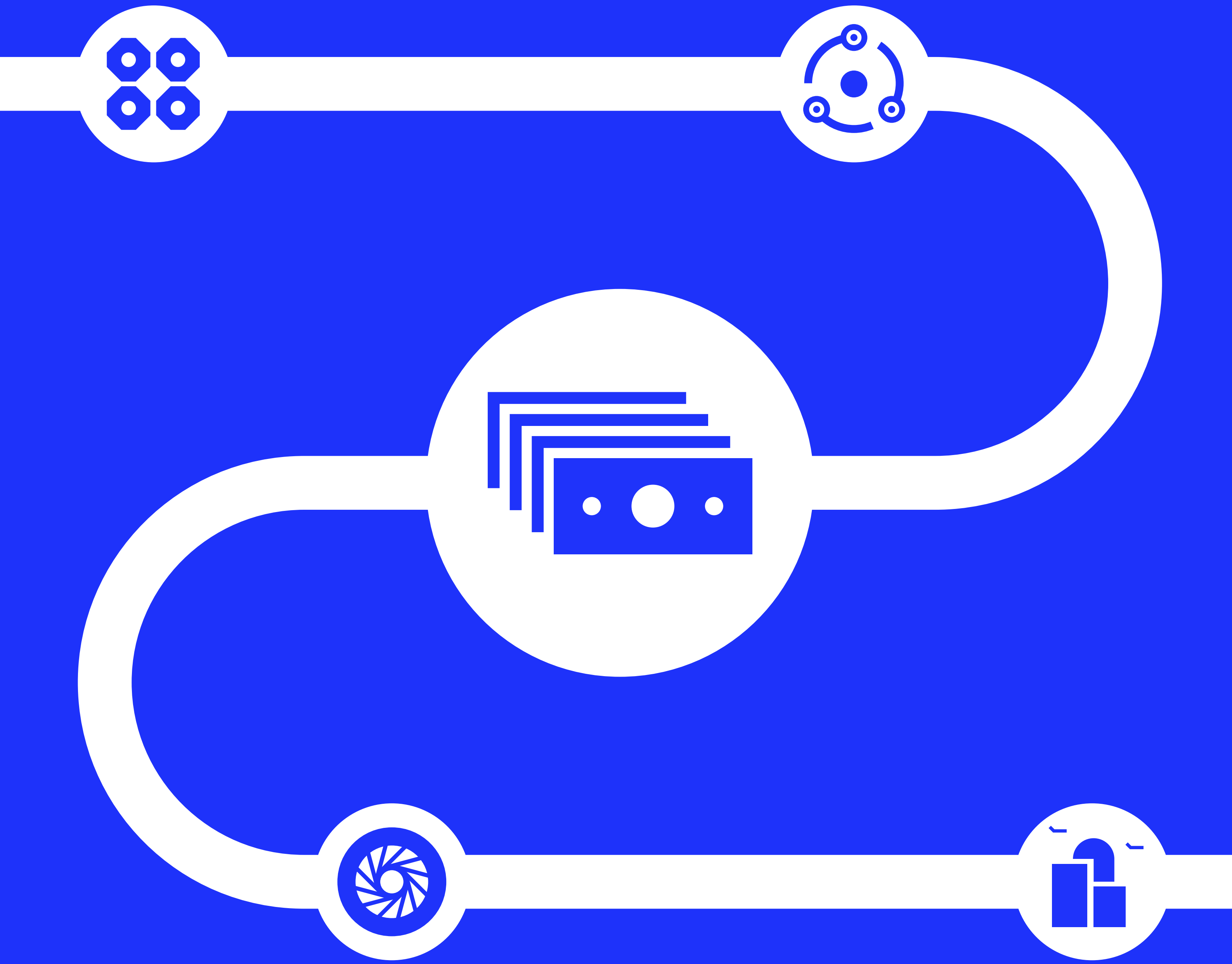
Finance
Net Zero Roadmap



Overview

IATA's Net Zero Roadmaps aim to provide greater clarity of the developments and actions needed for the airline industry to be able to deliver on its commitment to reaching net zero CO_2 emissions by 2050. The roadmaps cover aircraft technology, operations, infrastructure, policy, and finance. The first three roadmaps address the question "What do we need to reach net zero?", while the latter two tackle the question "How do we make that happen?". This Finance Roadmap outlines the key directions in which finance needs to develop to play its part in enabling net zero transition. As such, it presents:

1. The importance of enabling a sustainable future of aviation and why investment is required to reach the net zero objectives.
2. The role that various forms of funding and financing must play in the development and adoption of key technologies.
3. The gaps in funding and financing, and how these should be overcome to secure a sustainable future of aviation.

Additional detail regarding investment actors, technologies, and roadmap methodology is presented in the Appendix.

The importance of financing the aviation net zero transition

The value of a sustainable aviation future

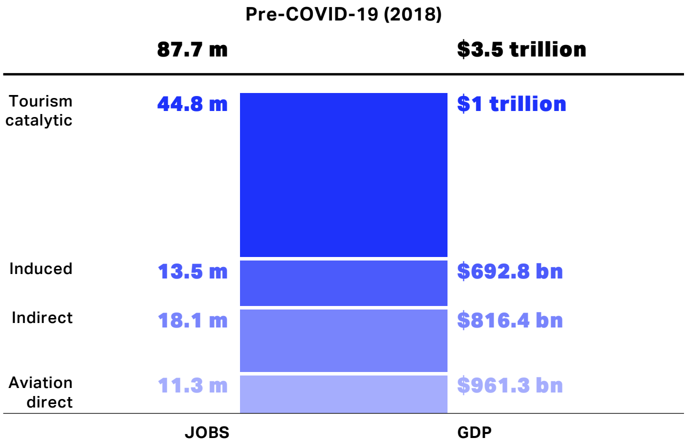
Several reports have analyzed the investment required to achieve the air transport industry's goal of reaching net zero CO_2 emissions by 2050. Estimates of the investments required to be undertaken in the 27-year period (2023-2050) amount up to USD 5.3 trillion [1] [2] [3]. This investment is necessary to ensure that aviation can continue to play a crucial role in driving economic development across the globe. Indeed, throughout economic history, advances in all forms of connectivity have helped propel economic welfare, and the poorest countries in the world are predominantly those sorely lacking in this respect, notably the landlocked countries in the center of Africa. Clearly, aviation is not sufficient to drive economic growth and development, but it is a necessary ingredient, as the COVID-19 crisis laid bare. Air Transport Action Group (ATAG) has also highlighted the contribution the air transport industry makes towards the fulfilment of 15 of the 17 United Nations' Sustainable Development Goals (SDGs), of which reducing poverty is #1.

Moreover, the IATA Value of Aviation reports [4] show that the aviation industry adds value both directly, through creating jobs within aviation and the broader value chain, but also indirectly, through connecting families, enabling businesses to grow, and making holiday destinations more widely accessible.

