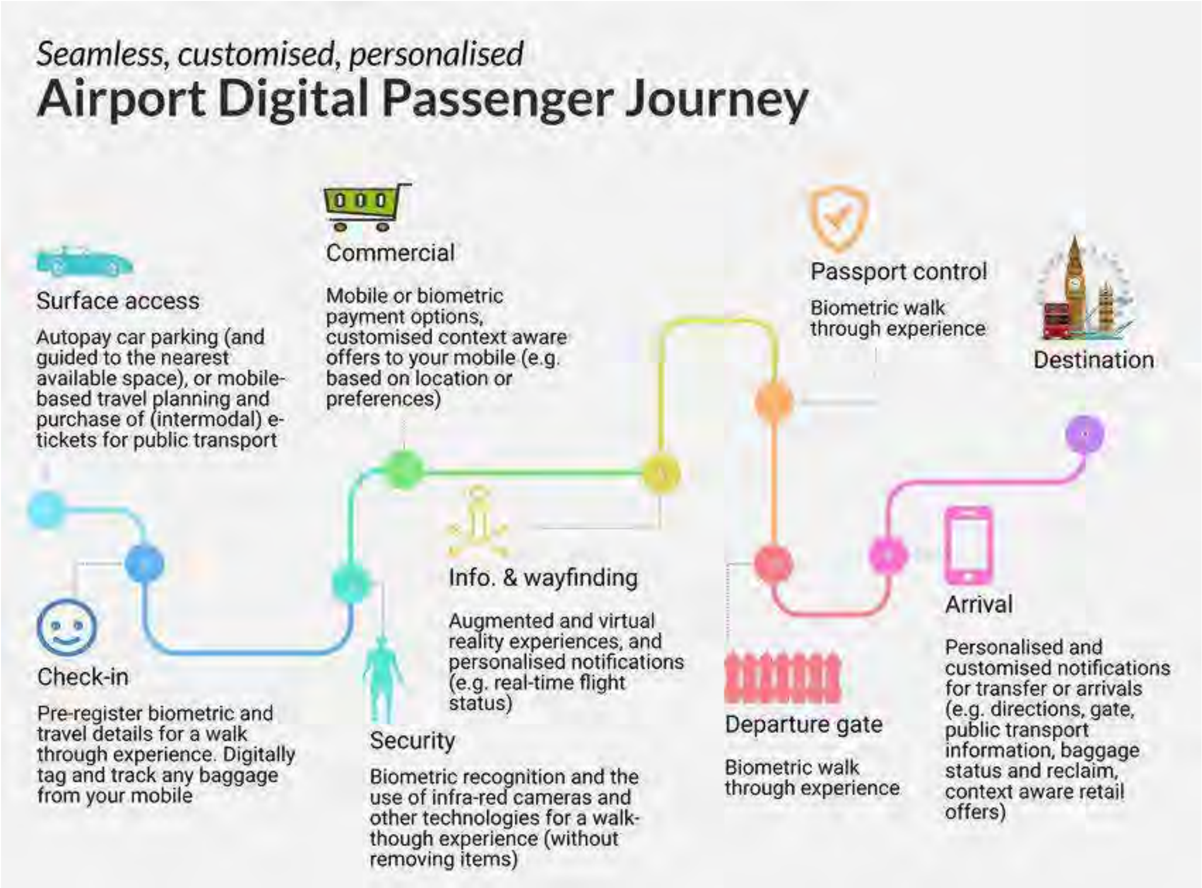
Share of airports worldwide expecting to trial new technologies in the next three years as of 2021, by type



Statista – 2022 (based on a survey conducted in 2020)

AP3.1 Terminal Seamless Flow

MORE DETAILS ON: OPERATION, SECURITY, PASSENGERS AND RETAIL



AP3.2 Electric and Autonomous Airside

INNOVATION READINESS LEVEL: **MEDIUM**

An Uber-like shuttle service for employees at Gatwick and automated snowploughs that can clear an area of 357,500 square meters an hour in Norway are just two examples proving that airports are leading the way in real-life applications of driverless vehicles. The IATA noted over 40 use cases for driverless technology in 2018. The list included self-driving jet bridges, aircraft tugs, baggage carts, de-icing and snow clearing, employee buses, maintenance vehicles, and passenger shuttles. Airports are viewed as safer because they offer more controlled, low-speed environments — like dedicated lanes for different types of groundside vehicles and open tarmacs with high visibility airside — that reduce the risk of accidents.

These autonomous vehicles are often electrified and therefore also have a positive effect on local and carbon emissions.

REGULATORY AND MARKET DEVELOPMENTS

Autonomous vehicles are under strict regulation as they are initially being integrated at European and national levels. The advantage of the airport airside is that it is in a closed environment and private. Challenges of interaction with other vehicles, and adapting the context so it is digitally connected remain, but can be more easily tackled within the airport environment.

Combined with electrification, airports can increase their efficiency and cost effectiveness while also decrasing their carbon footprint. However, close collaboration with GSE providers as well as ANSPs will be required as all stakeholders are involved.

ANALYSIS

- From baggage screening and air traffic control, to ground-handling and foreign object detection on runways, automation and industry 4.0 is revolutionising airside operations. New technologies are arisen, supported by telecommunication improvements such as 5G, connected airfield sensors (AGL, Meteo, etc.) for a better predictability, shorter capacity and increase safety limiting human factor.
- The electrification of vehicles has positive effects in sustainability and local environment reducing noise and limiting local emissions. More and more electric GSE are being available.
- In the automation process, one of the first steps can be the retrofitting of current airside vehicles. One good example of it is the Yeti technology for snow removal trucks that has been implemented in Norway and on some baggage handling system at Heathrow and Changi Airports.
- Both electrification and automation will significantly change operations and human adaptation and perception is a strong step to be taken in the process.

TIMELINE

2020 – Electrification of Airside.	2030 – Digitalisation of airside operations	2050 – Airside 4.0
Airside fleet is becoming electrified and initial trials are launched for digital/automated operations	All the airside operations are digitalised and through new technologies optimised	Processes are fully automated and fully interconnected with all stakeholders

OPPORTUNITIES

- System providers have a key role to play in developing the innovative solutions for airports
- Airside operations vary between airports and needs are different in different context and with different stakeholders. The variety of airports in the Netherlands offers the opportunity to test for every type of operations and validate the examples.
- Being a testbed at the airport is a good opportunity such as the taxibot at Schiphol Airport.
- Automation can increase the feasibility of electrification, as the recharging systems are more closely connected with the required workload of the GSE equipment. Timely and sufficient charging can best be achieved through automation.

AP3.2 Electric and Autonomous Airside

Security systems
- Drone and bird detection
- Safety and security (intrusion and FODS)

Maintenance/de-icing electric fleet, drones

Command center – A new traffic control
Digitalisation and 5G camera

RFFS/Bird Hazards/FODs
Robot firefighting vehicles.

Cargo

Ground handling equipment and driving
- Baggage handling is one of the most important (Autonomous and electric baggage handling system at Heathrow and Changi Airport, Fully automated by 2050 at Schiphol Airport)

- Buses
- Waste collection

AGL detailed monitor and control

Autonomous taxi
Taxibot

AP3.3 Intermobility

INNOVATION READINESS LEVEL: MEDIUM

For over a century, commercial airports have helped move people and goods quickly across the globe. The infrastructure needed has grown increasingly complex, but the common view of the airport has remained similar. However, recent trends like a focus on sustainability, future mobility, and the global pandemic have demonstrated that it is not only an opportunity – but a necessity – for the airport to become a destination in its own right. This includes becoming an intermodal hub for seamless travel, a crossroads of cross-industry collaboration and digital innovation, and an engine of economic growth driven by the needs of passengers above all else.

REGULATORY AND MARKET DEVELOPMENTS

At the end of 2020, the European commission presented its plan for green, smart and affordable mobility. In its 'Sustainable and Smart Mobility Strategy', the European commission enforced a number of initiatives to be taken for all types of transport and includes targets for intermobility:

- Innovation and digitalisation will shape how passengers and freight move around in the future if the right conditions are put in place. The strategy foresees:
- Making connected and automated multimodal mobility a reality – for instance by making it possible for passengers to buy tickets for multimodal journeys and freight to seamlessly switch between transport modes.
- Boosting innovation and the use of data and artificial intelligence (AI) for smarter mobility – for instance by fully supporting the deployment of drones and unmanned aircraft and further actions to build a European Common Mobility Data Space

ANALYSIS

- Through digital platforms, information on transport modes becomes available to optimize transport with bikes, carpooling, trams and trains. This gives passengers, employees and third party stakeholders the most recent and reliable information on their best option to travel from point A to B in a sustainable manner. Toulouse and Munich airport have partnered with system providers to develop such solutions. Digitalisation is also increasing efficiency within the cargo landside and airside mobility.
- Mobility as a service and on-demand become more popular and airports will have to adapt to this new type of service.
- Future transport modes are being developed, including eVTOLs but also Hyperloops and Spaceports. Airports must play into this and can take a leading role in development and understand current transport modes may be replaced by others. Airport, through their infrastructure and central position can become a hub for intermobility.
- The electrification and automation of landside mobility has also gained traction as multiple proofs of concept for autonomous parking and shuttles are being developed.

