The UK trade association for
aerospace, defence, security & space

REGIONAL AND RURAL AIR MOBILITY

THINKING OUTSIDE THE URBAN BOX

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CONTENTS

ACRONYMS

AAM	Advanced Air Mobility
ATM	Air Traffic Management
C-TOL	Conventional take-off and landing (aircraft)
DfT	Department for Transport
EV	Electric Vehicle
eVTOL	Electric Vertical Take-off and Landing
ICE	Internal Combustion Engine
PSO	Public Service Obligation route
RAM	Regional /Rural Air Mobility
ROI	Return on Investment
SAF	Sustainable Aviation Fuel
S-TOL	Short take-off and landing (aircraft)
UAM	Urban Air Mobility
UTM	Unmanned Traffic Management

FOREWORD

The concept of future air mobility solely as a solution for road traffic congestion in mega cities has evolved since the initial #UAM hype. eVTOLs may become a feasible additional transport option within hyper urbanised places, even those that are already highly connected. However, for disconnected and inaccessible remote and rural areas, it may be a necessity or even a lifeline. Future air mobility operations and services will be driven by three main factors: social need/desirability, sustainability targets and economic viability.

Social need/desirability has revealed the potential market opportunity for inter and intra-regional and rural air mobility. Social desirability is influenced by the needs, concerns, priorities, and safety of local communities, all of which underpin regulations, local planning, and policy – crucial enablers for the integration, operation, and adoption of new concepts of mobility.

Sustainability targets for the aviation sector continue to tighten. A long-term global aspirational goal (LTAG) for international aviation of net-zero carbon emissions by 2050 in support of the UNFCCC Paris Agreement's temperature goal, was adopted at the 41st ICAO Assembly. The UK's contribution to global carbon emissions can be reduced and national net-zero targets can be supported by rethinking domestic aviation. Making use of zero-carbon regional and rural air mobility and underused airports and airfields, operating across a highly distributed aviation network can offer greener transport routes.

The economic viability of some potential regional air mobility routes across the UK has been specified in the 2022 UKRI report - UK Advanced Air Mobility Market Assessment. Economic modelling thus far has considered transport demands across routes already connected by ground transport, disclosing where air mobility can provide an alternative option. In areas currently disconnected and inaccessible due to limited or no ground transport infrastructure, additional commercially viable routes for regional and rural air mobility can be expected.

This report provides valuable insights on the social need, sustainability targets and economic viability that can be achieved by thinking outside the urban box and considering regional and rural air mobility. It highlights the physical, digital, airspace, energy and financial infrastructure required to maximise air mobility to serve people and places that need it most. Furthermore, it offers useful recommendations for actors in the future air mobility ecosystem on next steps to explore the potential of UK regional and rural air mobility.

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President, Royal Aeronautical Society, 2023 -2024

1. THE NEED TO CONNECT

The way in which we travel within the U.K is transforming. Electrification of the railways, road vehicles, aviation and the introduction of eco-friendly shared mobility services indicates the advancement of this and the one common theme at its centre – clean, green, and sustainable.

There is a growing interest and demand for a more distributed and connected transportation network that will level up accessibility to goods, services, and opportunities for all communities within the United Kingdom.

Many communities in the UK suffer from poor connectivity. Transport services are infrequent, do not respond to demand and are poorly integrated. The lack of viable travel options to access employment, education or many essential services are driving residents and visitors to these areas to rely on private car use[1].

Poor access to transport options can enhance the effects of social isolation and have a negative effect on the mental wellbeing of residents who do not have access to a private vehicle. Reliant on a limited transport service to meet their basic needs, these communities are more likely to feel the effects of exclusion from mainstream society and limited access to opportunities - as a direct result of poor transport - will inevitably lead to outward migration from these areas.

Three in every five domestic flights are over water. Connectivity with Northern Ireland, Scottish islands, Isles of Scilly, and crown dependencies are all heavily reliant on air travel

What does this mean?

The primary objective of a resilient transport network should be choice.

Touted as the third revolution in air travel, Advanced Air Mobility (AAM) is fast approaching, bringing with it the opportunity to expand transportation options by utilising the airspace above us more effectively.

The idea of Regional / Rural Air Mobility (RRAM), connecting regions over long to mid-range distances, rural island communities to the mainland and facilitating the delivery of vital supplies and services to poorly linked areas has the potential to drastically enhance not only the way in which we travel but the way we live our lives.

We are only scratching the surface of what domestic air travel can bring. Through increased distribution, route network expansion, and improved seamless access working alongside innovative technologies, new opportunities, and ways of living once deemed unfeasible will become possible.

Connecting the roads and railways to the skies to provide one complementary mobility service will drastically reduce travel times and open new opportunities for all communities within the UK regardless of where you live.

[1] Transport in rural areas: local authority toolkit - GOV.UK (www.gov.uk)

2. WHERE WE ARE RIGHT NOW

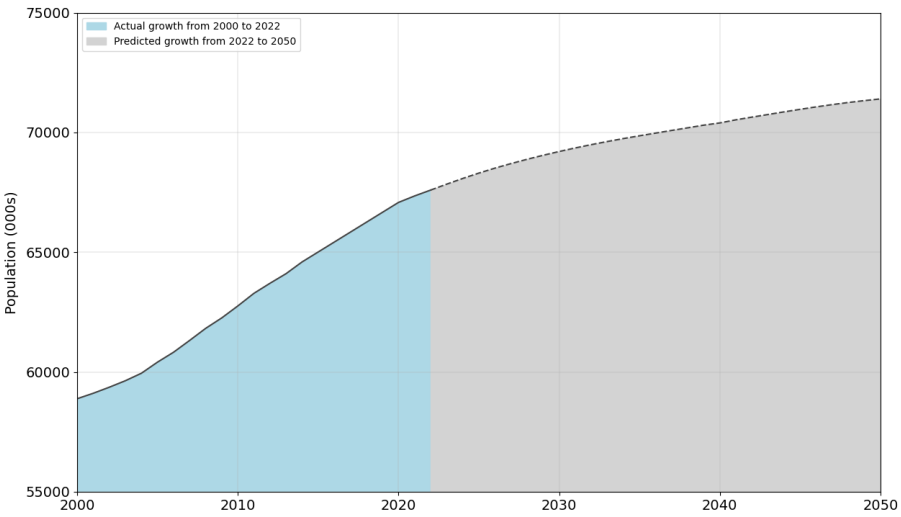
The data

Population levels within the U.K are rising fast

Projections from the Office for National Statistics show that the current UK population of 68.5 million[2] will rise to 71.6 million by 2033, passing 70 million by 2029.

What this data also shows is the declining population across 38 local authorities and an exponential increase within cities such as London and Manchester, as the trend of increasing urbanisation continues.

As a result of this, investment in transport infrastructure is likely to be concentrated on these locations to meet growing demand.



In addition, age groups of 65+ years are predicted to grow by approximately 50% in rural areas throughout the UK between 2018 and 2043, with virtually no increase predicted among the younger population aged 16-24 years[3]. This is a noteworthy trend with respect to mobility and increased isolation which may signify the slow decline of these communities over time.

