Ministry of Defence

Defence Suppliers Forum

Defence Aviation Net Zero Strategy

Foreword

by Baroness Goldie DL, Minister of State for Defence Climate Change and Sustainability

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Since the release of the MOD Climate Change and Sustainability Strategic Approach in 2021, the illegal war in Ukraine has made it clearer than ever that the global dependence upon fossil-fuels provides our adversaries with a means to weaponize the energy systems that our national security depends upon. Similarly, we are seeing an increasing number of extreme weather events that impact the demands and challenges faced by our Armed Forces personnel and the capabilities they operate.

At the same time, the UK's response to climate change has moved at pace, particularly for the hard-to abate sectors such as aviation where the release of the government's Jet Zero strategy sets clear ambition going forward. Noting the MOD strategic approach outlines Defence's role as a 'fast follower' to their civil counterparts, this document provides the necessary foundation for how the Defence Aviation sector can reach net zero.

Whilst Defence has recognised its role in addressing climate change and achieving the UK's legal commitment of net zero by 2050, the arguments above demonstrate why this must be considered within the context of increasing threats posed by climate change, the global energy transition, and the technology innovation disruption currently underway across the civil aviation sector. Defence must address these risks in order to formulate its approach to the future climate change and sustainability challenges.

As such, I welcome the release of the Defence Aviation Net Zero strategy which clearly sets out the potential risks to Defence activity alongside a clear and robust framework by which to mitigate any potential impacts, whilst simultaneously seeking to provide the UK with military, economic and technological advantage. Noting its development in collaboration with Defence industry and academic stakeholders, I am confident that the pursuit of this strategy will ensure that Defence's aviation operations will become more robust, resilient, and operationally effective despite the challenges ahead.

Introduction

The UK government has established a legal requirement for the country to reach net zero emissions by the year 2050.[1] In response to this, the Ministry of Defence (MOD) has issued its Climate Change and Sustainability Strategic Approach[2] outlining how defence will contribute to this requirement. In 2022 the Department for Transport (DfT) published the Government's Jet Zero Strategy to achieve net zero UK aviation by 2050[3][4]. Whilst emissions from military flying were not included in their emissions reduction trajectory, Defence is aligned with the Jet Zero Strategy and will lead the activity necessary for the UK's Defence Aviation to contribute to net zero by 2050, in-line with wider Defence policy. In addition, in 2021 the previous Chief of the Air Staff outlined his ambition, through the Astra vision for the RAF, to act as a Defence leader in this area and become the first net zero air force by 2040[5][6]. As such, this strategy accounts for both ambitions and timelines.

Defence Aviation emissions, attributable to the combustion of aviation fuel, contributed around 35% of the MOD's total emissions in 2019/20[7]. Aviation emissions are not only the largest contributor, but they are also seen as some of the hardest to abate due to the significant technological challenges that are involved. The strategy sets out the arguments for change: the scope, the military aviation context, and the mitigation options that form the decarbonisation pathway. These include rethinking capability provision; improved technical and operational efficiency; sustainable aviation fuel; zero emissions propulsion; and the necessity for carbon removals.

This strategy is intended to inform stakeholders across the Defence enterprise so that they can begin to plan for how their resources might be best directed towards this challenge. This includes internal organisations, but also setting the demand signal to defence suppliers (in the defence industrial base, the energy sector and beyond) to communicate Defence's requirement as their customer. It will also inform the UK's allies on how we plan to tackle this challenge, so that we can ensure interoperability is maintained. Finally, this strategy coheres appropriately with the wider Defence Operational Energy Strategy which considers Operational Energy through the energy transition from a Defence-wide perspective; together these will inform broader government so that Defence's transition is aligned with their approaches. Implementation of this strategy will be led through the Defence Suppliers Forum Climate Change and Sustainability Aviation Group.

