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SUSTAINABLE TECHNOLOGIES IN AVIATION

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DUBAI AIRSHOW

Introduction

Aviation contributes approximately 2% to 3% of all global CO_2 emissions with majority of it being contributed by aircraft movement. Emissions from the aviation industry have been increasing at an annual rate of about 3% in recent years, up until 2019. This growth can be attributed to the constant increase in passenger demand, which is expected to continue rising and expected to double by 2050 potentially resulting in aviation to account for 25% to 30% of all CO_2 emissions by 2050 if no actions are taken. When the negative impact and the forecasted growth of the industry are considered together, the need and urgency to take immediate action to achieve net-zero becomes even more critical.

Drive for Sustainability in Aviation

The rising social, regulatory, and economic pressures are increasingly putting the aviation industry under the microscope for its share in overall global emissions, requiring the industry stakeholders to ramp up efforts in achieving net-zero.

Government

The Sustainable Development Goals (SDGs), government regulations, policies by various regulatory bodies across the world are beginning to set targets to achieve net-zero for the aviation industry. As a result, aviation stakeholders are actively seeking ways to meet these requirements and achieve the established goals.

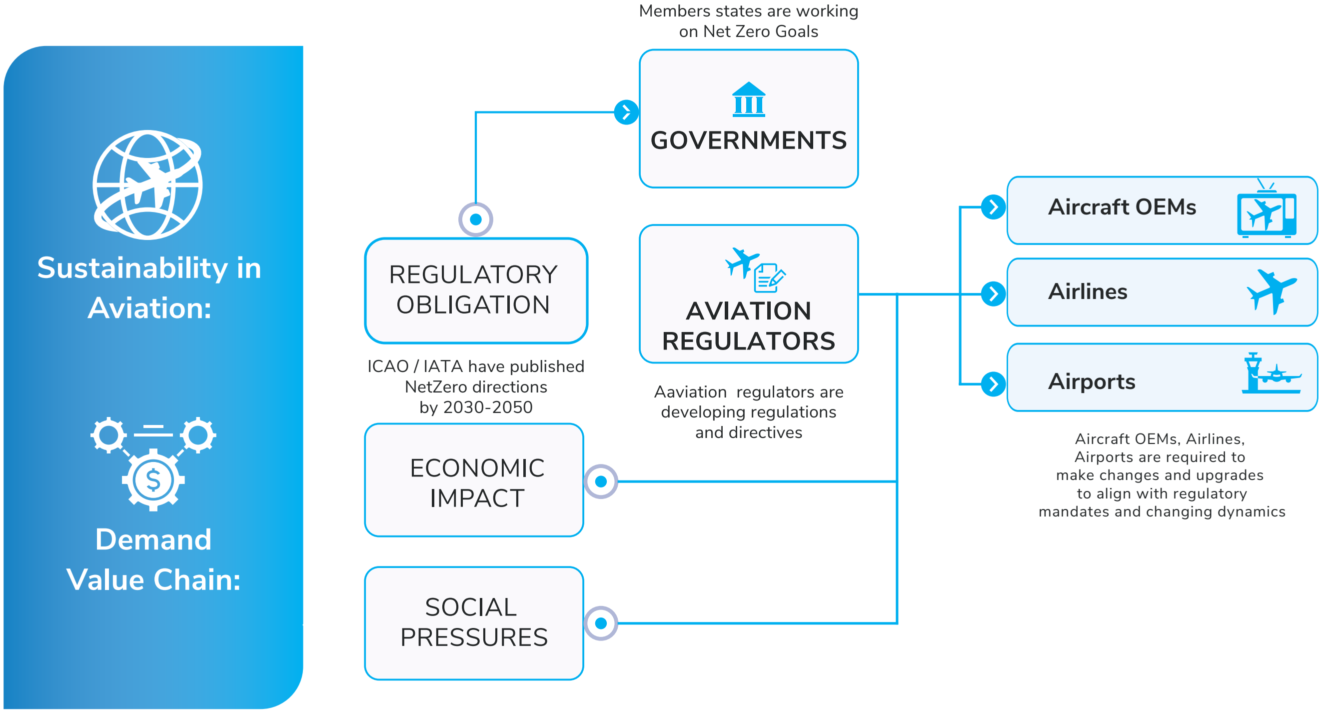
Social

Passengers are increasingly becoming aware and engaged in pursuing sustainability. In many regions, significant social pressure regarding decarbonising air travel is prompting stakeholders to act.