Time for Change

Rural and Regional Air Mobility (RRAM) could be a part of the solution towards overcoming these concerning statistics and bridging the gap between populations throughout the UK. Stepping away from notions of air travel being disproportionally accessible to high income groups only, this is a service that has the potential to become as common place as catching a bus in the not-too-distant future.

As we look ahead post pandemic, we must ensure physical connectivity - beyond the digital - comes back into focus once again. By connecting rural and regional areas to a multi-modal transportation network in which highly accessible air travel plays a crucial role, there will be increased choice in determining where you can live in relation to your place of work, as well as to leisure and entertainment facilities, healthcare, and others in our communities.

In turn, the urge and need to migrate away from previously poorly connected areas could be reduced and rural communities afforded the chance to endure and thrive.

A recent investigation conducted by the UK Government[4] where public surveys, interviews and focus groups sought to better

Defining rural

The definition of rural in the UK varies. In Scotland it is defined by settlement size of typically less than 3000 inhabitants. In England and Wales, it is defined as an area with a population of less than 10000. Rural Scotland accounts for 98% of the land mass of Scotland with 17% of the population residing there, and in England and Wales, rural areas make up 85% of the land area with approximately 18% of the population in residence. This reflects the dispersed nature of populations in rural areas throughout the U.K which, in total, is estimated to be at around 11 million

Source: https://www.statista.com/statistics/984702/urban-and-rural-population-of-the-uk

[2] United Kingdom Population 2022 (Demographics, Maps, Graphs) (worldpopulationreview.com)
[3] Living longer - Office for National Statistics (ons.gov.uk)
[4] Union Connectivity Review (publishing.service.gov.uk)

understand transport priorities and current challenges, found clear evidence of the value that UK citizens see in improving transport links:

Two in three

Proportion of respondents that thought that improved transport links would have a positive impact on people's ability to access job opportunities

Seven in ten

Proportion of respondents that thought improved transport links would make it easier for people to live in alternative areas and improve access to key transport hubs

Further to this, the Organisation for Economic Co-operation and Development (OECD) in a recent International Transport Forum (ITF) - Innovations for Better Rural Mobility report[5] suggests that convenient and affordable transport offer does not only improve access, but also provides the basis for incentivising more sustainable mobility behaviours, crucial in this age of net zero.

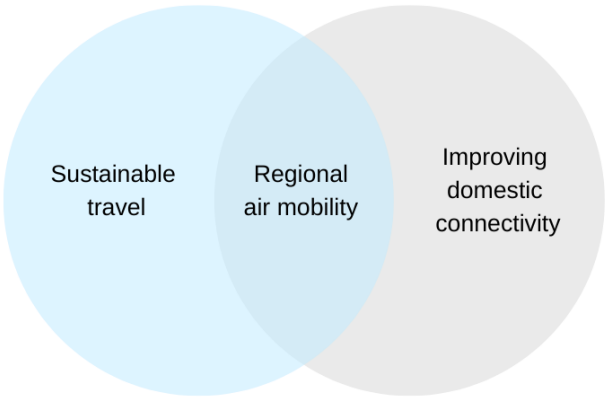
Improving domestic connectivity

RAM should be considered an integral function of the multi-modal transportation landscape of the future and as an enabler for the development of innovative technologies, renewable energy generation and investment opportunities. Operating in a vast area with less congestion and over unpopulated locations may help to refine these technologies and the regulations needed for denser airspace operations. In addition, there will be less need to expand road and rail networks at ground level, the construction of which can run into the tens of billions and cause major disruption to the surrounding areas.

Among the numerous recommendations issued in the 2021 Union Connectivity Review the following key messages with regards to UK aviation are clear:

- We must increase the drive towards sustainable domestic aviation; and
- take measures to improve domestic aviation connectivity.

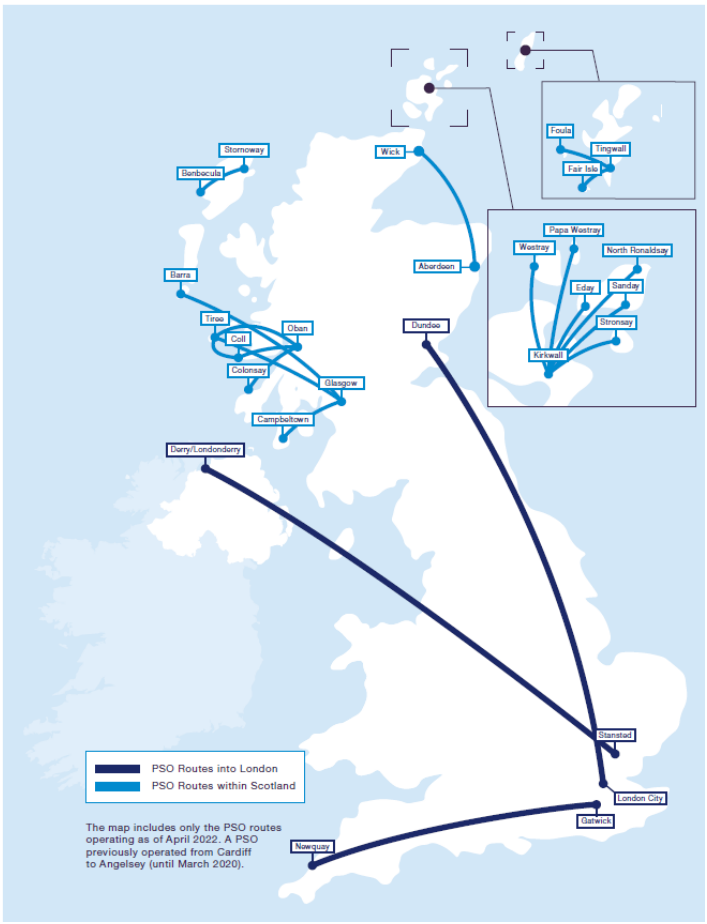
The review also endorses ambitions published by the DfT for net zero aviation which includes the commitment to assessing the feasibility of Public Service Obligation (PSO) routes with low carbon aviation which may prove to be a key enabler for AAM services in a regional use context. As stated in Flightpath to the Future[6], *PSO's play a vital role in supporting domestic connectivity and can support levelling up and enhance union connectivity.*



[5] https://www.itf-oecd.org/sites/default/files/docs/innovation-rural-mobility.pdf

[6] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1079042/flightpath-to-the-future.pdf

Domestic PSO routes in operation



Governed by regulation, there are 22 publicly subsidised 'lifeline' flights between geographically remote and/or inaccessible communities in Wales, Northern Ireland and Scotland which would not be commercially viable without public subsidy. They typically operate once a day or less frequently using small, specialised aircraft and are vulnerable to weather-related disruption[7]. Many of these routes could be viable options for RAM operations, affordably and sustainability connecting communities that might otherwise be isolated without heavy subsidies.

The development of a thriving and sustainable domestic aviation market, using technologies enabled by Regional Air Mobility, is particularly important will play a key role in delivering the UK's Net zero targets. According to a recent Element Energy report[8], the DfT's High Ambition scenario includes emerging high-risk technologies and uncertain policy in the forecasting of the emission abatements in 2035 – therefore more available, easier wins may be considered in the interim while these technologies are matured.

