Regional Air Mobility

How to unlock a new generation of mobility

Bauhaus Luftfahrt
The Aviation Think Tank

Roland Berger

EXECUTIVE SUMMARY

1 | We expect RAM (Regional Air Mobility) to see a rebound. Investments in the sector have already reached USD 2 billion, excluding the urban air mobility segment. However, more investments are needed to exploit the full potential of this new generation of mobility.

2 | Next-generation RAM is attractive due to its ease of implementation. It does not require major new development or landing technology, merely the addition of charging or hydrogen refueling facilities to existing infrastructure.

3 | The RAM sector has been in decline since 1998, with no additional growth anticipated under the current conditions and forecasts. However, the landscape is changing as both startups and established players work on new RAM vehicles.

4 | The main reason for RAM's decline is due to large, low-cost airline operators outperforming regional operators. Airlines have added new, more efficient larger aircraft to their fleets, flying them from tier 1 and tier 2 airports. As the costs are lower, this has generated more demand through larger airports. This boosts revenue for low-cost airlines, enabling them to buy more efficient narrowbody aircraft, while forcing regional operators to reduce their fleet size.

5 | Whether the factors for RAM's initial decline can be overcome remains to be seen. However, new electric and hydrogen propulsion technology could revitalize the sector by addressing the issues of cost as well as sustainability. RAM will complement research and development for these new propulsion technologies for medium- and long-haul aviation.

6 | We have identified three potential trajectories for the RAM market, which vary according to the development of the macroeconomic environment. The downside-case scenario predicts a market of USD 10 bn in 2050; the upside case is almost five times higher, at USD 50 bn. This will depend heavily on whether the industry can drive down costs. Succeed and RAM can become a mass-market form of mobility; fail and it will remain a niche option at a premium price for those seeking greater convenience, comfort or sustainability.

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Today's regional air mobility market

INNOVATION AND THE DRIVE FOR SUSTAINABILITY ARE BEGINNING TO RESHAPE REGIONAL AVIATION

Technological innovation and the drive for improved sustainability via alternative propulsion are reshaping the regional aviation market. There is now an advanced air mobility (AAM) sector that covers several types of transport for both passengers and cargo, from unmanned aerial vehicles (UAVs) up to regional air transport (RAT) for 19 passengers or more. → A

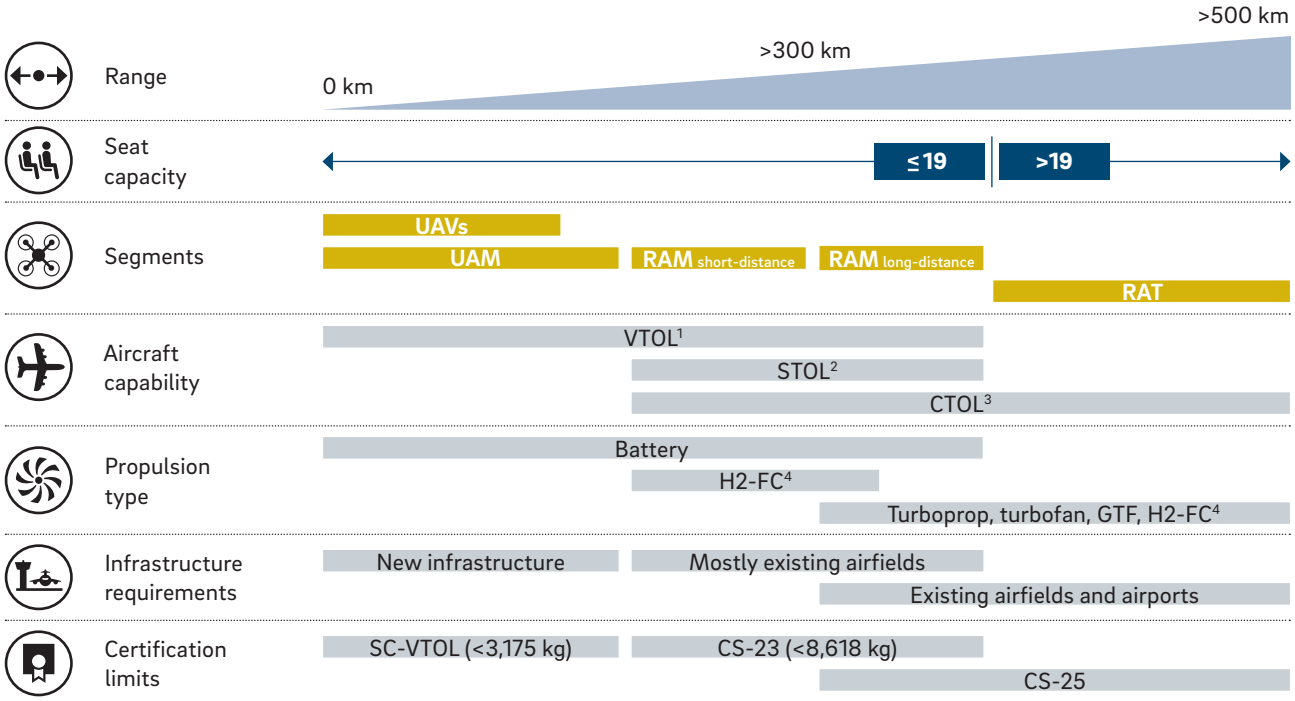
These vehicles serve a variety of purposes, using two main operational concepts: 1) unscheduled, private operations as charter or air taxi services; and 2) scheduled airline operations.

Use cases for regional air mobility include:

Standalone travel for passengers and/or cargo such as
- Inter-city
- Inter-island
- City to rural
- City to beach
- Special, temporary purposes (e.g. trade fairs, events)

Commercial air travel such as
- Feeder flights to major hubs (e.g. Nuremberg–Munich, Innsbruck–Munich)

A Different types of aircraft for a variety of use cases
Overview Advanced Air Mobility



1 Vertical take-off and landing 2 Short take-off and landing 3 Conventional take-off and landing 4 Hydrogen fuel cell

Source: Bauhaus Luftfahrt, Roland Berger

- Demand aggregator to non-hubs (e.g. from the neighboring German states of Brandenburg or Mecklenburg-Western Pomerania to Berlin)
- Frequency provider (e.g. intra-German flights either for premium passengers or as additional frequency, such as every 10 minutes with a 19-seater vs. every 60 minutes with an A319)
- Route opener (e.g. new, thin routes from major hubs such as Munich to Salzburg)
- Potentially replace conventional air services with less energy-intensive options

THE RAPID RISE IN SUSTAINABLE AIRCRAFT DEVELOPMENT

Research and development of alternative aircraft propulsion has been underway for much of the 21st century. Now the urgent need to reduce emissions fast to minimize climate impact is dramatically accelerating progress, with a particular focus on regional travel. Both venture capital firms and strategic investors have dramatically increased their involvement in the sector recently: 2020 alone saw more investment than the previous ten years combined, while 2021 recorded a further increase, predominantly in electric, hydrogen and hybrid technologies. The rise of special purpose acquisition (SPAC) investment models has allowed start-ups to secure critical financial investments by entering the public market. This has led to a rapid rise in projects, with almost 400 now focusing on alternative propulsion regional aircraft. → B → C

Most of these projects focus on either electric or hybrid (combustion + battery) propulsion. Fully electric propulsion is best suited to the UAM and RAM short-distance markets due to their lower range requirements. Hydrogen propulsion offers greater range but is only being explored by a small number of RAM long-distance and RAT projects due to current technological limitations of fuel cells and batteries.