ATAG estimates that in 2018, aviation contributed 11.3 million jobs directly and a total of 87.7 million jobs across the aviation supply chain, and that it enabled tourism across the globe. Aviation's annual direct contribution to global GDP was estimated at almost USD 1 trillion in 2018 and is forecast to grow to USD 1.7 trillion by 2038 [5].

From an economic perspective, there is an unequivocal return on investments in a sustainable future of aviation: IATA's research found evidence indicating that a 10% increase in air connectivity, relative to a country's GDP, will boost labor productivity levels by 0.1% [7].

Chart 1: Benefits of aviation



Source: ATAG [6]

Investment needed for transitioning aviation to net zero

As mentioned above, the investments required to enable a net zero transition of aviation are up to USD 5.3 trillion [1] [2] [7][10]. For net zero to become a reality, the investment must be coordinated across the value chain, and efforts must be made to ensure that interdependent challenges are managed. Funding and financing must be available to all actors involved, with special attention to the fact that investment needs will vary across technologies and regions.

While on its own, the overall investment requirement may seem prohibitively high, it must be considered in the context of the size and value of the industry. Over the past 10 years alone, airlines have invested USD 1 trillion in R&D related to the production of more efficient aircraft [11]. The Boeing Commercial Market Outlook estimates that the overall market value of aircraft deliveries completed between 2022 and 2041 will reach USD 7.2 trillion [12]. These deliveries are set to enable the replacement of 80% of the aircraft which were in service in 2019. The IATA Technology Roadmap estimates that new generation of aircraft could be 15-20% more efficient on average than the best technology available today. NLR and SEO estimate that in Europe, aircraft replacement costs could increase by 10% to compensate for the R&D investment undertaken by suppliers [13]. Finally, ACI estimates that USD 2.4 trillion of capital investment will be required over the next 20 years in the airport infrastructure domain, to ensure long-term growth [14].

Extrapolating the March 2023 IATA Passenger Forecast into 2050 shows that between 2023 and 2050, over 200 billion passenger journeys will be enabled by aviation connectivity [15]. The strongest growth is expected in developing countries, showing the link between growing an economy and the role of air travel.

For further perspective on the magnitude of the net zero related investments needed, we can spread it over the number of passenger journeys expected during the 2023-2050 period and find that the total investments would represent up to USD 45 per journey. These investments will also generate financial returns as well as cost savings. What the net effect on ticket prices might be is impossible to state at this juncture. Nevertheless, compared to the numbers explored here and above, the size of the investment challenge appears less intimidating and much more feasible.

Funding and financing mechanisms required

Actors involved in investing in aviation's net zero transition will require access to different funding and financing mechanisms depending on the maturity of the investment opportunity. This is because the risk is the highest at the R&D stage and decreases as the commercial viability of the solution grows. An overview of the different opportunities, risks, and cost characteristics for the different stages of technology development and adoption is provided in the table below.

Table 1: Types of technology archetypes (GFANZ finance roadmap), their associated lifecycle stage and profile

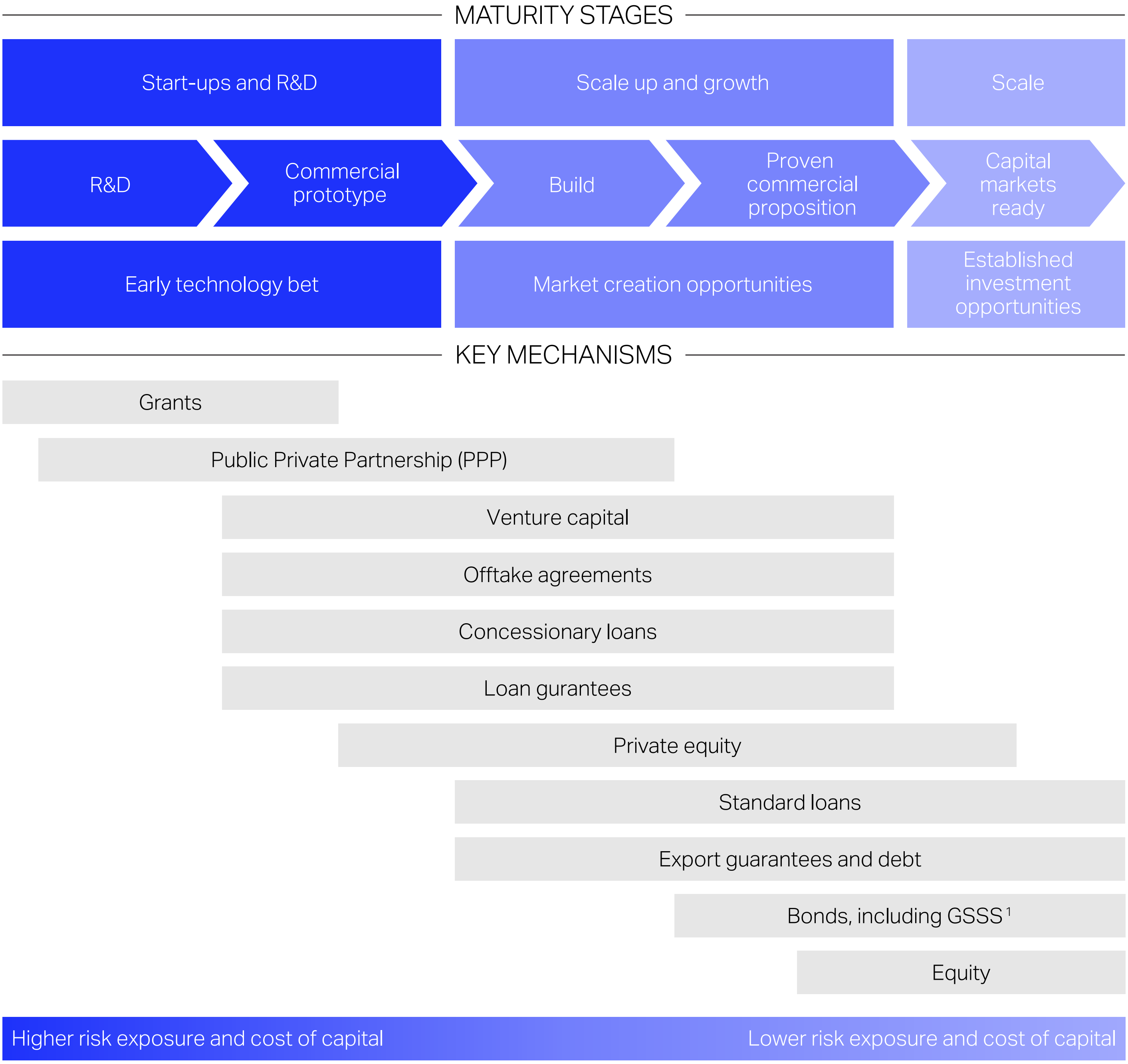
Type of technology archetype	Stages	Lifecycle stage of projects	Opportunities	Risks and costs	Finance mechanism consideration
Early technology bets	• R&D • Commercial prototype (minimum viable product)	• Start-ups and R&D	• Large return on investment possible if technology is successful	• High initial costs • High risk of project not succeeding • Early-stage projects with high business model and technology risks	• Unlikely eligibility for loan financing due to risk profile; reliance on private seed and venture capital and public grant funding
Market creation opportunities	• Build • Proven commercial proposition	• Scale Up and Growth	• Opportunities to gain the first mover advantage • Large growth opportunities	• Scale-up risks	• Involvement of government bodies to support industry in addressing market barriers • Growing involvement of private finance sector to provide loan financing
Established investment opportunity	• Capital markets ready	• Scale	• Stable growth opportunity • Stable and low risk-return on investment can be expected	• Competition risks	• Limited need for public funding/ government involvement other than to address market failures • Reliance on commercial loan and equity financing