Economic

The cost of fuel is constantly rising and is putting huge pressure on airline operators to maintain profitability, further compounded by the ongoing economic instability.

Sustainability in Aviation – Imperatives



Source: Frost & Sullivan

Sustainable Technologies

SAF – SUSTAINABLE AVIATION FUEL

Sustainable aviation fuel (SAF) is a type of fuel made from biological and non-biological non-fossil fuel-based sources. The bio side of it comes from feedstock such as using plant or animal material rather than using fossil fuel and the synthetic fuels come from atmospheric carbon capture. SAF can be used in majority of aircraft and engine without having to make any major technical modifications. While SAF is currently being mixed with conventional Jet Fuel based on the specified blending percentage as per the technology, the blending percentage is gradually expected to continue to increase as the technology develops with the aim of using 100% SAF without any blending.

Currently there are 3 Generations of SAF:

- **1st Generation** – The 1st generation biofuels are based on feedstock that consists of plants that can also be used as food or animal feed. These are, for example, corn, grain, sugar beet, rapeseed, palm, or soya oil.

- **2nd Generation** – The 2nd generation biofuels are based on feedstock that comprises of plants or parts of plants, such as cellulose, that are not edible. This is intended to defuse the ethical conflict between food shortage and transportation with that of 1st Gen biofuels.

- **3rd Generation** – The 3rd generation biofuels are based on feedstock that comprise of raw materials, biological residues such as straw, residual wood, or sawdust to produce biofuels. Algae, which have a significantly higher biomass productivity per area than plants, are also being researched. This generation of biofuel is in the early stages of development and is not yet available in large quantities. However, it promises advantages in terms of a broader residue base, improved land efficiency, and higher availability.

Currently there are about 11 pathways, and each have a specific blend percentage ranging from 5% to 50%, for example the technology that uses used cooking oil and waste animal fats currently has a blend percentage of about 5% while the one using energy crops, municipal solid wate, agricultural waste has blend percentage of about 50%. The aim of the industry is to fly aircraft completely on SAF that is 100% SAF with no blending required.

The pathway which is expected to have the most potential for large scale commercialisation while being truly net-zero is Power to Liquid (PTL), which is form of a synthetic fuel where carbon captured from the air or from other emissions is used as the main feedstock for producing SAF.

Current State of SAF

As per IATA (International Air Transport Association), the global production of SAF in 2022 was around 450 million litres, which is less than 0.05% of the global demand of jet fuel. However, this has been increasing multifold in the last few years. The main reason for limited production is high cost of production, availability of feedstock, and that setting up of SAF plant takes up around 3 years. Major SAF producers such as NESTE amongst others are constantly ramping up production of SAF and given the increase in investment from existing and new players SAF production is expected to increase multifold. The industry is experiencing wide range of partnerships and collaborations – one such partnership is between **Rolls Royce, Airbus and Shell.** Airlines, SAF producers, Aviation Regulatory authorities, and other stakeholders across the world are partnering to promote and accelerate the use of SAF.

Growth Potential of SAF

The industry is still a long way from reaching the required quantities of SAF, but as innovative technologies are developed, new and sustainable feedstock are introduced along with much more efficient production technologies, the production capacity will continue to increase multifold. Airlines have been placing offtake orders ranging in million of litres to be fulfilled in the next few years, which are further giving a push to the supply of SFA and injecting in the much needed investments. It is estimated that the production capacity needs to exceed 30 billion litres by 2030 and 450 billion litres by 2050 for airlines to be able to achieve net-zero targets.

SAF will continue to be the key solution for airlines to achieve net-zero targets while other advanced technologies are developed and deployed.

Aircraft Propulsion

New and established OEMs/Engine manufacturers have been working for more than a decade to develop, test, and certify alternate energy propulsion systems. The aim of having alternate fuel sources is to move away from using conventional fuel sources such as jet fuel to reduce emissions. Various types of propulsion technologies are being developed simultaneously.