INFOBOX

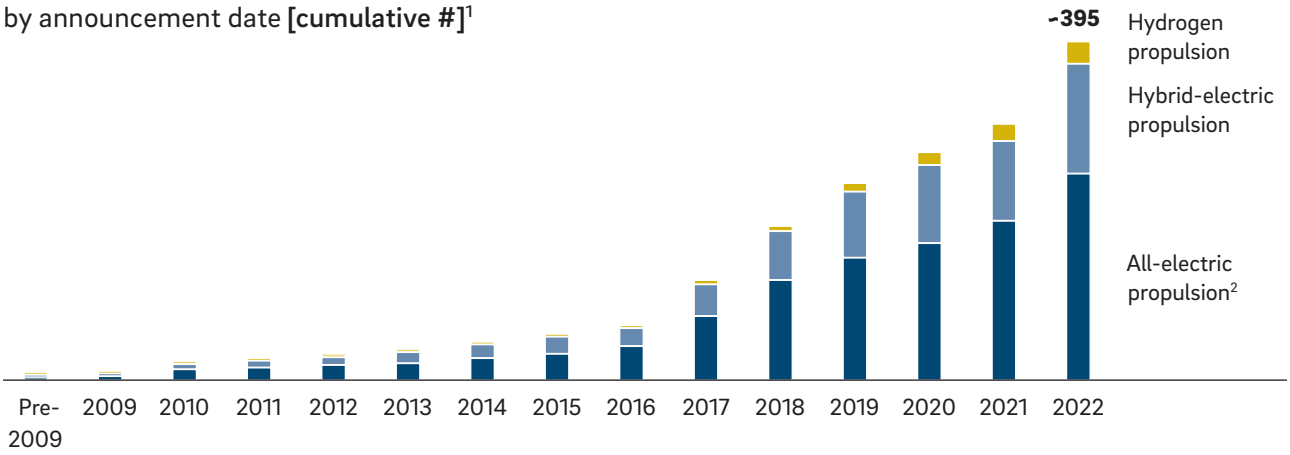
Types of advanced air mobility

As there are still no standard global definitions of the transport modes within the AAM sector, for the purposes of this report we have created the following clusters based on technical specifications published by the companies involved.

- **Urban air mobility (UAM)**
  Air transportation vehicles with ranges of less than 100 km, mainly used in urban environments.
- **Regional air mobility short-distance (RAM short-distance)**
  Air transportation vehicles with ranges of more than 100 km but less than 300 km.
- **Regional air mobility long-distance (RAM long-distance)**
  Air transportation vehicles with ranges greater than 300 km but a capacity of equal to or less than 19 passengers.
- **Regional air transport (RAT)**
  Air transportation vehicles with ranges of more than 300 km and a capacity of greater than 19 passengers.

B Almost 400 sustainable aircraft are currently in development, primarily all-electric or hybrid, but with a growing share of hydrogen-powered aircraft

Known electric and hydrogen-propelled aircraft developments by announcement date **[cumulative #]**[1]

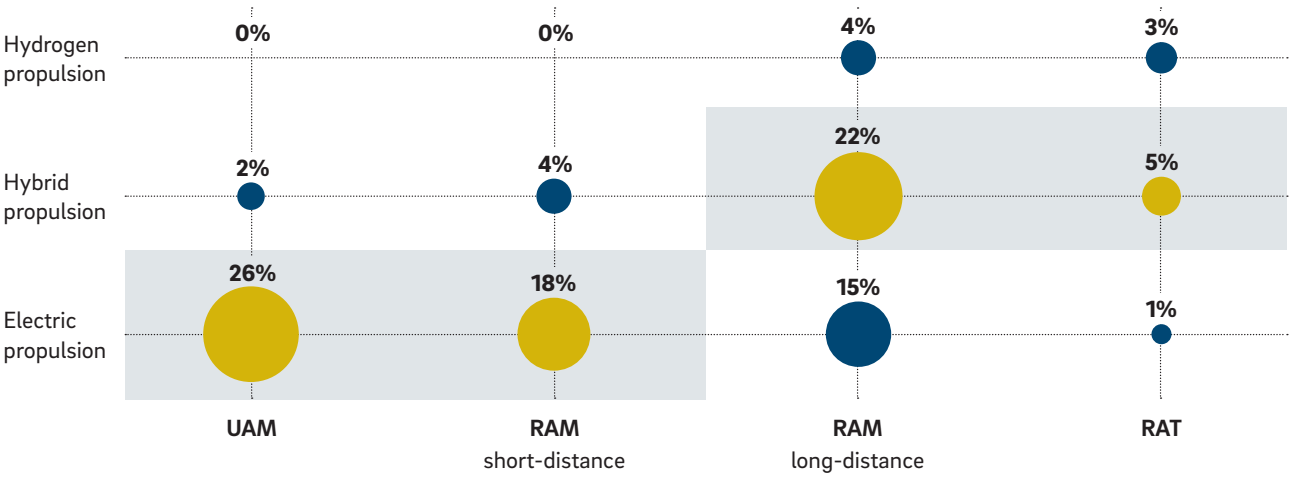


1 Only including developments with first flights after 2010 and major electric concepts; excluding UAVs and purely recreational developments 2 Including solar propulsion

Source: Roland Berger Sustainable Aircraft Database

C Which sectors are focusing on which type of alternative propulsion?