TIMELINE

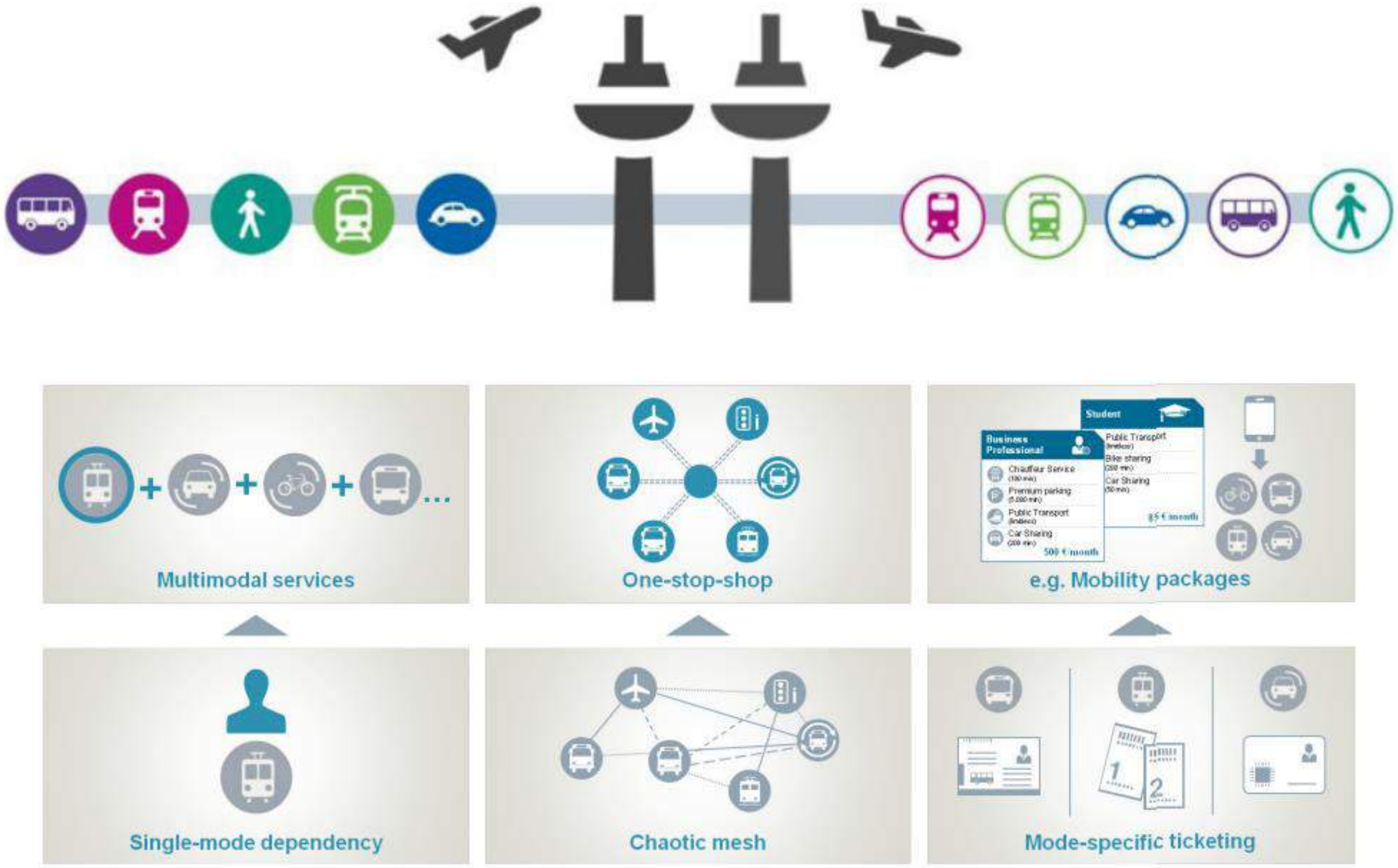
2020 – Development of intermobility.	2030 – A sustainable Journey	2050 – Airport as a sustainable multi-modal hub
Connections to airport via another mode than car is becoming more and more present	Development of new services to access the airport, developing and optimising transport mode	Airports become a hub for all transport mode offering the more sustainable option to travel from point A to B

OPPORTUNITIES

- New Business Models have to be implemented with less individual cars parked at airports
- New type of transport are coming bringing new way of traveling. Airport that take an active role can provide the infrastructure required and develop business models based on this.
- Schiphol with its position within Europe both in term of location (close in distance to major European capital and good connection with railway system) and role (one of the major hub of Europe) is well designated to be a frontrunner in the multi modal hub, already studying Hyperloop project with EIT InnoEnergy and Hardt Hyperloop, as well as eVTOLs.

AP3.3 Intermobility

MORE DETAILS ON: AIRPORT AS A MULTI-MODAL HUB



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4. INNOVATIONS IN AIRSPACE DESIGN

Introduction and Scope

Airspace users require a resilient and scalable air traffic management system to help ensure safe, efficient, equitable and sustainable operations, whether transporting passengers or cargo, or recreational flying. The type of traffic, traffic numbers, and the airspace environment they fly in will place significant demands on the ATM system that can only be met by automation. The ATM system must remain a combination of humans and machines and we must understand this relationship as a single functional unit to amplify the capabilities of both. Transitioning from tactical air traffic control services at the local level to strategic air traffic management at the network level is required. This will involve innovation in new airspace and technology concepts that are tailored to the airspace category or type of operations including low level urban air mobility or high-level space operations. This will include new airspace routes based on precision navigation capabilities as well as new air-to-ground and air-to-air communication and surveillance capabilities. To this extent the outcomes foreseen in this innovation area are:

Outcome AD1: Airspace rules, routes and flight procedures optimise flight operations and integrate aircraft seamlessly in all airspace

In order to meet the challenges of the integration of new entrants, environmental and capacity efficiencies, a new airspace architecture will be progressively introduced. This architecture shall be comprised of innovative airspace rules, routes and flight procedures that optimise flight operations and integrate aircraft seamlessly in all airspace. If successful, it promises to enable seamless European en-route and terminal airspace. This new architecture will connect and optimise resources across the network leveraging modern technology through a data rich and cyber-secured connected ecosystem. In this environment service providers will be able to collaborate and operate as if they were one organisation with both airspace and service provision optimised according to traffic patterns.

Drivers: AD1.1 Systemized En-Route and TMA Airspace | AD1.2 Arrival and Departure Operational Concepts | AD1.3 U-Space Airspace

Outcome AD2: Air traffic management capabilities are scalable to all airspace users and resilient to demand and supply disruption events

Currently and in future, new types of vehicles are entering European airspace at a rapid pace, COVID-19 has created an uncertain and fluctuating demand picture and National Aviation Authorities (NAAs), other government entities, and airspace users will increasingly collaborate to manage the system. These rapid changes call for equally rapid developments of new and innovative service providers models and rapid changes in the software that supports ATM.

Drivers: AD2.1 Air Traffic Service Providers | AD2.2 ATM Data Service Providers | AD2.3 U-Space Service Providers | AD2.4 Automation in ATM Tools

Outcome AD3: Surveillance and communication infrastructure is available on the ground or space to support all aircraft types

CNS infrastructure, and the radio spectrum they require, are the foundation of the aviation operational performance, enabling airspace capacity. Without them air transport would not exist. Currently, innovations are focusing on managing scarce resources , optimizing current CNS infrastructure performance, improving communications, navigation and surveillance and Preparing for performance-based CNS.

Drivers: AD3.1 Optimizing Current CNS Infrastructure | AD3.2 Advancement of New Surveillance and Communication Technology

AD1.1 Systemized En-Route and TMA Airspace

INNOVATION READINESS LEVEL: HIGH

Systemised airspace within the En-route and TMA environment enables more precise and efficient flying. Systemised airspace is a structured route network where aircraft follow defined routes between their departing airport and a point of exit from the airspace, or from the point of entry to state airspace and to their arrival airport. It will enable more efficient flight profiles and reduce the number of tactical interventions air traffic controllers need to make:

- Reduced flight time since most flights will be using the shortest routes possible;
- Reduced carbon emissions because of the reduced flight time;
- Reduced fuel waste is also a consequence of the reduced flight time and more optimal flight profiles;
- Fewer conflicts since the same number of aircraft are spread over more routes;
- Weight optimisation reduces the difference in distance between the planned route and the actual route. This in turn reduces the amount of extra fuel that needs to be carried potentially allowing for a heavier payload.

REGULATORY AND MARKET DEVELOPMENTS

Requirements for PBN for airborne navigation systems are set out in ICAO Doc 9613. PBN is being adopted world-wide and States are expected to modernise airspace through International, Regional and State level initiatives, including regulations. Regulatory instruments within Europe on ATM and Aircraft Operating procedures to support PBN within Europe are driving implementation. European regulation will prohibit the use of conventional navigation procedures from 2030 onwards, except in the event of PBN contingencies, i.e., situations where, for unexpected reasons beyond the control of ATM/ANS service providers, Global Navigation Satellite System (GNSS) or other methods used for PBN are no longer available. System Wide Information Management is a key enabler and at this stage only Eurocontrol Guidelines and Standards exists. Further standards development is required.

ANALYSIS

Performance-based navigation: PBN uses satellite technology to allow aircraft to fly routes with more precision and consistency by using way-points rather than ground-based navigation aids. PBN provides opportunity at the high-level airways and the lower-level arrival and departure routes into and out of airports including instrument approach procedures. PBN helps realise the concepts of FRA and TBO.

Free Route Airspace: FRA allows for airspace users to select the route they want between a defined entry and exit point rather than using these established routes. This allows airlines to fly an optimized flight path based on factors like weather and windspeed and will improve efficiency and reduce flight time, fuel burn and emissions. Within Europe, states have decided to start with a limited implementation (e.g., during night hours) and then gradually expand it. By the end of 2020, 46 area control centres had implemented FRA at least partially. Also, there are many cross-border implementations, i.e., more than one ACC participating in an FRA initiative.

Trajectory-based operations: TBO uses the flight trajectory of every in-service aircraft in four dimensions (4D) – latitude, longitude, altitude, and time — from departure airport to the destination. The data is used to smooth airspace and airport demand through data sharing across all industry partners. TBO is enabled by the sharing of information between States through the application of principles such as System Wide Information Management (SWIM) and FF-ICE (Flight and Flow Information for a Collaborative Environment). These concepts are under trial. Even though with PBN requirements mature the timelines for TBO are yet to be defined.

TIMELINE

2024	2025	2030+
Free Route Airspace (across Europe)	GANP SWIM Implementation	Trajectory Based Operations

OPPORTUNITIES

Performance-based navigation: in the Dutch PBN roadmap 2020-2030 the RNP APCH and RNP AR APCH specifications form the basis for approach elements In addition to the two navigation specifications, three 'supporting' concepts are considered opportunities in the roadmap (see slide 112). By combining the two navigation specifications with these concepts, an increased use of the relevant PBN element can be enabled:

- RNP APCH + RNP to xLS: allows RNP routings to ILS (especially for low visibility operations)
- RNP AR APCH + RNAV visual: enables non-RNP AR APCH compliant operators to fly the RNP AR APCH routings (under visual conditions)
- RNP AR APCH + Established on RNP (EoR): enables the use of independent parallel approaches (relevant for Schiphol operations only)

Free Route Airspace: in Dutch upper airspace free routes were already realised by the end of 2019. In lower airspace free routes can be considered an opportunity for the end situation of the Dutch Airspace Redesign Programme in 2035.

Trajectory Based Operations: KDC Schiphol developed the Dutch transition to TBO in 2021. The transition to TBO requires the deployment and utilisation of new technology, such as iCAS interoperability and air-ground datalink, but also requires conceptual changes, i.e., changes in the way controllers handle traffic, and changes in which controllers are trained. Some of the conceptual changes can be supported (in part) by conventional solutions and existing technology. Therefore, the transition to TBO does not start only after the introduction of iCAS: the transition to TBO could start in the present. Opportunities are to (1) start using SWIM to gain early benefits and (2) start developing applications by implementing small steps into operations and (3) involve all stakeholders in the transition to TBO.

