In collaboration with
Aviation Environment Federation

Target True Zero:
Government Policy Toolkit to Accelerate Uptake of Electric and Hydrogen Aircraft

WHITE PAPER

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Foreword

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Last year, the assembly of the UN's International Civil Aviation Organization agreed to set an aspirational goal of net-zero emissions by 2050, reinforcing targets and commitments made already by both industry and individual states for the sector. While net zero provides a common goal for aviation, it comes with a recognition that this sector is likely to be one of the hardest to abate. Most stakeholders agree that meeting this challenge will require a broad approach, encompassing both operational efficiencies and changing the ways we fuel flight.

This debate has seen the emergence of pioneering new concepts and technologies that have the potential to deliver zero-emissions aircraft. To realize this potential requires more than solving the engineering challenge. States have a crucial role to play in helping support the research and development of battery-electric and hydrogen-powered aircraft technologies. And – once these innovations are ready to enter into service – states must also ensure a level playing field and appropriate policy measures to encourage their uptake. Developing the right regulatory frameworks will touch on several policy areas and considerations, including the interactions between aviation, energy and industrial strategies.

This policy toolkit – created by the World Economic Forum and the Aviation Environment Federation, working together with other knowledge partners and stakeholders as part of the Target True Zero initiative – is designed to support governments in formulating their strategies. It provides a guide to setting and enabling a strategy, as well as summarizing a wide range of approaches to implementation. The work has been informed by early experiences of partnerships, collaborations and strategies in this field, as well as from lessons learned in other sectors.

The aim of this toolkit is to provide governments with both the opportunity and the options to help develop approaches towards accelerating the development of zero-emissions aircraft technologies as part of an overall decarbonization plan for the sector.

Executive summary

Policy-makers can accelerate the uptake of battery-electric and hydrogen aircraft through framing strategic goals and forward-looking policies.

To address the sector's contribution to climate change, the UN's International Civil Aviation Organization (ICAO), member states and the global industry have collectively committed to achieving net-zero carbon dioxide emissions by 2050. The additional climate impact from non-CO_2 effects, such as contrail formation, also presents an important challenge. Reducing these impacts requires a broad mix of operational and policy tools alongside new technologies and fuels, including the potential for innovative technologies such as battery-electric and hydrogen propulsion.

This government policy toolkit from Target True Zero focuses on the role that policy can play in helping realize the potential for battery-electric and hydrogen aircraft. As each country's circumstances will differ, it does not recommend specific policies that countries should adopt. Instead, the toolkit identifies three areas where governments can take action on alternative propulsion.

Frame a net-zero aviation strategy. A good foundation for setting a strategy is understanding a state's market segments, the size of aircraft typically serving those markets, airport infrastructure and the future supply of, or potential for, renewable electricity or hydrogen. Defining goals and intermediate milestones for battery-electric and hydrogen propulsion, based on these insights, can help governments set up a successful strategy to attract investors and spur industry action by reducing uncertainty. Building partnerships with all stakeholders, both nationally and internationally, can help to accelerate progress by identifying and establishing priority areas for policy development, as well as facilitating the development of blueprints and communication strategies.

Goals and strategies, including interim milestones, should be well defined and should set out applicable sustainability criteria to guide progress and investment. Aviation strategies should also be aligned with economy-wide plans that states may have to transition to a hydrogen economy, to develop battery production facilities, and to increase the supply of renewable energy infrastructure.

Create an enabling environment. As well as supporting ICAO initiatives, governments can facilitate the adoption of alternative propulsion by taking steps to support the development and deployment of battery-electric and hydrogen-powered aircraft through research and development activities. It is also important for governments to ensure access to the required infrastructure at airports.

Additionally, governments should review and, if necessary, update their regulatory frameworks to ensure they are technology-neutral and do not present unintended barriers to the introduction of alternative propulsion aircraft. This includes reviewing certification standards and airworthiness requirements. International collaboration can help accelerate progress, share learnings and harmonize key aspects such as approaches to certification.

Policy measures to accelerate uptake. Policy measures should be designed to encourage a rapid uptake of alternative propulsion technologies. Before implementing policies, states are encouraged to undertake an assessment of the costs and benefits, and to ensure that any requirements are technically feasible and proportionate given the capital investment in existing aircraft and the lead time necessary to take delivery of new orders.

Financial measures can help address the cost differentials for operators and increase competitiveness when adopting newer technologies. Examples include subsidies for green hydrogen and renewable electricity, low-interest loans to help with purchase costs, levies and market-based measures on fossil fuel products, as well as the structuring of fees for airport and navigation services.

Mandates and restrictions can help accelerate technology transfer by requiring the use of certain technologies or encouraging a shift away from more polluting technologies. States could also consider how "ecolabelling" might help to create public awareness and consumer demand for lower-emissions alternatives.

1 Introduction

Governments can play a key role in net-zero aviation through creating the right strategies, mandates and incentives.

Focus on battery-electric and hydrogen-powered aircraft

In 2019, global civil aviation (both international and domestic) emitted between 900 and 1,000 million tonnes of carbon dioxide (CO_2). Air traffic is expected to reach similar levels again by 2024, once the industry has fully recovered from the impact of the pandemic. On its current trajectory, aviation's demand for fuel and its contribution to climate change look set to double or even triple by 2050.

In response to this reality, the UN's International Civil Aviation Organization (ICAO) and the global industry have committed to ambitious goals for decarbonizing flight, setting net-zero by 2050 targets. But as if this were not challenging enough, CO_2 emissions are not the only concern the industry has to address. The latest scientific assessment concluded that, based on historical activity, aviation's non-CO_2 effects – notably from emissions of nitrogen oxides and the formation of contrails – were responsible for roughly double the climate-warming impact of aviation's CO_2 emissions.[1]

With net-zero goals agreed by both governments and industry, the focus is turning to how these can be delivered. Sustainable Aviation Fuels (SAF) have emerged as the key technology for addressing emissions now and in the medium term. Made from biomass, waste or synthetic sources, SAF can be used in existing aircraft to reduce lifecycle emissions. The potential for new, more radical alternative propulsion technologies, such as battery-electric and hydrogen, is also being pursued.

“ Aviation's non-CO_2 effects – notably from emissions of nitrogen oxides and the formation of contrails – are responsible for roughly double the climate-warming impact of aviation's CO_2 emissions.