Share of aircraft projects globally by type of propulsion [%]



Note: The total number of sustainable aircraft projects globally amounted to 395 in 2021

Source: Roland Berger

Going electric – Focus on RAM for long distances

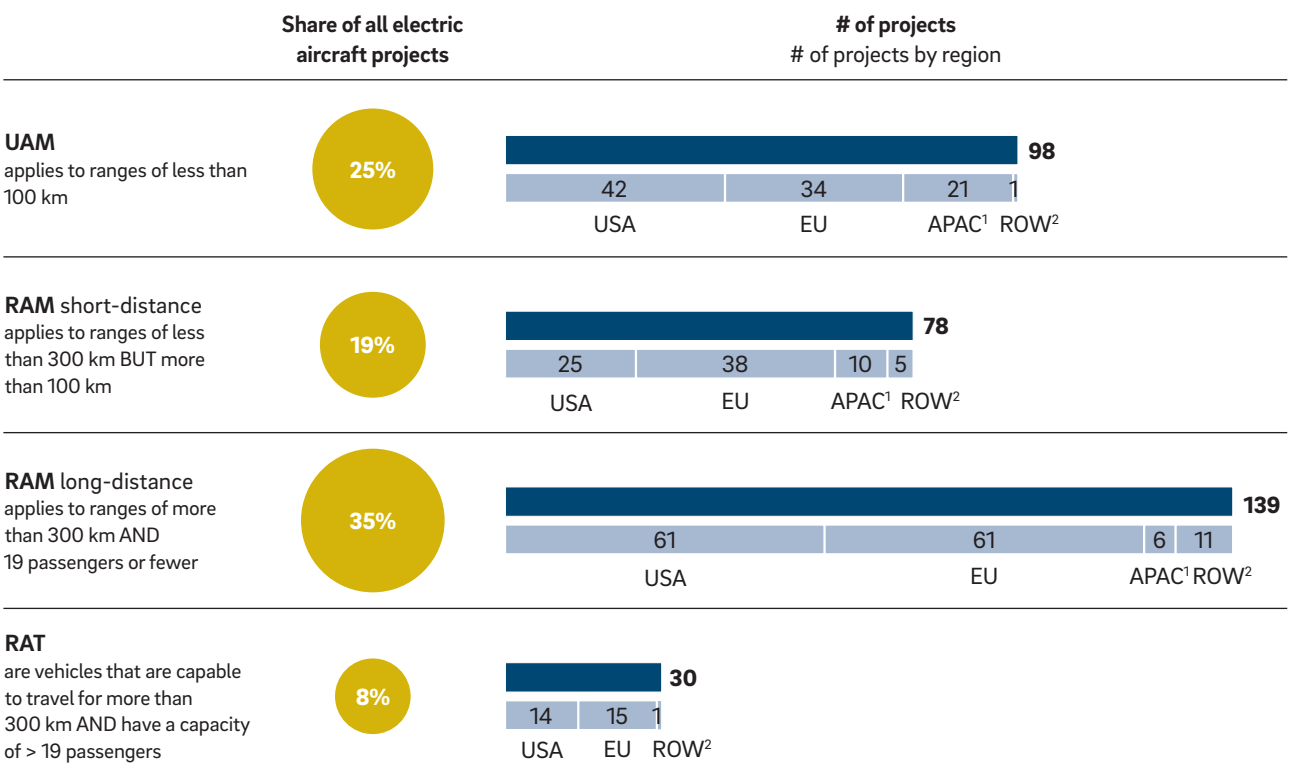
A closer look at the number of projects underway in each sector shows that RAM long-distance dominates, with 35% of all projects looking at ranges of more than 300 km and 19 passengers or fewer. This is extremely surprising as the vast majority of funding, particularly in 2021, went to projects looking at either the UAM or the RAM short-distance sectors. → D

Which sectors are attracting the most funding?

While entry into service for these aircraft is still several years away, considerable technological progress has been made. We believe this explains why many developers are now focusing on the RAM short-distance and RAM long-distance segments, which offer more attractive market potential overall (use cases and possibility for buildup/use of infrastructure). Investors,

D Majority of electric aircraft projects focus on the regional air mobility market with up to 19 passengers

Share of electric aircraft projects globally by use case [%]



1 Asia-Pacific 2 Rest of World

Note: All projects as of January 31, 2022; numbers do not add up to 100% because some projects are missing important information for cluster allocation

Source: Roland Berger

on the other hand, are either yet to realize this or are betting on more established UAM and RAM short-distance players with the intention of widening their scope once technology is ready and the market is more mature. → E

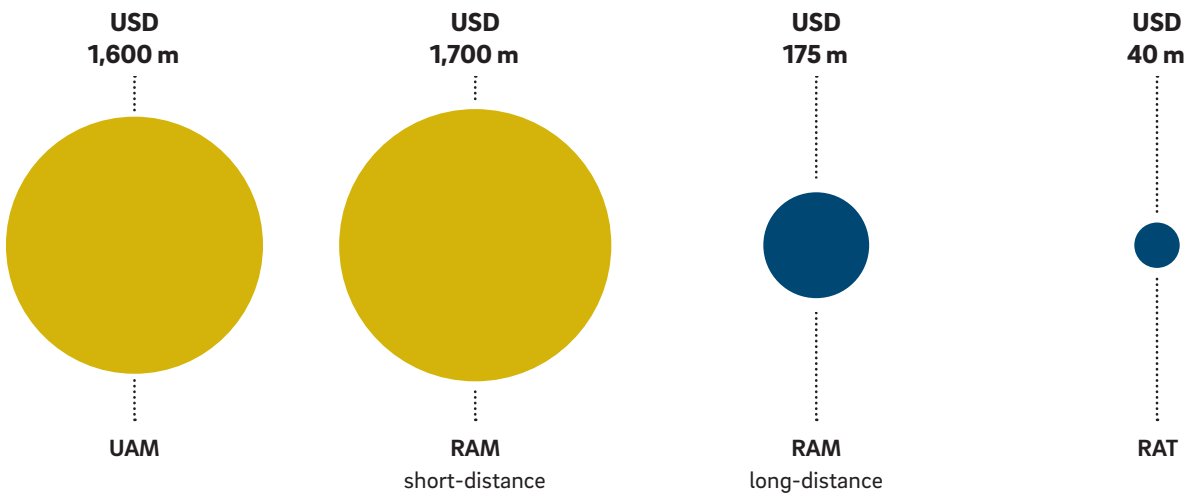
THE RAM MARKET: SMALL AND GETTING SMALLER ...