[1] UK becomes first major economy to pass net zero emissions law - GOV.UK (www.gov.uk)
[2] Defence outlines greener future - GOV.UK (www.gov.uk)
[3] Jet Zero strategy: delivering net zero aviation by 2050 - GOV.UK (www.gov.uk)
[4] States adopt net-zero 2050 global aspirational goal for international flight operations - ICAO
[5] CAS ASTRA Directive
[6] RAF NZ40 Strategy
[7] MOD Sectoral Approach Trajectory by TLBs (FY2019/20 to FY2050/51)

The Argument for Change

The MOD's Global Strategic Trends[8] analysis has, for the first time, recognised Climate Change as a serious factor in the future national security context. Alongside increased disruption and cost, there is also increasing likelihood for military intervention because of climate security challenges. This provides some justification for Defence to mitigate its own climate impact, to shield itself from spiralling costs and to limit security risks that require military personnel to be placed in harm's way. Noting its own emissions contribution is relatively small[9], this argument alone is often insufficient to justify change against numerous competing national security priorities and a finite Defence budget. However, there are several other operationally and strategically centred arguments that make climate change and sustainability an increasing priority, these include:

a. **Adapting to a climate changed air operating environment.** Defence Aviation must continue to deliver its operational output in increasingly volatile conditions. Examples include chronic issues such as higher atmospheric temperatures which will affect aircraft propulsive performance, but also acute challenges such as extreme weather e.g., flash floods. We must ensure our people, infrastructure, equipment, and processes are able to fight under all these scenarios.

b. **Enhancing operational resilience.** There will be an increase in resource volatility and competitivity, which will introduce greater supply-chain risk that could undermine our ability to operate. It is true that vulnerability already exists within our supply-chain because of the dependence upon fossil fuels, meaning the move to energy secure alternatives allows Defence Aviation to become more resilient to supply-chains risks.

c. **Preventing operational constraints that arise from global systemic transitions.** In the face of increasing pressure and regulation to mitigate climate impacts, civil aviation will be forced to move away from fossil fuel combustion technology towards alternative energy systems. An argument can be made that the importance of national security outweighs the environmental challenge, thus alleviating the pressure on Defence Aviation to change in the same way. However, should Defence Aviation stand still it could find itself operationally constrained as a result of civil-military interoperability being lost. If it is unable to function in parallel with global energy supply chains and civil airport infrastructure, it is also likely to face greater expense in order to operate in isolation. Military-military interoperability with our Allies is also essential for similar reasons. This means the argument to maintain the status-quo is simply not viable.

d. **Maintaining our 'License to Operate'.** As Defence engages in an increased level of climate-related conflict or providing humanitarian relief as a result

[8] Global Strategic Trends – The Future Starts Today - GOV.UK (www.gov.uk)
[9] Aviation capability emissions were estimated at 1.2MtCO2e as part of the Sectoral Approach analysis.

of extreme weather events, the legitimacy of its actions will be open to scrutiny if it is not seen to be tackling its own climate change impacts. Irrespective of tactical or operational successes, this narrative could be exploited by our adversaries to undermine the MOD's achievements and limit strategic success.

e. **Maintaining our cognitive edge.** Defence has recognised the importance of its people as our adversaries potentially close the capability gap on the UK and its allies. As societal sympathy towards climate change continues to increase across the UK's population, it is already being seen that many young people, as well as experienced professionals, are seeking employment in organisations that take climate change seriously. If Defence is unable to attract talented people from across the full breadth of society, it risks depleting its cognitive edge whilst also potentially introducing recruitment and retention pressures.

f. **Delivering broader UK prosperity benefits.** Defence spending has a significant impact on the UK economy. Whilst the MOD Strategic Approach identifies our capacity as a fast follower, it potentially has a role to positively catalyse the UK government's 'Build Back Greener' strategy[10] and to stimulate economic growth. For example, using defence to procure early offtake agreements for Sustainable Aviation Fuel (SAF) could provide market confidence that sees SAF production accelerate. Similarly, Defence investment in battery or hydrogen research and development could accelerate their route to market in general aviation applications.

