Delineating the Skyscape: Mapping Sustainable Aviation Policy Levers for Climate Risk

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ABSTRACT

The aviation sector faces a growing risk of failing to meet international climate targets, as current mitigation efforts fall short of the scale and pace required. Closing this gap demands the aligned mobilisation of technical, societal, and operational solutions across emerging transition pathways, underscoring the need for coherent and timely policy intervention. This viewpoint article provides a stocktake of sustainable aviation policy levers across five key impact domains identified in recent academic literature and research reports: system efficiency improvements, sustainable aviation fuels, alternative aircraft design, air travel demand management, and the mitigation of non-carbon dioxide climate effects. Together, these domains shape the sector's transition towards a climate-neutral future, offering an integrated perspective on how strategic and well-sequenced policy design can accelerate change. The article outlines key policy mechanisms for addressing aviation-related climate risk and introduces a heuristic framework for rethinking system-level governance. It highlights the need for the effective and coordinated deployment of regulatory, economic, voluntary, and capacity-building instruments across multiple stakeholder groups in the sector. Collectively, the design of policy strategy, the choice of instruments, and the styles of policy processes warrant greater attention from this cross-cutting scoping viewpoint.

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I. **Introduction**

The climate impact of aviation demands rapid and fundamental systemic transitions. The sector accounted for approximately 2.5% of global carbon dioxide emissions in 2023, with emissions growing at a faster rate than rail, road or shipping over recent decades.[1] Beyond carbon dioxide (CO_2), non-CO_2 emissions from aviation—including nitrogen oxides, water vapour, sulphur oxides, aerosols, contrails and contrail-induced cirrus clouds—contribute substantially to aviation's overall radiative forcing, with a warming impact of similar magnitude to that of aviation's CO_2 emissions.[2] Whilst CO_2 acts as a long-lived climate forcer operating over decades to millennia, non-carbon-dioxide emissions influence the climate over shorter timescales

[1] *European Aviation Environmental Report 2025*. European Union Aviation Safety Agency, 2025.

[2] Aviation Impact Accelerator. *Five Years to Chart a New Future for Aviation*. University of Cambridge, 2024.

ranging from weeks to decades.[3] Taken together, the cumulative climate impact of aviation underscores both the challenges of unlocking timely change in a complex sector and the need for a whole-system approach to transforming the sector toward climate neutrality.[4]

Although progress toward net zero remains deeply uncertain, emerging solutions offer promising pathways. In 2021, the International Air Transport Association (IATA) announced an industry target to achieve net zero carbon emissions from operations by 2050, aligned with the temperature goals of the Paris Agreement. By 2025, however, IATA warned that the sector is already off track.[5] Aviation is widely regarded as a hard-to-abate sector, where meaningful emissions reductions require the well-aligned development of technological, operational, business and financial levers across the whole aviation ecosystem.[6] Collective action among airlines, regulators, air traffic control, airports, airframe manufacturers, the financial sector and governments is essential for overcoming structural barriers and achieving timely decarbonisation.[7] In this context, sustainable aviation fuels, hydrogen and electrified propulsion, operational efficiency improvements, demand-management strategies, and the mitigation of non-CO_2 emissions are increasingly recognised as promising avenues for leveraging the transformative power of policy action. Recent system-modelling assessments indicate that several of these solutions are technically feasible and economically viable under appropriate policy conditions for the near-term window, provided that supportive policy frameworks in place.[8] Yet the sector's complexity and diversity of technologies, stakeholders and governance levels require policy levers to be clearly differentiated and strategically sequenced within an integrated sectoral policy roadmap. Identifying, integrating and coordinating policy levers is therefore crucial for overcoming bottlenecks, unlocking system-wide benefits and accelerating the transition toward climate neutrality.

Given the analytical complexity of the aviation system, mapping sustainable aviation policy levers to address climate risk requires a degree of disaggregation to enable effective operationalisation and to identify key intervention points. As a pre-analytical framing, five key impact domains are identified through recent academic literature and research reports:[9] system efficiency improvement, sustainable aviation fuel, alternative aircraft design, air travel demand management and the mitigation of non-CO_2 emissions. Building on recent scholarship that conceptualises sustainable transition policy mixes as combinations of strategic elements and policy instruments,[10] these impact domains, defined as areas affected by a mix of policy instruments that pursue one common or different strategies,[11] serve as a focusing device that enables a comprehensive examination of the policy levers across different sustainable aviation transition pathways. This approach is adopted because there is currently no widely recognised set of

[3] Significant scientific uncertainty remains, however, regarding the precise magnitude and temporal dynamics of these effects.
[4] Kallbekken, Steffen, et al. "Transforming Aviation's Impact on the Climate: Rethinking the Research Strategy." *Environmental Science & Technology*, vol. 58, no. 47, 2024, pp. 20849-20858.
[5] *ICAO Environmental Report 2025*. International Civil Aviation Organization, 2025.
[6] *ICAO Environmental Report 2022*. International Civil Aviation Organization, 2022.
[7] Aviation Impact Accelerator (n 2) *supra*.
[8] ibid.
[9] Aviation Impact Accelerator (n 2) *supra*; Kallbekken et al. (n 4) *supra*; Muehlberger, Clara-Marie, et al. "Socio-Technical Imaginaries of Climate-Neutral Aviation." *Energy Research & Social Science*, vol. 114, 2024, 103595.
[10] Rogge, Karoline, and Kristin Reichardt. "Policy Mixes for Sustainability Transitions: An Extended Concept and Framework for Analysis." *Research Policy*, vol. 45, no. 8, 2016, pp. 1620-1635; Rogge, Karoline, and Qi Song. "Policy Mixes for Addressing Environmental Challenges." *Routledge Handbook of Environmental Policy*, edited by Helge Jörgens et al., Routledge, 2023, pp. 327-346.
[11] Ossenbrink, Jan, et al. "Delineating Policy Mixes: Contrasting Top-down and Bottom-up Approaches to the Case of Energy-Storage Policy in California." *Research Policy*, vol. 48, no. 10, 2019, 103582.

strategic intentions at the sector level, and policy debates remain fragmented. Instead, discussions in both academic and policy arenas tend to cluster around a set of emerging solution pathways. Although there is some conceptual overlap among these domains, each comprises a distinct mix of regulatory, economic, and voluntary instruments, complemented by capacity-building measures that strengthen the skills, resources, infrastructure, and broader enabling conditions needed to deliver policy outcomes. The five impact domains identified here are not intended to be exhaustive, but rather to serve as an illustrative and analytically tractable framing of a complex policy landscape. Other domains—such as airport infrastructure, supply-chain decarbonisation or international governance reform—are recognised as important but are either subsumed within these categories or addressed indirectly through the policy levers considered.