To help build consensus around the role that these alternative propulsion technologies can play in decarbonizing the sector, and to accelerate the development and deployment of key aircraft technologies, the World Economic Forum – in conjunction with the Aviation Environment Federation, the University of Cambridge's Aviation Impact Accelerator and McKinsey & Company – has established the Target True Zero coalition to bring together key leaders in this space, complementing the work of the Forum's Clean Skies for Tomorrow coalition to scale-up the use of SAF by the industry.

This white paper, building off Target True Zero's previous work examining the technological and infrastructure questions associated with battery-electric and hydrogen aircraft, focuses on the role that policy can play in helping realize the potential of these aircraft to decarbonize the sector. Specifically, this report presents a government policy toolkit designed to help states understand the measures they can put in place that will allow battery-electric and hydrogen aircraft to support the industry's overall global goals, as well as additional national goals they may have.

Toolkit of national policies to accelerate alternative propulsion

The policy toolkit presented in this report has been produced by the Forum's Target True Zero initiative and the Aviation Environment Federation, a UK-based environmental NGO campaigning both nationally and internationally to reduce aviation's impacts on people and the environment. The contents of the toolkit reflect the outcomes from a series of Target True Zero workshops that brought government and industry participants together to understand the challenges that battery-electric and hydrogen aircraft currently face or are expected to face in the future, and to explore how support from governments could help address these challenges.

The toolkit draws on examples of policy mechanisms from related areas, such as SAF supply and demand, that can be applied to alternative propulsion. There may be examples of policies in other areas, such as those used to promote electric vehicles (EVs), that could also be adapted for these goals.

This report focuses on high-level policy options that states can consider to support the development and adoption of alternative propulsion technologies. It does not consider technical issues such as air-worthiness requirements or make specific recommendations about fiscal policies. Nor does it address the need for policies to support renewable power or hydrogen capacity and infrastructure more broadly, although these are critical considerations for scaling-up alternative aviation propulsion. Policy-makers should undertake appropriate analysis and impact assessments to develop specific policies to meet their own goals in line with their established processes.

Three priority areas of action for governments

There are three parts to this policy toolkit, detailed in subsequent chapters, that highlight the role of governments in accelerating alternative propulsion aircraft along their trajectory:

1 **Frame a net-zero aviation strategy:** All countries should develop a net-zero aviation strategy and understand the role that battery-electric and hydrogen aircraft can play within this strategy.

2 **Create an enabling environment:** Consider the steps needed to deliver this strategy. Depending on a country's individual circumstances, this could include supporting the research and development (R&D) of new technologies, reviewing regulations and mandates, investing in infrastructure and supporting the aviation industry to make the changes needed.

3 **Policy measures to accelerate uptake:** Implement measures to accelerate the uptake of alternative propulsion technologies once they have entered service – for example incentives, tax breaks, targets, mandates and public awareness.

The first two areas of action can be informed by lessons learned from the existing and ongoing work of some trailblazing governments. Most states are not yet at the uptake stage, so this third part of the toolkit will be largely forward-looking, but includes lessons learned from policies applied to other areas, such as the EV sector.

Important information about this toolkit

This policy toolkit is designed to provide governments with the information they need to decide how to support the development and adoption of alternative propulsion aircraft. This report does not seek to recommend specific policies that countries should adopt. Each country's circumstances will differ, and governments will need to identify which policies can help them best achieve their goals, including through consultation with their stakeholders.

Some governments – including those that contributed to this work – may or may not agree with all of the measures included in this toolkit. Even when states agree with the overall goals of a particular policy, there will be a variety of possible approaches to implementation that have different costs and benefits. This toolkit is intended to provide information on the range of ways that states can achieve their goals.

Nevertheless, some of the examples provided in this toolkit have been implemented or are actively being considered. It is important to share these examples to help policy-makers to understand the benefits, costs and implications of these approaches, as well as to consider whether other options may be more suitable for their particular circumstances or goals.

This toolkit aims to look at different approaches from both stakeholder and policy-maker perspectives and to help states identify the inputs they require to develop an industry- and stakeholder-wide perspective on these issues.

1

Frame a net-zero aviation strategy

Delivering net-zero aviation by 2050 requires states to frame strategies suited to national circumstances.

Key considerations

Policy-makers should consider the following questions when determining how alternative propulsion can contribute to their overall aviation decarbonization efforts:

- What emissions reductions are being aimed for and by when?
- Are goals and targets for alternative propulsion aligned with wider national policies covering energy production and industrial strategy?
- How are non-CO_2 emissions considered?
- What resources does a particular country or region have that will enable decarbonization of its aviation sector?
- What domestic and international route networks currently exist, and which technologies will be most suitable for decarbonizing these flights?
- Should goals be technology-agnostic or drive progress on defined technologies?
- Who are the relevant stakeholders that will be affected and what opportunities are there to work together?

1.1 Decide strategy and pace of change appropriate to national context

National policies must build on net-zero goal of ICAO

ICAO's long-term goal of net-zero international aviation by 2050 does not attribute specific emissions reduction goals to individual states.

ICAO clarifies its agreement on a "long-term global aspirational goal" (LTAG) for international aviation of net-zero carbon emissions by 2050 as follows:

"The LTAG **does not attribute specific obligations or commitments** in the form of emissions reduction goals to individual States. Instead, it recognizes that each State's **special circumstances and respective capabilities** (e.g., the level of development, maturity of aviation markets, sustainable growth of its international aviation, just transition, and national priorities of air transport development) will inform the ability of each State to contribute to the LTAG within its **own national timeframe**. Each State will contribute to achieving the goal in a **socially, economically and environmentally sustainable manner** and in accordance with its **national circumstances**."[2]

Therefore, while the LTAG provides a global framework and context for decarbonizing international aviation, and ICAO more generally has an important role to play in setting standards and recommending practices to facilitate cooperation between states, it does not impose particular reductions that individual states must achieve. Indeed, ICAO does not classify itself as a regulator and the majority of ICAO decisions need to be incorporated by states into national legislation to have legal effect. ICAO also has no influence over state-level fiscal policies that could unlock the potential for decarbonization efforts; nor does it take responsibility for domestic aviation, which accounted for 58% of global civil aviation passenger numbers in 2019.[3]

Consequently, there is a role for national policies and support that build on ICAO's efforts and that determine how and when individual states will reduce their emissions. For some countries whose aviation sectors are still growing, reaching net zero within this timeframe may not be possible. Meanwhile other countries that are expecting less growth may look to decarbonize all or part of their aviation sectors sooner. So in addition to the global goal, some countries have set their own national aviation targets that are consistent with ICAO's LTAG commitment or that seek action by an earlier date (see Figure 1).