[10] Net Zero Strategy: Build Back Greener - GOV.UK (www.gov.uk)

Scope, Methodology and Assumptions

The Defence Aviation Net Zero strategy looks to use decarbonisation as a measurable strategic framework to deliver all the military benefits outlined above. This will prioritise activity towards Defence Aviation's scope 1 and 2 emissions for flying activity across all Defence aviation platforms[11]. The scope-3 emissions will not be considered in detail, but it is recognised that they are important, and will be accounted for across other MOD activity (e.g., as part of 'Business-as-Usual' activity to determine the commercial requirements in future acquisition and through life support requirements).

Aviation activity is part of a wider system including the enabling aviation support equipment (ASE) and airbase infrastructure. Some these capabilities will be considered by other governance areas, such as the estate and land equipment strategies; this strategy will ensure it informs the requirements within these areas. However, certain elements of ASE not captured elsewhere will be included within the boundary of this strategy alongside the flying capabilities. These boundaries will continue to be examined, as assumptions and technology develop.

This strategy is designed to provide a direction of travel for Defence aviation organisations to direct, allocate and prioritise their resources in their net zero aviation ambitions. The development of this net zero pathway has been underpinned by several separate data-led analyses[12][13], which have considered the current availability and maturity of the relevant technologies as a means to assess their future potential. The analysis also considered the pathways developed by civil aviation and adapted their approaches to the capability needs of military air-systems (Figure 1). This ensures the pathway mitigation options remain closely aligned to the wider Government's Jet Zero approach.[14]

[11] Assuming the electrification of the UK national energy systems by 2035 - GOV.UK (www.gov.uk)
[12] "Assessing the Vulnerability of Net Zero Aviation Strategies, to Inform Military Decarbonisation Pathways" 2022
[13] "How We Plan to Achieve Net Zero RAF by 2040" 2022
[14] Jet Zero Strategy - Analytical Annex