References: GFANZ methodology [19], UK 2023 Green Finance Strategy [16]

The different risk profiles identified as the project matures give rise to the need for the involvement of different types of finance actors at each stage in order to ensure an end-to-end transition to a net zero aviation future. This roadmap covers the key mechanisms which are expected to be necessary to enable the net zero transition of aviation. In the future, new mechanisms are likely to emerge and help facilitate the transition further.

An overview of the stages of technology commercial maturity and related instruments is presented in the diagram below and shows that governments and NGOs play an important role in incentivizing R&D at the early technology development stages by providing grant funding. As technology maturity increases, the role of private sector financing grows, while that of governments fades and evolves to focusing on addressing any market failures. The role of associated mechanisms across the investment stages is presented in the subsections below.

Chart 2: Key mechanisms relevant for the aviation net zero transition technologies for each maturity stage



References: IATA's adaptation for aviation with reference to GFANZ methodology [9] and UK 2023 Green Finance Strategy [16]

1 Green, Social, Sustainability and Sustainability-linked

Financing of start-ups and R&D in aviation (early technology bet)

Risks are the highest at the earliest stages of investment projects, though if successful, the associated rewards can also be the largest. On the other hand, the project might fail, and all invested funds can be lost. Only investors with the means to tolerate that kind of risk can be involved at this early stage. With adequate support from the public sector, risk during this phase can be reduced, allowing more private investors to get involved during this phase.

There are a number of solutions which must be developed and implemented across the industry though not all industry participants might benefit from the investment. This is the case in air traffic management, for instance, where the technology often must be implemented by all actors across a wide area, but the benefits are realized in congested airspace or around busy airports. In such cases, grant funding may be required to ensure that all actors are willing to engage in the technology development and subsequent deployment. Governments are also actively supporting grant mechanisms where wide societal benefits are set to be enabled through a particular innovation, or if venture capital does not allow for the desired pace of innovation. Examples include the Clean Aviation Joint Undertaking in the European Union, Aerospace Technology Institute (ATI) in the United Kingdom, and Continuous Lower Energy, Emissions, and Noise (CLEEN) in the United States. The IATA Policy Roadmap touches on the policy framework required for such schemes, some of which have already benefited technologies mentioned in the IATA Aircraft Technology Roadmap.

The vast majority of technologies related to the aviation net zero transition are currently in the R&D stage. This includes important areas such as accelerating the development of electric and hydrogen aircraft, and novel Sustainable Aviation Fuels (SAF) production pathways (as described in Appendix D). As such, it is imperative that the commercial opportunities in the sector are advertised to venture capitalists and that governments monitor the industry for signs of lack of funding. Any delay in R&D activities will result in a shift of the planned technology uptake profiles, delaying the industry's timeline for achieving net zero.

Financing of growth of net zero aviation technologies (market creation opportunity)

At the technology market adoption stage, projects demonstrate clear commercial potential and actors involved focus on scaling up production, ensuring the solution becomes available across the globe and creating visibility of the product or technology solution to potential new customers. The importance of supply networks becomes more important while in parallel the risk profile of the project decreases. As such, private entities might at this stage be more likely to be involved in supporting the project through loan financing. Governments and public institutions must continue to de-risk also this investment phase, in order to ensure greater access to loan financing, and can play an important role in terms of reducing the cost of such funds.

Governments can create incentive mechanisms, credit enhancement mechanisms, provide concessional loans, loan guarantees, and tax credits, among others. It is vital, however, that any mechanism put in place remains technology agnostic, and allows market forces to make judgments regarding the investment proposition of specific solutions. These types of incentives are most likely necessary in order to accelerate the deployment of key aviation technologies. Guarantees are risk-reduction tools that provide credit enhancement or protect investors against capital losses. They are commitments in which a third party (a government entity) takes over (part or the entirety of) the debt obligations in the case the borrower defaults. This can vastly increase access to bank finance during a capacity-building phase of a project and can also enable more favorable financing terms.

To facilitate access to export markets, export credit agencies (ECAs) can offer a variety of support instruments including export guarantees, debt, and guarantees for overseas buyers. One ECA providing such support is the UK Export Finance (UKEF). UKEF typically backs first-of-a-kind commercial deployments, and later stage scaling-up and growth stages for technologies. For aviation, UKEF has supported Sustainability-Linked Loans (SLLs) through its Export Development Guarantee (EDG) product (such as for aircraft financing for Pegasus Airlines in January 2023).

Public private partnerships can be established, to allow the private sector to play a role in the delivery of a service which is normally the responsibility of the government. Examples of this include the provision of air traffic management in the United Kingdom.

Early market adoption considerations are currently particularly relevant for activities related to SAF production where large production and supply networks will have to be created to ensure that accessibility of the fuel is maintained. Additionally, activities around carbon dioxide capture, utilization, and storage solutions (CCUS) are vital to ensure permanent removal or utilization of CO_2 from the atmosphere (as described in Appendix D).

Financing the scaling of net zero aviation technologies (established investment opportunity)

Once a technology is proven and the supply networks established, investment is required to further innovate the solution and increase the market reach. During this market stage, the solution is considered lower risk and a stable investment return can likely be achieved. There is limited need for government intervention at this stage, other than addressing potential market failures. Financing is predominantly sourced from private sources through equity financing, bond issuance, and loan agreements.

Privately owned companies can of course continue to seek additional equity financing from their owners or other individual investors. Greater access to equity finance is afforded to publicly listed companies which stocks are traded on the stock market. This pool of funds was as large as USD 44 trillion as of March 2023, regarding the two largest exchange operators in the US (the New York Stock Exchange (NYSE) and the Nasdaq), representing 41.1% of the USD 107 trillion global equity market capitalization. However, only 11% of private financial funds were directed to emerging markets in 2014. Additionally, many companies refrain from listing on stock markets because of onerous reporting requirements and other stringent conditions. After peaking in 1996 at more than 8,000 companies, the number of domestic US-listed public companies traded on major US exchanges had declined by nearly 50% as per 2019. This decline is driven by multiple factors, including mergers and acquisitions as well as taxation, but it remains crucial for regulators to strike a balance and minimize perverse effects as they strive to facilitate the reallocation of capital that is needed for the transition to net zero CO_2 emissions. The majority of SAF producers and other firms involved in the earlier stages of the technologies necessary to bring about sustainable aviation are not publicly listed companies, and their access to this vast pool of global capital is therefore limited. The EU has recognized that the public listing process is cumbersome and costly for EU companies, and that many EU companies therefore miss out on the benefits of going public, including that of accessing a wider investor base. The EU Listing Act is in the process of being adopted and aims to simplify the listing and post-listing requirements, in order to make public capital markets more attractive for EU companies.