This work aims to delineate the landscape of policy levers for navigating climate risk across the aviation ecosystem. Drawing on a scoping review of the existing literature on sustainable aviation policy,[12] it takes a first step toward system-wide thinking that helps reweave currently fragmented and isolated policy actions. It is worth noting that this exercise provides a stocktaking of possible policy levers rather than a deep dive into real-world implementation, which is shaped by a range of barriers and contextual factors, as discussed in the concluding Section. In doing so, this article contributes to the current debate by connecting sectoral ambitions and targets with specific policy levers through a focus on meso-level impact domains. The following sections examine each of these domains in turn, and the conclusion summarises the overarching policy takeaways.

II. **Impact Domain I: System Efficiency Improvement**

As the first impact domain, system-level efficiency improvements within the existing aviation architecture represent one of the most immediate and scalable avenues for achieving cascading emissions reductions across the whole sector. Realising these gains, however, requires well-aligned action across a wide range of industrial stakeholders, including airline operators, aircraft and engine manufacturers and suppliers, airport and ground service providers, and airspace navigation and traffic management authorities. Discussions of potential policy instruments in this impact domain generally centre on at least four main intervention areas: fleet and technology efficiency; operational efficiency; airspace and network efficiency; and airport and ground infrastructure efficiency (as outlined in **Table 1**, below).

Improvements in fleet and technology efficiency undertaken by airline operators and technology manufacturers represent a complex but essential element of maximising the emissions-reduction potential of the sector's current technological architecture. Regulatory instruments form the foundation for progress in this area. These include fuel-efficiency standards, carbon dioxide and greenhouse-gas performance requirements, and baseline design criteria that apply to the technology supply side.[13] Complementary guidance and information tools—such as sustainability programmes, green fleet-management frameworks and voluntary aircraft-replacement schemes—can further support the adoption of more efficient technologies and fleet-planning practices. These voluntary approaches can mobilise the transformative potential of corporate actors and strengthen their leadership in addressing climate change. Economic instruments also play a crucial role. Emissions taxes or

[12] The review is based on keyword-based Scopus literature searches on sustainable aviation policy—which yielded 609 documents as of 14 Oct. 2025—as the primary dataset, alongside complementary internet searches.

[13] Proost, Stef. "Looking for Winning Policies to Address the Climate Issue in EU-Aviation." *Journal of Air Transport Management*, vol. 115, 2024, 102534.

subsidies that encourage investment in modern, fuel-efficient aircraft create financial signals that influence decisions on fleet renewal and technological upgrading.[14] Revenue generated from emissions-related taxation can be reinvested in the research, development and deployment of cleaner technologies, helping to create a positive innovation cycle.[15] The strategic relationship between technology providers and their major customers, particularly commercial airlines, is especially significant in this context. Targeted capacity-building measures, including support for technology road-mapping and fleet-efficiency planning, can help accelerate the deployment of higher-efficiency aircraft across existing fleets.

Operational efficiency forms another strategically important avenue for reducing the climate impacts of air travel. Here, airline and fleet operators have direct, day-to-day influence. Regulatory frameworks addressing operational practices can include provisions on weight and load optimisation, fuel-management procedures and slot utilisation. Reforms to slot-allocation rules (such as grandfather rights), for example, can discourage inefficient operations and foster more rational scheduling.[16] These regulatory tools can be strengthened through economic levers such as differential carbon taxes on various routes and environmental landing charges.[17] Alongside mandatory requirements, voluntary initiatives led by airlines often offer some of the most promising avenues for climate-oriented operational improvements, especially in areas where regulation is not yet feasible. Policy support for such initiatives can generate early-mover momentum and help identify best practices that may later be codified into formal regulation. Given the regulatory complexity of the aviation sector, clear operational guidance is also essential. Manuals and best-practice standards issued by organisations including the International Civil Aviation Organization (ICAO) and IATA provide authoritative reference points, while targeted capacity-building is required at both institutional and individual levels. Flight crews and ground-operations staff play a decisive role in determining the practical effectiveness of operational-efficiency measures.[18]

Adaptive regulatory coordination at the system and network level is central to advancing airspace modernisation and shaping international technical and operational standards that increasingly integrate climate considerations. This includes incorporating carbon-related performance requirements into international standards and implementing national airspace-redesign and restructuring frameworks. Large-scale initiatives such as the Single European Sky demonstrate how coordinated cross-border governance can contribute to emissions reductions by improving flight-path planning, reducing delays and enabling more efficient air traffic management.[19] Economic measures—such as differential carbon taxes that motivate airlines to adjust their route choices at the operational level, as discussed above—can complement these regulatory efforts by supporting improvements in network-level efficiency. System and network-efficiency

[14] Ovaere, Marten, and Stef Proost. "Strategic Climate Policy in Global Aviation: Aviation Fuel Taxes and Efficiency Standards with Duopolistic Aircraft Producers." *Economics of Transportation*, vol. 41, 2025, 100397.

[15] Wild, Peter, et al. "Impact of Political and Market-Based Measures on Aviation Emissions and Passenger Behaviors (a Swiss Case Study)." *Transportation Research Interdisciplinary Perspectives*, vol. 10, 2021, 100405.

[16] Kösters, Till, et al. "Effects of the Use-It-or-Lose-It Rule on Airline Strategy and Climate." *Transportation Research Part D: Transport and Environment*, vol. 115, 2023, 103570.

[17] Dray, Lynnette, and Khan Doyme. "Carbon Leakage in Aviation Policy." *Climate Policy*, vol. 19, no. 10, 2019, pp. 1284-1296; Rathore, Himanshu, and Suresh Kumar Jakhar. "Differential Carbon Tax Policy in Aviation: One Stone That Kills Two Birds?" *Journal of Cleaner Production*, vol. 296, 2021, 126479.

[18] Maleviti, Eva, and Sarah Talley. "Integrating Sustainability into Aviation Training." *International Journal of Aviation Research*, vol. 17, no. 1, 2025.

[19] Franchina, Federico, and Cinzia Ingratoci. "The Single European Sky and Aviation Sustainability." *Transport Transitions: Advancing Sustainable and Inclusive Mobility*, edited by Ciaran McNally et al., Springer, 2025, pp. 212-218.

measures yield the greatest benefits when combined with improvements in operational efficiency and enhanced voluntary collaboration across the sector. Examples include shifting from hub-and-spoke patterns to more direct routes, expanding joint programmes between airlines and air-navigation service providers, and fostering cross-operator coordination to streamline flows across the network.[20] Sustained improvements of this scale require substantial investment in capacity-building, including clearer guidance on airspace management, traffic-flow optimisation and network planning, alongside strengthened institutional capabilities in areas such as airspace design, controller training and integrated network-management systems. These coordinated efforts allow airspace modernisation and climate objectives to advance together within a coherent system-wide policy framework.