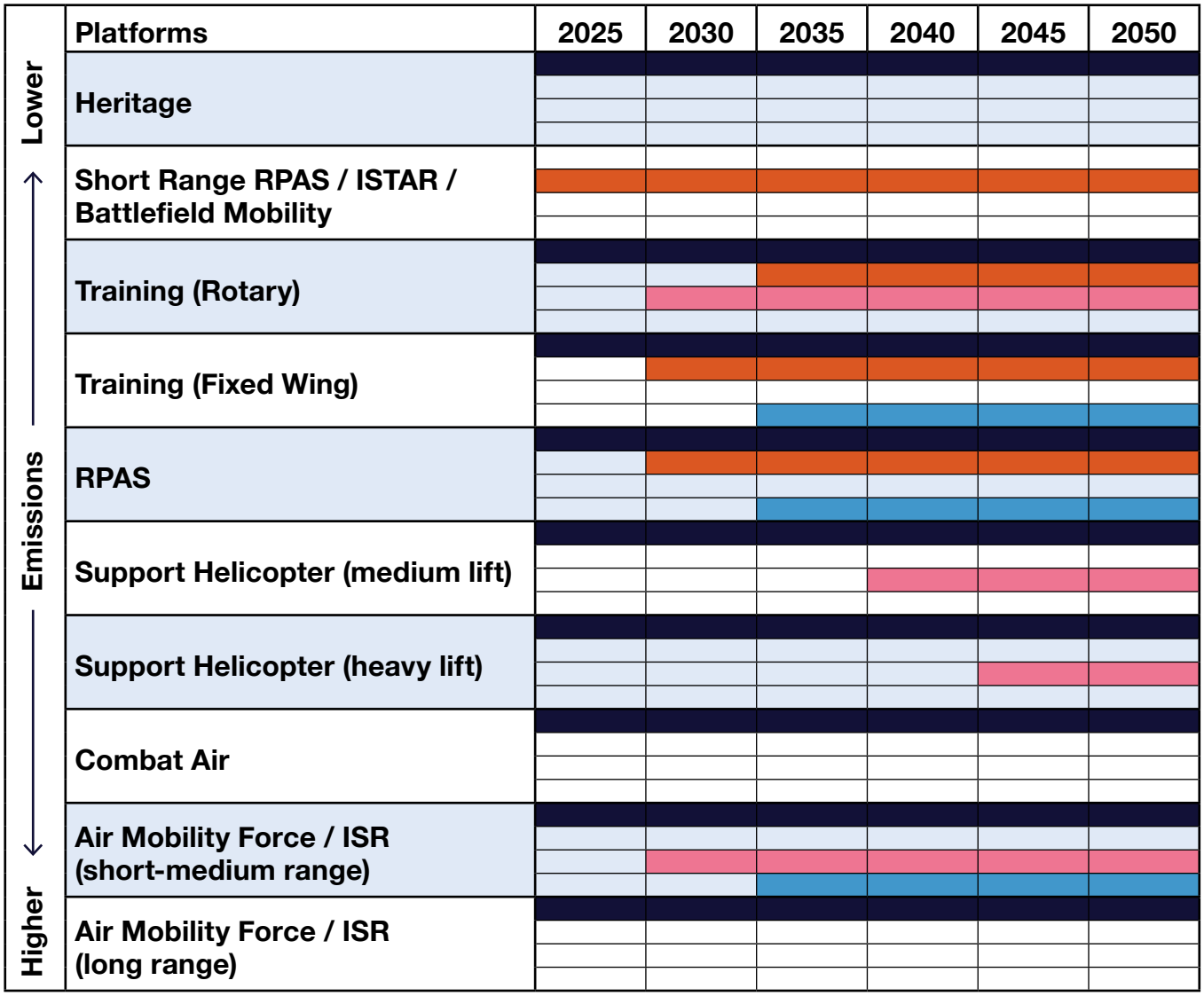

Figure 1 – MOD and Industry View of Aviation Decarbonisation Technology Potential.[15][16]

Key: SAF Battery Electric Hybrid SAF/Electric Hydrogen

[15] This diagram represents industry and MOD's 'most likely scenario'. Defence will seek to exploit new technologies, such as hydrogen, as they become available in each segment and can be demonstrated to offer operational advantage. Where hydrogen is seen in the short-medium range ISR role, this is currently envisaged being in the rapid exploitation of small, regional aircraft. Larger commercial derivative aircraft would follow 10-15 years after their commercial origin aircraft enter service and so fall outside of the 2050 window.

[16] SAF is most likely to be delivered in blends with traditional kerosene products, even beyond 2050. Therefore, SAF refers to the use of any approved, sustainable hydrocarbon fuel, blended up to 100% with its fossil equivalent.

Military Aviation Context

To achieve net zero there are two areas that must be considered. First, how we decarbonise the current fleet of air systems, and those that will enter service before the net zero ambition date. Second, we must recognise that decisions will be made regarding the requirements for several future capabilities prior to the ambition date and these will impact the emissions scope of air systems for 2050 and beyond. These capability decisions will be made in a rapidly evolving air operating environment that will be influenced by climate change. Defence Aviation's climate change and sustainability ambitions cannot come at the expense of its operational output and national security, a challenge that sets it apart from the commercial aviation challenge. However, whilst Defence mitigates the risks posed by climate change, this also presents opportunities to enhance its operational effectiveness and resilience at the same time[17].

The MOD's Strategic Approach outlines Defence's role as a 'fast follower' and Defence benefits from numerous synergies with the civil aviation sector that permit this approach. Especially as the majority of Defence aviation's emissions are caused by the RAF (Figure 2), which are predominantly attributable to its strategic air mobility platforms which hold several similarities with commercial airline capabilities. However, Defence also has many unique attributes that may require it to lead in certain areas. For example, the development of unique capabilities such as combat air systems, or military specific considerations such as platform security. These will require concerted efforts from within the defence aviation sector itself.