At first glance, the level of investment and innovation in the RAM market may seem surprising given its relatively minor role in the global aviation market. In 2018, which we selected as a representative pre-Covid-19 year, short-distance air travel of less than 400 km accounted for just 2% of the offered transport capacity (available seat kilometers, ASK) worldwide and 4% within Europe. This rises to 9% for trips of up to 800 km worldwide. Up to 19% of aviation's emission within Europe (as ASKs are a good first-level proxy for emissions) have the potential to be significantly reduced by RAM. → F

The regional air mobility sector has also been in decline for some time. After a rapid rise in the global fleet of 19-seater aircraft, their number has steadily sunk since the mid-1990s – mainly due to large, low-cost airlines outperforming regional operators. Over the last three decades, large airlines have increasingly added new, more efficient narrowbody aircraft (~100-200 seats) to their fleets, flying them from tier 1 and tier 2 airports. The lower operating (and therefore ticket) cost has generated more demand through larger airports. This boosts revenue for low-cost airlines, enabling them to buy yet more efficient narrowbody aircraft and forcing regional operators to reduce their fleet size. → G

E Contradictory developments: Most funding went into UAM and RAM short-distance, whereas the majority of projects are in RAM long-distance

Funding [USD million] by segment in 2021

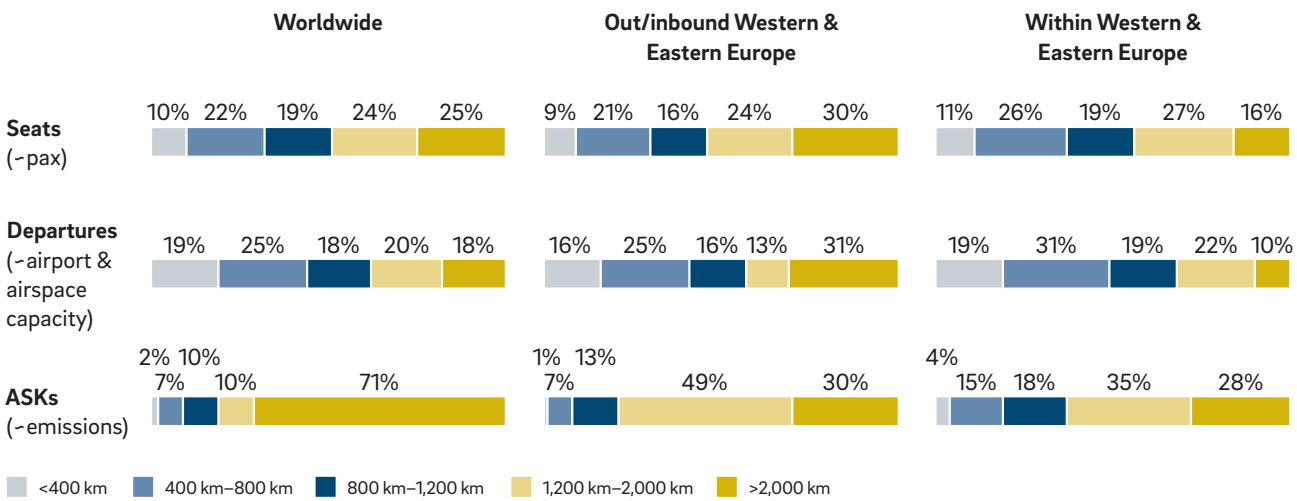


Note: The total number of sustainable aircraft projects globally amounted to 395 in 2021

Source: Roland Berger

F Worldwide vs. European air transport

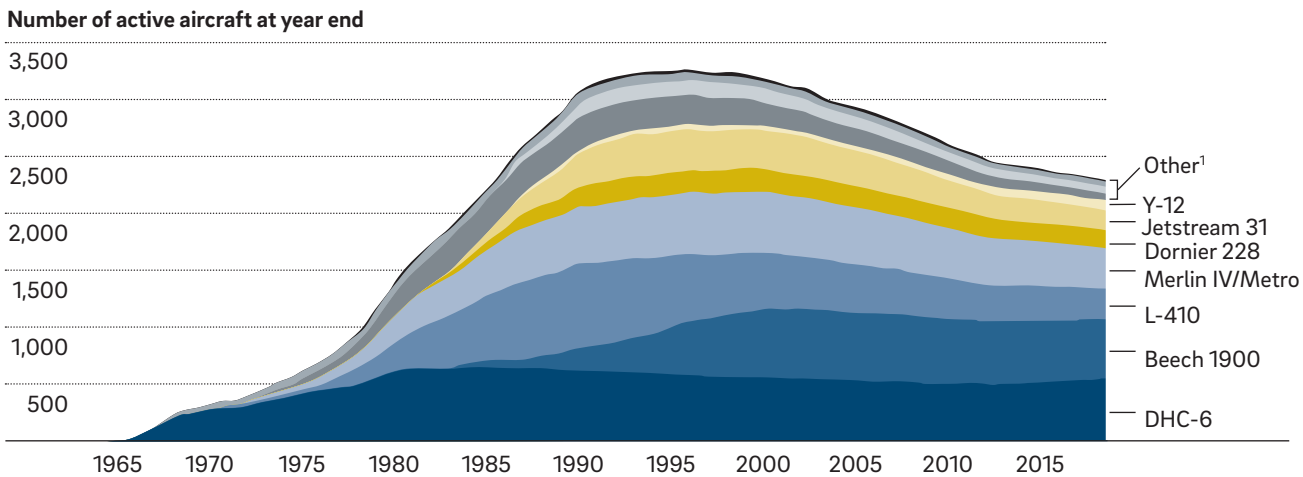
Key indicators in air transport



Source: Bauhaus Luftfahrt; Roland Berger based on OAG data 2018

G The regional air mobility market is small and getting smaller

Global civil 19-seater aircraft fleet



1 Arava, SC.7 Skyvan, Ab-28/M28, EMB-110

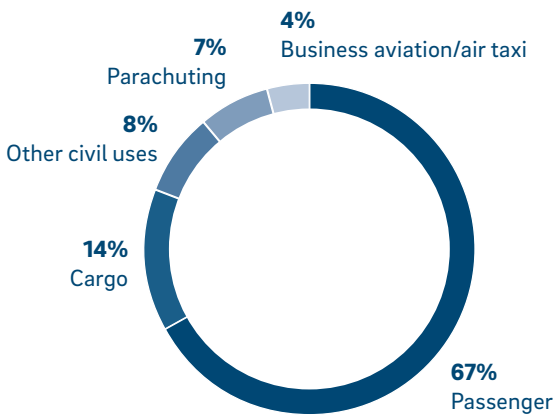
Source: A. Paul et al., Deutscher Luft- und Raumfahrtkongress 2019

INFOBOX

Civil uses for 19-seater aircraft

19-seater (≤ 19 seats) aircraft are used in a variety of areas. Passenger transport (67%), cargo transport (14%) and notably parachuting (7%) are the most common civil uses of 19-seater aircraft. Just 4% of active aircraft are dedicated to business aviation or air-taxi use, mostly in remote areas, for example by the mining or oil and gas industries. Around 8% of the fleet have other purposes, ranging from training schools to research.

Share of civil uses of 19-seater aircraft or smaller



Source: A. Paul et al., Deutscher Luft- und Raumfahrtkongress 2019

A closer look at the North American and European markets for regional aviation, the two biggest ones, over the last 20 years shows that both have experienced a significant decline in the number of flights, either due to ceased operations or the shift to larger, more cost-efficient aircraft. In Europe, there has been little change in the markets served during that period: around 27% of departures for 19-seater aircraft are from rural areas and approximately 40% from urban areas. In North America, however, there has been a strong shift towards rural flights. Considering the distinct geographical and regional characteristics of Europe and North America, the added value of using smaller aircraft to connect peripheral regions may be much higher in North America than in Europe. → H → I

… BUT WITH SIGNIFICANT POTENTIAL TO TRIAL INNOVATION?