Efficiency opportunities also extend to airport and ground-infrastructure systems. Regulatory and policy instruments can require sustainable terminal design, optimised surface operations, green taxiing systems and efficient pushback procedures, drawing on innovations such as electrified shuttle buses and electric taxiing technologies.[21] Implementing these measures necessitates robust life-cycle environmental assessment, comprehensive monitoring frameworks and clear operational guidance for all airport and ground-infrastructure actors. Smart-infrastructure investments and sustainable hub-design principles further strengthen the emissions-reduction potential of this domain.[22] Economic tools available to airports, including green bonds and targeted subsidies, can help finance sustainable infrastructure, electrified ground-support equipment and energy-efficient terminal upgrades.[23] Economy-wide instruments such as carbon taxes, green airport charges and incentives linked to sustainable aviation fuel can support the reorientation of long-term investment patterns towards low-carbon innovation.

As discussed above, a set of policy levers spans the full spectrum of system efficiency opportunities, ranging from improvements in aircraft and engine performance to enhanced operational practices, more efficient airspace management, and more sustainable airport and ground-based systems. Although each specific efficiency sub-domain encompasses distinct opportunities for deploying policy instruments, it must be noted that their overlap and interconnectedness often generate cascading benefits across domains, amplifying their contribution to sector-wide climate mitigation. With this in mind, a system-level roadmap for coordinated efficiency improvements should be central to near-term sustainable policy planning.

III. **Impact Domain II: Sustainable Aviation Fuel**

As the second impact domain, Sustainable Aviation Fuel (SAF) represents an incremental yet potentially transformative pathway for reducing the climate impacts of aviation. Its significance lies in its compatibility with existing aircraft, engine and fuel-distribution architectures, positioning SAF as one of the few technologically viable mitigation options available in the short and medium term, particularly for long-haul, high-density and other mission profiles where electrification and hydrogen propulsion remain commercially and operationally distant. The scalable phase-in of high-integrity SAF is

[20] Jamin, Solomon, et al. "Aviation Emissions and Abatement Policies in the United States: A City-Pair Analysis." *Transportation Research Part D: Transport and Environment*, vol. 9, no. 4, 2004, pp. 295-317.
[21] Avogadro, Nicolò, and Renato Redondi. "Pathways toward Sustainable Aviation: Analyzing Emissions from Air Operations in Europe to Support Policy Initiatives." *Transportation Research Part A: Policy and Practice*, vol. 186, 2024, 104121.
[22] Vinisha, Poornima, et al. "Sustainable Design Strategies for the Future of Aerospace Hubs: Integrating Green Technologies and Smart Infrastructure." *Proceedings of the 10th International Conference on Applying New Technology in Green Buildings (ATiGB)*, IEEE, 2025, pp. 854-863.
[23] Kumar, Bhavesh, et al. "Sustainable Aviation Finance: Integration of Environmental Impact Mitigation and Green Investment Strategies." *Research in Transportation Business & Management*, vol. 61, 2025, 101410.

intrinsically linked to the managed phasedown of conventional kerosene; treating these processes in isolation risks an analytically incomplete understanding of the transition dynamics. Accordingly, effective SAF policy must combine mutually reinforcing demand-side and supply-side measures that operate in parallel (as summarised in **Table 2**, below), while ensuring robust lifecycle sustainability across the entire value chain, from feedstock production and fuel processing to airline procurement, operational integration and environmental certification.

On the demand side, regulatory instruments such as blending mandates, minimum-use requirements and quota systems create guaranteed markets for sustainable aviation fuel and provide the long-term investment signals necessary for producers to scale. Recent policy initiatives such as the European ReFuelEU agenda and the United Kingdom's Sustainable Aviation Fuel Mandate exemplify the underlying design logic whereby compulsory market-creation instruments facilitate the early-stage deployment of alternative fuels that still require time to mature.[24] These measures increasingly sit within wider policy architectures shaped by the EU Green Deal and by existing and emerging international and regional carbon-pricing frameworks (e.g., EU Emissions Trading System),[25] which are intended to improve the market competitiveness of sustainable energy carriers.[26] In this context, economic instruments such as carbon pricing, differential fuel taxation and financial incentives encourage airlines and airports to procure SAF despite current price premiums.[27] The role of airline-airport partnerships is especially vital in this case, as they are instrumental in delivering the deployment of early niche markets for SAF.[28] Information and guidance tools assist airlines in complying with mandates, understanding blending logistics and planning for operational integration through compliance support measures, policy guidance on SAF adoption and frameworks clarifying blending strategies. Voluntary airline commitments, often exceeding regulatory requirements, contribute further by signalling corporate climate ambition, supporting early niche markets and strengthening reputational incentives for early action. Capacity-building instruments on the demand side are increasingly important, involving training programmes for airlines, airports and regulators on blending procedures, sustainability criteria and safety standards, and the strengthening of institutional capabilities for implementing conditional bailouts tied to emissions performance, which often include provisions promoting SAF uptake. A particularly notable measure is the progressive reduction of fossil fuel subsidies in aviation,[29] which helps correct existing price distortions and narrow the differential between SAF and conventional jet fuel.

On the supply side, scaling SAF production also depends on an integrated mix of regulatory, economic, voluntary and capacity-building instruments. Regulatory frameworks such as national and regional blending obligations create policy drivers not only for demand but also for supply, while certification schemes and harmonised technical standards provide predictable demand signals for producers and ensure consistency across

[24] Maulet, Nicolas. "UK Policy Instruments for Aviation Decarbonisation: The Sustainable Aviation Fuel Mandate and Policymaking Approach Underlying the Future UK Framework." *Global Energy Law and Sustainability*, vol. 5, no. 2, 2024, pp. 182-197.

[25] Reisdorf, Andrea, et al. "Opportunities and Challenges Arising from European Sustainable Aviation Fuel Regulations: A Case Study Approach." *Journal of the Air Transport Research Society*, vol. 5, 2025, 100085.

[26] Valdés, Rosa María Arnaldo, and Victor Fernando Gómez Comendador. "Strategies and Economics for Decarbonizing Aviation by 2050." *Sustainable Aviation*, 2025, pp. 227-265.

[27] Watson, M, et al. "Sustainable Aviation Fuel Technologies, Costs, Emissions, Policies, and Markets: A Critical Review." *Journal of Cleaner Production*, vol. 449, 2024, 141472.

[28] Varadarajan, Venugopal, et al. "Carbon Remediation for the Airline Industry via ATF Drop-in Substitution: Strategic and Operational Perspective." *SAE International Journal of Aerospace*, vol. 5, no. 1, 2012, pp. 1-10.