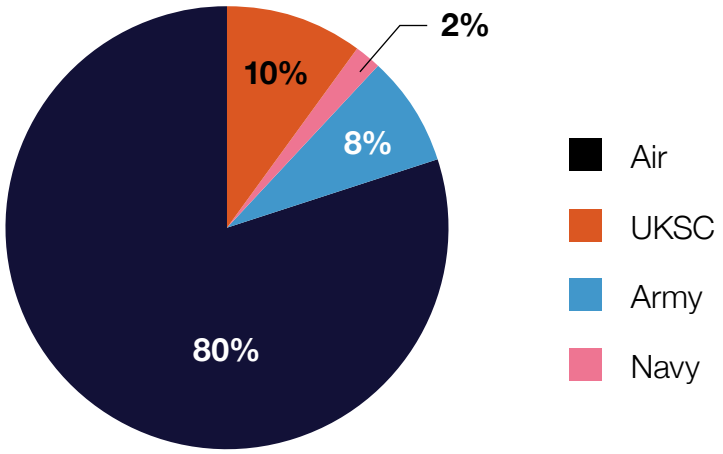

Figure 2 – Attribution of Defence aviation sector emissions for the 2018/19 baseline year.

[17] This strategy is also aligned with the Defence Operational Energy Strategy which will be published in Jun 23.