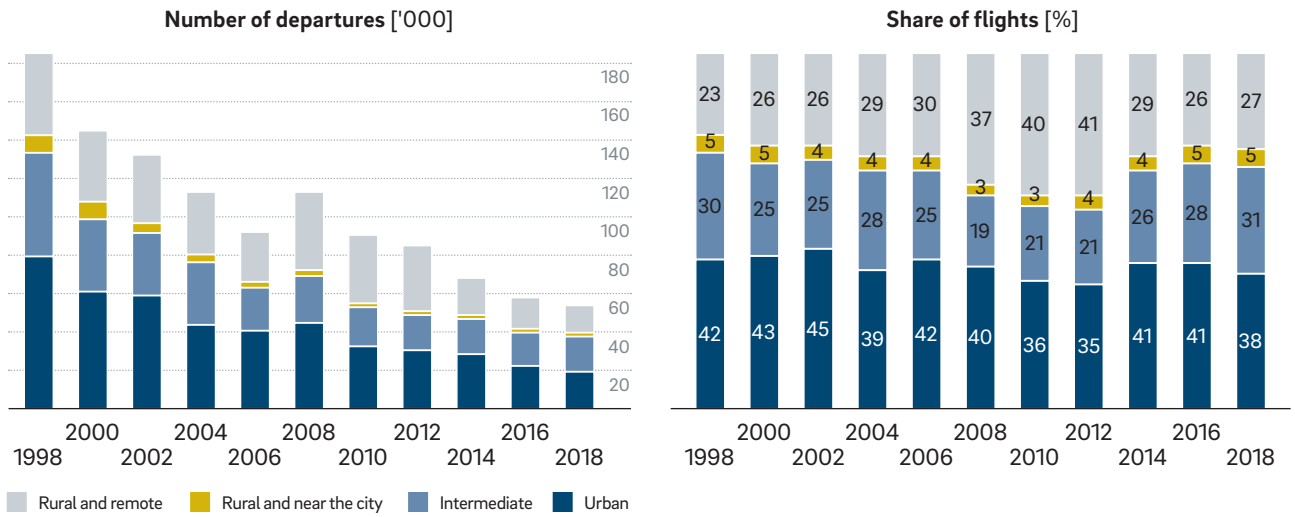
Despite the increasingly minor role that RAM (short- and long-distance) has played so far in the overall aviation market, there are two main reasons behind the raft of new projects and investment in the sector.

Firstly, even a relatively small RAM market share still equates to significant passenger volume: In 2016, more than 900 million passengers traveled on scheduled flights of less than 800 km. → J

The same applies to revenue from ticket sales. Scheduled flights of less than 400 km made up just 4% of total airline revenue in 2016, while flights of less than 800 km comprised 16%. Yet, despite these low numbers, revenue for flights of less than 400 km still totaled USD 29 billion, with flights of less than 800 km making up USD 116 billion. → K

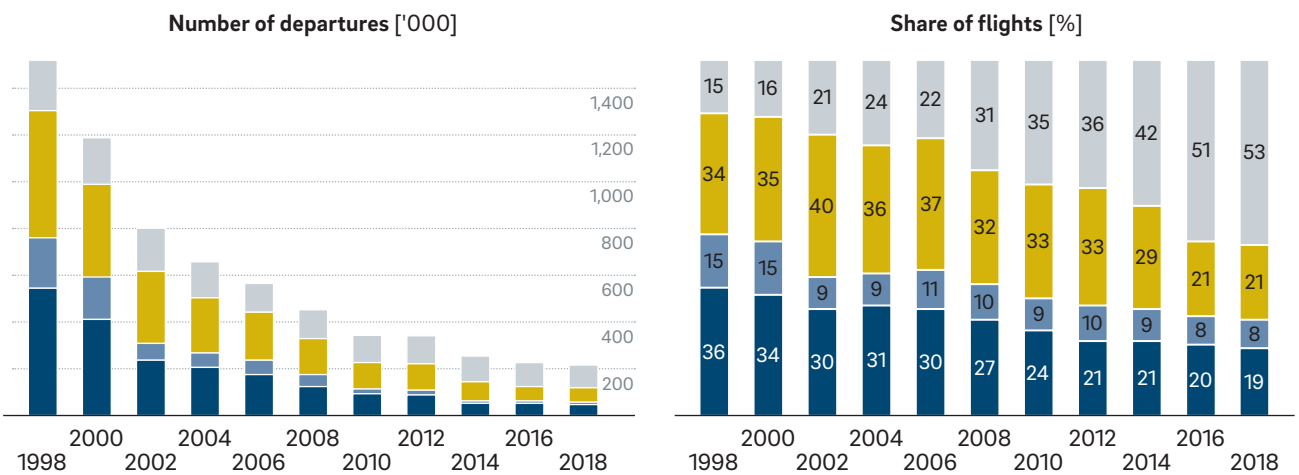
Secondly, and most importantly, short-distance flights are well suited to trialing technologies like electric, hydrogen and hybrid propulsion. The potential for hydrogen is particularly significant for the wider aviation

H The 19-seater market in Europe has shrunk over time but still connects urban and rural regions



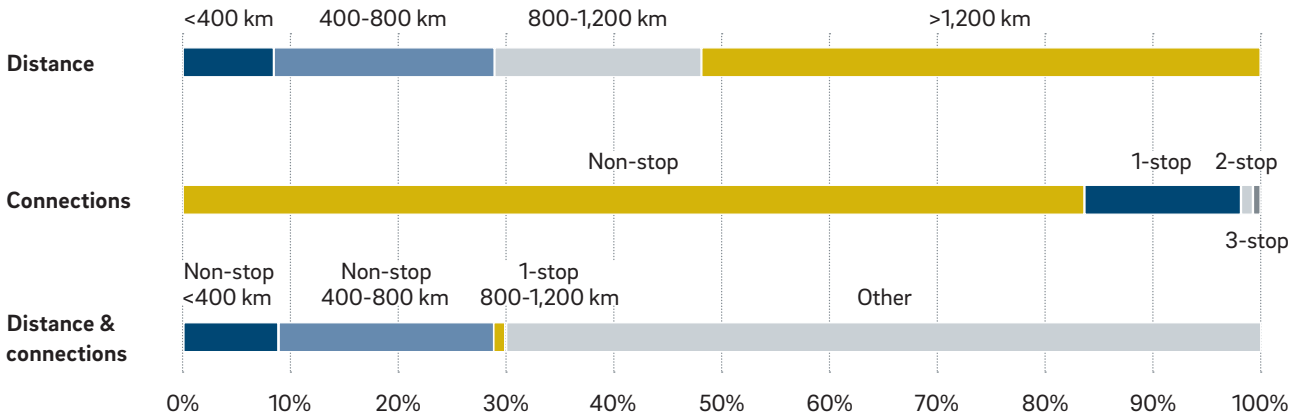
Source: J. Middel, Leibniz Universität Hannover, Institut für Wirtschafts- und Kulturgeographie