[7] Future of Mobility: the UK air transport system how and why is it changing? (publishing.service.gov.uk)

[8] https://www.aef.org.uk/uploads/2022/05/The-Role-of-Aviation-Demand-in-Decarbonisation-Full-Report.pdf

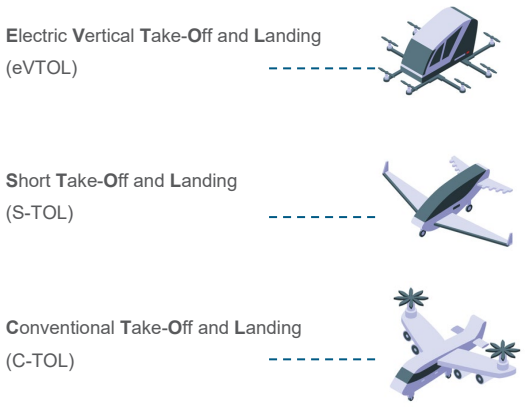
3. INFRASTRUCTURE

In order to provide a service that is accessible, dependable, and affordable, we should use existing infrastructure wherever possible.

Regional / Rural Air Mobility offers a cost-effective solution to connect communities that have been underserved by current aviation services on offer while also alleviating the pressure felt on aviation hubs with increasingly limited capacity. As a new generation of alternatively powered aircraft is developed, communities could welcome a transport system compatible with their needs as well as the new opportunities afforded by the development of their local airport infrastructure.

The question is however, how can this existing infrastructure be developed and scaled up? It is clear that for there to be a viable market for RAM in the UK, considerable investment is required across all aspects of infrastructure, for example: air traffic management systems, booking platforms, maintenance facilities, charging capabilities and flight operations – which will be key for implementing air mobility services in both urban and rural settings.

A range of aircraft



It is important to remember that the infrastructure proposed for AAM in an urban context does not necessarily translate to the requirements of more rural and regional located services. Vertiports and “Vertistops” commonly associated (as their names suggest) with vertical take-off and landing aircraft, vary in complexity and capability but typically remain in their design urban based, purpose-built facilities.

The infrastructure that would be required for regional and rural air mobility services would be simpler in design and function and be able to accommodate short or conventional runways to include a wider range of aircraft, i.e., C-TOL and S-TOL. There will be strategically placed hubs fitted with refuelling/charging capabilities, and onward transport connections complimenting and working with the regional transport network to which they belong[9]. These significant differences could see investments go a lot further.

[9] These commercial operations will most likely start at the existing 48 licenced aerodromes across the UK with smaller unlicenced airports following as operations mature

On the ground

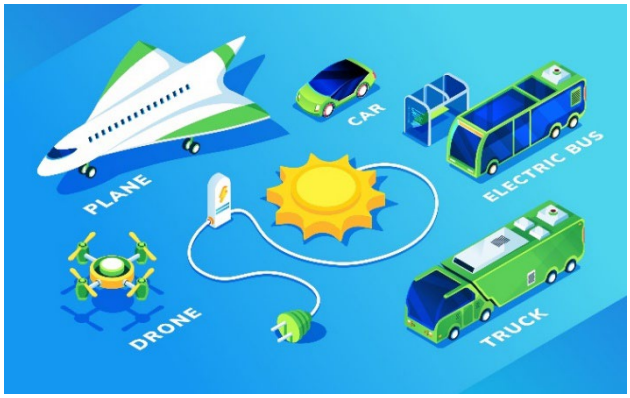
Generating and distributing energy

As of August 2021, there were over 2200 known airfields, helipads, grass strips and other flying sites located throughout the UK, approximately 200 of which are considered disused and abandoned.[10] The benefits that could be gained from utilising and re-purposing the existing land, associated airspace and ground facilities that already exist (or were previously in place) necessitates a comprehensive piece of research that should be undertaken before sourcing alternative locations and building brand new facilities. The Airfields of Britain Conservation Trust[11] suggest over 230 ”major” airfields have the land footprint to support RAM.

Furthermore, the majority of regional aerodromes in the UK typically sit on large areas of underutilised land (examples include Inverness, Wick, Oban, Newquay, Land's End) affording the space required for the transformation of such sites into renewable energy hubs.

In turn this energy could be used to not only charge the batteries of electric aircraft, but for non-aeronautical revenue purposes such as charging of ground vehicles and eventually hydrogen fuel source generation[12].

Through harnessing the power of modern solar technology and having bi-directional connection to the national grid, energy hubs for local communities could also be provided, simultaneously tackling the reduction of greenhouse gas emissions both in the air and on the ground. Whilst all of this relies on the individual evaluations of each site location, greater understanding, and modelling of the charging demands, how it is transmitted, distributed, generated and the power requirements across these potential sites could prove invaluable to future infrastructure development.



Learning from automotive

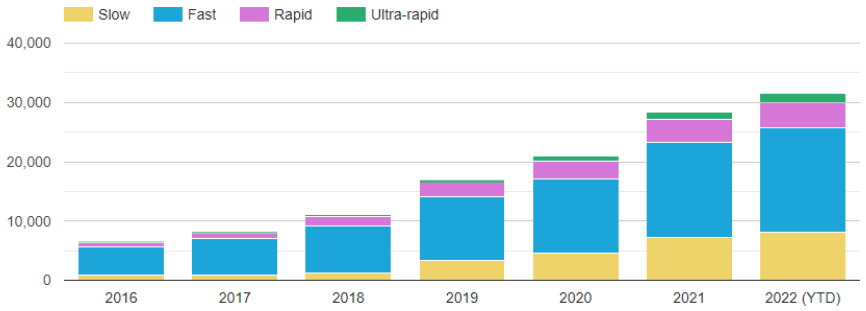
To give an insight into how quickly electric grid upgrades at airports could be completed, it is useful to learn from, and draw comparison to, the rate at which electric charging stations are constructed for EVs on the road.

With the UK Government intention to ban the purchase of new fossil fuel vehicles by 2030, and the drive to install EV charging facilities throughout the country gathering momentum, an opportunity is presented to ensure the national grid is expanded with initial AAM services in mind. An example of this would be a recent announcement from Shell UK who have shared plans to invest between £20 and £25 billion into the country’s energy system over the next decade[13], which includes the rollout of charging infrastructure for EV’s so that, by 2030, 90% of UK drivers will be no more than 10 minutes from a Shell rapid charger[14].

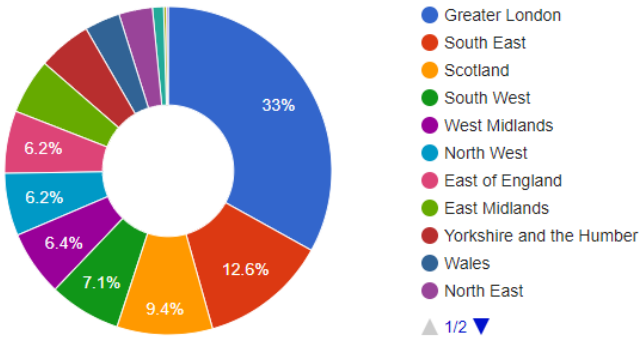
Between 2016 and 2021 the charge point network grew fourfold from **6500 to more than 28000** devices. As of the end of March 2022 there were over 30,000 devices distributed across the UK with numbers continuing to grow.