As the new technology progresses, issuing bonds can also become an option. Bonds are loans raised through capital markets which guarantee the repayment of the nominal amount borrowed at maturity and offers a coupon as a form of interest. Bond issuance requires a high degree of maturity of the issuing entity. Typically, large-scale infrastructure projects are compatible with bond financing when a reliable long-term return can be foreseen.

New forms of bonds have emerged that are linked to various sustainability-related achievements. These can be labelled "Green, Social, Sustainability and Sustainability-linked" (GSSS). In aviation, there are examples of green bonds and sustainability-linked bonds being issued in recent years. Examples include Etihad airline raising USD 600 million by issuing a Sustainability-Linked Sukuk (2020) [19], Korean Air raising KRW 200 billion through environmental, social and governance (ESG) bonds (2021)) [20], and British Airways' Sustainability Linked Bond raising USD 550 million (2021) [21], Japan Airlines (JAL) raising JPY 10 billion in Transition Bonds (2022) [22], among others. In the same vein we find sustainability-linked (often aircraft-secured) or use-of-proceeds loans and leases, examples of which include Braathens Regional Airways AB/Avation PLC aircraft financing through a Green Loan (2019) [23], Air France KLM raising a Sustainability-Linked aircraft-secured Loan (2022) [24], and Crianza Aviation's Sustainability Linked Operating Leases (2022) [25].

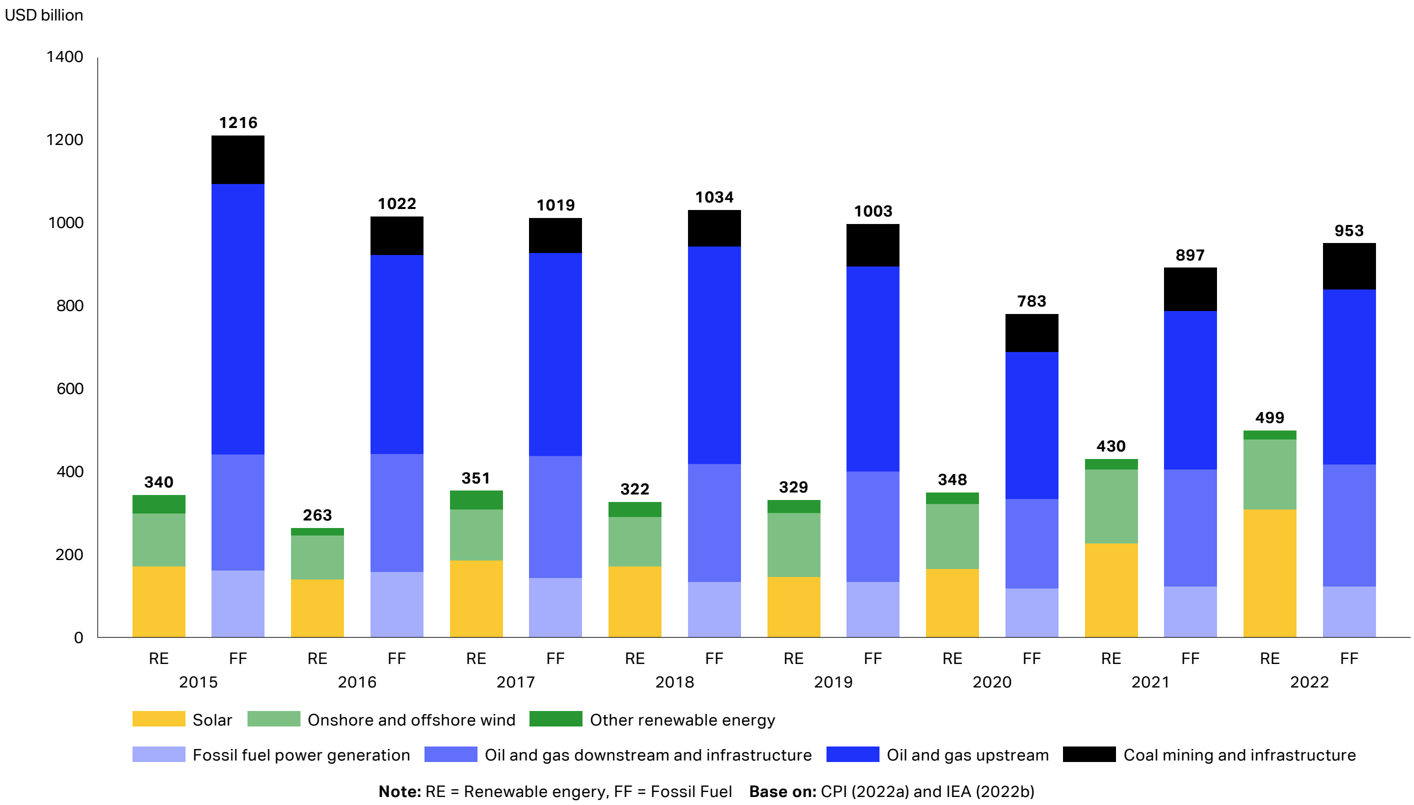
Conclusion

As discussed above, the higher end of estimated investments needed for aviation's transition to net zero CO_2 emissions on the 2050 horizon is USD 5 trillion. This equates to USD 178.6 billion per year from 2023 to 2050. Nearly a third of this funding could be achieved if current subsidies favoring fossil fuel producers could be redirected to the production of sustainable aviation fuels, as governments spent 55.6 billion per year on such fossil fuel subsidies over the years 2010-2021 [8]. This was also the share of public investments in total global investments in renewable energy over the years 2013-2020, while that from private sources was 67% [17].

More than three times the entire annual funding needed to achieve aviation's transition, a total of USD 570 billion, is estimated by the International Institute for Sustainable Development to be allocated to new oil and gas development and exploration every year until 2030. Amounts similar to those needed in aviation were invested in solar and wind energy between 2015 and 2022, according to the International Renewable Energy Agency (IRENA) and Climate Policy Initiative (CPI) (see Chart 3). These two industries employed 12.7 million people worldwide in 2021, according to the ILO, which compares to the 11.3 million people directly employed in global civil aviation.

Seen in this light, the necessary transformation in aviation seems possible. The investment needs to make aviation sustainable are certainly significant, but do not seem disproportionate, neither in relation to the public support enjoyed by the fossil fuel industry, nor in relation to the private investments allocated to fossil fuels, nor compared to other sustainable sectors.