I The 19-seater market in North America has significantly shrunk over time and shifted towards rural and remote regions



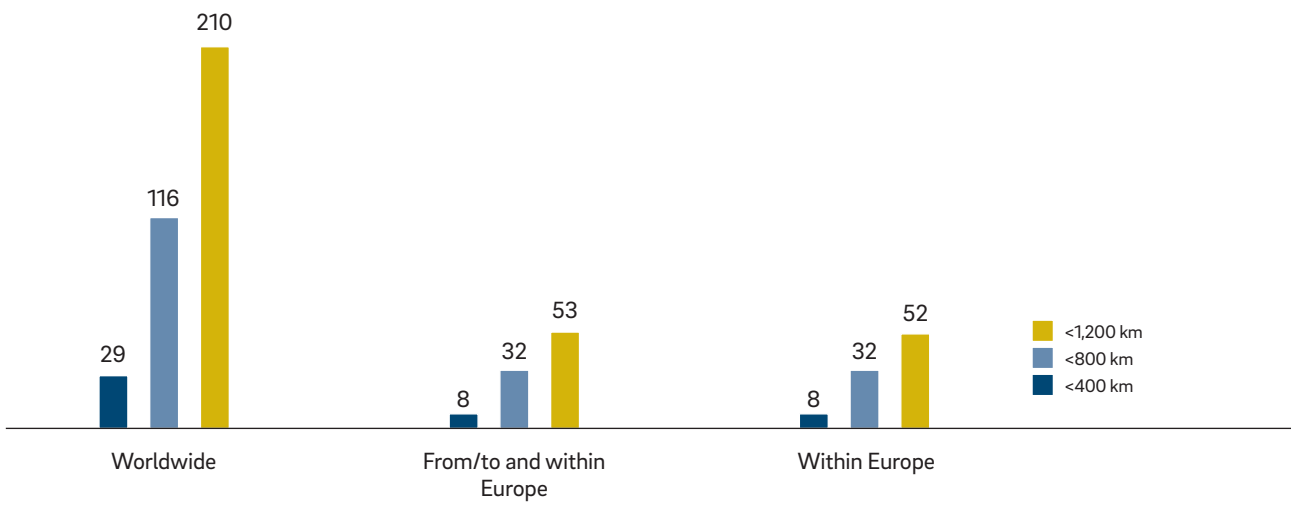
Source: J. Middel, Leibniz Universität Hannover, Institut für Wirtschafts- und Kulturgeographie

J Long-distance, non-stop air travel dominates in terms of passenger numbers
Share of worldwide passengers [%]



Source: SABRE 2016

K Short-distance air travel is a multi-billion-dollar market, even in Europe
Total passenger revenue (SABRE 2016) [USD bn]



Source: SABRE 2016

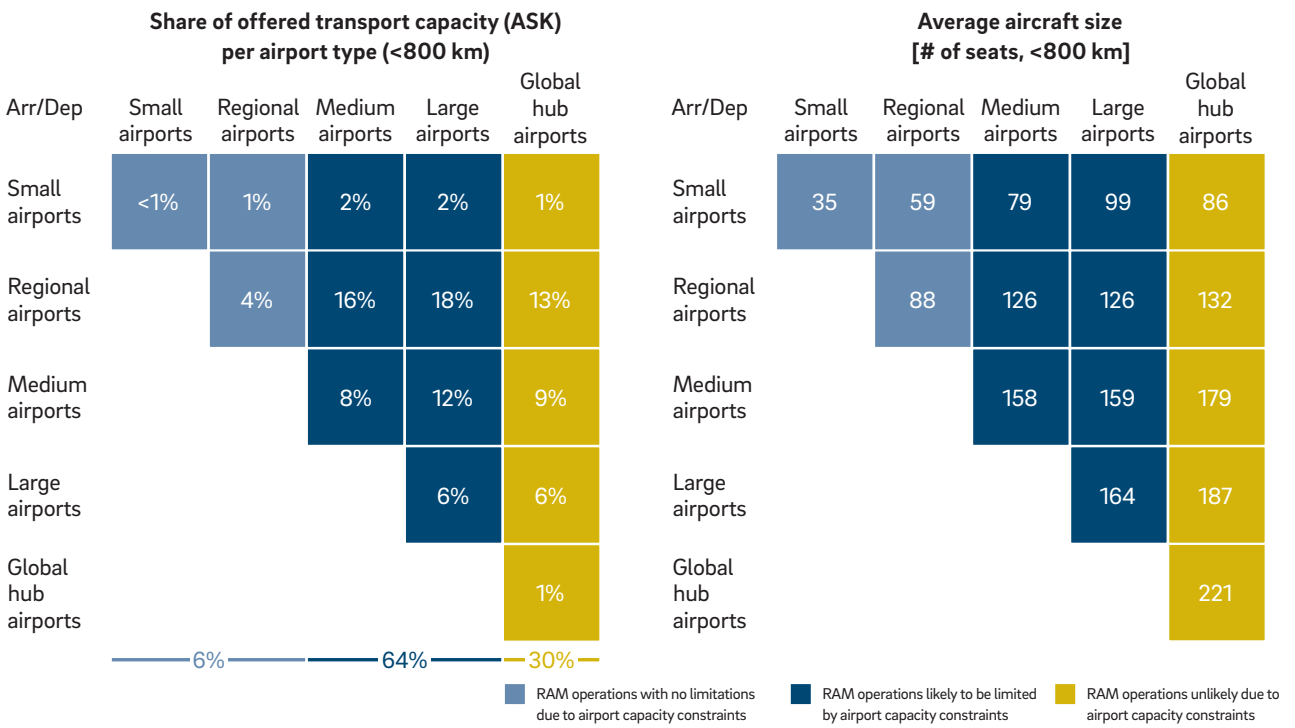
market. Hydrogen propulsion for regional application could deliver ranges of 2,000 km-plus, which would cover 70% of all transport capacity from, to and within Europe.