[10] Maps - UK Airfields
[11] Airfield Finder - Airfields of Britain Conservation Trust UK (abct.org.uk)
[12] Many UK airports currently generate renewable energy onsite. For those that do not, they possess the required space to adopt on-site generation.
[13] Shell UK aims to invest up to £25 billion in the UK energy system | Shell United Kingdom
[14] https://www.shell.co.uk/media/2022-media-releases/shell-uk-aims-for-90-percent-of-drivers-to-be-within-10-minutes-drive-of-a-shell-rapid-charger-by-2030.html

As demonstrated by the charts below, the automotive industry has seen a rapid increase in the availability of electric charging stations over the last few years, with a geographic spread across the country.



Number of public charging points by speed, 2016 to date



Distribution of chargers across the UK

In addressing the issue of energy storage facilities, the option of mobile charging - as suggested in the recent paper published by CPC Blueprint for Zero Emission Flight Infrastructure[15] - may also be considered where fixed charging infrastructure is either not viable or unavailable. These mobile charging vehicles may also at some stage be capable of alternative onboard energy storage options such as hydrogen fuel cell technology.

[15] CPC ZEFI report

In the air

One of the main challenges facing AAM in both regional/rural and urban contexts is airspace integration. The need for complex deconfliction services, cooperative surveillance, navigation, and communication technology and how all of this may be regulated and interface with air traffic is still a work in progress.

While it is widely accepted that initial operations will be piloted, the journey towards full automation has begun and the technology required to make this happen already exists[16].

The evolution of airspace integration will be progressive and modernisation strategies like those of the UK CAA[17] are already looking ahead towards 2040.

Figure 2 – examples of the complexity that airspace infrastructure will have to take into account[18]

One acknowledgment common to all such strategies is that engagement with regulatory authorities start at the very beginning of all development processes which will be crucial to ensuring standards are harmonized for interoperability across all new aircraft systems and seamless, controlled operations.

With RAM, this will be more easily accomplished and may advance developments and public acceptance as operations in less congested airspace, over unpopulated areas pose less risk to users and third parties. RAM operations are also less likely to be restricted by the current ATM systems used today while UTM systems are being developed as they would be operating in fewer numbers, throughout less obstacle rich environments and larger areas of airspace whilst possessing the technology to detect and avoid other air vehicles automatically with little to no human interaction required.

The ultimate goal for the management of airspace in the UK is to keep up with demand, innovation and provide enhanced digital control while avoiding the placement of burden on already overloaded ATCs on the ground. It is only if ALL airspace users are electronically conspicuous will we be able to achieve full integration.

Previous studies[19] have indicated that cooperative surveillance and communication technology will be a core aspect to ensuring full integration.

[16] DARPA completes first flight of Black Hawk helicopter with no crew onboard - Inceptive Mind
[17] Airspace modernisation | Civil Aviation Authority (caa.co.uk)
[18] UKRI's Future Flight Challenge Roadmap
[19] CAA Studies

Summary

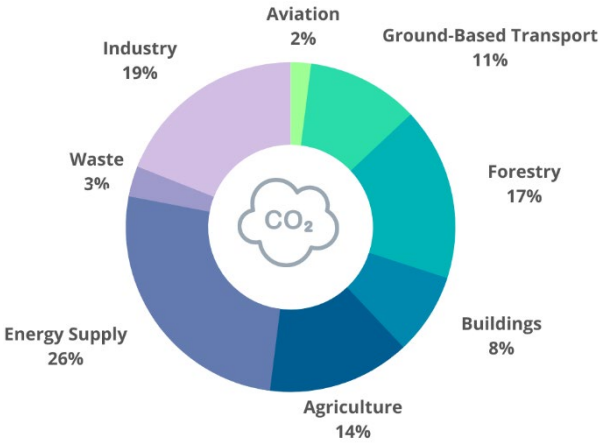
Maintaining high levels of safety in the operation of these services and new technologies requires prolonged and in-depth analysis, testing and substantial amounts of data gathering, therefore, there is an argument for learning to walk, before attempting to run.

This in no way suggests that innovation and progress should be stifled, but rather that in the very early stages, operations within less densely occupied airspace could collectively develop technologies, demonstrate to regulators, and nudge public acceptance in the right direction – safely.

4. ENVIRONMENTAL IMPACT

One of the most significant challenges facing the world today and one that we are increasingly feeling the impact of is climate change. With many countries now declaring climate emergencies, in 2019 the UK became the first major nation to commit to net zero and ending their contribution to carbon emissions by 2050. In addition to this, the Climate Change Committee (CCC) has also now advised a new interim target to reduce emissions by 78% in 2035 which has been accepted and adopted by the UK Government.

Aviation in its current form is responsible for a small but significant portion of global carbon emissions with current aviation technologies and operations run almost exclusively on fossil fuel energy sources.



Data from GAMA-IBAC

In addition to CO2 emissions however, there are growing concerns with the strong warming effects felt as a result of nitrous oxides, vapour trails, oxidised sulphur and cloud formations caused by aircraft flying at high altitudes. It is possible that these non-CO2 emissions contribute twice as much to global warming as aircraft CO2 and may be responsible for up to two thirds of aviation's impact on global warming[20]. More research is needed to determine the full extent of this.

We all know the statistics and the threat faced by rising sea levels and temperatures – but fewer experience the effects of these changes in the UK than those living in rural communities. Elderly and reduced mobility residents, those physically isolated and communities with poor transport links are particularly vulnerable to events such as flooding and storm damage – or rather the recovery from such events. Whilst this paper does not address the use of AAM vehicles and drones in an emergency/disaster relief capacity, regional and rural mobility air services located within operating range of danger areas, recovery efforts, damage assessment and even evacuation efforts would be assisted.

To approach the issue of urbanisation and population expansion from an environmental perspective is also worthy of note. Inevitably as populations grow, cities will need to expand their footprint outwards, potentially onto green belt land. Equally, the expansion and development of the transport network at ground level also threaten - or adversely impact - natural woodland and rural communities. As mentioned previously, providing rural populations with improved transport links will not only improve the lives of the people who use it, but will ensure a minimally invasive effect is felt on the environment.

The green opportunity of regional air mobility

With the continued development of battery technology and an increasing focus on decarbonisation, regional air mobility can form a foundational part of the broader net zero transport strategy. By connecting regions and cities that would otherwise require heavier carbon emitters, next generation aircraft can offer truly sustainable flight and alternative means of travel.

[20] Study reveals aviation's non-CO2 climate impact | Travel Weekly

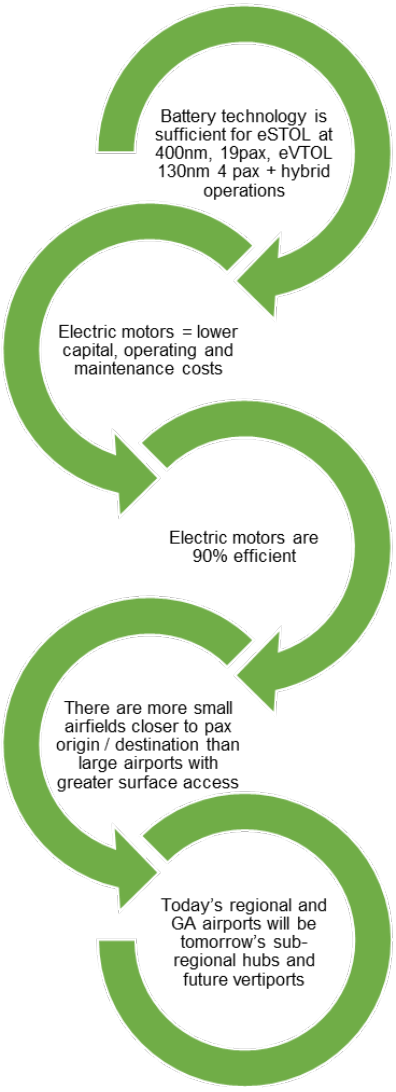
5. THE ECONOMICS

To understand the economic impact that a revolution in regional air connectivity would bring, is to understand the economies of individual regions throughout the U.K and the role that air transportation plays within them.