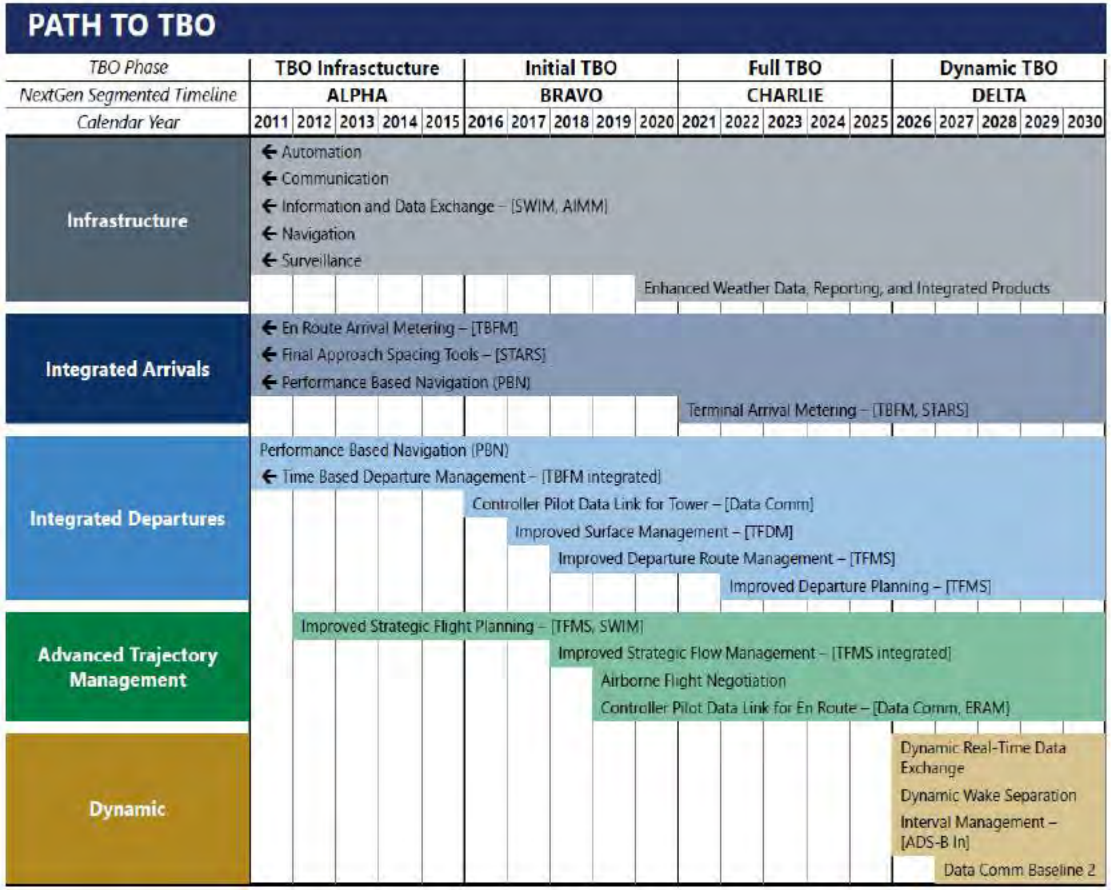
AD1.1 Systemized En-Route and TMA Airspace

TRAJECTORY BASED OPERATIONS

TBO is an ATM concept that enhances strategic planning of aircraft flows to reduce capacity-to-demand imbalances in the airspace and provides tools to air traffic controllers to help expedite aircraft movement between origin and destination airports. Through improved strategic planning and management of traffic flows, TBO helps reduce reactive decision-making and use of static miles-in-trail restrictions. Aircraft trajectory is the core tenant of TBO. Defined in four dimensions - latitude, longitude, altitude and time - the trajectory represents a common reference for where an aircraft is expected to be - and when - at key points along its route. The trajectory is defined prior to departure, updated in response to emerging conditions and operator inputs, and shared between stakeholders and systems. The aggregate set of aircraft trajectories on the day-of-operation defines demand and informs traffic management actions. A "day-of operation" refers to operating conditions during the day an operation takes place, including equipment outages, weather, airport conditions, airline delays and cancelations, and other temporary conditions in the NAS.

The key elements of TBO include:

- Time based management which helps manage traffic flows and trajectories by scheduling and metering aircraft through congested airspace resources or constraint points.
- PBN which enables aircraft to more accurately navigate along their trajectories and enables decision support tools to improve feasibility of schedules for constraint points as well as achieve greater compliance to schedules.
- Enabling technologies which expand and automate sharing of common information about aircraft trajectories and include system-wide information management, data communications, enhanced data exchange and many others.



Source: FAA NextGen, 2022

AD1.1 Systemized En-Route and TMA Airspace

The following technological solutions will be critical to enabling trajectory-based operations.

EXTENDED PROJECTED PROFILE (EPP) AVAILABILITY ON GROUND

'EPP availability on ground' technological solution is a first step towards a full ground-air trajectory synchronization required for the implementation of the targeted Trajectory based operations. It allows the provision to the ground systems of the aircraft view on the planned route and applicable restrictions known to the airborne system, together with the corresponding optimal planned trajectory computed on-board and speed preferences.

AIR TRAFFIC CONTROL (ATC) PLANNED TRAJECTORY PERFORMANCE IMPROVEMENT

The use of EPP data received by means of Automatic Dependent Surveillance - Contract (ADS-C) communication and EFPL, as well as further aircraft and flight related information will improve the ATC planned trajectory performance.

TACTICAL AND NETWORK MANAGER (NM) TRAJECTORY PERFORMANCE IMPROVEMENT

The focus is to investigate the performance benefits that could arise from the use of Extended Projected Profile data, EFPL and further aircraft and flight related information in Tactical and NM Trajectory Predictions.

ENHANCED SHORT TERM CONFLICT ALERT (STCA) FOR TERMINAL MANOEUVRING AREAS

Enhanced algorithms for a STCA prototype ensures earlier warning and lower false and nuisance alert rates, supporting controllers in identifying possible conflicts for steady and manoeuvring aircraft, in comparison to existing STCA technology.

AD1.2 Arrival and Departure Operational Concepts

INNOVATION READINESS LEVEL: HIGH

Optimized flight procedures are at the heart of current airspace modernization efforts across Europe with the aim of enabling more efficient flight profiles and reducing the number of tactical interventions ATCs need to make, particularly in the departure and arrival phases of flight. E.g. point merge is already in operation at more than 25 airports worldwide. Similarly, continuous decent operations (aircraft maintaining a steady angle of approach, thus reducing noise and emissions/fuel burn) is also widely implemented. The next stage of advanced flight procedures for arrivals and departures are maturing and early trials and operations are shown to be successful.

REGULATORY AND MARKET DEVELOPMENTS

The standardization of PBN is mature through ICAO and is available to support new advanced flight procedures in the vicinity of airports with low-tolerance navigation capabilities provided by RNP-AR. In Europe Implementing Rules supported by agreed set of PBN specifications and functionalities drive implementation. Experience from the US, Canada, New Zealand, Australia and China demonstrate the capabilities. New advanced concepts from SESAR such as Demand Capacity Balancing, Queue Management and Time-Based Separation continue to be advanced at major airports internationally, but the maturity is still low.

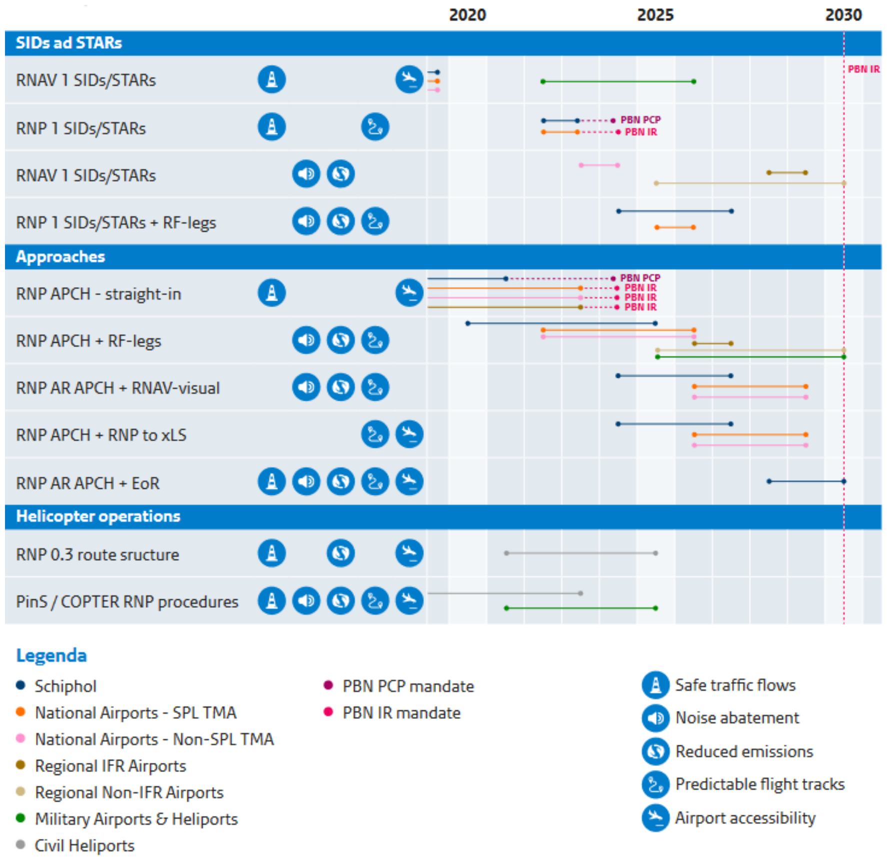
ANALYSIS

Over the past few years, ANSPs have been investigating concepts which aim to reduce the time spent by aircraft waiting to land as well as departing near airports at low levels. Whilst holding patterns will continue to be in use to ensure safety and resilience, we will continue to focus on reducing the amount of orbital holding through queue and capacity management enhancements.

In the near term, ANSPs are planning to introduce changes to procedures for existing holds to increase the efficiency of today's operation. Alongside that, there are a variety of concepts that will be implemented to enhance arrival and departure operations. These are:

- RNP & RNP-AR: PBN is an international concept that specifies aircraft RNP and RNAV systems performance requirements
- Demand Capacity Balancing (DCB): DCB extends an airport's operational plan by accurately forecasting demand, capacity and performance ahead of time.
- Cross-Border Queue Management: Even with the most efficient ways of managing final approach, effective management of arrival flows required collaboration with destination airports and with other ATSPs.
- Intelligent approach (including TBS): Intelligent approach is a suite of controller tools that safely optimise arrival spacing to maximise runway capacity, maintain operational resilience and provide better on time performance.