Chart 3: Annual investment in renewable energy versus fossil fuels, 2015 – 2022

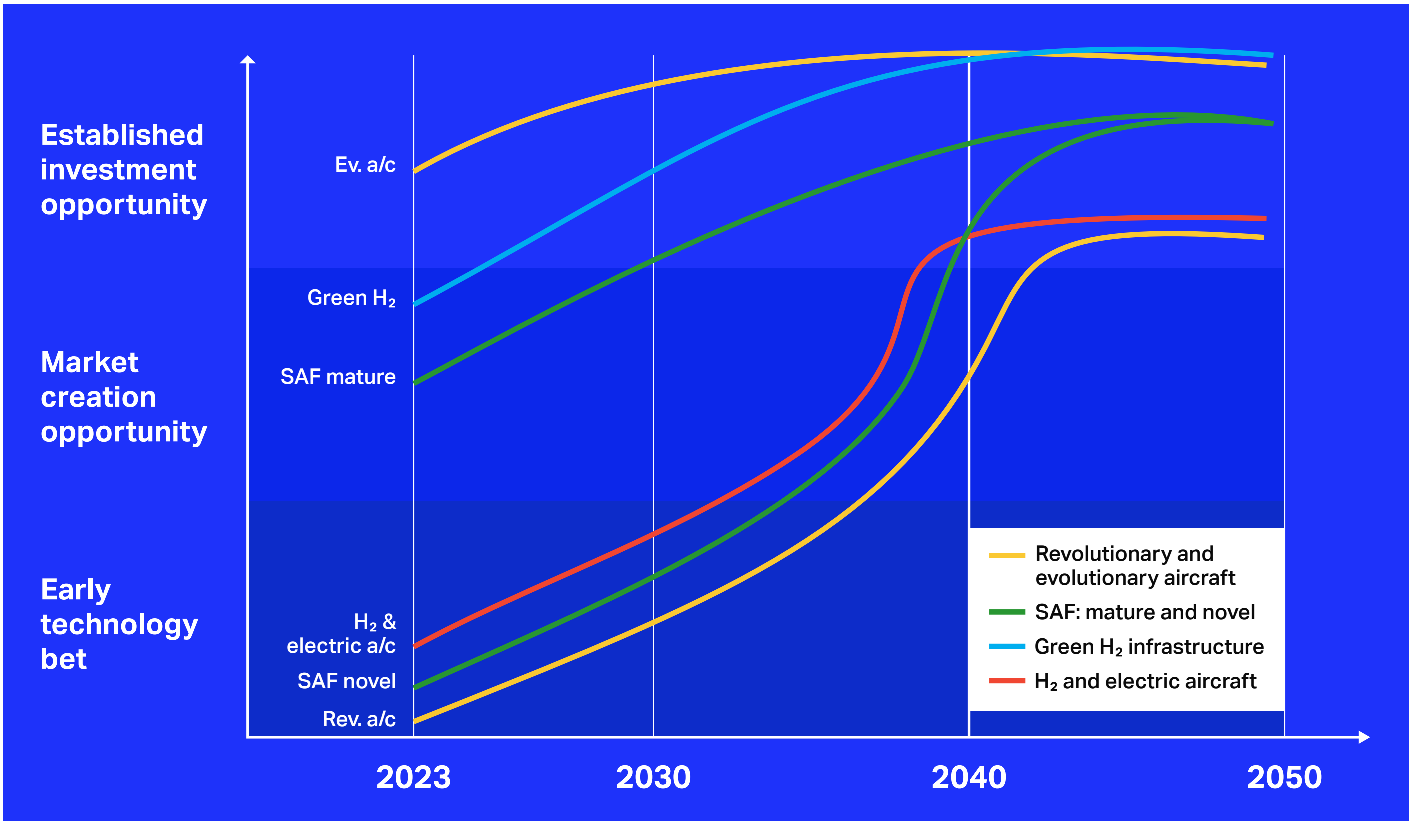


Sources: IRENA and CPI. Global landscape of renewable energy finance, 2023, International Renewable Energy Agency, Abu Dhabi

Clearly, the world is finding it difficult to bring about the reallocation of global capital, be it public or private, that is needed for the global task of decarbonizing the world economy. One important step on the way is to gather more data and to agree on harmonized and standardized metrics. While such efforts are necessary and valuable, they do not by themselves change behavior. It is not because we know how to calculate GDP that we bring about GDP growth.

There is no doubt that government support measures will have to be implemented to attract the kind of private capital that has benefitted the development of renewable energies such as wind and solar. This is particularly important during the early stages of bringing a new technology to market. While the need for public funds and support is therefore likely the greatest between now and 2030, the absolute amounts are in all probability more limited on that horizon (Chart 4). Most of the funds can be expected to be required during the 2030-2040 period when the scaling up of production and the development of market opportunities occur. Earlier public support should pave the way for the private sector to meet this need, and the share of public support of the total will likely wane over this period. One can even imagine a rush among private investors and institutions to these technologies, maybe during the latter half of that decade, as the true commercial opportunities and profit potential start to become apparent. Past 2040, the technologies will have for the most part matured enough to be able to rely on traditional capital market finance, and investment needs will be more tied to incremental improvements, supported by reliable revenue streams.

Chart 4: Average commercial maturity progression milestones for key emerging net zero aviation technologies



Source: IATA Sustainability and Economics

It is not the sums of investment capital needed that are the most intimidating in the context of the net zero aviation transition, but rather the speed at which they need to be mobilized, in aviation as in all industries, if the world is to achieve anything near the limits on global warming expressed in the Paris Agreement. Delay in mobilizing the financing will of course delay the bringing of the solutions to market, and push net zero emissions in aviation (and other industries) out beyond the 2050 targeted timeline. With early government support, such an outcome can be avoided.

In essence, governments need to:

- Advance technologies which enable the progressive elimination of CO_2 and non-CO_2 emissions in air transport.
- Remain technology agnostic.
- Engage all types of financial institutions, from supra-national to local, public and private, in the financing effort.
- Address regional disparities regarding the allocation of investments.
- Mitigate risks to attract private investors, notably in the early stages of development.
- Facilitate more capital market investment.
- Create mechanisms for pooling private and public finance.
- Create facilities dedicated to scaling up investments.