The time is fast approaching where local community leaders must acknowledge the changing transport landscape, the appetite for improved mobility and the substantial economic benefits that can be gained from employment opportunities, investment, and improved quality of life beyond the existing public service infrastructure which has evolved over many generations.

The ADS whitepaper Distributed Aviation[21] refers to RAM as a means to preserving and enhancing regional connectivity "***with traffic shifting out of hub airports additional regional capacity is gained and can be supported either by governments or hub airports through direct investment or by other means. This represents an opportunity to increase regional connectivity and wealth***."

Figure 5, right, represents how improving technological advances can unlock the economics of regional air mobility.[22]



Economically, it makes good business sense to ensure that this new era of mobility is done right first time around – to encourage passenger uptake in a regional use context, RAM should not operate as a stand-alone service but ensure that first and last mile travel is considered with a seamless passenger journey in mind at all times, connecting this to existing and future mobility hubs.

Fundamentally an AAM service will only be adopted if it offers greater convenience, speed, accessibility, and passenger experience at an affordable price point. Social arguments mentioned previously regarding sustaining populations, enabling longer commutes and increased access to hospitals as well as leisure services will be prominent arguments for the economics of RAM and enhanced rural connectivity.

In the UKRI Future Flight Socio Economic Study[23], a sub-regional use case directly connecting York to Preston was used to demonstrate the expected time and cost savings in comparison to rail. Assuming certain variables such as passenger capacity, it found that using an electric air taxi for this 108km journey would be 2 hours faster and 47% cheaper overall. Conversely it also suggests that a rural use case connecting village to village over 25km was almost 65% more costly when compared to private car use but still proved more time effective. If the variables effecting cost could be worked to reduce the additional expense from 65% to around 25%, that in conjunction with the time savings and convenience would be a more attractive premium.

Using regional air mobility, a 108km journey could be **2 hours faster and 47 percent cheaper** in comparison to rail

[21] https://www.adsgroup.org.uk/blog/distributed-aviation-a-new-economic-model-for-electric-aviation/
[22] Ibid
[23] UKRI study

With a majority of the technology pathways already sitting at an advanced maturity level, the immediate advantage of siting co-located power generation solutions to serve both ground and airborne vehicles offer a number of cost-benefits, but most importantly, we do not need to wait for AAM and RAM to be fully established before this can be implemented.

The use of technology and electricity to support a duality of RAM and road vehicles move the focus to situations where operators will start to see a solid return on investments. Additionally, the Union Connectivity Review of 2021 states:

"*Where journeys are too long to be reasonably taken by road or rail, the UK Government should: Revise existing subsidy rules for domestic aviation to allow support for routes between different regions of the UK (rather than just to and from London)*."

This acknowledges that at this time, Government intervention is needed to ensure the viability of existing Public Service Obligation (PSO) routes which total approximately £13m in subsidies. With rural power generation in place this enables RAM services, but without the PSO funds to kick-start commercial operation, RAM operators may not choose initial flights on this basis, which suggest a need for public funding in the first instance.

In the recent DfT report. Flight Path to the Future, this is supported by UK Government which states:

"*We set out the potential for future PSO routes to use SAF or zero emission technologies. Our aim is to have a thriving domestic aviation sector where there are no PSOs operating as they have all returned to commercial operations. However, this policy will protect vital connectivity that is in danger of being lost*".

Furthermore, increasing air connectivity for the exploitation of non-mobile industries such as agriculture, oil and gas, fishing, mining, and tourism will have a positive effect on the regional economies where these industries exist. The domino effect of increased tourism, the relocation of manufacturing, efficient and timely import/export, and the ability to carry out surveillance and inspection tasks at a lower cost, will lead to cheaper public services. Further to this, increased air traffic in an area can lead to an increase in GDP, service sector employment growth and in some cases act as an attractor for high technology jobs[24].

Funding

Consider the wider economic drivers behind mobility and the socio-economic make-up of the United Kingdom.

According to the OECD[25] London attracts nearly 30% of transport infrastructure investment, and this is reflected in the differences between labour productivity. With companies looking to pay less for working from home there will continue to be regional differences in labour productivity and living standards.

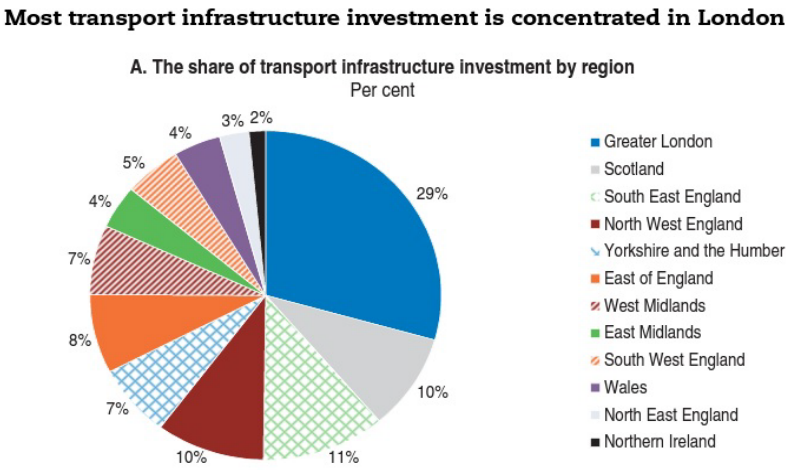
Yet despite this, the funding mix around RAM does indicate a definitive split between the current approach from central government's investment portfolio around "traditional" transport (road, rail, commercial aviation) and the new digitally native platforms of the future with a much different approach.

This is exacerbated in areas which may not be as economically attractive based on existing connectivity. The OECD report notes that "Infrastructure is essential in attracting foreign direct investment. For instance, a recent survey has found that transport infrastructure is the second most important criterion for multinational firms when choosing where to invest. Therefore, lack of connectivity can translate to a lack of investment.