RAM LONG-DISTANCE: BEST SUITED TO SMALLER AIRPORTS

If the total operating costs for RAM vehicles were to become competitive with RAT and conventional aviation, some existing demand for large commercial short-haul flights could be shifted to RAM long-distance flights. However, a move towards smaller, 19-seater aircraft would result in significantly more air traffic to achieve the same transport capacity (by ASK). Currently, the average aircraft size on a 800 km flight is 157 seats. As one might expect, the larger the airport, the larger the average number of installed seats. Even on flights from small to medium airports, the number of installed seats is 79 – four times the 19-seater segment.

Small and regional airports would be best positioned to serve extra flights due to their underutilization: they currently account for just 6% of transport capacity for flights of less than 800 km. For medium to large airports, however, it is a different story, as they account for 64% of total transport capacity. Highly constrained global hub airports offer 30% of transport capacity and are very unlikely to operate flights for 19-seater aircraft given that they are already utilized to a high level and often suffer capacity constraints for take-off and landings. → L

L RAM long-distance: Best suited to smaller airports



Source: OAG 2018 with airport type specification by J. Braatz, J. Michelmann, B. Gruber, F. Stroh, M. Hornung, TU Munich

02
Key drivers to unlock regional air mobility

WE HAVE IDENTIFIED KEY DRIVERS TO UNLOCK THE POTENTIAL OF REGIONAL AIR MOBILITY IN THE DIMENSIONS OF INNOVATIVE TECHNOLOGY AS WELL AS MARKET DRIVERS

Innovative technology

Driver 1: Innovative propulsion

Development projects cover three main technology areas: hydrogen, hybrid and full electric propulsion. Currently, the majority of hybrid projects combine electric with conventional propulsion. Just 15% focus on combining hydrogen with electric propulsion. This is not surprising given that many of the companies involved aim to first launch a hybrid combining electric and conventional propulsion, then switch to fully electric or potentially a hydrogen-powered vehicle once the technology is proven and provides sufficient range. Electric, distributed propulsion leads to improved take-off and landing performance, a significant reduction in maintenance and lower noise levels.

Driver 2: Improved battery performance

Over the next five to ten years, energy densities for lithium-ion battery packs could rise from 250 Wh/kg to 400 Wh/kg, enhancing the range capability. Improved recyclability will reduce dependency on certain critical materials and lower the likelihood of supply chain issues.

Driver 3: Innovative aircraft design

The new generation of regional air vehicles comprises a variety of designs, including multicopter (e.g. Volocopter 2X), lift and cruise (e.g. Beta Technologies ALIA or City Airbus NextGen) and vectored thrust (e.g. Joby Aviation S4). The latter includes tilt-x convertible aircraft as well as fixed-wing vectored-thrust aircraft designs. Most projects currently follow the vectored-thrust approach.

Driver 4: Data and digitalization

In order to be successful, RAM must be integrated with the existing transportation network to provide efficient and convenient door-to-door travel. There are several factors to consider. The location of landing sites is important, as is their integration into the existing mobility network; the RAM booking platform must also be integrated into other booking platforms; seamless travel chains, including feeder transport on the ground, require close cooperation with other transport providers.

Driver 5: Sustainable travel is gaining momentum

Regional air mobility will serve as a testbed and enabler of sustainable aviation in larger commercial aircraft – for example, Airbus plans to develop a hydrogen-powered commercial aircraft by 2035.

Market drivers

Driver 1: Aviation aims to become more sustainable

Conventional aircraft with e-fuels – synthetic fuels made with renewable energy – will be the future benchmark or reference case for comparison. On a passenger-kilometer basis, a fully electric 19-seater aircraft consumes less than a quarter of the energy compared to an ATR72/A320NEO with 100% sustainable aviation fuel. Furthermore, a battery-powered CTOL 19-seater aircraft consumes as much as an electric, privately driven car assuming current load factors.

Driver 2: Government strategies for equal living conditions in urban and rural areas

It is hard to justify investing in rail and road infrastructure in areas with low population density like Scandinavia, Canada and South America, hence governments fulfil public air service obligations where necessary. Regional airports are underutilized – for some, subsidies and, indeed, their entire operation are under debate.

Driver 3: Greater appeal of rural living and remote working after Covid-19

The widespread shift to remote work during the Covid-19 pandemic has caused a significant number of people to move from urban to rural areas with a more affordable, higher quality of life. This could lead to longer but less frequent commutes to work.

Driver 4: Increased acceptability of and willingness to pay for climate-friendly products

Slowly but surely, customers are choosing more environmentally friendly products. This will support the regional air mobility concept.

Driver 5: Increased demand for social distancing and less busy transport options

Covid-19 has led to people valuing privacy more and favoring transport with fewer passengers. Regional air mobility fills this sweet spot.

Driver 6: Growing trend towards traveling and buying locally

The trend towards local "staycations" that emerged during the pandemic is likely to persist: Geopolitical tensions have caused energy prices to increase considerably, which will contribute to a decrease in demand for long-haul travel. RAM could facilitate the increase in shorter journeys.

QUANTITATIVE ASSESSMENT OF THE FUTURE RAM (SHORT- AND LONG-DISTANCE) MARKET

We believe that the identified innovation and market drivers will have the potential to stop the downward trend of the RAM (short- and long-distance) market and even to lead (in the upside case) to a rebound of this market. However, the level of growth will be dependent on three main dimensions: → M

- Overall growth of the aviation market
- Availability of renewable energy and its price point
- Overall price level for RAM compared to other modes of transport

Scenario 1: Base case

- Aviation market returns post-Covid-19 and post-Russia/Ukraine crisis to its long-term growth path of ~4% CAGR
- Renewable energy will be available in sufficient quantity, but energy prices will be higher than they are today

Scenario 2: Downside case

- Sustainable energy will be available in sufficient quantity for the needs of consumers (e.g., private households, industry, aviation) – Remaining renewable energy will be split between different transport modes and/ or industries that are most efficient and/or keep economies running to prevent a decline in overall wealth
- Energy prices increase substantially due to geopolitical crises and to combat global warming
- The aviation market experiences a decline in growth to curb global warming (both for long-haul, short-haul and regional routes)