FIGURE 1 **Some national-level aviation targets**

	Scope	Year	Target
United Kingdom	All domestic and international flights departing UK airports	By 2050	Net-zero
Sweden	Departing international flights	By 2045	Fossil-free
United States	Domestic flights by all operators and international flights by US operators	By 2050	Net-zero greenhouse gas emissions (CO_2, N_2O and CH_4)

The rate of progress that countries target will inform decisions around how different technologies can support this ambition, including the role for alternative propulsion.

Progress towards achieving ICAO's LTAG is reported through the submission of state action plans. These plans require states to establish their long-term strategy on climate change for the international aviation sector, define a quantified baseline scenario, choose appropriate emissions mitigation measures, and calculate the expected results of implementing those measures. For example, Canada's state action plan sets out its emissions reduction goals, including how its strategic innovation fund and other policies are supporting alternative propulsion.[4]

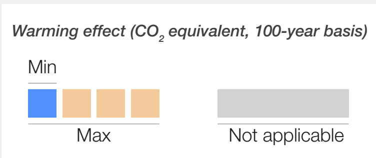
Addressing the non-CO_2 impacts of aviation

Another consideration for governments is deciding how to address the non-CO_2 impacts of aviation. Work is ongoing to ascertain whether changes to fuel properties and operations can help to manage and reduce these impacts from existing and future carbon-based fuels. For the total climate impact of conventional and alternative propulsion aircraft, including contrails, see Figure 2.

Battery-electric aircraft do not produce non-CO_2 impacts – although, given the short ranges over which these aircraft are likely to operate for the foreseeable future, the continuing operation of conventional aircraft along such routes is not expected to contribute significant contrail impacts anyway.

While the extent to which different types of hydrogen-powered aircraft will create climate warming contrails is uncertain, hydrogen fuel-cell aircraft could provide options to mitigate the formation of contrails through exhaust management. In addition, both hydrogen fuel-cell and hydrogen combustion could potentially reduce the formation and impact of contrails through operational procedures, such as changing the time, route or altitude of a flight. While conventional hydrocarbon-powered aircraft could adopt similar procedures to reduce contrails, the benefits would need to be balanced against the increased fuel burn required and the CO_2 emissions that would arise. However, for aircraft powered by green hydrogen, increased fuel burn would not be a climate-related concern.

FIGURE 2 | Total climate impact of conventional and alternative propulsion technologies



[1] As discussed in the report, fuel-cell aircraft have the technical capability to fly mid-range and even beyond, but whether in practice this will be achieved will depend on the achievable fuel-cell specific power.

[2] Battery-electric aircraft do not produce contrails, but neither do jet-fuel aircraft flying the same route (at low altitudes), to which they are referenced. Contrails could be avoided on fuel-cell aircraft through good water management but, if not managed, contrail formation is not well understood at the moment.

Source: Aviation Impact Accelerator[5]

1.2 Select cost-effective technologies best suited to national needs, development and resources

> While SAF is projected to provide the bulk of global emissions savings globally, decarbonizing the sector will require using all options available, including battery-electric and hydrogen-powered aircraft.

Decarbonizing aviation requires all options available

While SAF is projected to provide the bulk of global emissions savings globally, decarbonizing the sector will require using all options available, including battery-electric and hydrogen-powered aircraft. At the international level, various pathways for achieving net-zero aviation have been defined that attempt to identify the roles these different options can play.

Notable examples include ICAO's LTAG work, the Air Transport Action Group's *Waypoint 2050* report,[6] which is the global industry roadmap, and the Mission Possible Partnership's aviation transition strategy developed by the World Economic Forum and other stakeholders.[7]

At present, the exact amount each decarbonization option could contribute to the overall goals established for the sector is not clear and the roadmaps developed are therefore based on a range of assumptions. The final contribution of each option will depend on various factors, such as the rate of technology development for conventional and alternative propulsion aircraft, the extent to which various fuel types can be scaled-up, and economic considerations.

“ Battery-electric aviation technology could be particularly suited to operations among island archipelagos and for domestic feeder services.

Tailor strategy to specific needs and resources at national level

At the state level, governments should engage with their stakeholders to understand the specific needs of their industries and find an appropriate balance between technologies that are closer to market today and those disruptive technologies that may deliver over a longer timescale.

Countries should also assess the various resources they expect to be available, such as biogenic SAF feedstocks,[8] renewable electricity and green hydrogen, to identify the most cost-effective options for their industry. As part of this assessment, policy-makers should aim to understand where aviation fits into their country's wider decarbonization roadmaps and what the availability of different energy sources will be.

Governments will need to give consideration to the nature of their industries. Some states may already have companies developing technology for battery-electric or hydrogen aircraft, so government support for alternative propulsion may be a way to harness the benefits of emerging green industries and jobs. Airlines, airports and other stakeholders may also have their own environmental ambitions that governments can help to support.

Relative strengths of battery-electric and hydrogen-powered aircraft

A key consideration when determining the role different technologies will play is the structure of a state's aviation market. Generally speaking, those countries with a greater number of short-distance routes, especially commuter and regional routes, will be best-suited to battery-electric aircraft, as they are expected to have a range of just a few hundred kilometres for the foreseeable future. That said, electric hybrid aircraft – where different propulsion technologies augment each other's performance to deliver greater fuel efficiency and therefore greater range – could be available much sooner.[9]

Battery-electric aviation technology could be particularly suited to aviation operations among island archipelagos and for domestic feeder services. There are other examples of busy, short routes – such as between major cities on the US East Coast – but many of the aircraft that operate on these routes today are also used for longer distance journeys, so switching to battery-electric aircraft would require changes to existing business models.

Hydrogen aircraft could provide options for short-haul and medium-haul travel in the near term. Identifying such routes – domestic or international – where hydrogen aircraft could be viable and economical is therefore important. Hydrogen aircraft technology is continuing to develop and could theoretically enable long-haul airliners to enter the market by the middle of the 2030s, provided that key safety, distribution, infrastructure and regulatory aspects are addressed at the same pace. However, for many longer distance routes, SAF will remain the primary fuel option for the foreseeable future – and the only one compatible with aircraft currently in service today.

Identifying key routes and new forms of transportation

The distribution of aviation activity in a state is another consideration. Independent of route length, the aviation industry will find it easier to justify investing in "thick" routes (those that carry the largest number of passengers and have the most activity), both in terms of the aircraft and associated infrastructure needed. A large number of airports will require infrastructure investment, so identifying key routes could be an effective strategy for governments that wish to become early adopters of new technologies. Concepts such as green corridors, which can help with this, are explored in the next chapter.