TIMELINE



Dutch PBN roadmap 2020-2030

AD1.2 Arrival and Departure Operational Concepts

RNP & RNP-AR

PBN is an international concept that specifies aircraft RNP RNAV systems performance requirements. RNP enhances RNAV by providing on-board performance monitoring and alerting plus increased accuracy which allows routes to be designed to avoid flight over noise sensitive areas and reduce emissions/fuel burn. RNP-AR approach procedures offer an even greater accuracy but are only available to those aircraft and aircrews that have a specific authorisation. The number of aircraft equipped, and authorised crews make RNP-AR unsuitable for applications in the short-term.

DEMAND CAPACITY BALANCING (DCB)

DCB extends an airport's operational plan by accurately forecasting demand, capacity and performance ahead of time - from 90 minutes at the day of operations and up to six months in advance. DCB is part of a SESAR concept developed to improve airport participation in the collaborative decision-making process between the EUROCONTROL network manager and the ANSP.

CROSS-BORDER QUEUE MANAGEMENT

Even with the most efficient ways of managing final approach, effective management of arrival flows required collaboration with destination airports and with other ATSPs. Cross-border queue management makes it possible to work with neighbouring ANSPs to slow aircraft down up to 550 nautical miles from landing. This better manages the flow of aircraft into airspace by absorbing delays en-route. Underpinned by System Wide Information Management these capabilities are now being trialled and deployed.

INTELLIGENT APPROACH

Intelligent Approach, developed by UK ANSP NATS, is a suite of controller tools that safely optimise arrival spacing to maximise runway capacity, maintain operational resilience and provide better on time performance. Refining separation standards can provide significant benefits to airports during peak times or disruptive conditions. The Intelligent Approach suite of tools is based on a common platform that's designed to help all airports increase capacity and resilience at a fraction of the cost of adding taxiways and runways. By optimising the safe separation of aircraft, Intelligent Approach can help to decrease delays and cancellations caused by poor weather conditions. Intelligent Approach also reduces the need for stack holding, saving fuel and decreasing detrimental environmental impacts. Intelligent Approach is made up of the following three core modules that can be tailored to the needs of the airport operation and provide benefits to airports, airlines and ANSPs:

- Distance Based Separation improves the consistency of approach spacing all the way to the runway threshold, by using optimised wake spacing rules that provide controllers with a visual indication of the required separation between aircraft.
- Enhanced Time-based Separation (eTBS) provides ATCs with separation indications to the runway based on aircraft weight. This is supported by an Optimised Runway Delivery tool, which models the compression between aircraft pairs as they slow down to their landing speed. The tools also provide controllers with runway occupancy indications for pairs of arriving aircraft when that is more limiting than wake separation.
- Optimised Mixed Mode has been specifically designed for mixed mode runways to safely reduce inbound separation by taking account of departure runway occupancy.

AD1.3 U-Space Airspace

INNOVATION READINESS LEVEL: **MEDIUM**

U-space is an enabling framework including a set of new services along with specific procedures designed to support safe, efficient and secure access to airspace for large numbers of drones. It will rely on a high level of digitalization and automation of functions, whether on board the drone or an element of the ground-based environment. As such the implementation of new services is associated to airborne capabilities and adequate/qualified ground infrastructure. Complementary infrastructure may be required if the existing ATM infrastructure does not meet necessary requirements.

REGULATORY AND MARKET DEVELOPMENTS

Regulatory frameworks for traffic management services for uncrewed vehicles is managed regionally. In April 2021, the EU published a comprehensive regulatory package aimed at providing a framework for the establishment and deployment of U-space in Europe. In addition to describing the rules to be followed in U-space airspace, the regulatory package indicates the services that pilots must use in order to operate their drones safely in U-space airspace. 4 phases of U-Space services from U1 to U4 set the roadmap for services development within Europe. The definition of CONOPS internationally, at local European Level through SESAR and by individual States continues to influence emerging policy. Examples include FAA Next Generation Concept of Operations, SESAR U-Space CORUS, Swiss U-Space Implementation, Airservices Australia Urban ATM Concept of Operations. The Financing Structure for U-Space remains undetermined.

ANALYSIS

Air Traffic Management services for new uncrewed air vehicles in low-level airspace will ensure the ICAO performance attributes of aviation for example, safety, flight efficiency, capacity and access equity, flexibility and predictability.

U-space vehicles are expected to operate primarily below 1,500 ft Above Ground Level (AGL) but will also operate above this level. Other airspace users, including helicopters, hot-air balloons, drones and fixed-wing aircraft will also use low-level airspace. In the future, there will be greater variety in the types of vehicles, operators and missions in the low-level airspace, including a mix of piloted and autonomous vehicles. No single category of operators will have exclusive use of airspace, and all operations will need to be integrated. Some airspace will be dedicated primarily to U-space vehicle operations. Conversely, there will be airspace from which UAM vehicle operations will be restricted. Some restrictions will be permanent (e.g., some military airspace) while some will be dynamic (e.g., emergency response or some forms of TRA/TFR). Traditional airspace users will periodically need to use airspace that is dedicated primarily to UAM vehicle operations. UAM vehicles will at times need to fly through controlled airspace to access airports or vertiports that are located close to airports.

TIMELINE

2024	2027	2030+
• Late-stage certification testing and operational demonstration in limited environments • Low Density and Complexity Commercial Operations with Assistive Automation	• Low Density, Medium Complexity Operations with Comprehensive Safety Assurance Automation • Medium Density and Complexity Operations with Collaborative and Responsible Automated Systems	• High Density and Complexity Operations with Highly-Integrated Automated Networks • Ubiquitous UAM Operations with System-Wide Automated Optimization

OPPORTUNITIES

The ASTM International working group WK63418 is developing a set of standards for UTM services and interoperability. These draft standards provide the foundations for the architecture and open API used by this project to develop and prove the concept of interoperability.

NASA's UTM project introduced a new Air Traffic Management (ATM) architecture that utilizes industry's ability to exchange relevant air vehicle information among the UAS operations and between the UTM and the conventional ATM system. In the project, the UTM requirements and architecture are generalized to become Extensible Traffic Management (xTM) that serve new non-traditional aircraft such as eVTOL and High-Altitude Platforms.

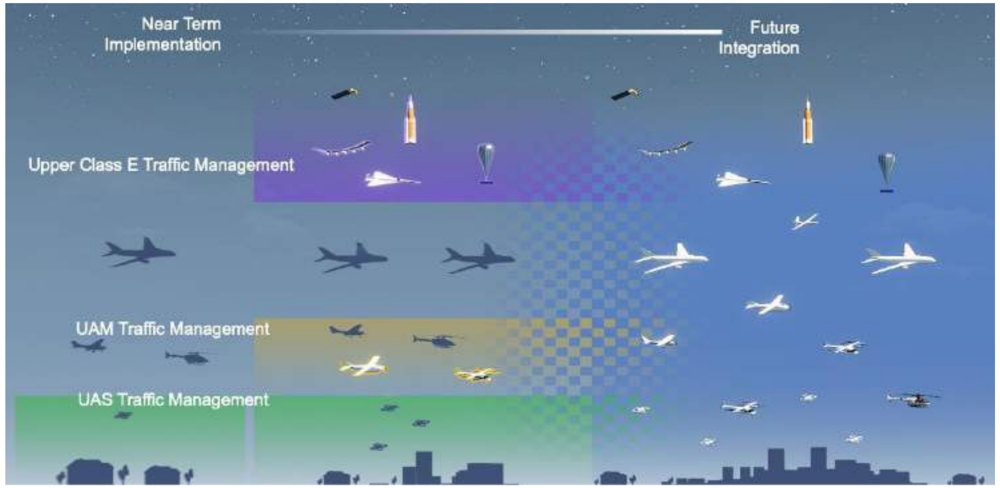
The U-space framework regulations are published and will entry into force from January 2023. It lays down the framework for the initial services in the EU, other services are to be developed. The local implementation in The Netherlands still takes various options to fill in, but also gives independence to customise elements of the implementation based on examples from other, international UTM implementations.

AD1.3 U-Space Airspace

MORE DETAILS ON: EXTENSIBLE TRAFFIC MANAGEMENT (XTM)

NASA's UTM project introduced a new ATM architecture that utilizes industry's ability to supply industry-developed, third-party services that work complementarily with the FAA-provided Air Traffic Service to exchange relevant air vehicle information among the UAS operations and between the UTM and the conventional ATM system. The UTM architecture was used to successfully demonstrate the feasibility of safe, efficient, and scalable small UAS operations in low altitudes below 400 feet above ground level. Following the success and adoption of UTM architecture, the foundational UTM requirements and core properties were generalized to become xTM requirements to support operations of new entrants beyond small UAS, such as operations in high altitudes over 60,000 feet, designated as upper-Class E in the US National Airspace System.

In the early stages of xTM development, xTM operations are expected to operate mainly without ATC supervision. However, on occasions, they are also expected to transit through ATC-managed airspace, sometimes as a part of nominal operations and other times to handle off-nominal / emergency situations. In these situations, there has been a concern that even if all xTM systems meet the same high-level requirements, each xTM system may have its own way of communicating operation intent, vehicle state, other flight plan-related information, and operational procedures. These differences pose significant challenges to the ATC when different xTM systems serviced vehicles enter his/her airspace with different operating goals and practices, in which ATC is expected to provide different types of services and maintain safety within his/her controlled airspace. Therefore, NASA is planning to examine the potential xTM-ATC interactions across multiple xTM systems and identify common coordination procedures, ATC roles/responsibilities, and data exchange requirements across different xTM-ATC interactions that occur under similar trigger events.



Source: NASA, 2022

AD2.1 Air Traffic Service Providers

INNOVATION READINESS LEVEL: **MEDIUM**

Europe's ATM is in many cases composed of country-based systems and processes, each requiring customized system adaptations. This fragmentation or proliferation of systems results in a lack of interoperability and increased costs of air navigation services across Europe, which ultimately stands in the way of a more sustainable and competitive aviation industry. New innovative concepts such as remote towers and virtual centers provide increased flexibility in organizing air traffic control operations in and between the air traffic service units (ATSUs), as well as enabling multiple ATSUs to perform services seamlessly from an airspace user's perspective. However, the increased digitalization of ATM may introduce new threats particularly pertinent in the area of cyber security, the exploitation of which could result in undesirable impacts.