Hybrid Propulsion

Hybrid propulsion type uses a combination of conventional jet fuel powered propulsion along with an electric powered propulsion or a hydrogen powered propulsion. Having a combination of propulsion systems on board that use conventional jet fuel and an alternate source, supports in reducing the overall emissions from the aircraft.

These hybrid propulsion systems with a combination of two separate energy sources can be used in various formats. The most common hybrid propulsion system is expected to use jet fuel-powered propulsion for take-off (where maximum thrust is required) and use alternate fuel-powered propulsion for the rest of the flight. OEMs and other stakeholders are working on deploying hybrid propulsion options for current airframes as well as for new/in development airframes.

In the medium term, it is expected that adopting hybrid propulsion would be the key solution for reducing CO2 emissions from aircraft.

Current State of Advanced Propulsion Technologies

Companies are working together to develop and test hybrid-electric propulsion technologies. **GE** along with **Boeing** and **NASA** are developing a hybrid electric aircraft test bed. Airbus along with its partners is also working on hybrid electric propulsion. Engine manufactures such as **GE** and **Safran**, **Pratt & Whitney**, and **Collins** and others are also developing hybrid engine technology. Few other manufacturers such as **Ampaire, Raytheon**, **Heart Aerospace**, amongst others have been developing and testing hybrid-electric aircraft test beds on existing platforms and/or designing completely new platforms. Various combinations of electric and conventional fuel propulsion are being tested in different configurations to find the best approach. Apart from hybrid electric, few players are also working on hybrid hydrogen propulsion technology – **GE, Universal Hydrogen**, **Heart Aerospace** and others have been conducting tests and moving closer towards deployment of hybrid hydrogen propulsion systems.

All-Electric Propulsion

All-Electric propulsion type uses electric energy as power source instead of jet fuel. Electric energy will be stored in on-board batteries, which will have to be recharged or swapped during turn-around. This electric energy will be used to run the aircraft engines. In such type of propulsion technology, the aircraft will completely run on electric energy and not use any jet fuel. These are expected to be the most sustainable solutions given the lack of CO2 emissions, however, to become net-zero, the course of electricity generation will also need to be from renewable sources.

Many OEMs are currently in the process of developing an all-electric aircraft for commercial use and few are currently in prototyping and testing phase. These all-electric aircraft would either be current airframes converted to run on electric propulsion or completely new aircraft designed for electric propulsion.

All-electric aircraft are expected to be commercially deployable in the long-term and will be the key solution for achieving net-zero targets and reducing the overall impact on the environment.

Current State of All-Electric Propulsion

As the development of hybrid-electric propulsion continues, few companies are also developing all-electric solutions to support net-zero emission targets. The challenges linked to all-electric are more than those of hybrid given the lack of a backup option of having a conventional powered engine. Many manufacturers such as **Eviation** with its **Alice** project, **Wright Electric** with its **Spirit, MagniX** with its **eCaravan**, and **Airbus** and **Boeing** are in the process of developing and testing all-electric aircraft. Companies are engaging in a variety of approaches for all-electric propulsion with some leveraging existing aircraft platforms and retrofitting them to support all-electric propulsion. Developers continue to focus on increasing the motor capacity and efficiency and develop high power density with lower weights battery technology.

Hydrogen Propulsion

Hydrogen propulsion uses hydrogen (which is stored and processed onboard) as the fuel source for propulsion. Aircraft may use conventional engines powered by hydrogen or may have a specially designed engine to run on hydrogen. Using hydrogen as fuel supports in having completely net-zero flying with the only by-product being water.

A few OEMs are in the processing of developing hydrogen propulsion systems for commercial use either in tandem with a conventional powered engine or a fully hydrogen powered propulsion system.