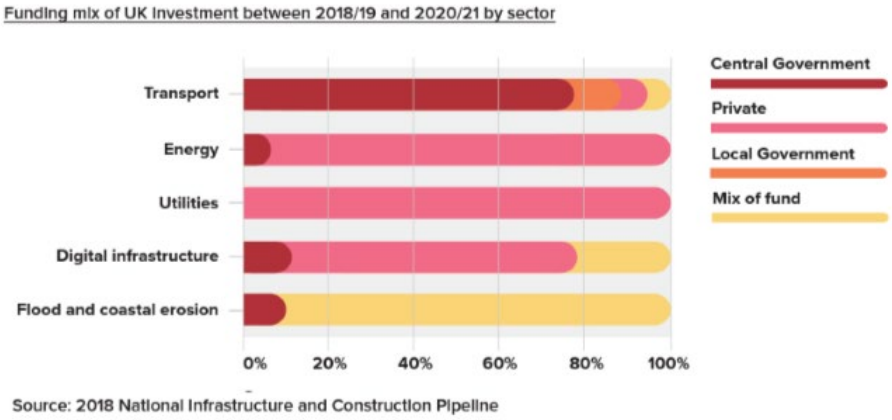
[24] Wider Economic Impacts of Regional Air Connectivity (publishing.service.gov.uk)

[25] Improving Infrastructure in the United-Kingdom (oecd.org)

The 2018 National Infrastructure and Construction Pipeline report[26] showcases this very clearly and needs to be resolved before any sort of RAM operations can be viable.



RAM investment within infrastructure seems to fall between two funding stools, that of transport and digital infrastructure (see below image) which can mean it struggles to attract attention. Digital aviation falls under both pipelines in some respects but is unlikely to be a priority to either group. This may mean less appetite to drive infrastructure change at a political level, placing greater reliance on transformative industries.



Summary

This section intends to highlight the bridge that has yet to be constructed to resolve these emerging issues. In 2021 the UK Infrastructure Bank (UKIB) was launched to provide finance for local and private infrastructure projects. By dovetailing this into future National Infrastructure and Construction Pipeline, there is an opportunity to tie this into the £650 billion of public and private investment. Furthermore, pension funds and insurers will be able to invest between £150 billion and £190 billion in infrastructure over the next ten years as developing the sector requires patient capital and long-term investment for the stability and sustainability of emergent and related industries in support of national objectives[27]. A longer timeframe helps to attract talent and build a resilient sector in terms of skills and supply chain. It needs to be publicly seeded and privately funded to move at pace.

[26] NICP Report
[27] CP 329 – National Infrastructure Strategy – Fairer, faster, greener – November 2020 (publishing.service.gov.uk)

6. THE TECHNOLOGY

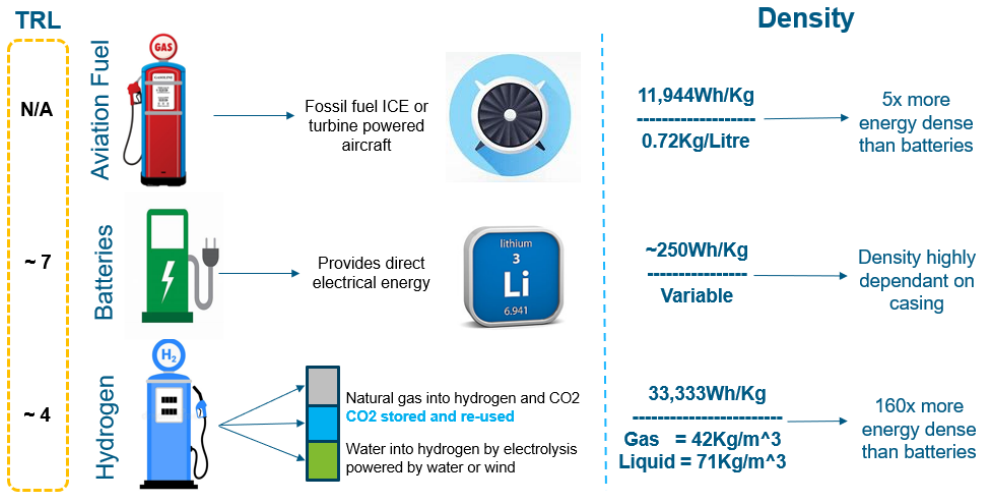
Aircraft Propulsion Technology

Aviation is currently going through an electrification revolution. Nothing else can be deemed as disruptive and innovative since the invention of the turbine which opened doors to new ways of travelling further, quicker, cheaply, and safely. This new era brings with it advantages by way of simpler design, distributed propulsion, and low production, operational and maintenance costs. As with all things however, there are some developmental hurdles to overcome.

The ADS distributed aviation paper, argues why current fossil fuel ICE or turbine powered aircraft are not economically viable for many RAM routes and that electrification offers a potential route to reduce the overall life cycle cost of RAM operations, leading to the opening up of more commercially viable RAM routes within the UK and globally.

It is expected that electrification of RAM aircraft will comprise a mixture of electric propulsion technologies based on hybrid, Battery, and Hydrogen Fuel cell electric technologies; all of which are in use today at high TRL levels and are maturing rapidly for use in aviation as a result of zero carbon initiatives. This is especially true for small sub regional aircraft applications (Up to 20 seats). It is expected that within the next five years aircraft of each type will have been certified and will be operating RAM routes cost effectively.

With respect to battery electric power in particular, the technology is very limiting in terms of energy density; currently offering energy densities in the region of 200WH/Kg to 250WH/Kg which are really only suitable for small 4–6-seater aircraft with limited range requirements. It has been suggested by many industry leaders that an energy density around 350-400Wh/Kg[28] will be necessary for this propulsion technology to really take off. To put this into context, these density levels will allow only small < 9 seat VTOL aircraft to achieve ranges of 100-200km and CTOL perhaps around 400-500km. You would need at least 500WH/kg to 1000WH/Kg to start to achieve something close to conventional regional jet range.



From the data provided in the above image, it is clear that regular aviation fuel has advantages over hydrogen and batteries in terms of energy and volumetric density, although, fossil fuel ICE or turbine powered aircraft have poor overall efficiencies turning this into usable propulsive power (25-30%); when used in hybrid electric applications to power a turbine driving an electric generator, efficiencies can be maximised. Using SAF can subsequently make hybrid electric an attractive "zero carbon" solution with high TRL levels for aviation applications. It's also scalable for applications in sub regional/regional size aircraft although there remains concern that greenhouse

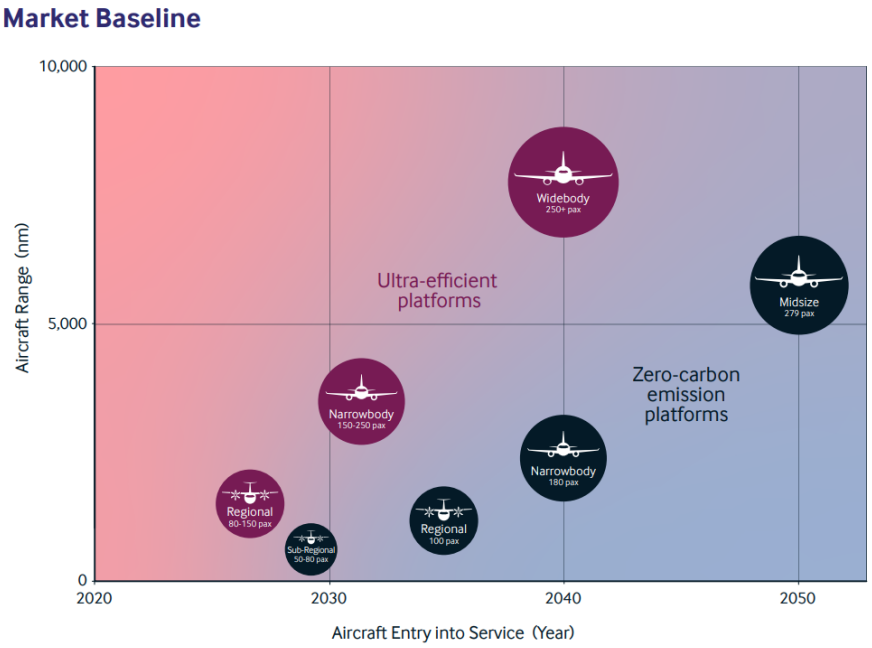
[28] The Batteries Behind the Electric Aircraft Revolution - Aviation Today

gasses are still delivered into the atmosphere at altitude. More research is needed in this area to determine the true long-term impact of this.