REGULATORY AND MARKET DEVELOPMENTS

Regulation (EU) 2017/373 is the regulatory instrument for the certification of ATSPs and all other ATM/ANS providers. It also forms the initial basis for the certification of U-Space service providers. Initial industry efforts, research and policies have focused on demonstrating the technical feasibility of decoupling the provision of the air traffic service from the provision of ATM data and technical services, such as flight data distribution and management, as well as surveillance data. The EU regulation is an enabler for this concept by recognizing different ATM/ANS service providers. The fragmentation of service provision is being further promoted on a voluntary basis in the recent SES2+ proposals through the development of a new ATM Data service providers (this is detailed in a separate section)

ANALYSIS

As an initial step, SESAR members have started to define open service interfaces that could be used across a wide area of network connections interoperable across ANSPs and vendor independent ATC center system solutions. Furthermore, the interfaces and the data transmitted have been designed to allow remote connections between CWPs and ATM data and technical service providers, as well as for the local deployment at ANSP premises (ATSUs).

The ability to provide ATS from a remote location is relevant in all operating environments: airport, TMA, or en-route. In TMA, extended TMA and en-route environments, the virtual-center concept allows a geographical sector to be managed from any place subject to the availability of some services crucial for the provision of ATS, namely Communication Navigation Services (CNS), Meteorological Services (MET), aeronautical information services (AIS) and all data related to the flight plan. By using standardized operating methods, procedures and technical equipment, the services will be perceived as a single system from the user's perspective.

This will be enabled by cloud-based data centers as well as data management processes and governance, provided remotely. In airport environments, the remote tower concept supports several use cases that allow the provision of ATS from a remote tower center (RTC), with a dynamic allocation of several physical aerodromes to remote tower modules. It offers new alternatives for the provision of tower related ATS and in some cases reduces ANS costs. The integration of approach services to these airports through a remote virtual center is also possible. Currently, this is being explored for Airport Flight Information Services in Norway by Avinor ANS.

TIMELINE

2025	2030	2035	2040+
Deployment of remotely provided ATS for multiple aerodromes and virtual center concept	Remote towers fully operational	Virtual centres fully operational	Delegation of services amongst ATSUs HMI interaction modes for ATC centres and airport towers Multiple remote towers and remote tower centre

OPPORTUNITIES

The concept of 'virtualizing' Air Traffic Service Providers based on standard service interfaces is an opportunity to achieve the following benefits:

- Increased cost efficiency with the rationalization and standardization of systems and services, enabling ATC infrastructure and processes;
- Increased flexibility made possible through workload balancing between ATSUs;
- Harmonized ATM functionalities and seamless cross-border and cross-ATSUs transitions for airspace users, allowing for overall increased capacity;
- Increased agility and cost efficiency to implement and commission new ATM functionalities throughout European ANSPs;
- Increased capability for contingency planning.

AD2.1 Air Traffic Service Providers

MORE DETAILS ON: VIRTUALISATION OF ATM

SINGLE EUROPEAN AIRSPACE SYSTEM

The architecture of the future air navigation system is based on a service orientated approach where traditional service provision is replaced with a layered service provider architecture. This new architecture is described by a series of resources that are connected and optimised across the network leveraging modern technology through a data rich and cyber-secured connected ecosystem. In this environment service providers would be able to collaborate and operate as if they were one organisation with both airspace and service provision optimised according to traffic patterns.

Source: SESAR ATM Masterplan, 2020

AD2.1 Air Traffic Service Providers

MORE DETAILS ON: VIRTUALISATION OF AIR TRAFFIC MANAGEMENT (CONT'D)

VIRTUALISATION OF SERVICE PROVISION

The ability to provide air traffic services from a remote location is relevant in all operating environments either it is airport, TMA, or en-route. In TMA, and en-route environments, the virtual centre concept allows a geographical sector to be managed from anyplace subject to the availability of some services crucial for the provision of ATS, namely, CNS, MET, AIS and all data related to the flight plan.

The virtualisation of service provision will:

- be perceived as a unique system from the user's perspective;
- be enabled by cloud-based data centres as well as data-processes management and governance remotely provided;
- allow the provision of air traffic services from a RTC, with a dynamic allocation of a number of physical aerodromes to Remote Tower Modules;
- bring new alternatives in the provision of tower related ATS and in some cases benefits on ANS costs.

VIRTUAL CENTRES

A virtual centre is a single ATSU or a grouping of collaborative ATSUs using data services provided by an ADSP. The concept provides, at least, geographical decoupling between ADSP(s) and some ATSU(s), through service interfaces defined in Service Level Agreements. One ATSU may use data services from multiple ADSPs, just as an ADSP may serve multiple ATSUs. The objective of a virtual centre is to allow decoupling that could deliver the flexibility and performance aspects of the services to ensure the ability of the virtual centre solution to at least support or to improve the operational performance. This solution encompasses en-route and TMA and environments.

DIGITAL OR REMOTE TOWERS

Remotely Provided Air Traffic Service for Multiple Aerodromes includes the provision of Aerodrome Control Service or Aerodrome Flight Information Service (AFIS) for more than one aerodrome by a single air traffic controller (ATCO)/AFIS officer (AFISO) from a remote location, i.e. not from a control tower local to any of the aerodromes. The ATCO (or AFISO) in this facility performs the remote ATS for the concerned aerodromes. It includes further development of the CWP and MET information from multiple airports.

AD2.1 Air Traffic Service Providers

MORE DETAILS ON: ROLE OF THE HUMAN

ATCO COMPETENCIES AND UNIT ENDORSEMENTS (SYSTEM VALIDATIONS)

SESAR is exploring the concept of ‘any controller any airspace’ under PJ10-06. This is where endorsement for ATCOs are based only on the tools that they used and there is no geographical qualification constraints. This requires changes to how ATCOs are endorsed and licensed to provide air traffic control services. There is currently no roadmap for how this can be realised.

Currently, the dominance is on unit endorsements for ATCOs based on geographically defined volumes of airspace. This is primarily because of the characteristics of the local airspace environment in terms of configuration, available routes, exit and entry points to the lower airspace, and traffic patterns. This is applicable to both lower and upper airspace sectors. For optimal performance an ATCO in a sector, he or she must hold not only a generic controller licence, but also be trained and certified to understand and deal with the specificities of the sector.

Trials have been conducted by ANSPs including NATS, Skyguide and LFV with support of technology partner INDRA to identify the local factors to identify where innovation in technology can help reduce or mitigate these local factors.

https://www.sesarju.eu/news/any-controller-any-airspace

COMPETENCIES FOR TECHNICAL STAFF IN END-TO-END TECHNICAL SYSTEM

ATSEP (Air Traffic Safety Electronic Personnel) are directly involved in all services within the ATM/ANS functional system. This includes services supplied directly in support of ATS and to the aircraft (i.e. Navigation). The key functions, covering site and field infrastructure equipment, are within the direct responsibility of ATSEP.

According to ICAO Doc. 10057, the term ATSEP potentially covers all technical personnel working to provide, from specification to decommissioning, and support, the electronics and software which enable ATM/ANS systems to function. This encompasses engineers, technicians and computer hardware and software experts who are responsible for all functional systems. This is not a definition but a description of ATSEP profession. Under ICAO Doc. 10057, each State is responsible for further defining the roles and responsibilities of ATSEP. Commission Implementing Regulation (EU) 2017/373 defines ATSEP as any authorised personnel who are competent to operate, maintain, release from, and return into operations the equipment of the functional system.

EU terminology does not represent all technical activities that are conducted in the lifecycle of the technical system. For example, specification, design and installation of equipment, are excluded from scope of ATSEP duties.

Changes to the technology platforms as a result of virtualised platforms and changes to business delivery models will fragment the current technology platform. The key operational function is to attain a system wide situational awareness, where the ATSEP creates an accurate and up-to-date picture of the health status of all services under their control including those supporting services provided by third parties. The status of upstream and downstream services of neighbouring sites is also required as part of this awareness.

AD2.2 ATM Data Service Providers

INNOVATION READINESS LEVEL: **LOW**

ADSPs is a European concept introduced to support the service-orientated approach that SESAR is promoting within the European ATM Master Plan and the Digital European Sky strategy within the European Architecture Study.

An ADSP is an entity that will manage the delivery of data services to one or more Air Traffic Service Providers.

REGULATORY AND MARKET DEVELOPMENTS

The SES2+ and the establishment of the Common Project One (CP1) supports the modernization of ATM and is a key enabler to achieve the Green Deal objectives and ensuring the long-term resilience of the aviation sector. The European Regulatory SES2+ package published in 2021 has provisions for the voluntary setup of ADSPs. ANSPs are forming partnerships for the delivery of common information service provision to multiple ANSPs. Possible ADSP will be formed to realise this partnership.

Regulation (EU) 2017/373 provides the framework for the certification of different components of the ATM/ANS system. Specific detail introduced by Reg. 2017/373 related to safety also provides the basis for introduction of ADSPs.

ANALYSIS

An ADSP is an entity, which manages ATM data processing and produces associated services for Air Traffic Supervisors (ATS). Its services can be provided in two ways:

1. For a given ATS, it is possible to have several ADSPs providing different services. For example, ADSP X provides a flight plan processing service and an ADSP Y provides a radar service.
2. Alternatively, a single ADSP can provide all services for an ATS or several ATS.

The ADSP concept will develop and mature as a result of the implementation of Virtual Centres and the predicted increased demand for out-sourcing of ATM data services, leaving ATS Units (ATSU) to remain focused on the core business with air traffic control.

The ADSP participates in the decoupling of the ATM architecture, in fact data is provided on one side and data processing on the other. There are therefore pure data providers and service providers (data processing). This is possible due to new architecture such as event driven architecture and the loose coupling of the ATM systems components.

TIMELINE

2021	2024	2027	2030+
European Commission adoption of CP1	SES2+ Regulation creates voluntary ATM Data Service Provision	Enabling framework for ADSPs First ADSP certified	ADSPs and virtual centres providing capacity of demand

OPPORTUNITIES

The integration of ADSPs provide various opportunities within the Netherlands to optimise traffic management operations during peak hours or at night by delegating airspace. It could also optimise internal technical support, since part of it, is managed by the ADSPs. Additionally, ADSP can:

- be driven by a service-based approach and a performance-based approach;
- enable the de-coupling of CNS service provision from air traffic services, ATM data services;
- lead ATM/UTM systems to be more flexible and resilient, allowing scalability;
- create business opportunities for affordable services with a strong incentive for service providers to compete resulting in cost-efficient services;
- enable the virtualization of ATM (consisting in decoupling the provision of ATM data services from ATS);
- enable ANSPs to make implementation choices on how new services are provided;
- provide a strong incentive for service providers to cooperate across national boundaries, to optimize the use of technologies as well as the geographical distribution of equipment (and hence optimize spectrum use);
- provide a better environment for the integration of new CNS services – such as space-based automatic dependent surveillance broadcast (ADS-B) and satellite communications.