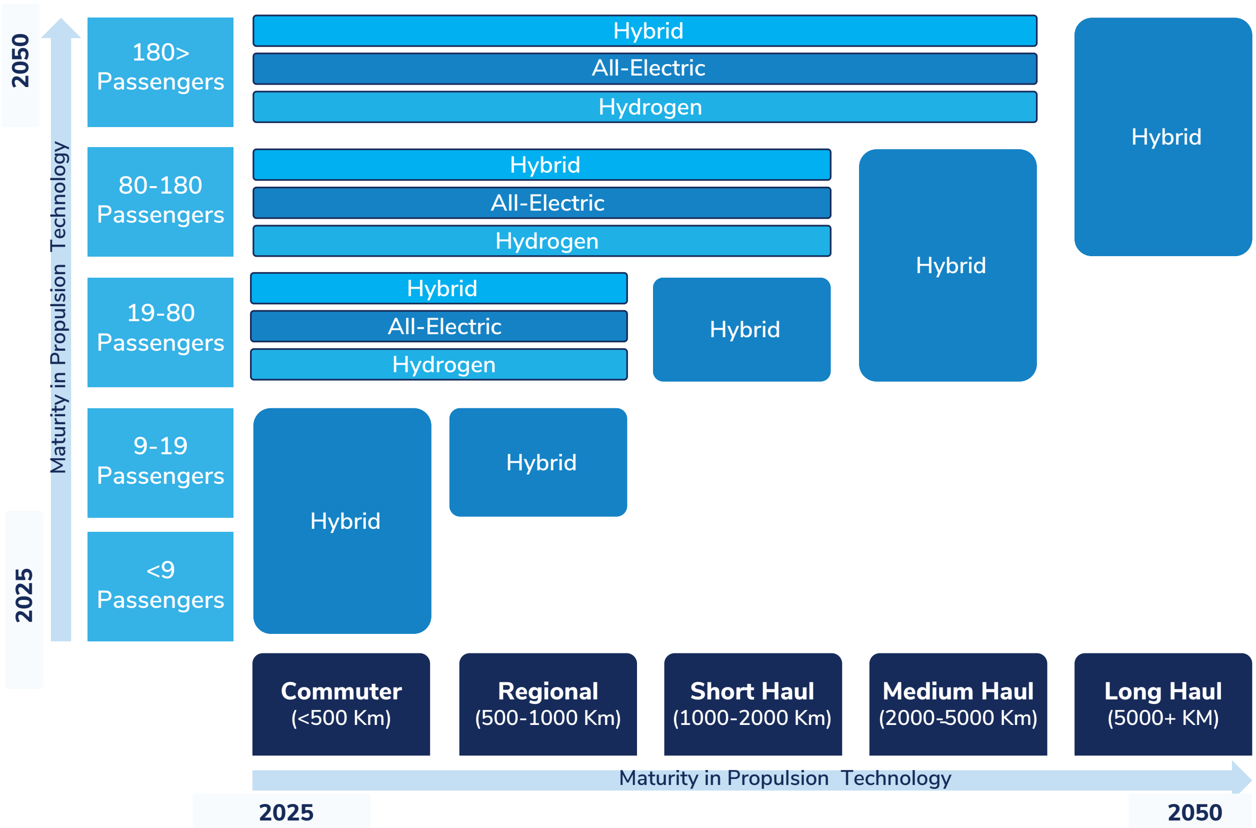
Hydrogen propulsion aircraft are expected to be deployed in the long-term with the aim of being completely net-zero though there are certain challenges that need to be addressed such as fuel storage, safety, and certification.

Current State of Hydrogen Propulsion

Hydrogen propulsion is much more recent compared to electric propulsion, it has been the focus of many companies due to its net-zero emissions. Certain key hydrogen propulsion projects include **ZEROe** by **Airbus**, **HY4** by **H2FLY**, **HyFlyer** by **ZeroAvia**, Universal Hydrogen, **Rolls Royce** with its hydrogen powered jet engine, **MTU** and **DLR and others**. Having a commercially viable hydrogen aircraft propulsion is closer than ever with many companies involved in the development. Majority of companies continue to face challenges in using hydrogen propulsion for commercial use– the most common challenge is storage.