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Appendix

Appendix A: Key financial actors per commercial maturity stage of project

Table 2: Key financial actors per commercial maturity stage of project

Type of financial actors	Main areas of activity	Lifecycle stage of projects & enterprises	Examples
Governments Government Donor agencies (DAs) State-owned financial institutions (SOFIs) State-owned enterprises (SOEs)	• Limited supply of finance to approach market weaknesses • Donor agencies: official development assistance (ODA) or other mechanisms	• Start-ups & R&D	• Donor agencies: USAID, GIZ, UK DFID
Development finance institutions (DFIs)	• Loans, technical assistance, policy advice	• Start-ups & R&D • Scale Up & Growth	• IMF, WB
Multilateral development banks (MDBs)	• Infrastructure development and thematical investments		• African Development Bank, Asian Development Bank, Inter-American Development Bank
Export Credit Agencies (ECAs)	• Support instruments including export guarantees, debt, and guarantees (for overseas buyers)	• Scale Up & Growth • Scale	• UK Export Finance, EX-IM US

References: GFANZ methodology [9], WEF/OECD [18], ATAG [17], UK strategy

Appendix B: Examples of financing needs

Table 3: Examples of the financing required across the value chain for aviation to reach net zero carbon emissions by 2050

Types of financing needs	Examples of financing needs
Aircraft technology and efficiency improvements	• Bring new aircraft, engines, and supporting technologies (batteries, hydrogen storage, etc.) to a demonstrated functional level • Develop the infrastructure and procedures to industrialize and certify new aircraft architectures, engines, and systems • Purchase and operationalize new aircraft (training of flight and cabin crews, maintenance, ground handling, etc.) • Research the impact of non-CO_2 aviation emissions • Install fixed electrical ground power at airport gates • Deploy new air traffic management (ATM) technologies and airspace infrastructure design
Infrastructure for new fuels and energy carriers	• Build-up and scale-up sustainable aviation fuel (SAF) production and blending facilities • Mature research on new SAF feedstocks and pathways • R&D into infrastructure for new energy and fuels, particularly pursuing efficiency gains • Build hydrogen (H2) infrastructure to support SAF and as well as liquefaction facilities for LH2 powered aircraft • Build infrastructure for carbon capture to produce SAF and for carbon removals • Build airport infrastructure including new distribution systems for green electricity and hydrogen for airport use and aircraft supply
Carbon capture technologies	• R&D into carbon capture technologies focused on improving efficiency • Invest into offsetting opportunities such as forestry, natural carbon sinks, as well as novel approaches including carbon capture or direct air capture technology and bring such solutions to maturity and to market

References: ICAO LTAG report, ATAG Waypoint 2050

20 Glasgow Financial Alliance for Net Zero (GFANZ). Net Zero Financing Roadmaps, methodology. 2021.
21 Organisation for Economic Co-operation and Development (OECD), Word Economic Forum (WEF), Blended Finance in the Private Sector Context.
22 Air Transport Action Group (ATAG). Briefing blended finance. 2023.

Appendix C: Roadmap methodology

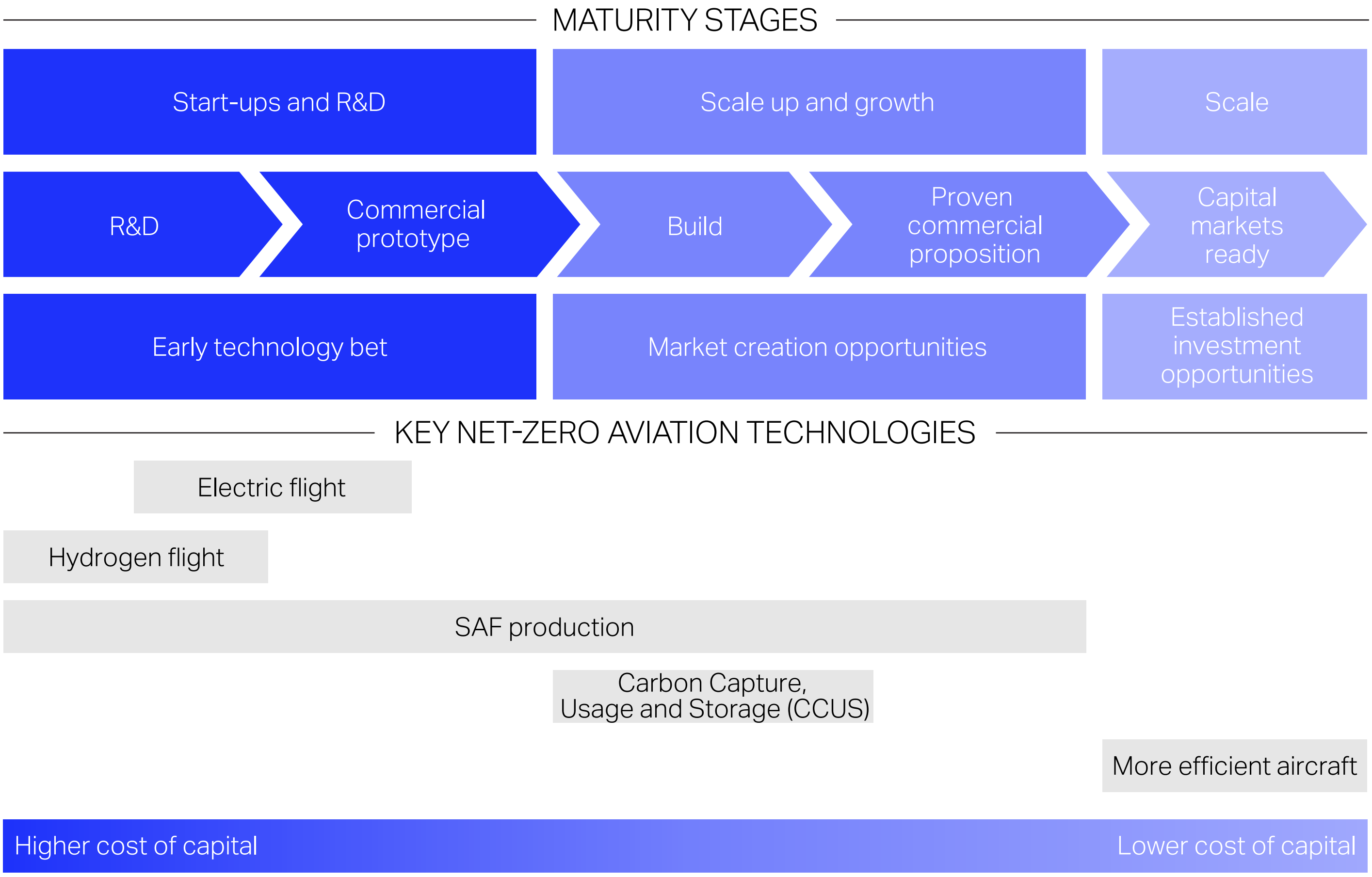
This Finance Roadmap follows the Glasgow Financial Alliance for Net Zero (GFANZ) Finance Roadmap Methodology [9] to set out the framework around financial actors, financing types, and technology archetypes[2]. GFANZ is the largest coalition of financial institutions globally with the aim to "coordinate efforts across all sectors of the financial system to accelerate the transition to a net zero global economy"[3]. GFANZ brings together sector-specific Alliances[4], joined by many of the most important aviation value chain financial institutions.

This roadmap was shared with experts from the investment and financial community, as well as industry actors, through direct engagements between IATA and individual organizations.