Finally, some alternative propulsion technologies offer the possibility of enabling new forms of transportation such as Urban Air Mobility or expanding options for Regional Air Mobility,[10] which serve communities near smaller airports where commercial air services are not currently economically viable. While these may not directly support the decarbonization of the existing commercial aviation sector, the lower operating costs of some alternative propulsion aircraft could provide zero-emissions, convenient and high-speed travel options for citizens in hard-to-reach locations.

1.3 Set strategic goals and build partnerships to benchmark progress and maintain momentum

States should carefully consider whether to set goals that are outcome-focused or technology-specific.

Guided by these key questions and considerations, states can set strategic goals and build partnerships that will clarify roles, benchmark progress, bring insights and maintain momentum.

Setting goals clarifies roles and attracts investment

Setting goals, commitments and targets for alternative propulsion can help all stakeholders understand their potential roles. Goals not only serve as a benchmark for associated delivery plans, they can also help attract investors and spur industry action by reducing uncertainty.

ICAO's net-zero by 2050 goal provides a global framework and context for decarbonizing international aviation, but national goals and targets can help to identify the actions that states must take to make progress towards ICAO's goal, as well as addressing emissions from domestic aviation.

There can be many different stages to goal-setting. For instance, the first stage may be deciding an overall target for emissions reductions while later stages may involve assigning specific reductions to different pathways.

States should carefully consider whether to set goals that are outcome-focused and technology-agnostic (e.g. all domestic flights to be net-zero by 2040), or goals that are technology-specific – such as Norway's goal for all domestic flights to be battery-electric by 2040. While both types of goal can deliver the intended environmental impact, policy-makers will need to assess the costs and benefits of prescribing a specific technology. Such an assessment could include the value of supporting its national industry, the transition costs for industry and the feasibility of reaching a prescribed technology-specific goal as opposed to a more general outcome-focused goal.

Goals can act as a benchmark to monitor progress and review policy levers. When developing goals, governments should balance ambition with feasibility, and consider interim milestones and frameworks to monitor and review progress. ICAO provides guidance for countries on producing state action plans that can serve as a useful first step for governments in this area.[11]

Aviation strategies should be aligned with economy-wide plans that states may have to transition to a hydrogen economy, develop battery production facilities and increase the supply of renewable energy infrastructure. Canada's industrial strategy, for example, sets out priority sectors for the delivery of its net-zero ambitions.[12]

Goals and strategies should be well defined and should set out applicable sustainability criteria to guide progress and investment: for example, a requirement that the energy required to support zero-emissions flight comes from renewable energy and green hydrogen production.

EXAMPLE

Nordic states

In the Nordic states, Sweden and Denmark have committed to fossil-free domestic aviation by 2030, Norway has committed to making all domestic flights battery-electric by 2040, while Finland's goal is zero-emissions domestic aviation by 2045. Sweden has also committed to fossil-free international aviation by 2045.

These goals have galvanized the governments, industry players and other stakeholders to take action and, as a result, the Nordic region is at the forefront of the transition to battery-electric aircraft technologies.

Dialogue with stakeholders can help inform policies, strategies and investments to support clean aviation technologies.

Building partnerships brings insights and maintains momentum

Building partnerships with key stakeholders can accelerate progress by providing a forum for states, industry and other stakeholders to meet, define plans, share updates and swap lessons learned. Partnerships also help maintain political momentum.

By engaging with original equipment manufacturers (OEMs), airlines, airports and other actors, policy-makers can better understand industry plans for decarbonizing aviation (especially hydrogen and battery-electric aviation) and can develop plans to support these accordingly. Many governments will have already established forums for engaging with stakeholder groups, but dedicated consortiums can help drive targeted progress on alternative propulsion technologies.

In particular, policy-makers can gain valuable insights into progress being made and the challenges faced by new entrants, existing aircraft manufacturers and potential operators. This dialogue with stakeholders can help inform policies, strategies and investments to support or incentivize the use of clean aviation technologies by industry.

Partnerships can also create public awareness, especially when accompanied by a communications strategy. This can include educating the public about the opportunities and limitations of alternative propulsion, addressing concerns about the safety of new types of aircraft, and ensuring that the wider ecosystem needed to support hydrogen and battery-electric aircraft (e.g. fuel and energy producers, pilots, maintenance workers) is ready for the changes that these aircraft will bring.

Limiting engagement to national stakeholders could be a missed opportunity. States are encouraged to learn from initiatives being pursued by other governments. ICAO is starting to consider some of the key issues that will be needed to harmonize the introduction of battery-electric and hydrogen aircraft. It is giving a platform to new developments through its annual stocktaking series. Initiatives such as the Forum's Target True Zero also aim to connect policy-makers and industry around the globe to address key challenges.

Examples of public-private partnerships to promote zero-emissions aviation include the UK's Jet Zero Council and the Nordic Network for Electric Aviation (see Examples below), as well as the SAF task force in France,[13] Japan's Act for Skies,[14] and Australia's jet zero-style council.[15]

Working with stakeholders can help governments develop blueprints and plan out how they will implement alternative propulsion aircraft within their jurisdictions. These implementation measures are discussed in the next chapter.

EXAMPLE

UK Government's Jet Zero Council

In 2020, the UK government established the Jet Zero Council, a partnership between industry and government with the aim of "driving the ambitious delivery of new technologies and innovative ways to cut aviation emissions". The council comprises ministers and chief executive officer-level representatives of industry and other stakeholders to provide political support for the process and a top-down view from within industry.

The council oversees technical workstreams on SAF and zero-emissions aircraft (ZEA). The ZEA work is focused on the innovation of zero-emissions aircraft, the ground infrastructure to support zero-emissions flight and the regulatory requirements.

EXAMPLE

Nordic Network for Electric Aviation (NEA)

NEA is an initiative run by the Nordic Council of Ministers through its Nordic Innovation organization to accelerate the introduction of battery-electric aircraft in the Nordic region by:

- developing standardized battery-electric air infrastructure
- developing business models for regional point-to-point connectivity between Nordic countries
- developing aircraft technology for Nordic weather conditions
- creating a platform for European and global collaboration

The NEA's work is led by a consortium of Nordic industry players. This industry-led approach has enabled the NEA to identify current barriers to adoption and operation by airlines, such as the longer turnaround times needed which could impact on operating costs and airport operational efficiency, and to propose solutions to address these.