[29] Posada, Eduardo, et al. *Fossil Fuel Subsidy Reform in Aviation and Shipping*. International Institute for Sustainable Development, Feb. 2025.

production pathways.[30] Economic and financial instruments remain essential for overcoming the high capital and operating costs associated with early-stage SAF facilities.[31] Public funding through tax credits, capital grants, feedstock subsidies, output-based credits, support for carbon capture integration and green finance mechanisms significantly reduce financial risk and accelerate novel projects. Additional financial support for enabling technologies, such as renewable hydrogen for power-to-liquid pathways or carbon capture at biorefineries, further strengthens investor confidence. Knowledge sharing and voluntary initiatives, including pilot plants, collaborative research and development programmes, regional SAF demonstration projects, techno-economic modelling and cross-industry experimentation platforms help derisk innovation, build legitimacy and ensure knowledge transfer across SAF pathways. Capacity-building measures for supply chain scale-up are equally important, requiring strengthened research institutions, new centres of excellence, more effective technology transfer arrangements and deeper expertise in supply chain coordination. This includes strengthening national and international certification bodies, expanding institutional capacity for lifecycle reporting and supporting research networks that underpin the expansion of the SAF ecosystem.

Ensuring the environmental integrity of SAF constitutes a third and indispensable dimension of the transition. Robust sustainability regulations, harmonised fuel quality standards and lifecycle carbon accounting frameworks protect against indirect land use change, unsustainable feedstock sourcing and inconsistent environmental credentials.[32] Renewable fuel standards, harmonised sustainability protocols for alternative jet fuels and international certification frameworks help set clear requirements for environmental and social safeguards. At the same time, robust governance and transparency are required to prevent SAF research and deployment from being instrumentalised to delay near-term emissions reductions, dilute regulatory ambition or enable greenwashing through overstated climate benefits or selective lifecycle accounting. Economic instruments can reinforce sustainability by rewarding high integrity fuels through differentiated crediting systems, multiplier mechanisms, certified feedstock premiums and green taxation frameworks. Information and guidance tools such as lifecycle assessment methodologies, feedstock sustainability guidelines, best practice documents for low-carbon production and emerging global SAF sustainability frameworks support producer compliance and improve transparency. Strong institutional capacity is essential for monitoring lifecycle emissions, verifying sustainability criteria and administering certification systems. This requires the strengthening of data infrastructures, improvements in biofuel certification usability, training for auditors, harmonisation of regional sustainability protocols and alignment with global disclosure frameworks that shape reporting requirements for fuel lifecycle impacts. Moreover, recent literature has indicated the potential of SAF allocation strategies to reduce non-CO_2 climate impacts from aviation.[33]

In this vein, the policy levers shaping the deployment of sustainable aviation fuel constitute an integrated architecture spanning demand creation, supply-side scale-up and sustainability governance. Their effectiveness depends on coherent implementation across all three dimensions, supported by aligned

[30] Prussi, Matteo. "The Sustainability Dimension for Sustainable Aviation Fuels (SAF): Comparing Regional and International Approaches." *Sustainability*, vol. 17, no. 18, 2025, 8401.
[31] Zheng, Shiyuan, et al. "Carrot or Stick? Environmental and Welfare Implications of Sustainable Aviation Fuel Policies." *Transportation Research Part B: Methodological*, vol. 188, 2024, 103062.
[32] Prussi (n 30) *supra*.
[33] Woeldgen, Elisabeth, et al. "Sustainable Aviation Fuel Deployment Strategies in Europe: Supply Chain Implications and Climate Benefits." *Environmental Science & Technology*, vol. 59, no. 25, 2025, pp. 12447-12457.

regulatory signals, targeted economic incentives, clear technical guidance, voluntary action and robust institutional capacity. When deployed in a coordinated manner, these instruments enable SAF to contribute meaningfully to climate mitigation while supporting a credible, scalable and environmentally sound transition for the global aviation sector.

IV. **Impact Domain III: Alternative Aircraft Design**

Alternative aircraft design represents the most transformative yet also the most uncertain impact domain in aviation's transition toward deep decarbonisation. Whilst system efficiency improvements and sustainable aviation fuels can deliver substantial near and mid-term emissions reductions, long-term climate neutrality ultimately depends on reshaping the technological foundations of aircraft itself. Hydrogen-powered aircraft, battery-electric propulsion, hybrid-electric platforms and emerging electric vertical take-off and landing (eVTOL) aircrafts offer the prospect of zero or near-zero operational emissions. Yet each remains constrained by technological immaturity, infrastructure and energy system requirements, safety certification challenges and uncertain early markets. Effective policy therefore requires a balanced mix of technology push instruments that accelerate research and development and reduce innovation risk, and market-pull instruments that create credible early demand signals, encourage commercial uptake and support the emergence of viable markets for next-generation aircraft (**Table 3**, below).

Technology-push instruments form the foundation for advancing disruptive propulsion technologies by reducing early-stage risk and enabling scientific and industrial progress.[34] Regulatory instruments provide direction and legitimacy by establishing innovation roadmaps, technical standards and legal frameworks for hydrogen, electric and eVTOL aircraft, including rules for certifying new propulsion systems and aircraft categories. Economic instruments reinforce this by delivering large public investments in hydrogen and electric propulsion alternatives, offering financial support for prototype development and reinvesting environmental revenues into clean aircraft research and development.[35] Information and guidance instruments such as foresight studies, long-term innovation strategies and policies promoting technological partnerships help align research ecosystems and support the exchange of emerging knowledge. Voluntary instruments, including collaborative research programmes led by academic institutions, joint testing initiatives, and industry-driven innovation efforts, enhance experimentation and risk sharing among manufacturers, airports, and energy providers. Examples include the Bennett Innovation Lab hosted by the Whittle Laboratory at the University of Cambridge. Capacity-building instruments complement these measures by expanding research facilities, specialised skills and institutional capabilities, including support for high-risk technological alternatives, public-private research frameworks and work on integrating eVTOL technologies into the wider aviation system. Taken together, these technology-push instruments lay the groundwork for sustained progress across the aviation innovation pipeline.[36]

Market-pull instruments complement the supply side efforts by creating early demand, reducing commercial uncertainty and preparing aviation markets for the wider adoption of transformative aircraft technologies. Regulatory instruments such as clean aircraft deployment targets, performance-based certification rules and policies enabling the commercial use of new

[34] Kallbekken, Steffen, and David Victor. "A Cleaner Future for Flight—Aviation Needs a Radical Redesign." *Nature*, vol. 609, no. 7928, 2022, pp. 673-675.
[35] Huete, Jon, et al. "A Strategy to Decarbonize Civil Aviation: A Phased Innovation Approach to Hydrogen Technologies." *IEEE Electrification Magazine*, vol. 10, no. 2, 2022, pp. 27-33.
[36] Victor, David, et al. "Mobilizing Capital and Technology for a Clean Aviation Industry." *Science*, vol. 390, no. 6770, Oct. 2025, pp. 242-245.