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Decarbonisation Pathway

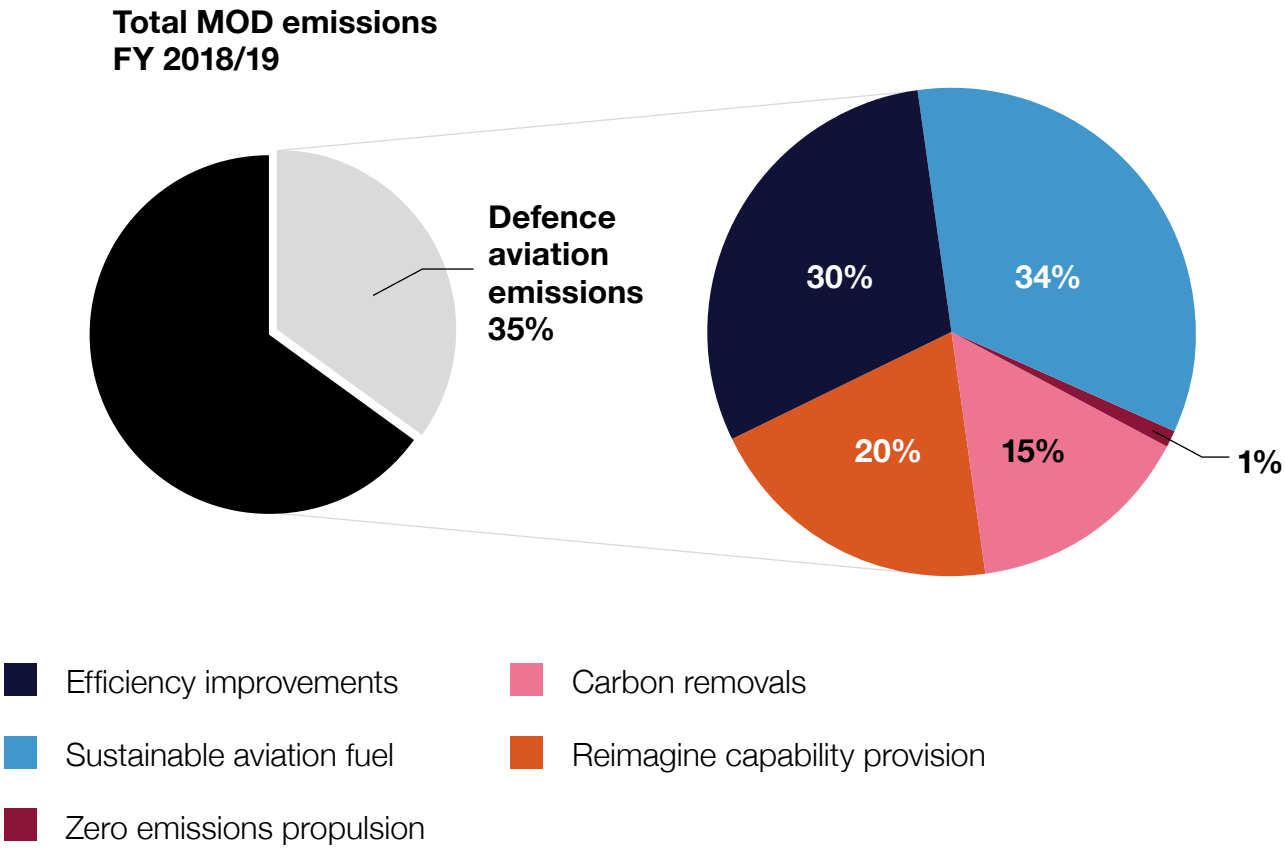

Figure 3 – Defence Aviation Net Zero Pathway.

The pathway to achieve net zero in Defence aviation will be through the combination of five mitigating options: rethinking capability provision; improving technical & operational efficiency; introduction of sustainable aviation fuel (SAF); zero emissions propulsion; and carbon removals. Whilst these link to the various mitigating options that are proposed in civil aviation net zero strategies[18], they are appropriately different to reflect the nature of Defence. Figure 3 shows the anticipated contribution of each option to the Defence Aviation net zero pathway. This is based upon our initial analysis to provide early planning assumptions; however, this will be regularly reviewed to update assumptions and reforecast against real-time progress on a periodic basis.

[18] Such as the six measures detailed in the Jet Zero Strategy (Page 25, Paragraph 3.1).

Each mitigation option is explained below[19]:

Rethinking Capability Provision (20%)

Whilst the Defence Aviation's net zero ambition cannot impede its operational effectiveness, the service can consider demand side interventions that continue to deliver effective warfighting capability via less emission intensive means. Defence aviation should aim for a 20% reduction in its aviation demand. The following paragraphs provide examples of how this could be achieved:

1. **Increasing synthetic training.** Shifting demands from live to synthetic training environments will not only reduce overall energy requirements, but this energy can also be delivered using low-emissions sources from national infrastructure or the Defence estate. This can lower emissions without loss in training capability delivery and it is hoped that the evolution of augmented and virtual reality, along with concepts such as platform surrogacy, can even deliver an enhanced training experience. For example, within the RAF, the first milestone in the CAS' ASTRA blueprint expects a 30:70 in favour of synthetic training by 2030.
2. **Alternative means of capability delivery.** This requires capability owners to determine whether they can deliver the same, or enhanced levels of output, using alternative conceptual approaches. For example, migrating delivery from crewed Air-systems to space or uncrewed assets has the potential to reduce energy requirements for the same level of operational output. Opportunities exist across: Intelligence; Surveillance and Reconnaissance; Air Command and Control (C2); Air Mobility and Strike capabilities.

[19] Pathway percentages are derived from: "Assessing the Vulnerability of Net Zero Aviation Strategies, to Inform Military Decarbonisation Pathways".

Improving Technical and Operational Efficiency (30%)

Whilst the Service has always sought out greater efficiency in the resources available to it, the net zero agenda presents an opportunity to justify greater investment in fuel efficient technologies. It is expected that 30% efficiency savings will be required to contribute to the overall goal. This will be delivered via several measures:

1. **Air-System Technical Changes (20%).** This includes technology that delivers greater fuel efficiency via improved aerodynamic (e.g., improved surface finishes, airflow enhancements, removal of redundant systems etc), propulsive (e.g., improved washing regimes) and weight reduction measures. These technologies can be integrated via fleet renewal, by ensuring platform efficiency metrics are included in the early requirement setting phase, or via modification of those systems that are already operational and will remain in service beyond 2040. The prioritisation of efficiency technologies will be best judged at an individual capability level by agreeing progressive efficiency targets with platform Delivery Teams.
2. **Air and Ground Operations (10%).** There is significant potential to improve operational efficiencies from the point of taxi to the final parking position. In the air this can be achieved through traffic management optimisation and improving flight planning considerations (e.g., route optimisation, continual descent approaches). On the ground this can be done via measures such as single engine taxiing, optimised ground taxi routes, and zero emissions support vehicles.