2

Create an enabling environment

States should support R&D, ensure access to infrastructure, update regulations and collaborate to accelerate alternative propulsion.

Key considerations

Policy-makers should consider the following questions when working to create an enabling environment for alternative propulsion:

- Which industry, academia or other stakeholders exist that could play a role in supporting alternative propulsion?
- What resources are available to support R&D and what other options exist to support R&D that don't require direct funding?
- What energy requirements will alternative propulsion demand and how can these be delivered?
- What kinds of infrastructure will be required and what level of government support will be needed?
- What sort of support will stakeholders need to help them prepare for alternative propulsion?
- What regulatory changes will alternative propulsion entail to ensure new aircraft operate on a level playing field?
- How can regulators keep up with the pace of technological development?
- What opportunities are there to learn from and collaborate with international partners?

2.1 Support R&D to help accelerate battery-electric and hydrogen-powered aircraft

For countries with established or new-entrant aerospace firms, they can look to support research and development to help accelerate the evolution and market entry of battery-electric and hydrogen-powered aircraft.

Governments can directly support the development of, for example, aircraft, propulsion systems and enabling technologies such as cryogenics, energy storage and materials. Direct R&D funding can take the form of grants, awards or public-private partnerships. Governments will want to consider the extent to which they allocate funding between more established companies that may be able to bring technologies to market sooner, and new entrants that are inclined to take greater risks to develop more long-term, disruptive solutions.

An additional consideration for aerospace R&D is the need to develop specific subsystems for aviation purposes. Given that the requirements for aviation can be much higher than in other sectors such as the automobile industry, while the demand can be much lower, the development of subsystems to supply components such as batteries or fuel cells may need specific support to be viable for manufacturers to pursue.

EXAMPLE

UK Government-funded R&D programme

In February 2023, the UK Government announced a new round of funding for battery-electric and hydrogen-powered aircraft technology through the Aerospace Technology Institute, a public-private programme. The £113.6 million grant allocation is split between Rolls Royce – to receive £82.8 million for three projects looking at engine layouts for hydrogen combustion, delivering a liquid hydrogen gas turbine engine and technologies for the combustor element of a liquid hydrogen gas turbine – and Vertical Aerospace, which will create a prototype propulsion battery system for battery-electric vertical take-off and landing aircraft (eVTOL).

Policy measures include tax breaks for investments and clear goals for alternative propulsion, to provide investors with assurances.

Governments can also encourage private investment into new or existing firms working on key technologies. Direct policy measures could include offering tax breaks for such investments. Less direct measures could entail setting clear goals for alternative propulsion, to provide investors with assurances that there will be a future market for these new products.

Governments can also consider providing regulatory sandboxes – an approach that allows the testing of innovations for a time-bound period, under a regulator's oversight – to help accelerate learning and iteration of new technologies.

Funding for academic research can help address areas where there are existing gaps in knowledge. Particularly relevant areas for aviation are the climate impact of contrails, and the comparative costs and benefits of battery-electric and hydrogen propulsion.

The World Economic Forum's insight report *Target True Zero: Unlocking Sustainable Battery and Hydrogen-Powered Flight*, published in July 2022, identified eight critical "technology unlocks" that would be required for realizing sustainable alternative propulsion (see Figure 3). These unlocks represent the kinds of issues that states may want to support with their R&D efforts.

FIGURE 3 **Target True Zero's eight technology unlocks**

Technology unlock 1 – Ensuring aviation batteries are charged with renewable energy

Technology unlock 2 – Accelerating the introduction of green hydrogen

Technology unlock 3 – Improving battery lifecycles and management for aviation

Technology unlock 4 – Improving battery-electric aircraft energy density

Technology unlock 5 – Developing lighter fuel cell systems

Technology unlock 6 – Developing lighter storage tanks for liquid hydrogen

Technology unlock 7 – Redesigning aircraft for optimized hydrogen performance

Technology unlock 8 – Contrail research and mitigation

Source: World Economic Forum[16]

2.2 Ensure access to infrastructure for alternative propulsion technologies

Ensuring access to infrastructure for alternative propulsion will need to be a key priority for governments to ensure battery-electric and hydrogen aircraft can be operated.

A fundamental requirement for alternative propulsion will be access to adequate amounts of clean electricity and hydrogen available for powering battery-electric and hydrogen aircraft. Given the huge amount of energy required for alternative propulsion, which could be a significant proportion of a country's overall supply, governments will need to develop plans for how aviation fits into overall renewable energy and green hydrogen plans.

> Given the huge amount of energy required for alternative propulsion, governments will need to develop plans for how aviation fits into overall renewable energy and green hydrogen plans.

The World Economic Forum's April 2023 white paper, *Target True Zero: Delivering the Infrastructure for Battery and Hydrogen-Powered Flight*, identified that around 90% of the energy and investments required for enabling alternative propulsion will be required offsite. This illustrates the important role policy-makers must play in facilitating collaboration between the aviation sector and other stakeholders. The 10 key insights from this report are outlined in Box 1.

In addition to upstream infrastructure, new on-airport infrastructure will also be required. Governments should work with their aviation industries to help provide guidance on the changes that will be required and when.

While mobile infrastructure may allow early operations of battery-electric and hydrogen aircraft to scale-up with minimal physical infrastructure upgrades and investment, widespread adoption – especially for hydrogen-powered aircraft – will involve large costs and potential disruption for airports. Governments may want to provide funding, support or incentives for airports to make such investments.

BOX 1

Target True Zero – 10 key infrastructure insights

1. Global demand for **alternative propulsion could require 600-1,700 TWh of clean energy** by 2050. This is equivalent to the energy generated by around 10-25 of the world's largest wind farms, or a solar farm half the size of Belgium.

2. **Large airports could consume 5-10 times more electricity by 2050** than they do today, to support alternative propulsion.

3. Alternative propulsion will require **two new infrastructure value chains** – one for battery-electric aviation and one for hydrogen – which may include a whole variety of new partners that are not currently part of the aviation ecosystem.

4. **Most airports have space for hydrogen liquefaction and storage infrastructure**, but not enough land to generate all of the clean energy needed to power battery-electric and hydrogen aircraft.

5. Shifting to alternative propulsion will require a **capital investment of between $700 billion and $1.7 trillion** across the value chain by 2050. Approximately 90% of this investment will be for off-airport infrastructure, primarily power generation and hydrogen electrolysis and liquefaction.