propulsion systems help guarantee early market access and provide predictable signals to investors and manufacturers. Economic instruments including support for early adopters, preferential financing schemes and the allocation of environmental revenues to zero-emission aircraft deployment help bridge cost gaps and stimulate first-mover activity.[37] Information and guidance instruments aimed at passengers, operators and the wider public build social acceptance by increasing familiarity with hydrogen, electric and eVTOL technologies and communicating their operational and environmental benefits. Voluntary instruments including airline, manufacturer and airport partnerships, pilot testing programmes and collaborative innovation initiatives create participatory networks that accelerate early operational learning. Capacity-building instruments prepare markets and institutions for long-term diffusion by strengthening certification capabilities, developing supply chains, expanding workforce skills and investing in the infrastructure needed to support the introduction of hydrogen, methane, electric or alternative innovative aircraft.

Overall, radical innovation in aviation emerges not as a spontaneous outcome but as the product of sustained and coordinated policy intervention. It requires deliberate, long-term governance capable of stimulating technological discovery, supporting early markets and cultivating the institutional and industrial capacity needed for widespread adoption.

By balancing technology-push and market-pull approaches, policymakers can nurture an innovation ecosystem that accelerates the development, demonstration and diffusion of transformative aircraft technologies and places aviation on a credible pathway toward deep decarbonisation.

V. **Impact Domain IV: Air Travel Demand**

Travel and demand efficiency represents a critical yet politically sensitive impact domain of aviation decarbonisation. Even with substantial efficiency gains, large-scale adoption of alternative fuels and the emergence of radical technological innovations, long-term climate goals cannot be achieved without moderating growth in air travel demand. Demand management therefore spans systemic measures affecting all travellers, targeted interventions focused on high-emitting groups, and policies that address the specific patterns of business and organisational travel. Effective policy design must balance the societal value of air connectivity with the urgent need to reduce emissions, while recognising that a relatively small proportion of travellers accounts for a disproportionate share of total demand. Conceptually, as summarised in **Table 4** below, policy instruments operate across three levels: system-wide measures that affect all passengers, measures directed at individual travellers, and measures tailored to business and organisational travel.

System-wide measures affecting all passengers aim to reshape aggregate travel behaviour by altering regulatory, economic and informational conditions across the aviation system. Regulatory instruments include capacity limits at congested airports, restrictions on super short-haul flights, distance-based travel thresholds, and international agreements that incorporate sufficiency principles.[38] Economic instruments influence overall demand by internalising environmental costs through aviation carbon taxes, distance-based passenger charges and harmonised global air travel levies.[39] Voluntary instruments include airline-wide offset programmes and broad climate-responsibility schemes that invite passengers to engage proactively with their

[37] Wild et al. (n 15) *supra*.

[38] Dobruszkes, Frédéric, et al. "Banning Super Short-Haul Flights: Environmental Evidence or Political Turbulence?" *Journal of Transport Geography*, vol. 104, 2022, 103457.

[39] Fouquet, Roger, and Tanya O'Garra. "In Pursuit of Progressive and Effective Climate Policies: Comparing an Air Travel Carbon Tax and a Frequent Flyer Levy." *Energy Policy*, vol. 171, 2022, 113278.

environmental impact.[40] Capacity-building instruments operate at the systemic level by integrating sustainability and sufficiency considerations into national tourism and mobility planning, and by developing monitoring, evaluation and coordination frameworks capable of supporting long-term demand management.

Discussions of possible measures directed at individual travellers focus on specific passenger segments, particularly high-emitting and frequent luxury passengers whose behaviour disproportionately drives aviation emissions. Regulatory instruments include mandatory reporting of individual travel emissions and measures that promote modal substitution, particularly through the expansion and integration of high-speed rail networks. Economic instruments can apply either flat incentives or progressive responsibilities to the highest-emitting individuals, for example through frequent-flyer levies, premium-class taxes and surcharges for long-distance or luxury travel.[41] Voluntary instruments support behavioural change through personal carbon budgets, participation in sustainability programmes and greater uptake of low-carbon alternatives. Capacity-building instruments help individuals reduce carbon-intensive travel through support for videoconferencing in professional contexts, guidance on low-carbon mobility for short trips, and tools that allow travellers to monitor and reduce their flight frequency. It is worth noting that debates over the distribution of climate responsibilities between frequent flyers and ordinary users are ongoing, underscoring the need for a fair transition solution in the future.

Measures tailored to business and organisational travel target a segment historically responsible for a significant share of emissions within the organisational setting. Regulatory instruments include mandatory emissions reporting for corporations and public institutions, as well as compliance requirements that limit non-essential travel within organisational sustainability strategies. A prime case discussed is academic travel, which offers promising avenues to reduce emissions.[42] Economic instruments such as internal carbon pricing, corporate air travel levies and the redirection of aviation tax revenues toward low-carbon mobility alternatives reshape organisational incentives. Voluntary instruments include institutional travel-reduction pledges, organisational offset programmes and partnerships with airlines to explore lower-emission travel options, often reinforced by reputational competition through green-branding initiatives. Capacity-building instruments strengthen organisational transitions by establishing robust travel-reporting systems, training staff in sustainable mobility planning and investing in infrastructure and service integration that supports a shift from air to rail, particularly for business travel.

As shown above, aviation demand management relies on a combination of systemic action, targeted interventions and institutional transformation. The emphasis is not solely on constraining air travel but on creating supportive conditions that enable behavioural, cultural and structural changes towards a low-carbon mobility system.[43]

With coordinated governance, socially equitable policies and integrated multi-modal planning, it is possible to reduce aviation demand while preserving essential connectivity and promoting sustainable alternatives.

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[40] Becken, Susanne. "Tourists' Perception of International Air Travel's Impact on the Global Climate and Potential Climate Change Policies." *Journal of Sustainable Tourism*, vol. 15, no. 4, 2007, pp. 351-368.

[41] Kogler, Marie, et al. "Short-Term Emission Reductions in Leisure and Business Air Travel: Assessment of Taxation, Regulations, Sustainable Aviation Fuels and Personal Intentions." *Journal of Sustainable Tourism*, 2025, pp. 1-23.

[42] Ben-Ari, Tamara, et al. "Flight Quotas Outperform Focused Mitigation Strategies in Reducing the Carbon Footprint of Academic Travel." *Environmental Research Letters*, vol. 19, no. 5, 2024, 054008.

[43] Muehlberger et al. (n 9) *supra*.