Following the GFANZ Finance Roadmap Methodology, there are two types of financing actors: public and private. Public financing actors include governments, state-owned enterprises (SOEs, e.g., state-owned airlines and airports), state-owned financial institutions (SOFIs, e.g., state-owned banks, etc), development finance institutions (DFIs), multilateral development banks (MDBs), and multilateral climate funds (MCFs) important public institutions that play a role in financing include Export Credit Agencies (ECAs). Private financing actors include corporations (e.g., airlines, aircraft manufacturers, airports) commercial financial institutions (e.g. banks), private equity and venture capital funds, institutional investors (e.g. pension funds, insurance companies, sovereign wealth funds), infrastructure funds, NGOs and philanthropic investors, and households and individuals.

Appendix D: Funding and financing needs across technologies[5]

Chart 5: Commercial maturity of key aviation technologies for decarbonization (snapshot)



References: IATA's adaptation for aviation with reference to GFANZ methodology [9], UK 2023 Green Finance Strategy [16]

2 Considerations and assumptions of the GFANZ Methodology include for the private sector the hypothesis that investment decisions are primarily made based on risk-return consideration, while for the public sector the constraints on the funding can be allocated to decarbonization given other policy priorities.
3 Launched in April 2021 by UN Special Envoy on Climate Action and Finance Mark Carney and the COP26 presidency, in partnership with the UNFCCC Race to Zero campaign.
4 Net Zero Asset Owner Alliance (NZAOA), Net Zero Asset Managers initiative (NZAM), Paris Aligned Asset Owners (PAAO), Net Zero Banking Alliance (NZBA), Net Zero Insurance Alliance (NZIA), Net Zero Financial Service Providers Alliance (NZFSPA), Net Zero Investment Consultants Initiative (NZICI).
5 Infrastructure for SAF, hydrogen and electric aircraft, as well as carbon capture would fall under the "market creation opportunities" archetype until further information becomes available on the commercial maturity of the projects involved.

Example of early technology bets in aviation: New fuels and energy carriers: Hydrogen, electric, and novel SAF pathways

Following the description in Table 1, electric and hydrogen aircraft technology fall under the "early technology bet" archetype. Such projects have not reached commercial viability and attracting capital is difficult given the high start-up costs, unproven business models, and elevated technology risks. Given the long aircraft life cycle and the slow implementation of technological changes, the risk is elevated that investments are overtaken by developments and thus fail to generate the returns on investment originally anticipated. Such assets can become "stranded", i.e. inoperable or of low value. While this is of great concern to investors, protecting their interests poses a risk of technology lock-in, where investments in the early stages of low-carbon technology development prevent the adoption of newer and better potential technologies in the future. For instance, significant investment in electric aircraft might prevent investments in other emerging technologies, such as hydrogen, though the latter could maybe make a greater contribution to decarbonization. Additionally, investors could seek better risk return opportunities that are less capital intensive. To mitigate the financing risks and lower the development costs, public support would be needed. It is critical that any mechanism put in place remains technology agnostic, and supports broad range of low-carbon technologies, as well as maintain flexibility in regulatory frameworks to adapt to new and emerging technologies. In practical terms that support could involve research and development, demonstrators, loan guarantees, commercialization funding, demand-pull policies, and the building of infrastructure to facilitate the development and distribution of new technology products.

Similarly, many novel SAF productions pathways have not been demonstrated at scale. Investment to advance the research and development regarding conversion pathways, and to build full-scale demonstrator plants is still required. Several feedstock sources still have a very low readiness index. This combination of having low technology maturity and low feedstock maturity entails great financial risk. Virtually all the SAF which is available today is produced by refining Hydrotreated Esters and Fatty Acids (HEFA), such as waste fats, oils and greases vegetable oils, waste fats, or greases (also known as 2nd generation feedstock) into SAF. This is equally reflected across capacity projections out to 2030, which estimates that over 80% of SAF output [18] between now and the end of the decade will be derived via the HEFA pathway[6]. However, with 2nd generation feedstock facing impending supply constraints, associated with the limitations of wastes derived from human demand cycles, it points to a broader need and inevitability behind the diversification of SAF production pathways and feedstock. In turn, there is an urgent need for both the scaling of emerging production pathways and the fast-tracking of new technologies pursuing industry certification.

Example of market creation investment need in aviation

Mature SAF production pathways

Mature SAF pathways, such as HEFA today, fall under the "market creation opportunities" archetype because the production technology is viable, and its commercialization is already under way. However, the net zero transition of aviation will require vastly increased volumes of SAF by 2050. This creates a major scaling up challenge which is exacerbated currently by under-developed feedstock, markets, market infrastructure, and a fragmented policy landscape. All these factors are contributing to maintaining the cost of SAF significantly above that of petroleum-based jet fuel. To overcome the specific challenge of attracting investment into this field, policies need ensure that the competitive landscape encourages new entrants, and offers favourable conditions which could include loan guarantees, tax credits, adapted amortization, various price-stability mechanisms. Government support for scaling-up of SAF production will be particularly required in emerging economies, as only 11% of private financial funds were directed to emerging markets in 2014[7].

Emerging SAF production pathways (AtJ & FT)

Whilst emerging SAF production pathways like Alcohol-to-Jet (AtJ) and Fischer-Tropsch (FT) can also be classified under the "market creation opportunities" archetype, they do require separation from HEFA, given their lack of commercial scaling. Critically, these production pathways already hold technological viability, as they have received American Society for Testing and Materials International (ASTM)[8] approval as a drop-in SAF solution. However, whereas HEFA refineries often can be converted out of previous refining infrastructure (thereby reducing capital expenditure), AtJ and FT refineries will need to be built from scratch and will almost always be a first of that production pathway for a given country. In turn, this creates a high level of required up-front investment, which often cannot be met by the producer alone; thereby placing a high importance on government investment or funding, as well as in an ideal circumstance, airline backing by way of an upfront, long-term offtake agreement.

Positively, once the high capital expenditure is accounted for amongst these AtJ and FT projects, they will likely be associated with lower operational expenditure, noting these pathways tend to leverage third generation feedstock. As inputs that are either naturally/abundantly occurring wastes or cultivated on otherwise compromised land, third generation feedstock have lower intrinsic values and therefore tend to be sold for lower prices, relative to a constrained supply sets like second generation. Moreover, given that when these feedstocks are aggregated or cultivated the process tends to have associated environmental restoration or regeneration properties associated, it therefore leads to the possibility of attracting nature-repair or biodiversity credits, of which are anticipated to become more prominent in financial markets over the coming decade. This in turn points to the fact that SAF production pathways (not limited to AtJ and FT) that can leverage third generation feedstock, have the best ability to future proof themselves from a bankability and policy-resilience perspective.

6 For more details of HEFA, refer to the other IATA Net Zero Roadmaps.
7 Organisation for Economic Co-operation and Development (OECD), Word Economic Forum (WEF), Blended Finance in the Private Sector Context.
8 For more details on this approval process, refer to the Policy Roadmap.