Sustainable Aviation Fuel (SAF) (34%)

As with commercial aviation strategies, SAF will form the backbone of emissions reductions, responsible for up to 34% of the pathway. To achieve 100% SAF uptake requires further effort to certify fuel pathways that minimises technical changes to current capabilities. However, the predominant challenge will come in establishing robust supply-chains to meet Defence Aviation's fuel demands. The other options of this strategy help to reduce fuel requirements by up to 51% by 2040. Beyond this, Defence is already being proactive to improve supply, with a RAF Voyager test flight using 100% SAF taking place in November 2022[20]; regulatory approvals were approved for all aircraft to use 50% SAF blends; and an initial purchasing agreement is being proposed from FY 2023/24. Early adoption by Defence should improve investor confidence to expand UK SAF production capacity. Further uptake should continue to align with the UK's proposed SAF mandate, with the first key milestones set to be 10% SAF uptake by 2030[3] so that the UK remains a leader in clearing and operating SAF. We must continue to support our Allies and Partners in NATO and beyond in their efforts to clear SAF for use in military platforms. This will support continued allied Military-Military and Military-Commercial interoperability.

Carbon Removals (15%)

Most sensible forecasts recognise that net zero aviation is unachievable without the use of carbon removals to address residual emissions and Defence Aviation estimates a deficit of around 15%. UK government agencies will not utilise purchasable carbon offsets that are available to commercial organisations through schemes such as CORSIA. However, through its significant estate, the RAF is aspiring for its holdings to become Net Negative by 2040 as a means to offset any remaining emissions. This may be possible by expanding the natural capital to support carbon removal, or potentially via Carbon Capture Storage and Utilisation (CCUS), in the form of Direct Air Capture (DAC) to create feedstocks for future synthetic fuel supply. These technologies have the potential to improve resilience and provide a source of operational advantage.

[20] Royal Air Force completes world-first sustainable fuel military transporter flight - GOV.UK (www.gov.uk).

Zero Emissions Propulsion (1%)

The emissions pathway shows that these technologies are only likely to play a small part in Defence's decarbonisation pathway, which is largely due to the relative immaturity of these technologies, their applicability to Defence capabilities, and the current timelines for fleet renewal. However, due to the technology's significant longer-term potential they are likely to play a far greater role as Defence considers future capability requirement for platforms entering beyond 2050. For this reason, the Defence Sector must continue to develop the science and technology behind the following propulsion capabilities to be used military aviation applications.

1. Current projections for the development of battery-electric technology over the coming decades suggest that they will be unable to meet the performance requirements for most Defence aviation capabilities, except for specific systems such as flying training platforms. However, it is essential that we continue to innovate and develop battery technology, alongside novel applications such as electronic vertical take-off and landing (e-VTOL), which have the potential to positively disrupt short-medium range air mobility platforms in the future[21].
2. Hydrogen has been envisaged to offer significant potential in the future civil aviation sector[22] and it is likely to have cross-cutting applicability with many future military capabilities. However, it requires a significant deviation from current air-system architecture. Especially when military specific requirements are considered, such as: the volumetric and aerodynamic challenges of supersonic aircraft; safety during operations in kinetic environments; and the provision of air-to-air refuelling. To maintain synergies between military airbase and commercial airport infrastructure, hydrogen must be a consideration in future capability decisions, but it is unlikely to play a significant role in decarbonising fleets before 2040, with the potential exception of niche capabilities entering service.