Growth Potential of Advanced Propulsion Technologies

As the supporting technology develops and evolves supported by current and new players both small and large, the rate of development will also speed up. Successful development of advanced propulsion technologies is linked to the development of supporting technology, battery, motor efficiency and power for electric propulsion, storage, and fuel cell performance solutions for hydrogen. In the short-term, hybrid propulsion is expected to be the key to achieving net-zero taking into consideration technology evolution and regulations & certifications. Hydrogen and all-electric propulsion are expected to be long-term propositions. Hybrid propulsion will continue to be the main technology in use in the medium term as hydrogen and all-electric are being developed parallelly. Airlines have already begun placing orders for hybrid/all-electric/hydrogen aircraft to be delivered in the next decade or so, thus further supporting development of these technologies



Source: Frost & Sullivan

Innovative Propulsion Technology Adoption Roadmap

Aircraft/Engine Design

Aircraft and engine manufacturers are in the process of developing new designs to further reduce fuel consumption, reduce noise, and make flying even more sustainable.

Blended Wing Body

A BWB aircraft design is one where the entire aircraft is in a singular wing form as the fuselage and wings are blended that make up the airframe. Unlike the conventional aircraft design which has a tube with wings attached to it, in the BWB design the entire aircraft resembles a large wing of an aircraft which encompasses the space for passengers as well as the engines and the fuel tanks.

The aim of BWB aircraft design is to generate maximum lift with minimum drag, as the entire aircraft is capable of generating lift unlike in conventional aircraft design where only the wings generate lift. BWB due to its increased aerodynamics reduces the drag potentially further bringing down fuel burn resulting in lower emissions and lower costs.

BWBs are also expected to make much less noise and could be operated from existing airports. Furthermore, BWB aircraft could be manufactured using advanced materials which are stronger and lighter, further bringing down the overall weight of the aircraft while having the ability to carry same number of passengers or more passengers than a wide-body aircraft while having the range of a long range aircraft.

While BWB has been used in the past mainly for military purposes, the one currently under development could be used for both commercial cargo and passenger use. There are a few potential challenges such as having the fuselage large enough to house passengers/cargo while still being drag efficient and manoeuvrable.

There are also commercialisation aspects such as cost of development, certification, safety, and real-world benefits that have to be considered. However, as the technology ecosystem matures, and innovative technology/materials become available they will further support development and deployment of BWB aircraft design.

Open Rotor Engine

Open rotor engine is an iteration of the conventional high-bypass-ratio engine which does away with the use of fan duct/casing and has two sets of propellers placed one behind the other rotating in opposite direction with potentially one or both sets of propellers having variable pitch. Each set of propellers will have a separate hub. The aim of such a design is to reduce swirl in the air behind the engine and thus achieve higher propulsion efficiency resulting in reduced fuel consumption. This type of engine may be fuel agnostic and can run on conventional jet fuel, SAF, electric or hydrogen fuel source.

OEMs have been working on designing and developing an open rotor engine for many years, but now as the need for decarbonisation increases, stakeholders have ramped up their efforts to deploy it in the next few years.

There are certain potential challenges that the stakeholders will have to address including higher noise levels, vibration, integration into current and/or future airframes as well addressing safety, certification, and cost aspects.

Truss-Braced Wings

An aircraft which is lightweight, ultra-thin, and has high aspect ratio wings mounted from top of the aircraft body and supported by diagonal trusses, which are connected to the bottom of the aircraft can be described as having the Truss Braced Wing aircraft design. The top mounted wings which are thin while having larger wingspan offer increased lift without increase in weight, while making it possible to fit larger engines to it.

The aim of such a design is to have lower drag and increased lift to improve fuel efficiency. Such wing designs could be used on current airframe or on a completely new airframe specifically designed for it. This aircraft design is primarily being designed as a narrow body aircraft.

This comes with some challenges of its own, such as having to reposition the fuel tanks from the wings to the fuselage given the thin structure of the wings. This may impact the weight distribution of the aircraft and the passenger/cargo carrying capacity of the aircraft. The large wings may also not fit in current infrastructure though developers are working on making them foldable to address this issue. Like for any other new technology, commercialisation aspects such as certification, safety, and cost-benefit will also need to be considered.