VI. **Impact Domain V: Non-CO_2 Climate Effects**

As primary non-CO_2 climate forcers in aviation, contrails including contrail cirrus and nitrogen oxides (NOx),[44] represent an impact domain that highlights both the scientific complexity and the operational challenges involved in managing aviation's climate effects.[45] Specifically, a growing body of research indicates that contrails account for a substantial share of aviation's short-term climate impact, particularly when an aircraft passes through ice supersaturated regions.[46] Persistent gaps in atmospheric measurement, modelling capacity, and data infrastructure continue to limit the production of consistent real-world evidence.[47] At the same time, the processes through which emerging scientific understanding feeds into regulatory design, operational decision-making and market-based instruments are still evolving (**Table 5**, below). Acting on the best available evidence now can help break cycles of policy inaction, generate real-world implementation experience and, in turn, provide critical feedback that enables scientific understanding and policy frameworks to co-evolve within this rapidly developing governance space.

Contrail avoidance can be broadly divided into two parts: pre-tactical mitigation and tactical mitigation. Pre-tactical mitigation focuses on planning measures incorporated before a flight departs. Regulatory instruments shape this stage by requiring airlines and air navigation service providers to integrate contrail considerations into route scheduling and design, altitude and speed planning, and the strategic avoidance of ice-supersaturated regions, alongside technical requirements for new engine designs and energy carriers that reduce contrail formation across the fleet. Economic instruments reinforce these rules through funding for measurement campaigns and by shaping multi-species market signals, such as proposals to include all climate-relevant emissions in the European Emissions Trading System (ETS),[48] or to impose "climate charges" on airlines operating in certain airspace areas.[49] However, it must be acknowledged that such measures remain subject to ongoing debate and that multiple options are still under consideration, requiring close communication with the industry. Information and scientific standardisation instruments support the evidence base, including international methods for measuring particle size distribution and non-volatile particulate matter. Capacity-building instruments, including public support for data acquisition and modelling infrastructure, help operators embed contrail-aware planning in routine practice.

Tactical mitigation concerns real-time operational adjustments made during the flight. Regulatory instruments influence this phase through requirements or permissions for in-flight altitude changes, heading adjustments, and dynamic re-routing to avoid atmospheric conditions conducive to

[44] Further detailed technical discussion of the mechanisms through which aviation-induced contrail cirrus and NO_x emissions impact climate can be found here: Burkhardt, Ulrike, and Bernd Kärcher. "Global Radiative Forcing from Contrail Cirrus." *Nature Climate Change*, vol. 1, no. 1, 2011, pp. 54-58; Gilmore, Christopher, et al. "Temporal and Spatial Variability in the Aviation NOx-Related O_3 Impact." *Environmental Research Letters*, vol. 8, no. 3, 2013, 034027.

[45] *Contrails and Contrail Management: A Royal Aeronautical Society Briefing Paper*. RAS, Apr. 2023.

[46] Petzold, Andreas, et al. "Most Long-Lived Contrails Form within Cirrus Clouds with Uncertain Climate Impact." *Nature Communications*, vol. 16, no. 1, 2025, p. 9695; Singh, Dharmendra Kumar, et al. "Understanding the Role of Contrails and Contrail Cirrus in Climate Change: A Global Perspective." *Atmospheric Chemistry and Physics*, vol. 24, no. 16, 2024, pp. 9219-9262.

[47] Pushparaj, Nishanth, et al. "Real-Time Contrail Monitoring and Mitigation Using CubeSat Constellations." *Atmosphere*, vol. 15, no. 12, 2024, p. 1543; Sarna, Aaron, et al. "Benchmarking and Improving Algorithms for Attributing Satellite-Observed Contrails to Flights." *Atmospheric Measurement Techniques*, vol. 18, no. 14, 2025, pp. 3495-3532.

[48] Scheelhaase, Janina D. "How to Regulate Aviation's Full Climate Impact as Intended by the EU Council from 2020 Onwards." *Journal of Air Transport Management*, vol. 75, 2019, pp. 68-74.

[49] Niklaß, Malte, et al. "Concept of Climate-Charged Airspaces: A Potential Policy Instrument for Internalizing Aviation's Climate Impact of Non-CO_2 Effects." *Climate Policy*, vol. 21, no. 8, 2021, pp. 1066-1085.

persistent contrails. Voluntary instruments are particularly influential here, as demonstration flights and industry-led trials provide empirical evidence of feasibility under operational constraints. Economic instruments play a smaller but growing role in encouraging airlines to trial climate-friendly trajectories. Capacity-building instruments are essential, including Living Lab Airspace Trials for real-world experimentation, scientific programmes that improve measurement and modelling, and training for pilots, controllers, and dispatch teams to ensure safe and consistent implementation of tactical contrail mitigation. Many of these considerations apply to both pre-tactical and tactical avoidance, underscoring the need for a coherent policy framework that aligns planning-stage decisions with real-time operational practices.

Nitrogen oxides represent a separate non-CO_2 impact pathway shaped by complex atmospheric chemistry. Regulatory instruments include engine emission standards, combustor design requirements, and emerging multi-species climate governance frameworks. Economic instruments provide incentives for research, development, and efficiency improvements, and may eventually include pricing signals that reflect NO_x-related climate impacts. Voluntary instruments support operational experimentation, such as trials of altitude optimisation to influence net NO_x climate effects. Capacity-building instruments strengthen atmospheric modelling, monitoring systems, and reporting standards, enabling operators and regulators to make decisions that reflect the full climate consequences of NO_x emissions.

Overall, non-CO_2 climate impacts, particularly contrail and contrail-induced cirrus formation, offer a near-term mitigation opportunity for aviation policy. Initiatives such as contrails.org suggest that targeted contrail avoidance could deliver meaningful climate benefits at relatively low cost through operational adjustments rather than major technological change. Compared with deep CO_2 mitigation measures, such as large-scale deployment of sustainable aviation fuels, non-CO_2 options like contrail avoidance require less system-wide transformation and therefore represent an attractive complementary pathway within a broader aviation decarbonisation strategy.