[21] USAF Research Laboratory - Agility Prime – A New Era of Aerospace
[22] Aerospace Technology Institute - Destination Zero

Addressing Non-CO_2 Effects

A unique issue to aviation is that carbon emissions are not the sole contributor to global warming, where non-CO_2 emissions such as nitric oxides (NOx), and emissions related effects such as contrail production. Under certain conditions, these will have a detrimental global warming effect. The impact of these products in the atmosphere is far less understood and much more uncertain compared to that of CO_2. The UK Jet Zero strategy has committed to increasing the understanding of these impacts, and Defence must also understand any unique impacts that arise from its capabilities and operating models. This also warrants further understanding as contrails can also have military specific consequences such as platform security. It is anticipated that as the understanding of non-CO_2 effects increase, emissions reporting is likely to change to reflect its importance and see it included in accounting frameworks.

Enabling Activity

The activity outlined in this strategy is an ambitious programme of work that will require input from across the military whole-force. In addition, it requires engagement with wider government departments, the civil aviation sector and energy providers. The RAF has been designated as the Aviation sectoral lead and will continue to cohere pan-defence aviation activity through its Air Climate Change and Sustainability (CC&S) team. They will continue to engage with the single service leads, the MOD CC&S Directorate and DfT stakeholders on the evolving strategic direction.

This decarbonisation pathway provides the strategic levers and an initial estimate of their contribution potential to enable stakeholders to shape their early planning assumptions. These estimates are not meant to be definitive, and through continued engagement with the relevant stakeholders, they will continue to be refined before they are formally established using set using the relevant governance processes. This is necessary to inform a host of considerations so that organisations can focus their resources accordingly. From airport infrastructure requirement for DIO; future SAF demand for the Operational Energy Authority; science and technology requirements for DSTL; regulatory considerations for the MAA; or platform requirements for DE&S Delivery Teams. It also assists Original Equipment Manufacturers and broader Industry Suppliers with the direction needed to drive the technological evolution of current platforms and future capability requirements.

Defence personnel will be essential to drive innovation in the pursuit of this strategy. Everyone is encouraged to participate through established change processes, or when business-as-usual processes do not permit this, through existing MOD and single service innovation schemes. As the sector lead, the Air CC&S team will provide co-ordinated SME advice on Defence aviation activity and provide coherence in line with this strategic direction, reporting into the Aviation Sector Climate Change & Sustainability Defence Suppliers Working Group.

Finally, the UK MOD and its allies have made robust commitments to collaborate on their net zero aviation transitions using existing alliances and the Global Air Forces' Climate Challenge Collaboration framework.[23] NATO members have pledged to "significantly reduce greenhouse gas emissions from military activities" in a way that does not impact personnel safety or the effectiveness of their operations.[24] Ensuring the interoperability with our international allies is essential to operational effectiveness, making collaboration on technology and operating concepts integral to this plan.

[23] Global Air and Space Chief's Conference 2022 | Royal Air Force (mod.uk)
[24] NATO - News: Brussels Summit Communiqué issued by NATO Heads of State and Government (2021)

Measuring Success

This strategy enables capability energy emissions reporting as directed in the MOD CC&S Sectoral Approach. As previously stated, any emissions reduction must occur alongside the organisation's continued operational effectiveness, and the underlying reporting mechanisms to demonstrate this will require further development. These will be established through a series of sub-working groups to the DSF's CC&S Aviation Sector Working Group based around the strategy mitigation areas and draw upon the best practice across the civil aviation sector whilst accommodating Defence's needs.

This strategy is also a means to inform everyone involved of the importance that Climate Change and Sustainability poses to Defence Aviation, whilst also changing behaviours to drive progress across the strategic mitigation areas. The DSF working group will ensure that all necessary stakeholders are routinely informed of the strategy's intent and can access it easily. A periodic assessment of these attitudes and behaviours across Defence sector personnel will allow the DSF working group to monitor the progress of this cultural change.

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