Current State of Advanced Aircraft/Engine Designs

Manufactures have for long being working on making the aircraft/engine design more aerodynamic in an effort to increase fuel efficiency and reduce noise and emissions. Now as new materials are being developed, manufacturers are going a step further by looking at completely new aircraft designs platforms. **NASA, Boeing, Airbus**, and **JetZero** among others have been working on designing advanced aircraft platforms that will further aid in achieving sustainability. Engine manufacturers including CFM, Rolls Royce, and others are developing new engine types to support these new aircraft platforms to further reduce emissions and be compatible with alternate fuels.

Growth Opportunities of Advanced Aircraft/Engine Design

In the short- to medium-term, OEMs will continue to improvise current design in use to make them more energy efficient and sustainable as they continue to develop innovative designs to be deployed in the long-term. As new materials are developed and tested, they will further support development of new aircraft/engine designs. Aircraft and Engine OEMs will increasingly collaborate and partner with wide range of organisations to speed up efforts. The key solution to success will be the evolution of supporting of technologies and timely certification supported by airline operators in terms of creating the necessary demand.

Impact of Sustainable Strategies on Travel Trends

RISE IN GREEN CORRIDORS

There will be rise in so called Green Corridors to support early use of sustainable technologies such as SAF, hybrid/electric/hydrogen propulsion, wherein the departure and arrival destination have the required infrastructure set in place for use of advanced technologies. These special corridors in the short-term will aid in successful deployment until they are deployed on a mass scale.

FOCUS ON SUSTAINABLE INTERMODAL TRANSPORTATION

Large amounts of emissions are generated by travelling to and from airports and with possible deployment of solutions such as Urban Air Mobility (UAM)/ Advanced Air Mobility (AAM), airports and airlines will have to integrate their operations with these solutions to support the drive to net-zero.

NEW BUSINESS MODELS

There will be a host of new business models being deployed and adopted by airlines, airports, OEMs, and others across the value chain to support successful deployment of sustainable technologies. These business models will focus on cost sharing and funding in an effort to create the required demand to support innovation and development.

CHOOSING AIRPORT/AIRLINE BASED ON SUSTAINABILITY

As passengers become even more involved and aware about sustainability, passengers may choose their destination, the airline they fly on, and the airport they fly to dependent on the sustainable quotient of the various touchpoints involved.

ALTERNATE MODES OF TRANSPORT FOR SHORT DISTANCES

In the short-term, until the use of alternate energy becomes mainstream passengers as well as governments may prefer/promote using flights for short distances where sustainable alternatives are available possibly leading airlines, airports to adapt to this change from a scheduling, routing, and fleet structure perspective.

RISE IN NEW ROUTES/ DESTINATIONS

Deploying all-electric/hydrogen powered aircraft, airlines would be able to offer flights on shorter routes as well as to airports closer to city as it addresses many issues such as fuel in-efficiency, noise, and other negative aspects that currently hinder airlines from doing so.

CHANGE IN PRICING MODEL

As airlines, airports, and other stakeholders begin adopting decarbonisation initiatives/ solutions, passenger may face an additional cost component to support sustainability efforts such as cost difference between using jet fuel and SFA. Currently SAF costs about 2 to 4 times that of conventional jet fuel and so as airlines increase the usage of SAF and till the time the price of SAF matches that of jet fuel, at least some part of the cost difference may have to be paid by the passengers which may lead to increase in ticket prices.

CHANGES IN FLIGHT SCHEDULES

In the short-term, airports may restrict flight operation only during specific time slots to reduce noise pollution impact on the surrounding community while in the long run when aircraft engines with reduced noise come into use, airports in/ closer to the city would be able to offer all day operations without impacting the community.

Potential Challenges

TECHNOLOGY LIMITATION

Current technology available for commercial use to support sustainability is still in its nascent stage, such as for instance batteries offering limited power-to-weight ratio that makes it difficult for aircraft to have smaller and lighter batteries to fly longer and with more passengers. Hydrogen propulsion technology is still in prototype/testing stage and considerable improvements are needed in terms of storage and processing till the technology can provide the desired results. Similarly, with SAF, the blending percentage to reach a full 100% will be based on how the blending technology evolves and can be standardised across the aviation industry.