While there are complex challenges that need to be overcome with regards to battery usage as a primary source of power in aviation and in-particular scaling this for sub regional and regional applications, their use in smaller aircraft over shorter ranges is viable now. The high efficiencies provided by direct battery power alone can, to some degree, offset density issues and make use of existing distribution systems allowing battery powered aircraft to potential rely on cheaper energy in comparison to aviation fuel. This assumes that the electricity will be sourced from renewables i.e., green electric batteries and the associated electrical power systems, that also require potentially less maintenance than conventional ICE/Turbine aircraft.

In summary, battery technology is expected to be used extensively in small 4 to 9 seat aircraft with ranges of up to 190 miles for the foreseeable future unless significant improvements are made to energy density.

Hydrogen powered aircraft using either gaseous H2 or liquid LH2 is another viable option in the bid to sustainably decarbonise the aviation sector and with higher energy density per kilogram, it is most suited for use in short to long haul flights. Within the UK at this time, most hydrogen productions originate from fossil fuels, however, through UK government lead initiatives, a move towards green hydrogen produced through electrolysis and blue hydrogen from carbon captured gas steam are paving the way for this to become a viable alternative to depending on battery technologies alone. This is expected to lead the way for Hydrogen as a cheap alternative to fossil fuel for aviation usage. As attractive as this alternative appears though, the technology readiness levels of the storage tanks required for H2 and LH2 (in aviation) are still relatively low and yet to comply with stringent aviation safety standards – although this, along with the production and distribution infrastructure, is expected to rapidly improve over the coming years[29]. In comparison to batteries even with the complexities of storage and energy conversion, Hydrogen systems are capable of achieving in the region of 10x better energy density which makes them very attractive as a green power solution for RAM applications.



The Aerospace Technology Institute (ATI)'s 2022 strategy, Destination Zero, sets out the technological pathway for aerospace in the UK, which includes a detailed look at the potential entry into service dates for zero-carbon emission platforms. While midsize LH2 platforms may not be in

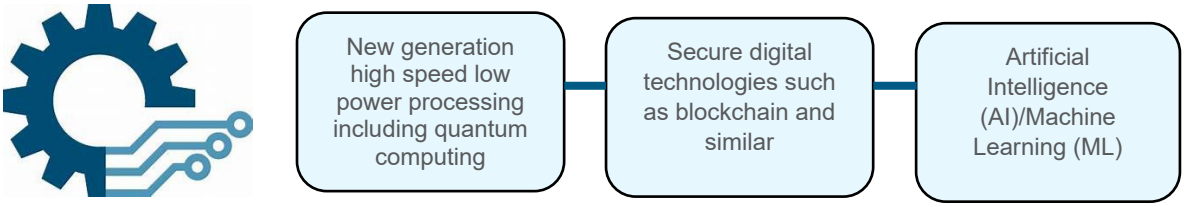
[29] WEF_Target_True_Zero_Aviation_ROUND_2022.pdf (weforum.org)

service until the middle of the century, the ‘sub regional’ and ‘regional’ platforms could be viable by 2030 or 2035, as demonstrated by the above chart.[30]

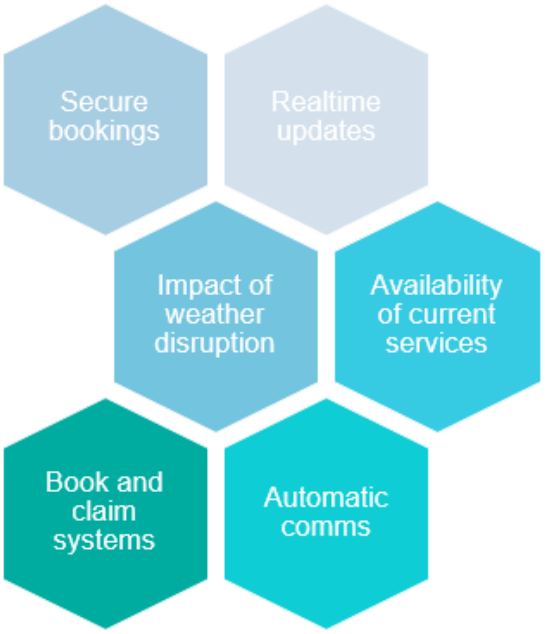
To summarise, with significant investment being made in electric power system technologies both Battery and Hydrogen power technologies are improving rapidly offering higher efficiency, higher energy density solutions whilst also using more sustainable, lighter composite materials in their production. Electrification is also expected to reduce the maintenance costs of such systems with respect to existing ICE/Turbine aircraft. As a result, the life cycle costs are expected to reduce below that of fossil fuel powered aircraft for RAM applications, potentially opening up a wider market for RAM operations that would otherwise not be commercially viable.

Digital Technology

Improvements in digital technologies will also be a key driver in the success of RAM operations. Digitisation is already improving the design/certification of AAM air vehicles, flight planning, air space management, ground system design and operations, efficiency and hence cost. The three areas of interest underpinning potentially large steps in AAM success are



Starting with AAM ground infrastructure, the digital technologies listed above will be essential in ensuring that AAM can be operated as part of a multi modal transport system allowing secure booking of travel from start to finish.



Such systems will also allow secure bookings to be updated either as a result of changes in customer circumstances or due to changes in the travel system i.e., weather disruption, availability of services etc. In fact, these technologies are already being used in similar sectors of aviation with high TRL levels so it is expected that AAM will be able to leverage from these areas from the outset.

In the design and certification of the air vehicles, digital technology in the areas above is already in use and improving in TRL.

High speed multi core processors are now being used in many applications allowing significant improvement in digital throughput against power consumption and are providing

realisable platforms for the operation of using artificial intelligence (AI) and machine learning (which can be considered part of AI) across the development lifecycle of AAM air vehicles.

Regulatory agencies have recognised this and have already released guidance and are working regulation to cover this new evolving area of technology area. EASA have recently released its Artificial Intelligence roadmap[31] in recognition that they will have to support this with regulation in

[30] ATI Destination Zero, available at: i.org.uk/wp-content/uploads/2022/04/ATI-Tech-Strategy-2022-Destination-Zero.pdf

[31] EASA Artificial Intelligence Roadmap 1.0 published - A human-centric approach to AI in aviation | EASA (europa.eu)

the coming years. In the context of aircraft embedded AI/ML, automation or pilot-less AAM air vehicles are already being developed by a few eVTOL companies today.

Whilst it is expected that full certification of passenger carrying pilot-less AAM air vehicles is more than five years out, this technology, leveraging from AI, is considered to be key to increasing AAM traffic volume and reducing overall service cost i.e., predominantly through a reduction in the dependency on human pilots.