VII. **Concluding Remarks**

To address the climate risk in the aviation sector, a comprehensive policy mix approach that covers a wide set of impact domains is required in today's sustainable aviation policymaking, as shown in the preceding analysis. This spans incremental improvements in system-wide efficiency and the development of SAFs, ambitious moonshot projects laying the foundation for transformative innovation breakthroughs, fundamental rethinking of demand-side travel behaviours in the coming decades, and attention to often-overlooked non-CO_2 climate impacts. Achieving the Paris Agreement targets requires the effective deployment of regulatory, economic, voluntary, and capacity-building instruments for multiple stakeholder groups across the whole sector, and across all five key impact domains, in a coherent and consistent manner. Collectively, the design of policy strategy, the choice of instruments, and the styles of policy processes merit greater attention from this cross-cutting scoping viewpoint. When re-weaving currently fragmented sustainable aviation policy levers to address climate risk, it is critical that policy actions align with overarching, credible system pathways for each impact domain, guided by a well-defined policy strategy. To achieve this, a set of actionable principle plans with well-defined policy objectives for each impact domain needs to be developed and packaged as top-level guiding frameworks. This will inform strategic ambitions for a climate-friendly aviation future.[50] This builds

[50] Rogge, Karoline, and Qi Song. "Policy Mixes for Addressing Environmental Challenges." *Routledge Handbook of Environmental Policy*, edited by Helge Jörgens et al., Routledge, 2023, pp. 327-346; Nemet, Gregory, et al. "Addressing Policy Credibility Problems

a traceable and credible chain of system thinking that helps integrate currently isolated policy actions, moving from high-level targets with quantified ambition levels, to principled plans outlining the general pathway for each impact domain, to policy levers addressing various intervention points related to climate risk. As shown in this stocktaking exercise, interactions between measures such as innovative aircraft design, SAF deployment and contrail avoidance point to the need for a whole-system approach that addresses within-domain goals while recognising cross-domain linkages. While individual impact domains may deliver substantial emissions reductions if pursued aggressively, none is sufficient on its own to deliver a robust, system-wide transformation of aviation. Each domain faces inherent constraints, uncertainties and implementation risks—whether related to technological maturity, feedstock availability, operational feasibility or governance—which limit the reliability of single-track strategies. Over-reliance on one domain therefore risks delaying progress, creating lock-in or amplifying failure if expected gains do not materialise at scale. A diversified portfolio of aligned policy levers across impact domains reduces these risks, enables complementarities between solutions with different temporal profiles and increases the likelihood of achieving sustained and credible climate outcomes. This systems logic should be reflected in forthcoming top-level strategy discussions and roadmap development, guiding resource allocation and priority-setting over time.

The choice, implementation, and assessment of policy instruments—from regulatory and economic to voluntary and capacity-building—and their mixes, should be reconsidered case by case, based on each impact domain, target group, and governance level.[51] As discussed, the nature of climate-risk problems differs substantially across impact domains. Likewise, sustainable aviation solution developers vary across stakeholder groups, as does the potential for resistance. Governance resources and legislative authority also differ across international, national, and regional levels, all of which will require greater attention in the future. The contextual conditions must be considered when developing coherent policy processes, particularly in deliberately sequencing policy levers in a time-wise approach over the coming years. In particular, attention is needed to exploit near-term opportunities that can open windows for cascading transformation.[52] The hard-to-abate nature of aviation should not serve as an excuse for delaying transformative action; instead, it should motivate the identification and prioritisation of policy levers that can create positive feedback loops and accelerate the transition.[53] Future inquiries should focus on nuanced analyses of specific policy levers within particular impact domains, taking account of techno-economic viability, socio-political feasibility, resource constraints and governance arrangements, alongside their effectiveness in delivering both short-term and long-term climate benefits. In doing so, such analyses will support the development of a time-sequenced approach to selecting and sequencing policy mixes, with potential feedback loops taken into account, enabling cascading system changes toward a sustainable aviation future.

Finally, regarding the styles of policy processes, it is important to acknowledge the

for Low-Carbon Investment." *Global Environmental Change*, vol. 42, 2017, pp. 47-57.

[51] Howlett, Michael, and Pablo del Rio. "The Parameters of Policy Portfolios: Verticality and Horizontality in Design Spaces and Their Consequences for Policy Mix Formulation." *Environment and Planning C: Government and Policy*, vol. 33, no. 5, 2015, pp. 1233-1245; Mavrot, Céline, et al. "Mapping the Mix: Linking Instruments, Settings and Target Groups in the Study of Policy Mixes." *Research Policy*, vol. 48, no. 10, 2019, 103614.

[52] Meckling, Jonas, et al. "Winning Coalitions for Climate Policy." *Science*, vol. 349, no. 6253, 2015, pp. 1170-1171.

[53] Geels, Frank, and Martina Ayoub. "Policy Feedbacks and Socio-Technical Feedbacks in Accelerated Low-Carbon Transitions: An Integrated Conceptual Framework Illustrated with Case Studies of Lighting and Smart Meters." *Research Policy*, vol. 54, no. 8, 2025, 105294.

high complexity and uncertainty inherent in the aviation transition, which will persist over time.[54] Uncertainties span incomplete scientific understanding of certain climate-risk mechanisms, such as contrail effects, long development timelines and performance risks associated with radical aircraft technologies, and evolving socio-economic drivers of air travel demand. These conditions limit the effectiveness of static or prescriptive policy approaches and instead call for experimental, adaptive and learning-oriented policy styles.[55] Policy strategies should therefore embed mechanisms for iterative learning, evidence generation and adjustment over time, supported by capacity-building instruments that strengthen analytical capability, transparency and stakeholder participation. Progress toward climate-friendly aviation will depend less on predetermined technological fixes than on governance systems capable of operating under uncertainty, testing interventions in real-world contexts and recalibrating pathways as knowledge evolves. Under these conditions, transformative leadership is required to sustain commitment, accelerate implementation where transformative potential has been demonstrated, enable the timely deployment of emerging solutions, and remain responsive to new evidence and changing circumstances.

To conclude, this viewpoint article has provided a stocktaking overview of sustainable aviation policy levers for addressing climate risk across key impact domains in the entire aviation sector. In doing so, it offers a more granular perspective and a heuristic framework for rethinking the system-level deployment of policy levers. The variety, complementarity, and cascading synergies across instruments showcased in the analysis highlight promising avenues for future research to deepen inquiry into specific policy interactions and implementation pathways. Acknowledging policy complexity is the first step toward navigating it. Now is the time to chart a clear course for take-off.

Impact Domain I: System Efficiency Improvement	**Instrument Type**			
	Regulatory	**Economic**	**Voluntary**	**Capacity-building**
Fleet & Technology Efficiency	Fuel efficiency standards, carbon and greenhouse gas performance requirements, baseline aircraft design criteria.	Emissions taxes, subsidies and incentives supporting fleet renewal and efficient aircraft investment.	Sustainability programmes, green fleet management schemes, voluntary aircraft replacement initiatives.	Technology road mapping, fleet planning support, institutional capability for evaluating efficiency gains.
Operational Efficiency	Rules on flight age, weight and load optimisation, fuel management procedures, slot allocation and utilisation reforms.	Differential carbon taxes, environmental landing charges, delay-based pricing.	Airline-led operational improvement initiatives and best-practice demonstration projects.	Training for flight crews and ground staff, operational guidance from international bodies such as ICAO and IATA.
Airspace & Network Efficiency	Airspace redesign frameworks, international performance standards, cross-border coordination mechanisms such as Single European Sky.	Route-linked carbon pricing, incentives for optimised routing and network-level planning.	Collaborative programmes between airlines and air navigation service providers to improve routing.	Institutional capacity for airspace design, controller training, traffic-flow optimisation and integrated network-management systems.