6. Investment needed for airport infrastructure will be significantly higher for large airports than for smaller airports, but of **similar magnitude to other major investments such as building a new terminal**.

7. Costs to operators of alternative propulsion are expected to be **around 76%-86% over the market price for green electricity** – reflecting additional aviation infrastructure operating costs.

8. The investments needed to meet 2050 goals must start now. The first elements of **on-airport infrastructure must be in place by 2025** to meet expected energy demand.

9. To harness the power of network effects and regional connectivity, **coordination of infrastructure investment** will be required to make alternative propulsion operations feasible.

10. The aviation industry will need to **partner with other industries to secure enough green electricity and hydrogen** in a supply-constrained environment and have a voice in shaping the future of the hydrogen ecosystem.

Source: World Economic Forum[17]

EXAMPLE

Acceleration of hydrogen penetration in Paris airports

Groupe ADP, Air France-KLM Group, Airbus, Ile-de-France Region and Choose Paris Region (the business growth and destination agency for Paris Region) have established the H_2 Hub Airport in France.[18]

This initiative has selected partners to accelerate the transformation of airports into hydrogen hubs (covering the entire hydrogen value chain within the airport), with a focus on the production, storage, transportation and delivery of hydrogen, the diversification of use cases in airports and aeronautics, and the circular economy around hydrogen.

Together these projects are designed to address the different aspects of developing the H_2 Hub Airport. They pave the way for the introduction of hydrogen at airports in the short term and the subsequent operation of liquid H_2-powered aircraft.

EXAMPLE

Singapore creates public-private partnership to assess feasibility of hydrogen-powered aviation

Singapore has begun studying the development of hydrogen supply and infrastructure for aviation. As part of a public-private partnership, the Civil Aviation Authority of Singapore, Changi Airport Group, Airbus and Linde signed a cooperation agreement in February 2022. Under the agreement, the parties will:

1. Conduct a market analysis of projected aviation demand and supply for hydrogen, regional readiness and commercial feasibility of hydrogen adoption.
2. Evaluate the infrastructure requirements for a hydrogen airport hub and the electrification of airport operations using hydrogen fuel-cell technologies

The partnership leverages the respective parties' knowledge and expertise and will allow Singapore's aviation sector to explore the longer-term potential for hydrogen-powered flight.

2.3 Update regulations to smooth the introduction of alternative propulsion aircraft

There are currently no certification criteria for hydrogen aircraft or larger battery-electric aircraft. Uncertainty around the risk that they will not be certified could prevent industry from committing to the development of these aircraft. When developing rules, aviation regulators will want to consider whether standards are needed to ensure these aircraft deliver the intended environmental benefits – for example, in the case of hydrogen aircraft, to regulate water vapour emissions. States are encouraged to work through ICAO to ensure harmonization.

Aviation regulators will need to consider areas where differences in these aircraft require modifications of existing rules and formulas. For example, formulas used by airports and navigation service providers to calculate landing and navigation fees are based on an aircraft's maximum take-off weight (MTOW). But battery-electric aircraft will be heavier than traditional aircraft, leaving them at a disadvantage under current regulations. One solution to this may be to subtract the weight of the aircraft battery from its MTOW for the purposes of setting charges.

Regulators should ensure that their organizations are prepared for the growing number of new types of aircraft expected in the coming years. Considerations include training sufficient numbers of employees in the skills and knowledge required to regulate aspects of hydrogen or battery-electric aircraft, especially those specializing in aircraft certification.

It will be important for regulators to determine how best to maintain the same levels of safety without slowing down innovation in the industry. Bilateral aviation safety agreements are one measure that could allow a state without its own rules to use another jurisdiction's rules to approve an aircraft for operation within its airspace – providing that aircraft has been certified by another regulator. This would avoid the adoption process for aircraft being slowed down by a lack of standards in some countries and in the absence of ICAO standards.

EXAMPLE

Japan's Civil Aviation Bureau and the European Union Aviation Safety Agency

In the field of Advanced Air Mobility (AAM), which falls outside the scope of this toolkit, Japan's Civil Aviation Bureau (JCAB) is cooperating with the European Union Aviation Safety Agency (EASA) on the parallel "type certification"[19] of a German eVTOL aircraft.[20] While EASA already has VTOL regulations, Japan's experience of two other eVTOL type certification applications will contribute towards a shared knowledge of established aircraft design and manufacturing procedures, and support for the development of a common set of requirements.

JCAB has also signed a declaration of cooperation with the US Federal Aviation Administration (FAA) to support future AAM certification and validation, production, continued airworthiness, operations and personnel licensing.[21]

> **The definition of public transport used in EU policies is confined to surface transportation, which would make aviation applications ineligible for public transport subsidies.**

Flexibility will be required to ensure the certification process for new technologies does not prevent innovation. Aircraft certification places demands on regulators, which should ensure they have the necessary capacity to issue approvals without unreasonable delay and to transpose ICAO Standards and Recommended Practices (SARPs) into national legislation where applicable.

There may be a need to update regulations to recognize the existence of battery-electric and hydrogen aircraft. For instance, countries or regions with SAF mandates, sub-mandates for synthetic e-fuels or operating bans may want to update these rules, or build in rules from the outset for new regulations, to exempt operators using battery-electric or hydrogen aircraft or allow these technologies to contribute to meeting the requirements.

There are also non-aviation-specific regulations that may need updating. For instance, health and safety rules for handling hydrogen may need to be reviewed to permit safe use at airports or for refuelling aircraft, along with rules related to transportation of batteries and their recycling. As noted earlier, alternative propulsion technologies can support new aviation business models, such as those enabled by Advanced Air Mobility, to play a role in public transport and provide enhanced mobility options for communities. However, this may require changes to regulations. For example, the definition of public transport used in European Union policies is confined to surface transportation, which would make these aviation applications ineligible for public transport subsidies.

EXAMPLE

UK's Health and Safety Executive and National Aviation Authority

In the UK, the Health and Safety Executive has partnered with the Aerospace Technology Institute to "assess the risks and safety implications that the storage, distribution and refuelling of hydrogen, on both the ground and on aircraft, may pose". This process includes reviewing existing regulations, codes and standards that may need to be modified for hydrogen aircraft to safely operate.[22]

More generally, in 2022, the UK Government announced the creation of the National Aviation Authority network with the "mission to foster cooperation between world-leading aviation regulators on emerging challenges in aviation and aerospace, improving innovation and safety".[23]

2.4 Create international collaborations to accelerate progress, share learnings and promote harmonization

Some challenges can only be resolved through international collaboration, such as the harmonization of charging and refuelling infrastructure.