AD2.2 ATM Data Service Providers

MORE DETAILS ON: ADSP CONCEPT

The ADSP concept is a stepping-stone towards realising the virtual de-fragmentation of European skies, and ultimately developing a more sustainable and competitive aviation industry. When ADSPs are geographically decoupled and use standardized services, it enables several beneficial strategies for contingency within a State and via supply of cross-border services to another State. This will require new regulations and standardization relating to data integrity, ATCO and ATSEP competency and other legal provisions related to decision making.

ADSPs could also enable infrastructure to be rationalized, contributing to economic sustainability. This rationalization could save costs for air traffic service providers in terms of purchasing, maintenance and training of ATSEPs on technical systems. Just as with data providers in other markets today (for example, financial services), an air traffic service provider will have a choice on where it sources its ATM data services. This assumes sufficient interoperability is in place.

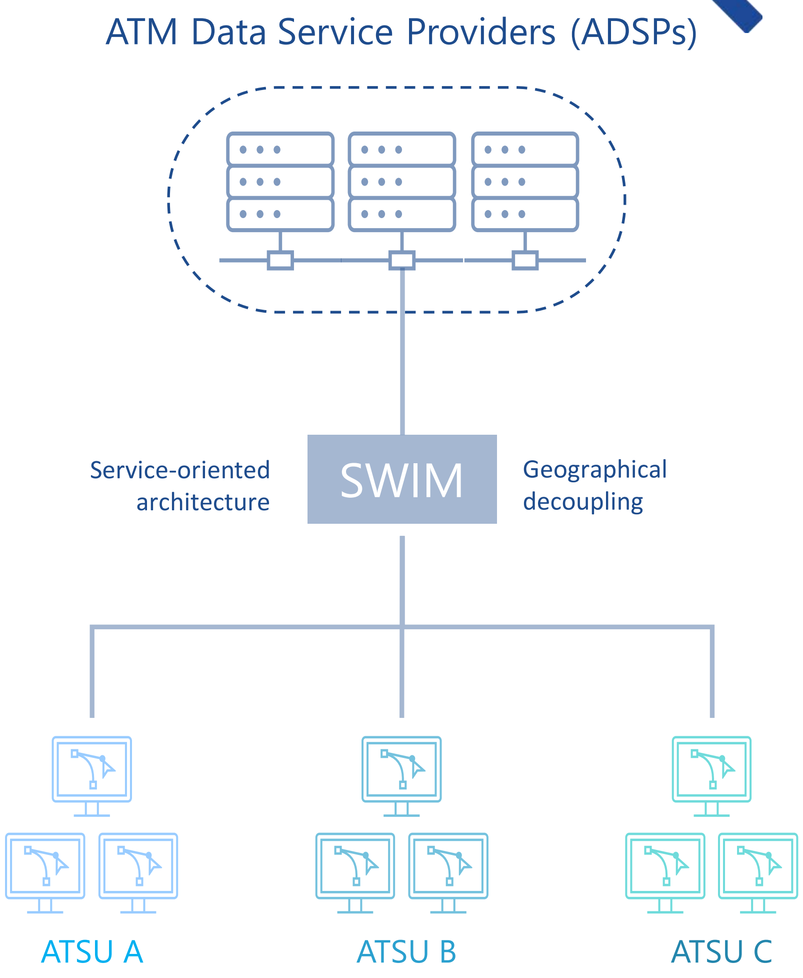
An ADSP providing data to several ATSUs can increase cost efficiency in developing and commissioning new ATM functionality for several ATSUs at the same time, independently from their locations. And this sharing of ADSPs by several ATSUs can also significantly enhance data coordination between ATSUs and enable multiple ATSUs to be perceived as a single system from the airspace user's perspective.

For air traffic service providers, it will also open new pathways towards:

- optimizing ATM operations with delegation of airspace between ATSUs during peak hours or night-time;
- optimizing internal technical support.

Some air navigation service providers that own or have developed their systems could be interested in creating an internal ADSP service for their own ATSUs. Once done, why not offer this service to external stakeholders? It will probably be necessary to create a legal structure for this, with or without the involvement of an industrial player. For example, Maastricht UAC (EUROCONTROL) providing services to Slovenia, or DSNA/ENAV to skyguide via Coflight Cloud Services.

Finally, major companies that specialise in cloud computing (Amazon, Google, Microsoft…) could also be interested in positioning themselves in this new ADSP market in ATM. There would be many more critical systems to handle compared to those they use today. Once again, partnerships with other stakeholders (ATM industrials, air navigation service providers…) might be an optimum solution.



AD2.3 U-Space Service Providers

INNOVATION READINESS LEVEL: **MEDIUM**

The U-space service provider (USSP) is the Generic stakeholder who provides at least one of the U-space services. The entity that provides U-space service access to drone operators, to pilots and/or to drones, to other operators visiting non-controlled very-low-level airspace. Depending on the architecture deployment options and the services, multiple services could be provided by different U-space service providers. It is possible to distinguish between the providers of centralized services (i.e., Principle USSP) and concurrent service providers aiming to interface with the drone and drone operator (operator USSP).

REGULATORY AND MARKET DEVELOPMENTS

U-space service providers support the safe and efficient movement of drones in the U-space airspace and ensure coordination with manned aircraft. These organizations will require full and comprehensive certification to provide U-space services in one or more European member states. To become certified, organizations will be required to provide four mandatory U-space services: network identification, geo-awareness, traffic information, and UAS flight authorization. That means providers must be equipped to share critical airspace data (e.g., airspace restrictions, air traffic) with drone operators and exchange UAS operational data with air navigation service providers.

ANALYSIS

U-space service providers (USSP) are expected to be the customer-facing component of the U-space ecosystem, providing traffic management services to UAS operators in low-level airspace. A USSP will act as a communication bridge between an ANSP and UAS operator when necessary. The USSP will be an industry or government organisation(s) delegated or approved by the National Aviation Authority (NAA) or be executed directly by the ANSP, depending on each nation's policy or their implementation of UTM and regulatory arrangements.

It is highly likely that in many nations, multiple USSPs will serve UAS operators in the same geographical region. It is likely that every USSP will interface with a centralized, government-owned or -controlled UTM sub-system, often referred to as a Flight Information Management System (FIMS) or Common Information Service (CIS) to ensure safety, integrity, oversight and security.

A USSP will receive real-time information regarding airspace constraints and intentions of other aircraft available through ANSPs. A USSP will provide some UTM services that are typically only provided by ANSPs in manned aviation, including but not limited to strategic deconfliction and conformance monitoring for UAS operations.

The primary means of communicating and coordinating between the ANPS, USSPs, operators and other stakeholders will be through a distributed network of machine-to-machine APIs and not between pilots and ATCOs via voice comms.

TIMELINE

2019	2021	2025	2030+
Foundation services (U1) (registration, identification, geo-fencing)	Initial services (U2) (planning & approval, tracking, airspace dynamic information, procedural interface with ATC)	Advanced services (U3) (capacity management, assistance for detection)	Full services (U4) (integrated interfaces with manned aviation, additional new services)

OPPORTUNITIES

A collaboration between U-space service providers, ANSPs and other stakeholders will be vital in:

- Ensuring the safety of all airspace users operating in the U-space framework, as well as people on the ground;
- Enabling high-density operations with multiple automated drones under the supervision of fleet operators
- Guaranteeing equitable and fair access to airspace for all users; and
- Enabling competitive and cost-effective service provision, supporting the business models of drone operators.

AD2.4 Automation in ATM Tools

INNOVATION READINESS LEVEL: **MEDIUM**

In today's environment, the use of automation is limited to the provision of information / advice to the controller. The controller remains responsible for decision making. The industry vision is that ATM tasks will be automated with limited controller interventions being an exception.

Full automation of en-route ATM can be achieved with a combination of automated planning (and plan updates) in a look-ahead time horizon of up to several hours complemented with automated tactic conflict resolution functions. The benefits of full automation are assumed to be significant additional overall system capacity and safety.

However, there is no strategy to achieve this transition to full automation within traditional ATM.

REGULATORY AND MARKET DEVELOPMENTS

Two prevalent themes emerge when analyzing current policy, and regulatory developments regarding automation. Firstly, it is recognized by industry and regulators that the more restrictive the regulation, the less innovation and adoption of automation occurs. Thus, regulation should aim to set boundaries within which adoption of automation and further innovation can occur. This effort is, in some cases, being combined with overlapping policies surrounding 5G infrastructure and STEM education. Where automation has the potential to threaten jobs, the European Union has adopted a policy which aims to encourage investments that focus on those technologies that minimize the direct threat of automation for to workers and that maximize the positive countervailing effects that increase labor demand.

ANALYSIS

Automation is hardly a new concept for the aviation industry. For several years, on-board datalink systems have transmitted aircraft information to ground control centers, while the autopilot is routinely used to direct flights. Similarly, automation has also been successfully been applied to help increase visibility at airports and enhance communications with pilots. Furthermore, automated communication, navigation and surveillance tools such as TCAS have helped ATCOs in being alerted with sufficient time to resolve conflicting trajectories.

As these tools become more and more vital to safety and increased efficiency, the industry is asking questions about the controller's role and how this is both positively and negatively impacted by the increasing role of automation. While automation is already providing operational benefits for ATM, any move to introduce further automation comes with its risks. ATM is a highly complex system that includes a high level of ambiguity which current machines struggle to manage. This presents a significant barrier to ATM and future UTM becoming fully autonomous without a human-in-the-loop. Standards to design the system as a single system where the human and machine are considered as single system are being developed to support automation transition.

However, it is generally accepted that digitized and automated services will be necessary for some if not all UTM services. Examples of such services are:

- Automated information exchanges (e.g., flight authorization for UAS)
- Automated system monitoring (e.g., aircraft conformance to authorized 4D trajectory; airspace capacity; met conditions)
- Automated conflict management

TIMELINE

Today	2030	2040+
Low automation Decision support tools	Task execution support Conditional automation	High Automation Full autonomy

OPPORTUNITIES

The automation of existing ATM could achieve the following benefits:

- Routine tasks are automated – reduces ATCO workload and increases capacity;
- Enhanced Situational Awareness - essential information is derived from different sources, effectively integrated and presented, and exchanged between ATC centers in real-time while unnecessary or unimportant information is filtered out;
- Optimise Human Performance –certain calculations and computations are automated to increase speed and accuracy to support human capabilities. In addition, the system may prevent or provide warnings in case of certain incorrect inputs;
- Efficiency at management level - tools that suggest optimal sector configurations help achieve efficient personnel use while preserving the required levels of safety.

AD2.4 Automation in ATM Tools

MORE DETAILS ON: LEVELS OF AUTOMATION IN ATM AND THE JOINT HUMAN MACHINE SYSTEM CONCEPT

Strategies to increase automation in ATM are required to provide a safe and efficient transition from todays environment. Strategies that separate the design of the automation from the role of the human to respond to the limitations will not be effective (as demonstrated by the recent 737 MAX accidents). The system must be designed as single system where the design of the system matches the capabilities of the human and the machine to amplify the contribution of both.