[54] Peeters, Paul, et al. "Are Technology Myths Stalling Aviation Climate Policy?" *Transportation Research Part D: Transport and Environment*, vol. 44, 2016, pp. 30-42.

[55] Kallbekken et al. (n 4) *supra*.

Airport & Ground Infrastructure Efficiency	Requirements for sustainable terminal design, surface operations optimisation, electric taxiing and ground-mobility standards.	Green bonds, targeted subsidies, carbon taxes and green airport charges supporting low-carbon infrastructure.	Airport-led sustainability initiatives and cooperation with operators to improve ground-efficiency practices.	Infrastructure planning support, lifecycle assessment capability, staff training and monitoring systems for sustainable ground operations.

Table 1: Impact Domain I—Summary of Policy Levers for System Efficiency Improvement.

Impact Domain II: Sustainable Aviation Fuel	**Instrument Type**			
	Regulatory	**Economic**	**Voluntary**	**Capacity-building**
Demand-Side	Blending mandates, minimum use requirements, quota systems, harmonised regional rules, lead market initiatives (e.g., Fit for 55), conditional bailouts tied to emissions performance.	Carbon pricing, differential fuel taxation, carbon credits for e-fuels, green financing mechanisms such as green bonds and sustainability linked loans, joint procurement models.	Airline commitments to exceed mandate levels, corporate SAF purchase agreements.	Training on blending procedures and sustainability criteria, institutional capacity for mandate implementation and emissions linked conditions.
Supply-Side	Certification schemes such as ASTM D7566, harmonised technical standards, dedicated alternative jet fuel regulations, EU Green Deal frameworks for scale up.	Tax credits, capital grants, feedstock subsidies, output based credits, green finance for innovative facilities and wider infrastructure development, support for enabling technologies such as renewable hydrogen and carbon capture.	Pilot plants, collaborative research and development, industry led demonstration projects and experimentation platforms.	Expansion of research institutions and centres of excellence, technology transfer systems, strengthened certification bodies and supply chain coordination expertise.
Lifecycle Sustainability	Sustainability protocols, renewable fuel standards, harmonised lifecycle carbon accounting, international certification frameworks and safeguards.	Differentiated crediting schemes, multiplier mechanisms, certified feedstock premiums, green taxation aligned with lifecycle integrity.	Sustainability guidelines, lifecycle assessment methodologies, best practice frameworks for low-carbon production.	Data infrastructures for lifecycle monitoring, auditor training, usability improvements in certification systems, harmonisation of regional sustainability protocols and global disclosure frameworks.

Table 2: Impact Domain II—Summary of Policy Levers for Sustainable Aviation Fuel.

Impact Domain III: Alternative Aircraft Design	**Instrument Type**			
	Regulatory	**Economic**	**Voluntary**	**Capacity-building**
Technology-Push	Innovation roadmaps and technical standards for hydrogen, electric, hybrid electric and eVTOL systems; certification frameworks for new propulsion and aircraft categories.	Public investment in early-stage R&D, prototype development and demonstration projects; financial support for high-risk technological alternatives.	Collaborative research programmes, joint testing initiatives and industry led innovation partnerships.	Expansion of research facilities, specialised skills and institutional capabilities supporting early-stage innovation.

Market-Pull	Clean aircraft deployment targets and performance linked certification rules; policies enabling commercial operation of new propulsion technologies.	Incentives for early adopters; preferential financing and allocation of environmental revenues to support zero-emission aircraft uptake.	Airline, manufacturer and airport alliances for pilot testing and early market trials.	Development of supply chains, workforce skills, certification capacity and infrastructure enabling large scale adoption.

Table 3: Impact Domain III—Summary of Policy Levers for Alternative Aircraft Design.

Impact Domain IV: Air Travel Demand	**Instrument Type**			
	Regulatory	**Economic**	**Voluntary**	**Capacity-building**
System-Wide Measures	Flight taxes and levies, capacity limits, restrictions on super short-haul flights, distance thresholds, international sufficiency agreements.	Aviation carbon taxes, distance-based passenger charges, global or regional travel levies.	Airline-wide offset schemes, general climate-responsibility programmes.	Integration of demand management into tourism and mobility planning, system-wide monitoring and coordination frameworks.
Individual Travellers	Mandatory travel-emissions reporting, policies promoting modal shift, especially high-speed rail.	Frequent-flyer levies, premium-class surcharges, additional charges on long-distance or luxury travel.	Personal carbon budgets, participation in sustainability programmes, voluntary flying reduction.	Support for videoconferencing, guidance on low-carbon mobility, tools for tracking and reducing flight frequency.
Business and Organisational Travels	Mandatory reporting for corporations and public institutions (including universities), organisational travel-compliance requirements.	Internal carbon pricing, corporate travel levies, redirected revenues for low-carbon mobility.	Institutional travel-reduction pledges, organisational offset initiatives, partnerships for lower-emission travel options.	Travel-reporting systems, training in sustainable mobility planning, investments in rail-air integration for business travel (e.g. internet access).

Table 4: Impact Domain IV—Summary of Policy Levers for Air Travel Demand.

Impact Domain V: Non-CO_2 Climate Effects	**Instrument Type**			
	Regulatory	**Economic**	**Voluntary**	**Capacity-building**
Contrail	Altitude, time, speed and trajectory planning requirements, avoidance of ice-supersaturated regions, integration of contrail impacts into multi-species regulation and emissions trading, standardised measurement protocols for nvPM and PSD, contrail-aware aircraft or fuel-based technical requirements.	Funding for measurement campaigns and modelling, financial incentives for contrail-aware routing, adjustments to market signals within ETS.	Demonstration flights testing altitude adjustments, optimal routing, and real-time avoidance of climate-sensitive regions.	Development of measurement standards, Living Lab Airspace Trials, operational training for pilots, dispatchers, and air traffic controllers.
NOx	Emission standards for engines and combustors, integration of NO_x into multi-species climate governance frameworks.	R&D funding supporting engine efficiency and combustor innovation, potential multi-species pricing signals.	Operational experimentation with altitude optimisation and routing strategies to reduce climate-sensitive NO_x effects.	Advances in atmospheric chemistry modelling, improved monitoring and reporting systems, training to interpret multi-species climate metrics.

Table 5: Impact Domain V—Summary of Policy Levers for Non-CO_2 Climate Effects.