International collaboration can help to accelerate progress through the sharing of knowledge, examples and lessons learned. This is particularly relevant in helping countries with developing aviation markets to learn from what others are doing and to tap into the benefits that these new technologies can offer. ICAO already facilitates capacity building schemes such as the CORSIA Buddy Partnerships and the LTAG Resolution encourages similar approaches. The International Aviation Climate Ambition Coalition has 60 state signatories and also promotes capacity building among its members.

Some challenges can only be resolved through international collaboration, such as the harmonization or interoperability of charging and refuelling infrastructure – essential for alternative propulsion aircraft to operate internationally. ICAO promotes harmonization for international aviation through its SARPs and states are encouraged to support ICAO in its work. In the event that the first battery-electric and hydrogen aircraft pre-date the finalization of this work by ICAO, leading governments in this space could, as an interim measure, help shape future regulations by working together on a bilateral or multilateral basis.

International collaboration can also help to ensure that investments in infrastructure are coordinated so they are delivered in different countries or regions at a similar time to allow international operations. Green corridors and similar initiatives can help develop international markets for these new technologies.

EXAMPLE

New Zealand and Singapore

New Zealand and Singapore have signed an agreement to introduce "green lanes" between the two countries. Both countries have committed to working together to support the deployment of sustainable fuels for aviation – including alternative propulsion hydrogen aircraft. The initiative covers four key areas:

- Policy and regulation
- Industry development (including coordination of R&D)
- Testing sustainable fuels
- Future infrastructure planning

The initiative focuses on transforming airports and boosting the commercial viability of alternative propulsion aircraft by developing "green lanes", encouraging consumer uptake and increasing the skills of the workforce.

3 Accelerate uptake with incentives and targets

Governments can accelerate zero-emissions aviation through subsidies, economic instruments, mandates and greater transparency.

Key considerations

Policy-makers should consider the following questions when considering how they can support the uptake of alternative propulsion:

– In which areas can regulation support the adoption of alternative propulsion?

– What impacts will different regulations have on stakeholders?

– Will overall goals be better achieved by technology-agnostic or technology-specific regulations?

– What are the costs and benefits of different options – e.g. subsidies versus carbon pricing or mandates versus incentives?

3.1 Financial measures

Financial measures can help address the cost differentials that operators may encounter when adopting newer technologies such as battery-electric and hydrogen aircraft. Governments will need to undertake impact assessments to explore the potential effectiveness of different types of financial measures. Some examples are explored further below.

Subsidies for alternative fuels. Governments could offer subsidies or tax breaks on green hydrogen and renewable electricity used for aviation, to reduce the price for operators and increase competitiveness with fossil fuel options.

Support with capital costs. Governments could support operators with the capital costs of purchasing new alternative propulsion aircraft or retrofitting existing aircraft with new technologies. This could be in the form of direct subsidies, low-interest loans or other incentives, potentially drawing on the example of state incentives for the acquisition of EVs.

EXAMPLE

US Sustainable Skies Act and California Low Carbon Fuel Standard

The United States Sustainable Skies Act has recently introduced a Sustainable Aviation Fuel Credit of $1.25 per gallon of SAF, as long as the SAF has "a minimum reduction of 50% in lifecycle greenhouse gas emissions". The credit goes up to a maximum of $1.75 per gallon for SAF delivering a 100% reduction in GHG emissions.[26]

Within the US, there is also the California Low Carbon Fuel Standard that puts a value on carbon reductions generated from renewable fuels when compared with conventional jet fuel. Such regulations could serve as a template for similar policies to reduce the operating costs of other types of propulsion.

Carbon pricing. Instead of offering incentives for alternative propulsion, states could look to reduce demand for fossil fuel by implementing measures to raise the price of kerosene-based fuel to encourage the uptake of more sustainable alternatives. Carbon pricing initiatives such as the EU's Emissions Trading Scheme (ETS) are an example of how this could be introduced. Taxes could also be applied directly to fossil-fuel products based on their lifecycle emissions.[27]

Carbon markets. Governments could update existing market-based measures, such as carbon markets and emissions trading schemes, to recognize alternative propulsion within their frameworks. To help scale-up new technologies, market-based measures could incorporate additional benefits for early adopters of battery-electric or hydrogen aircraft, such as providing additional carbon credits for emissions avoided for a period of time.

Passenger (and other) levies. States could consider whether existing aviation-related taxes could be used to help incentivize battery-electric and hydrogen propulsion. Passengers travelling on battery-electric aircraft or those powered by green hydrogen could pay a lower rate of passenger departure tax or air passenger duty. Renewable electricity used for aviation could get the same tax benefits as electricity used for trains, for example. Additionally, revenues from new or existing aviation-based taxes could be earmarked to help fund R&D or other measures that support the industry's transition to cleaner fuels.

Landing and navigation fees. Governments could regulate or encourage airports and air navigation service providers to set fee structures that incentivize lower-carbon flying. Some airports have offered to waive landing charges for a year for the first operators of zero-emissions aircraft. Manchester Airport in UK has offered to waive landing fees for the first five years (an estimated saving of £1.3 million in current prices) to the airline that operates the first zero-emissions aircraft. Similarly, London Heathrow Airport has announced that it will waive landing fees for one year for the first battery-electric aircraft.

Review weight-based navigation fees. As noted earlier, operators of battery-electric aircraft can be disadvantaged by current fee structures. While these technologies are likely to benefit from the differentiated noise and emissions-related components of landing fees (where applied), core landing and navigation fees are usually based on maximum take-off weight (MTOW) – and battery-electric aircraft are likely to weigh more than comparable conventional aircraft due to the weight of their batteries. Charging structures could consider subtracting the weight of the aircraft battery from the MTOW calculation to address this point.

> “ The US Sustainable Skies Act has recently introduced a Sustainable Aviation Fuel Credit that ranges from $1.25-$1.75 per gallon depending on overall emissions reductions.

EXAMPLE

Europe's Emissions Trading Scheme

Within the EU's Emissions Trading Scheme, to help encourage SAF uptake by the industry, the use of SAF is "zero-rated" meaning that airlines can claim a 100% emission reduction regardless of the actual net lifecycle carbon reductions. The EU is further considering whether to allow double-crediting of power-to-liquid SAFs. In effect, this would enable operators to claim a credit for twice the amount of carbon that would have otherwise been released with standard aviation fuel. Similar incentives could be adopted for battery-electric and hydrogen-powered flights.