Level 0 – No automation	Level 1 – Task assistance	Level 2 – Partial automation	Level 3 – Highly automated	Level 4 – Fully automated	Level 5 – autonomous
Human performs all aspects of a task Warning & Intervention Systems may be present	Human delegates execution of a specific action/limited responsibility of a task to a specific system Human performs all remaining aspects of the task Human monitors performance of the system	Human delegates execution of multiple aspects of a task to one or more systems Human performs all remaining aspects of the task Human monitors performance of the system	Human delegates flight phase specific execution of a task to an automated system Human performs a limited set of actions in support of the task Human monitors automation an will respond if intervention is requested / required	Human delegates execution of all aspects of a task in any flight phase to an automated system Automation can manage most aspects of the task under most conditions Automation is capable of safe/reasonable responses if human does not respond to requests for intervention Human monitors automated system and has full authority over the task	Execution of all aspects of a task in all flight phases by an automated system Automation can manage all aspects of the task under the conditions that can be managed by a human

AD3.1 Optimizing Current CNS Infrastructure

INNOVATION READINESS LEVEL: **HIGH**

The CNS infrastructure is driven by the new technologies and entrance of new users.

In order to increase efficiency and capacity, the aviation community is progressively digitalizing its data exchanges - replacing or enhancing legacy communications systems.

Navigation and surveillance are key enablers of aviation, involving sophisticated technology and efficient coordination between pilot and air traffic is a cornerstone of aviation, providing users with knowledge of ‘who’ is ‘where’ and ‘when’.

REGULATORY AND MARKET DEVELOPMENTS

The EU strategies and policies for Europe (COM (2016) 705) and (EU) 2018/1139 Regulation, with respect to space-related technologies, encourage the uptake of solutions that are enabled by EGNOS and Galileo. In this respect, the EU Air Navigation Strategy (2018) developed by the EC and presented to the Single Sky Committee in the context of performance-based navigation (PBN) implementation roadmap, confirms the availability of PBN applications as from 2015. It states that, in order to ensure necessary independence when GNSS is the primary means of navigation, Galileo and EGNOS will become GNSS components required in the EU, for the multi-frequency, multi-constellation GNSS system. For end users, the technological solutions will be packaged or merged in a way that guarantees availability, integrity, safety and security and performance requirements, mandated by relevant authorities.

ANALYSIS

The CNS domain evolutions will be driven by a service-based approach and a performance-based approach. This will enable the de-coupling of CNS service provision from air traffic services, ATM data services. This change will lead the European ATM system to be more flexible and resilient, allowing scalability. Through a service-based approach, the CNS services will be specified through contractual relationships between customers and providers with clearly defined, European-wide harmonized services and level of quality. This approach will create business opportunities for affordable services with a strong incentive for service providers to compete resulting in cost-efficient services. The future CNS infrastructure will be based on an integrated CNS backbone comprising multi-link pan-European network service , GNSS and Automatic Dependent Surveillance-Broadcast (ADS-B).

Aireon is providing the first ever, global air traffic surveillance system using a space-based ADS-B network that meets the strict, real-time Air Traffic Service surveillance requirements for air traffic separation services anywhere in the world.

TIMELINE

2022+	2025+	2030+
Optimization of current CNS & demonstration of performance-based CNS.	Phase out of legacy CNS infrastructure & scaling of performance based CNS.	Performance based CNS infrastructure.

OPPORTUNITIES

The European CNS Roadmap sets a path for digitalization and rationalization of the surveillance and communication infrastructure with main objectives to:

- increase digitalization, connectivity and higher automation levels
- implement a safe, secure and resilient infrastructure
- move from physical assets management to CNS services
- develop performance-based and integrated CNS concepts
- combine satellite-based airborne and ground-based CNS
- rationalize infrastructure
- increase civil-military synergies and dual-use
- ensure an efficient and long-term availability of suitable spectrum

AD3.1 Optimizing Current CNS Infrastructure

MORE DETAILS ON: CNS INFRASTRUCTURE

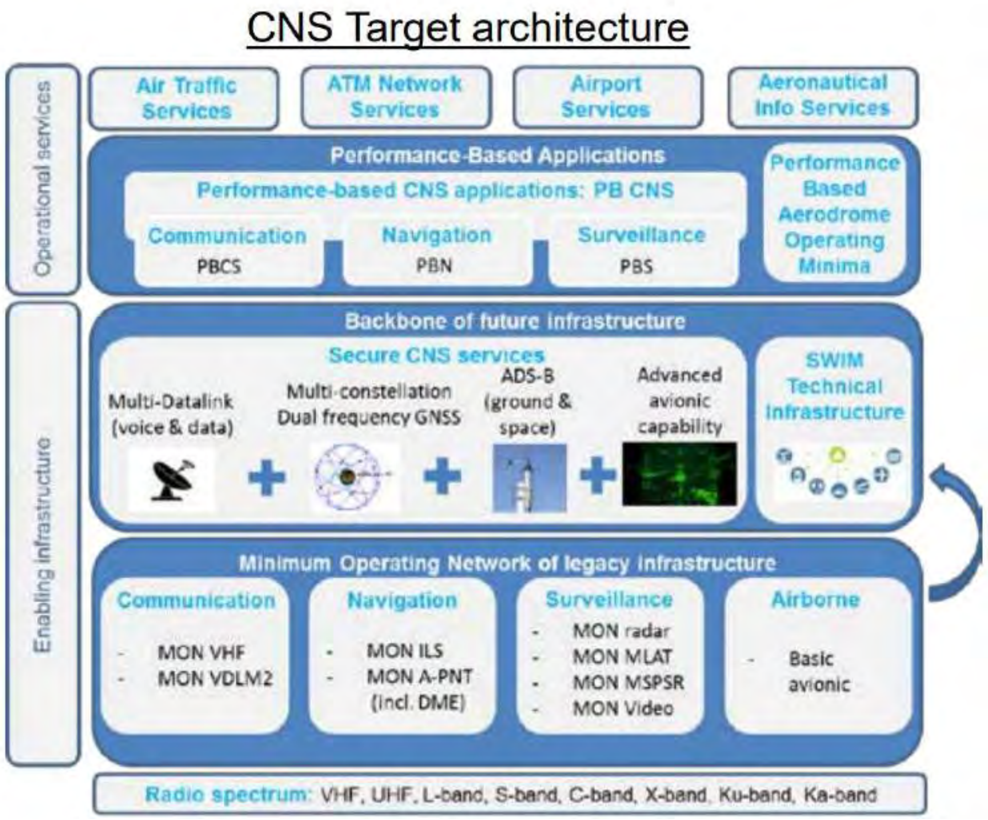
Traffic over Europe is already at record levels and will continue growing over the next twenty years. To safely accommodate this growth, it is essential to manage scarce resources like radio frequency bands, secondary surveillance radar (SSR) codes and Mode S interrogator codes sustainably.

Network performance requires a resilient CNS infrastructure supported by a monitoring system for early detection and prevention of issues with the potential to impact network operations.

Efficient and stable communication channels are the bonds that ensure aviation operates efficiently, predictably and safely. They ensure that information is exchanged efficiently among ATCOs and between ATCOs and pilots.

In order to increase efficiency and capacity, the aviation community is progressively digitalizing its data exchanges - replacing or enhancing legacy communications systems. Navigation is a key enabler of aviation, involving sophisticated technology and efficient coordination between pilot and air traffic controller. Surveillance is a cornerstone of aviation, providing users with knowledge of ‘who’ is ‘where” and ‘when’.

The next step foreseen is to get a collaborative U-space-ATM interface, currently studied within the project FACT. EUROCONTROL has published this year a document on the CNS infrastructure evolution opportunities. The assessment estimates the potential net savings coming from rationalising current CNS infrastructure within the European ATM Network. Building upon previous economic assessments – themselves based on substantial stakeholder involvement, it consolidates results for the SES and ECAC Areas over the period 2021-2040 and considers the latest Regulatory Developments and the CNS roadmap in the ATM Master Plan. However, the assessment does not quantify all potential net savings enabled by the introduction of new CNS technologies during the 2021-2040 period. For example, savings related to ILS decommissioning enabled by the introduction of Satellite-based Augmentation Systems (SBAS) and Ground Based Augmentation Systems (GBAS). SBAS and GBAS are not evaluated as it is too soon to estimate those savings reliably.



Source: SESAR CNS Roadmap & Strategy, 2020

AD3.2 Advancement of New Surveillance and Communication Technology

INNOVATION READINESS LEVEL: **HIGH**

The introduction of new CNS Infrastructure or the re-use of existing capabilities is being explored by the industry to support existing airspace and low-level airspace categories and, crucially, will be driven by the new digital technologies. These new digital CNS technologies will need to be backed up by an increase in connectivity capacity, speed and reliability. Different technologies and standards, such as 5G and satellite-based solutions will allow this to happen. Furthermore, future air-ground digital communications concepts such as Remote ID will be required to overcome the current VHF limitations and the enable growth of future transport solutions such as Advanced Air Mobility.

REGULATORY AND MARKET DEVELOPMENTS

Regulatory developments in this area are small. Within the USA they published their rules for Remote Identification of UAS on 15 January 2021 with an original effective date of 21 April 2021. For most operators this will mean flying a Standard Remote ID Drone, equipping with a broadcast module, or flying at an FAA-recognized identification area (FRIA).

Market developments Within Europe, there is growing concern that the use of ADS B out on 1090MHz by a growing number of existing and new operators at lower altitudes in Class G leads to frequency congestion. Industry is exploring how deployment of an ADS B 978MHz Conspicuity System be a viable option.

ANALYSIS

Telecommunication Network 5G - Mobile networks are well suited to support low-altitude drone communication and to be integrated with UTM systems. The licensed mobile spectrum serves as the foundation for mobile networks to provide wide-area, high-quality and secure connectivity that can enable BVLOS drone operations. Current mobile networks can serve drones in the low-altitude airspace. Specific performance enhancements can optimize LTE/5G connectivity toward more effective and efficient connectivity for connected drones while maintaining the performance of mobile devices on the ground.

Satellite Based Inmarsat's Global Satellite Network and ATM Communication expertise provides surveillance infrastructure to support remote UTM.

Use of 978 MHZ UAT for ADS-B Out Applications –Use of 978MHZ is progressing within the USA faster than within Europe. In the USA the FAA encourages planes flying under 18000ft to use UAT as their ADS-B frequency. In Europe it is not generally accepted as a viable option. UK CAA has initiated a Study in 2021 into the possible use of 978MHZ UAT for Drone Electronic Conspicuity.