7. CHALLENGES AND FURTHER CONSIDERATIONS

There are additional challenges and considerations when it comes to establishing and integrating Regional / Rural Air Mobility services, in any context - some of which are summarised below.

Licencing

Ensuring the development of a comprehensive and effective licencing regime will be critical. This will need to cover all aspects of the RAM ecosystem, including pilots, mechanics, security personnel and air traffic controllers.

Weather systems

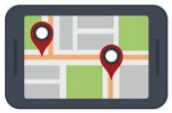
Aside from the obvious gaps in suitable licencing frameworks, RAM operations will undoubtedly be exposed to more demanding weather conditions on a repetitive basis. In such conditions pilots will have reduced visibility to detect and avoid other obstacles or aircraft leading to greater reliance on automatic detect and avoid technology.

These systems however must possess the appropriate robustness and accuracy to be deemed safe to use. Along with this is the issue of potential cancellations and delays to services that could become more prevalent in ever changing climate conditions which reinforces the multimodal mobility as a service (MaaS) concept whereby alternative travel arrangements can be made should one become unavailable.

Public acceptance

The undisputed heavyweight underpinning the success of AAM services across all use cases – urban and regional – is public acceptance. Many social and stakeholder studies have been performed for this and continue to form the framework for the adoption of AAM and its associated ecosystem.

Common challenges exist between UAM and RAM such as the perceived change in noise and visual pollution. From a social desirability standpoint, the cost of travel must be considered with a pull from the public through transparent communications and advertisement of desirable attributes, rather than a push from industry.



Connected to this would be lack of accessibility and limited route availability that traditional aviation services have not been able to facilitate due to rising operating costs and, in places, a lack of alternatives such as Demand Responsive Transport (DRT).

For RAM to be taken up seriously it will have to prove that it can save cost and time overall in comparison with other forms of transport. Consider too other traditional forms of transport heading towards Net zero faster than aviation – green credentials are important but may not be a differentiator for RAM vs UAM. This inevitably leads to the question of, will passengers tolerate unfamiliar aircraft and the price point of using them in the name of Net zero alone?

Should a more distributed and interconnected network not be established throughout the UK, another key challenge we may see in the mobility landscape of the future will be managing the inequalities of access to new technologies[32].

[32] Future of mobility: inequalities in mobility and access in the UK Transport System (publishing.service.gov.uk)

Regulatory frameworks

Regulatory frameworks for AAM are developing slowly and inform the outcome of many of the topics discussed in this section. Some lesser discussed considerations are the regulatory penalties such as emissions charging; the transition to a low carbon economy in the domestic transport sector could impose costs on all passengers and are likely to be disproportionate across market segments.

Technological risks

Regarding the technology, Hydrogen fuel cells whilst mature in other sectors, have many challenges when applied to aviation, not to mention the risks for aviation use especially concerning storage capability onboard aircraft. They are currently limited in scalability of electrical power output and have relatively low efficiencies in the region of 40 - 60%**.

Also, with Hydrogen fuel cells producing 9kg water to every 1kg of Hydrogen consumed as by-product, water vapor released at altitude to form contrails, also act as a greenhouse gas. Research has shown hydrogen contrails could also form at lower altitudes, cover greater areas and be thicker and longer than those produced by burning jet fuel[33]. Further research will be needed to determine the long-term effects of these non-CO2 emissions on the environment and may go on to inform the design and use of hydrogen aircraft in the future.

Battery sourcing

With regards to batteries, there are significant concerns when it comes to the through life management and disposal of these. Greenpeace estimates that 12m tonnes of EV batteries will be retired between 2021 and 2030. The environmental impact associated with the disposal of EV (namely lithium-ion) batteries could be catastrophic if recycling processes are not followed. When these batteries end up in landfills, they release contaminants including toxic heavy metals and create underground fires that burn for long periods of time releasing further contaminants. Through recycling, the production of virgin materials can be reduced however at present it is proving cheaper to do this over recycling which calls for greater regulation and collaborative, smarter thinking: organisations such as The Global Battery Alliance (GBA)[34] are bringing attention to this issue.

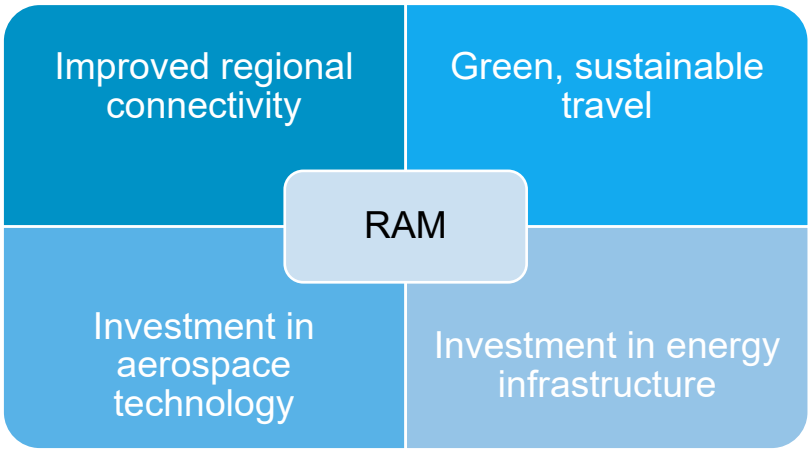
The Royal Society of Chemistry (RSC) points out that geopolitical unrest, including the war in Ukraine, has also caused huge spikes in the price of materials like nickel, a key element in EV batteries. This volatility in the market for elements is causing "chaos in supply chains" that enable the production of electronics. Combined with the surge in demand, this caused the price of lithium - another important component in battery technology - to increase by almost 500% between 2021 and 2022.

[33] WEF_Target_True_Zero_Aviation_ROUND_2022.pdf (weforum.org)
[34] The GBA (globalbattery.org)

8. CONCLUSION AND RECOMMENDATIONS

Potential of regional air mobility

As this paper has discussed, regional air mobility can offer several advantages over conventional aviation:



But these benefits will not be realised overnight; there is a challenging path ahead with many hurdles that will need to be overcome. The aviation industry has a long and proud history of overcoming problems that many thought to be intractable, whether that be supersonic flight, turbine engines or indeed flight itself.

This report is primarily a thought-piece on the potential of RAM to disrupt the way we view aviation and allow thoughts of social value to permeate the conversation. There are, however, a number of potential avenues that industry could explore to greater enable a RAM-connected future.

Recommendations

1. Develop a roadmap to implement AAM operations
2. Undertake further research into the environmental impacts of all aspects of aviation, including non-CO2
3. A comprehensive and study bringing together use cases, market analysis, viable technology, infrastructure requirements, environmental assessment, and community engagement
4. Develop a UK capabilities database to showcase the strengths of the UK industry in a RAM context

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ABOUT ADS

ADS represents and supports more than 1100 UK businesses operating in the aerospace, defence, security and space sectors. Our membership ranges from major multinational businesses with substantial UK presences, to hundreds of small and medium sized companies in every part of the country.

Whether representing industry, connecting our members with business opportunities or driving forward innovation and growth, ADS is at the forefront of an array of activities, events and programmes that benefit our members.

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