3.2 Mandates, targets and restrictions

Phase-outs for noisier types of aircraft were used in the 1990s and 2000s to accelerate fleet replacement with less-polluting alternatives.

Mandates, targets and restrictions can help accelerate the transition towards zero-emissions aviation by requiring the use of certain technologies or encouraging a shift away from more polluting technologies. Some examples are explored below.

Phase-outs. Phase-outs for certain types of aircraft have been used historically to accelerate fleet replacement of aircraft with less-polluting alternatives. This approach was used by states in North America, Europe, Japan, Australia and New Zealand in the 1990s and 2000s to encourage the phase-out of noisier aircraft. Operators were given sufficient advance notice (10 years in the case of the Chapter 2 phase-out in Europe),[28] with staged reductions and the granting of some limited exemptions based on economic criteria. A similar approach could be used for those aircraft with the lowest emissions performance to help accelerate the uptake of new, cleaner aircraft including those using alternative propulsion systems.

Prescribed activities or routes. Governments could require operators to use certain types of aircraft to perform prescribed activities or operate on prescribed routes. For Public Service Obligation routes,[29] environmental performance could be added to existing criteria when selecting operators. As an alternative to prescribing the use of specific technologies, governments could consider basing requirements on net-zero or other environmental criteria that would provide operators with flexibility in how they meet these criteria.

Bans and exemptions. Several states either have operating bans in place for short-haul flights or are considering them. Where bans exist, states could consider relaxing requirements to permit zero-emissions aircraft to operate on these routes. If similar options are considered in the future, providing exceptions from the outset for zero-emissions aircraft, or requiring certain routes to be performed by zero-emissions aircraft, would provide an incentive to operators to purchase these aircraft and help the scaling-up of new technologies.

Mandates. Governments could mandate targets that require operators or fuel suppliers to use a prescribed volume of a particular fuel or energy type, or attain a defined level of reduction in overall emissions or emission intensities, by a certain date.

EXAMPLE

France

France recently decided to ban flights between cities that are linked by a train journey of less than two-and-a-half hours. It has also raised the possibility of a ban on private jets in the future.[30]

EXAMPLE

EU Fit for 55 package

To deliver the European Climate Law, the "Fit for 55" package (to reduce net greenhouse gas emissions by at least 55% by 2030 compared with 1990 levels) includes a mandate on fuel suppliers and airlines to use a minimum amount of SAF in all flights departing from European airports.[31] Eligible fuels must comply with the sustainability and greenhouse gas emissions criteria laid down in the EU's Renewable Energy Directive.

The SAF mandate targets start at 2% in 2025 and rise to 5% in 2030. The mandate includes a sub-target for synthetic fuels (renewable fuels of non-biological origin).[32] To ensure the early investment needed to scale-up synthetic fuels, the EU's rules set a sub-target for synthetic fuels of 0.7% by 2030.

The EU's mandate creates a framework to ensure that alternative fuels contribute to aviation's decarbonization pathway. It provides the policy certainty that will lead to investment in the necessary infrastructure, and helps to promote and develop the most promising long-term SAF pathways, while recognizing that the scale of production is likely to be modest before 2030.

EXAMPLE

UK Government's SAF mandate

In March 2023, the UK Government launched a consultation on its SAF mandate that aims to create demand for SAF, achieve greenhouse gas emissions savings and provide price support for SAF supply. This consultation is the second phase of a process begun by the UK Government two years earlier. The proposed mandate will begin in 2025 and will require jet fuel suppliers to ensure that at least 10% of jet fuel is made from sustainable feedstocks by 2030.

3.3 Measures to encourage consumer awareness

One issue to consider is how to encourage consumer awareness and acceptance of new technologies. Consumer demand can be a powerful tool to drive industry behaviour. The use of "ecolabelling" and other tools that enable standardized, transparent disclosure of emissions information is one way to help create public awareness and demand for lower-emissions alternatives.

EXAMPLE

Creating demand for green flights through transparency on emissions

Several flight booking sites provide consumers with an understanding of the environmental impact of their flights, such as Google Flights and Skyscanner. Both provide a ranking for available flights on a given route that shows the "greenest" option. The ranking is based on either a percentage improvement compared to the average for that route or a figure for the CO_2 emissions associated with each flight.

EASA has been developing a proposal for an ecolabelling scheme to score the overall environmental performance of an aircraft according to various parameters, including CO_2 emissions and noise. It proposes to present the results using a traffic light system, where aircraft are graded green, amber or red.

Separately, the UK Civil Aviation Authority has issued a call for evidence to support a future proposal to mandate airlines to provide consumers with CO_2 data before or at the point of sale.

Conclusion

Zero-emissions flight cannot take off without successful policy frameworks based on global collaboration and standardization.

The public and private sectors have both made global commitments to decarbonizing aviation to ensure the sector reaches net zero by 2050. Battery-electric and hydrogen aircraft, coupled with the availability of clean renewables and green hydrogen, can play an important role in meeting these targets by offering the potential for zero-emissions flight. It is important for states to put in place timely policy and regulatory frameworks to accelerate the development, testing and entry into service of these technologies.

To encourage standardization through common approaches and to share experiences, collaboration with other states and stakeholders will be key. ICAO continues to provide a forum for international collaboration and coordination. States may wish to supplement these global discussions through bilateral partnerships to explore how battery-electric and hydrogen aircraft could provide solutions for particular geographies and market segments that fall outside ICAO's remit.

Successful policy frameworks will deliver timely interventions. Stakeholder engagement will be key from the outset in identifying issues from a variety of perspectives. It will be important to engage with not just OEMs, but also new entrants, investors, consumers, civil society and local government – as the latter may play a pivotal role in facilitating necessary infrastructure. Governments should review existing policies to ensure they are "technology-neutral" and do not discriminate or disadvantage emerging technologies.

This policy toolkit has been created in light of the fact that states will be starting from different points in terms of the work undertaken to date. Some governments may need to focus on bringing these technologies to market. Others may need to encourage uptake by operators after these technologies have entered service. And some states may be facing both challenges at once.

Each of the three steps detailed in this report – framing a net-zero aviation strategy, creating an enabling environment and accelerating uptake – includes examples from within the sector. But many of the challenges facing battery-electric and hydrogen aircraft are common to other sectors in transition. Take road vehicles, for example, with the challenges around market access and securing supply that have accompanied the introduction of EVs. These sectors are developing constantly and states are encouraged to continue to review and learn from these experiences.

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