Remote ID - provides a means to address public concerns and protect for public safety vulnerabilities associated with low altitude UAS operations, including privacy and security threats. It allows electronic identification of a UA/Operator through use of a unique identifier (similar in concept to an automobile license plate) and enables accountability and traceability, particularly for BVLOS operations, where an Operator and vehicle are not co-located.

TIMELINE

2023	2025+	2030+
Remote ID manufacturing compliance in USA	Telecomms 5G Standards and Mandate in compliance with EASA	New surveillance and communication technology fully used

OPPORTUNITIES

The advancement of surveillance and communication is a significant enabler to unlocking the benefits of UAS operations BVLOS.

Electronic Conspicuity relates to the 'in-flight capability' to transmit position and/or to receive, process and display information about other aircraft, airspace or weather in a real time with the objective to enhance pilots' situational awareness

Remote Identification provides a means to address public concerns and protect for public safety vulnerabilities associated with low altitude UAS operations, including privacy and security threats.

AD3.2 Advancement of New Surveillance and Communication Technology

MORE DETAILS ON: TECHNOLOGY IMPLEMENTATION

TELECOMMUNICATION NETWORK 5G

Mobile networks are well suited to support low-altitude drone communication and to be integrated with UTM systems. The licensed mobile spectrum serves as the foundation for mobile networks to provide wide-area, high-quality and secure connectivity that can enable BVLOS drone operations. Current mobile networks can serve drones in the low-altitude airspace. Specific performance enhancements can optimize LTE/5G connectivity toward more effective and efficient connectivity for connected drones while maintaining the performance of mobile devices on the ground.

EASA are conducting a study to evaluate suitability of using existing mobile telephony technology as one of the solutions for compliance with SERA.6005(c) which for U-space airspace states ‘Manned aircraft operating in airspace designated by the competent authority as a U-space airspace, and not provided with an air traffic control service by the ANSP, shall continuously make themselves electronically conspicuous to the U-space service providers’.

SATELLITE BASED SURVEILLANCE AND COMMUNICATIONS FOR UAS

Inmarsat’s Global Satellite Network and ATM Communication expertise provides surveillance infrastructure to support remote UTM. Trials conducted in Turkey involved numerous BVLOS flights, connected and tracked using Inmarsat’s global L-band satellite network with traffic management provided by the Altitude Angel UTM tools.

REMOTE ID

Remote ID provides a means to address public concerns and protect for public safety vulnerabilities associated with low altitude UAS operations, including privacy and security threats. It allows electronic identification of a UA/Operator through use of a unique identifier (similar in concept to an automobile license plate) and enables accountability and traceability, particularly for BVLOS operations, where an Operator and vehicle are not co-located. The FAA has developed a Remote ID rule (RIN 2120–AL31) and the identification requirements within can be met by drone pilots using three methods:

1. Operate a Standard Remote ID Drone (PDF) that broadcasts identification and location information about the drone and its control station. A Standard Remote ID Drone is one that is produced with built-in remote ID broadcast capability in accordance with the remote ID rule's requirements.
2. Operate a drone with a remote ID broadcast module (PDF). A broadcast module is a device that broadcasts identification and location information about the drone and its take-off location in accordance with the remote ID rule's requirements. The broadcast module can be added to a drone to retrofit it with remote ID capability. Persons operating a drone with a remote ID broadcast module must be able to always see their drone during flight.
3. Operate (without remote ID equipment) (PDF) at FRIAs sponsored by community-based organizations or educational institutions. FRIAs are the only locations unmanned aircraft (drones and radio-controlled airplanes) may operate without broadcasting remote ID message elements.

Link: https://www.faa.gov/uas/getting_started/remote_id/

AD3.2 Advancement of New Surveillance and Communication Technology

MORE DETAILS ON: AIR-TO-AIR AND AIR-TO-GROUND ELECTRONIC CONSPICUITY

ELECTRONIC CONSPICUITY

Electronic Conspicuity relates to the ‘in-flight capability’ to transmit position and/or to receive, process and display information about other aircraft, airspace or weather in a real time with the objective to enhance pilots’ situational awareness.

UAS can use systems initially designed for mainstream aviation such as Transponders and other Transceivers (e.g. FLARM). Manufacturers have successfully miniaturised these systems and addressed SWaP (Size, Weight and Power) limitations for UAS. There are some small, lightweight, and low-power EC devices available today. In some cases, some EC devices, especially low power Mode S transponders, do not meet a TSO's performance requirement due to its low power- lower than any existing standards allow.

USE OF 978 MHZ UAT FOR ADS-B OUT APPLICATIONS

Within Europe, there is growing concern that the use of ADS-B out on 1090MHz by a growing number of existing and new operators at lower altitudes in Class G leads to frequency congestion. Industry is exploring how deployment of an ADS B 978MHz Conspicuity System be a viable option. Use of 978MHZ is progressing within the USA faster than within Europe. In the US the FAA encourages planes flying under 18000ft to use UAT as their ADS-B frequency. In Europe it is not generally accepted as a viable option. UK CAA has initiated a Study in 2021 into the possible use of 978MHZ UAT for Drone Electronic Conspicuity.

DETECT AND AVOID

Detect and Avoid (DAA) systems are technologies that allow unmanned aerial vehicles (UAVs) and drones to integrate safely into civilian airspace, avoiding collisions with other aircraft, buildings, power lines, birds and other obstacles. These systems observe the environment surrounding the drone, decide whether a collision is imminent, and generate a new flight path in order to avoid collision. Drones may use systems originally designed for manned aviation, such as TCAS (traffic collision and avoidance systems) or ADS-B (automatic dependent surveillance–broadcast), that periodically broadcast and receive identity, position and other information. This solution, however, relies on the co-operation of all aircraft within an airspace, and does not account for non-aviation obstacles. SESAR JU envisions automated DAA functionalities and more reliable means of communication, including V2X (46), to enable a significant increase in operations in all environments and will reinforce interfaces with ATM/ATC and manned aviation and to be implemented in Phase U3 (+2027).

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LIST OF ABBREVIATIONS

List of Abbreviations

Abbreviation	Meaning
AAM	Advanced Air Mobility
ACI	Airports Council International
AD	Airspace Design and Infrastructure
ADS-B	Automatic Dependent Surveillance-Broadcast
ADSP	ATM Data Service Provider
AFIS	Aerodrome Flight Information Service
AMS	Amsterdam
ANSP	Air Navigation Service Provider
AP	Aircraft Platforms
ASTM	American Society for Testing and Materials
ATAG	Air Transport Action Group
ATC	Air Traffic Control(ler)
ATCO	Air Traffic Controller
ATFCM	Air Traffic Flow and Capacity Management
ATM	Air Traffic Management
ATS	Air Traffic Supervisor
ATSEP	Air Traffic Safety Electronic Personnel
ATSP	Air Traffic Service Providers
ATSU	Air Traffic Service Units
BREEAM	Building Research Establishment Environmental Assessment Method

Abbreviation	Meaning
BMWi	Bundesministerium für Wirtschaft und Energie
BVLOS	Beyond Visual Line of Sight
BWB	Blended Wing Body
CAA	Certification Authority Authorization
CANSO	Civil Air Navigation Services Organization
CNS	Communication, Navigation and Surveillance
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
CP1	Common Project One
CS	Certification Specification
CWP	Controller Working Position
DAA	Detect and Avoid
DGB	Directeur-Generaal Bereikbaarheid
DLR	Deutsche Zentrum für Luft- und Raumfahrt
DOA	Design Organisation Approval
EASA	European Union Aviation Safety Agency
EC	European Commission
eCTOL	Electric Conventional Take-Off and Landing
EFPL	Extended Flight Plan
EIS	Entry into Service
EPFD	Electrified Powertrain Flight Demonstration
EPP	Extended Projected Profile

List of Abbreviations

Abbreviation	Meaning
ESG	Environmental, Social and Governance
eSTOL	Electric Short Take-Off and Landing
ETSI	European Telecommunications Standards Institute
EU	European Union
EUROCAE	European Organisation for Civil Aviation Equipment
eVTOL	Electric Vertical Take-off and Landing
FAA	Federal Aviation Administration
FF	Future Fuels and Infrastructure
FRA	Free Route Airspace
FRIA	FAA-Recognized Identification Area
GA	General Aviation
GANP	Global Air Navigation Plan
GASP	Global Aviation Safety Plan
GBAS	Ground Based Augmentation System
GNSS	Global Navigation Satellite System
GRI	Global Reporting Initiative
GSE	Ground Support Equipment
H_2	Hydrogen
HAPSS	Hydrogen Aircraft Powertrain and Storage Systems
HEFA	Hydroprocessed Ester and Fatty Acid
HTSM	Hightech Systemen & Materialen

Abbreviation	Meaning
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
ILT	Inspectie Leefomgeving en Transport
IR	Implementing Rule
IT	Information Technology
IenW	Infrastructure and Water Management
LEED	Leadership in Energy and Environmental Design
LH_2	Liquid Hydrogen
LSSIP	Local Single Sky ImPlementation plans
LSA	Light-Sport Aircraft
LuFo	Luftfahrtforschungsprogramm
MET	Meteorological Services
MOA	Maintenance Organisation Approval
MRO	Maintenance, Repair and Operations
NAA	National Aviation Authority
NASA	National Aeronautics and Space Administration
NLR	Nederlands Lucht- en Ruimtevaartcentrum
NM	Network Manager
OEM	Original Equipment Manufacturer
PBN	Performance Based Navigation
PM	Particle Matter

List of Abbreviations

Abbreviation	Meaning
POA	Production Organisation Approval
R&D	Research & Development
RNAV	Area Navigation
RNP	Required Navigation Performance
RNP-AR	RNP Authorisation Required
ROT	Rotterdam
RTC	Remote Tower Center
RTCA	Radio Technical Commission for Aeronautics
RTHA	Rotterdam The Hague Airport
SAE	Society of Automotive Engineers
SAF	Sustainable Aviation Fuel
SARP	Standards and Recommended Practice
SBAS	Satellite-based Augmentation System
SBTI	Science based Targets Initiative
SES	Single European Sky
SESAR	Single European Sky's ATM Research
SESAR JU	SESAR Joint Undertaking
SME	Small and Medium-sized Enterprise
SWaP	Size, Weight and Power
TBO	Trajectory Based Operations
TKI	Topconsortium voor Kennis en Innovatie

Abbreviation	Meaning
TMA	Terminal Manoeuvring Area
TRL	Technology Readiness Level
UAM	Urban Air Mobility
UAS	Unmanned Aircraft System
UFP	Ultra Fine Particle
UIC2	UAM Initiative Cities Community
USA	United States of America
USSP	U-space Service Provider
UTM	Unmanned Traffic Management
xTM	Extensible Traffic Management