Emerging Feedstock Conversion Technologies

Finally, certain feedstock conversion technologies can also fall under the "market creation opportunities" archetype, as they themselves are mature processes, that are on the precipice of receiving industry certification. Such conversion technologies have the ability to transform a feedstock into an intermediary product such as a synthetic gas or a bio-oil, with that intermediary then becoming viable for a production pathway that the original feedstock will have ordinarily not been compatible with. This is specifically relevant in the context of taking globally abundant feedstocks like solid forestry and agricultural wastes, or even wet wastes and sewerage, and transforming them into compatible feedstock for HEFA refineries. If the technological challenges can be overcome, feedstock conversion technology has the potential to both expand the viable feedstock pool expand for HEFA, thereby foregoing the need to build alternative and expensive refining infrastructure, but it also benefits from accessing feedstocks with lower associated operational costs of production.

Carbon Capture, Usage and Storage (CCUS)

Carbon Capture, Usage and Storage (CCUS) technology can be considered under the "market creation opportunities" archetype, though it is still in the early stages of proving its commercial viability. This technology has important use cases. It can remove residual CO_2 from the atmosphere and store it permanently. It will be necessary in the process of generating SAF from atmospheric CO_2 capture, and it can neutralize the residual CO_2 footprint of the SAF manufacturing processes. In order to attract sufficient investment capital into this technology and allow the market to develop, public support similar to that outlined under the SAF production sections above will be needed.

Example of market creation investment need in aviation

The transition to the best-in-class aircraft technology available today, though underway, still has some considerable distance to cover, as discussed in our Aircraft Technology and Infrastructure Roadmap. The ongoing fleet replacement which sees, for example, many Airbus A320s being replaced by A320neos, and Boeing 737s by 737-Max, will provide a reduction in in-flight energy use. Recent technology assessments for evolutionary aircraft predict that future aircraft can deliver another 15-20% improvement in energy efficiency compared to the best technology available today. These gains will come through the introduction of more efficient engines, lighter materials, and improved aerodynamics.

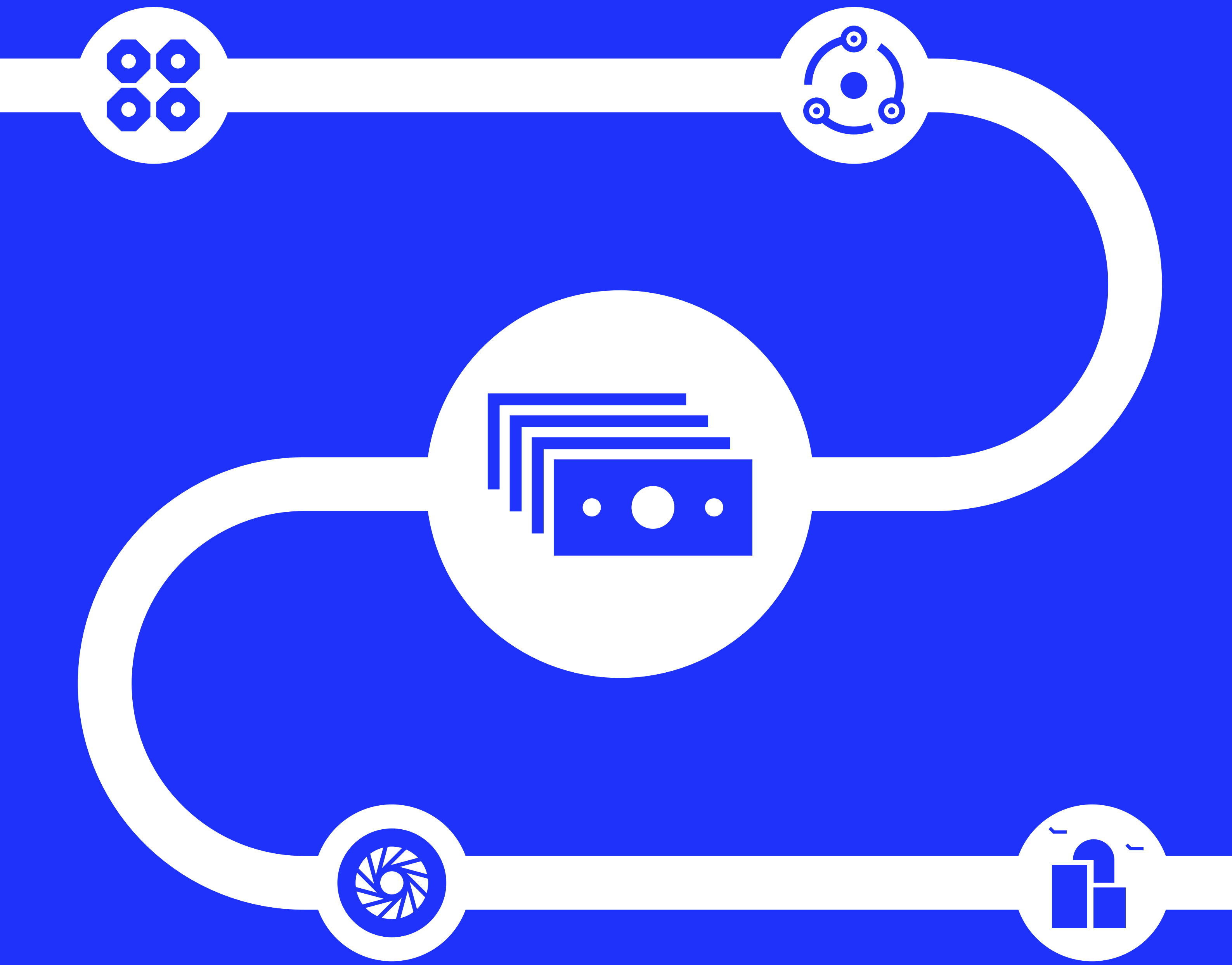
These evolutionary efficiency gains are expected to be delivered mostly by well-established aircraft original equipment manufacturers and the companies that support them, and as such fall under the "established investment opportunities" archetype. Accelerating their development would benefit from regulatory and planning environments in order to facilitate investment and technology uptake.

Appendix E: Examples of existing sustainable financing opportunities

Table 4: Examples of sustainable financing opportunities

Financial Institution	Financing amount	Financing focus
Bank of America	$2bn	Production of SAF and other low-carbon aviation solutions
UK Government (Green Fuels, Green Skies competition and Advanced Fuels Fund)	£2.4m £11m	Commercial scale plant converting black bin bag waste into sustainable aviation fuel (Alfanar Energy)
First Abu Dhabi Bank	$75bn	Aviation/SAF key topic in commitment for sustainable financing
Banque de Montreal	$60m	Bio energy, CCS and hydrogen are eligible sectors (sustainable financing guarantee programme sharing 50% of the risk on loans)
Asian Development Bank	$4.5bn	Renewable energy projects (Non-sovereign finance window in 2020 to stimulate private sector investments, 25% of project cost coverage)
Green Climate fund	$11.3bn	Energy and transport projects (range of financing instruments)
Brasil Development Bank	R$80m	Clean energy investments (Climate Fund- low interest rates and a ceiling)
Green Investment Group	$30bn	Green energy projects

References: ICAO, UK 2023 Green Finance Strategy



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