DIFFICULTY/DELAY IN OBTAINING CERTIFICATION

Certification for commercial use involves a stringent and lengthy process. It often takes years to obtain certification which involves multiple stakeholders and steps. Moreover, every time a change is made, it needs to be recertified, which adds to the complexity and delay in deploying the innovative technology sooner than the industry would want it to be.

COST IMPLICATIONS

There is always cost attached to developing and deploying a new technology and this cost needs to be absorbed by one or more stakeholders. This many a times becomes a major hurdle in developing and deploying the technology. Upfront costs and recurring costs need to be considered and need to justify the deployment. If the costs are higher than the benefits, it becomes challenging for the stakeholder to take up the additional cost.

USABLE LIFE

If the stakeholders are unsure of the true usable life of these advanced technologies as many of these are in the prototype stage and so for them to invest in these technologies, they are keen on first understanding how long these technologies will last and how often would they need to be replaced and overhauled.

MANPOWER

As these technologies will be deployed across the globe, OEMs/stakeholders will need to recruit and train the workforce to support these technologies throughout the value chain.

SUPPORTING INFRASTRUCTURE

For the advanced technologies to be successfully deployed and adopted, it is key to have the supporting infrastructure in place to supports its operation. For instance, with use of SAF, it is crucial that airports have SAF supply set in place, for electric aircraft airports will need to have enough power supply and storage to support battery charging and for hydrogen aircraft airports will need to have hydrogen storage tanks, supply infrastructure, and other required components. If the required infrastructure is not ready to support, it is difficult to deploy these technologies. The ecosystem – be it maintenance or ground operations or airport operations – needs to be developed in tandem at the same rate with the development of the advanced technologies.

OPERATIONAL CHALLENGES

As airlines begin deploying innovative technologies alongside the conventional technology in use parallelly, it will be challenging for them to operate and manage various airframe/ engine types.

Adoption of Advanced Sustainable Technologies

Short-Term (2025-2030)

In the short-term, SAF will continue to be the key solution that will be used on a mass scale to achieve reduced emissions. As the supply chain and blending technology of SAF evolves, the usage of SAF across the region will increase and so will the blending percentage. Other innovative technologies will continue to be researched, developed, prototyped, and tested.

Medium-Term (2030-2040)

In the medium-term, though SAF will continue to be the main solution for reduced emissions, other technologies such as hybrid-electric propulsion technologies may start becoming commercialised across the regions. Some new variants of the engine along with certain new aircraft design which are based on current airframe types such as truss-braced wings may also see commercialisation.

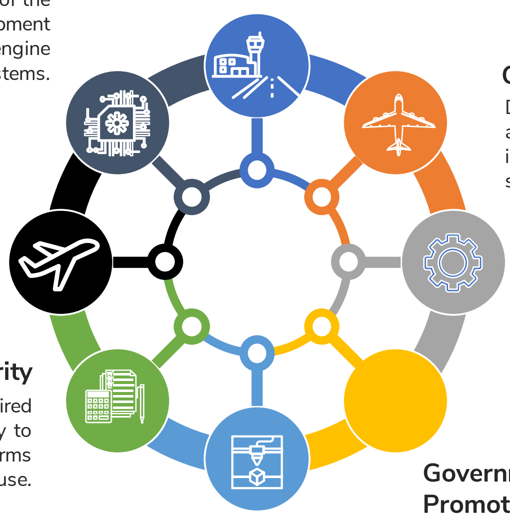
Long-Term (2040 and beyond)

In the long-term, the industry will gradually see commercialisation of in all-electric and hydrogen aircraft propulsion along with new aircraft design such as Blended Wing, Double Bubble amongst others. SAF, hybrid-electric propulsion, new energy efficient engines, and modified airframes will continue to be mainstream while other technologies gradually come into service.

Future Growth Outlook

As the industry inches towards 2050, the drive towards achieving net-zero becomes even more crucial as pressure from multiple points – social, economic, and governments – becomes even more prominent. This will lead to increased innovations and developments of advanced innovative technologies to support decarbonising the industry. Such developments are expected to take place across the industry value chain in effect resulting in increased availability of solutions/technologies to support wide range of requirements while addressing multiple touchpoints across the ecosystem.

Roles of Key STAKEHOLDERS IN development of Advanced technologies



Source: Frost & Sullivan

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