Scenario 3: Upside case

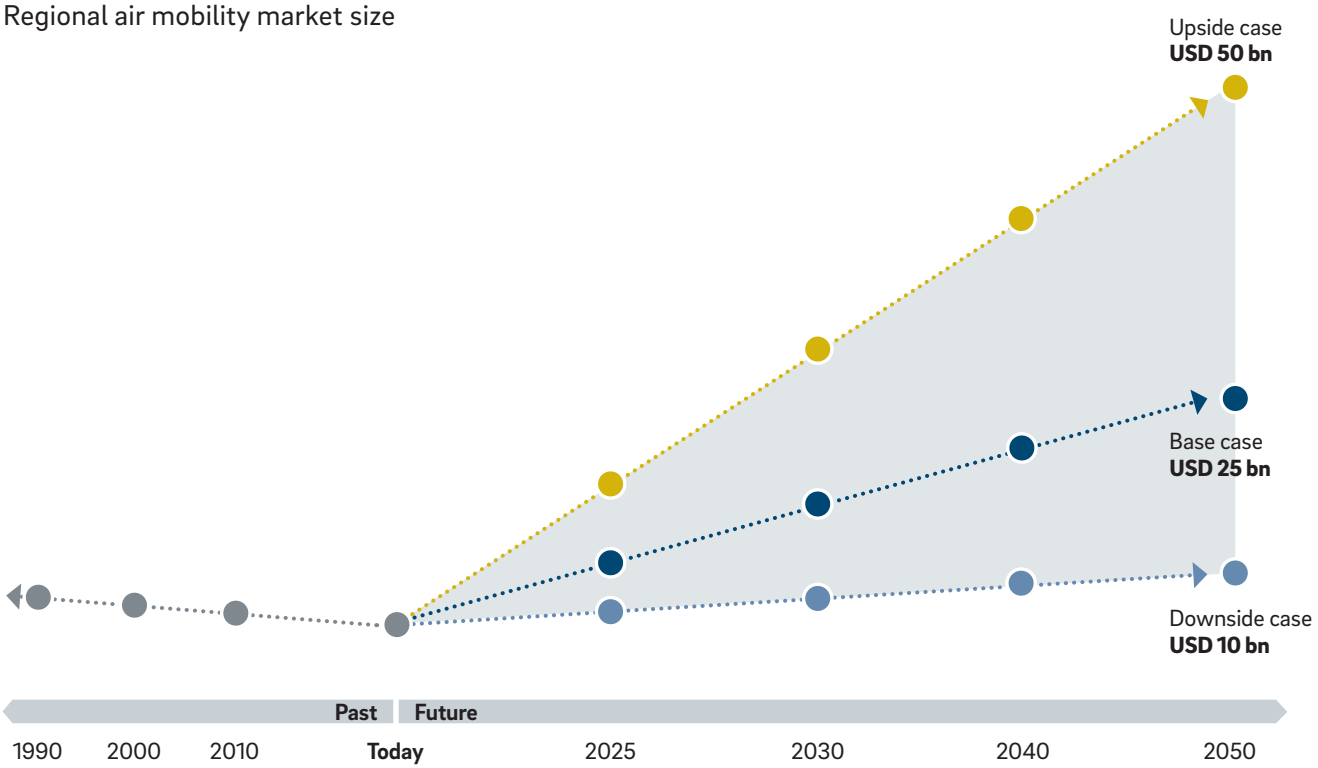
- Renewable energy will be available in sufficient quantity
- Energy prices remain relatively stable, showing only slight growth compared to today
- The aviation market continues to grow, especially the regional segment
- RAM (short- and long-distance) will be able to achieve a price point for the customer (ticket price) that will be competitive with other modes of transport (e.g., train, cars)

TURNING RAM (SHORT- AND LONG-DISTANCE) INTO AN ATTRACTIVE AND EFFECTIVE TRAVEL OPTION

However, to stimulate demand and make RAM (short- and long-distance) an appealing mode of transport, it must be:

- **Convenient:** By providing fast door-to-door access to regional airports, including rapid airport security checks
- **Comfortable:** By offering a smooth, pleasant travel experience
- **Accessible:** By using transparent booking platforms with one ticket for intermodal journeys
- **Affordable:** By offering a price point that is much lower than current RAM (short- and long-distance) options. Prices should be comparable to general aviation, including fixed and variable costs for security checks at airports
- **Sustainable:** By combining zero-emission options for an entire intermodal journey. RAM is superior to any mode of transport using combustion engines, competitive with electric cars but not better than electrified trains
- **Reliable:** By providing regular services with a low number of weather-related disruptions

M Turning RAM into an attractive travel option can result in a USD 50 bn market
Regional air mobility market size



Source: Roland Berger

There are a number of important areas that underpin these factors:

Public acceptance

Public acceptance is key to the adoption of new technologies. This may be easier for RAM than for UAM, which will operate in more densely populated urban environments. Public acceptance at smaller airports and airfields that are already heavily used is likely to be more widespread than those that are less busy and would face an increase in traffic due to RAM.

Certification

The ease of obtaining certification will likely vary depending on the type of aircraft. Completely new vertical take-off and landing vehicles, for example, are likely to be more complex than retrofitting existing aircraft with electric or hydrogen propulsion systems, although these will also present their own challenges. Developments in the UAM market may aid certification for RAM.

Infrastructure

Some new infrastructure will be required to make RAM successful. Charging or hydrogen facilities, for example, are crucial, although the number required will be much smaller than for the automotive industry. Technology for autonomous operations, like lidar and radar, may be needed. Some infrastructure is already in place, but it must be thoroughly analyzed to see if it fulfils requirements. Regional airfields may need approval for commercial operations, upgrades to passenger and runway facilities and satisfactory connections to other transport options, for instance.

Pilot availability

RAM would compete for pilots not just with UAM, but also to a certain extent with larger regional and commercial aircraft as well as business aviation. Envisaged higher autonomy up to pilotless operations could alleviate the competition.

Air traffic management

Air traffic management (ATM) and unmanned traffic management (UTM) are important building blocks for the next generation of aviation. There are numerous challenges to overcome, most notably integrating new aircraft into busy airfields and airports, and managing increased traffic in urban areas while considering aspects such as safety and visual and noise pollution.

03
Key results, conclusion and future outlook

Based on our analysis of the advanced air mobility market, we conclude that the existing 19-seater market will embrace new propulsion concepts, such as electric, for example, but otherwise remain largely unchanged. However, in the event that some of the drivers mentioned in the previous section become more prominent, the market could grow, with new routes for 19-seater aircraft that rely largely on existing infrastructure, for example Hamburg to Stockholm.

In order to bring the market to life, RAM (short- and long-distance) vehicle manufacturers must ensure the technology is ready and certification is in place. But that is not all – they must also give careful consideration to potential routes and ensure the necessary infrastructure, such as charging stations, is in place by discussing or partnering with aircraft operators and owners. Airfields must be integrated into ground transportation networks and booking platforms must run seamlessly. Developing a new generation of regional air mobility is about much more than developing, certifying and producing new vehicles.

KEY TAKEAWAYS

1 | The regional air mobility (RAM) sector has been in decline since 1998, with no additional growth anticipated under the current conditions and forecasts. However, the landscape is changing as both startups and established players work on new RAM vehicles.

2 | The main reason for RAM's decline is due to large, low-cost airline operators outperforming regional operators. Airlines have added new, more efficient larger aircraft to their fleets, flying them from tier 1 and tier 2 airports. As the costs are lower, this has generated more demand through larger airports. This boosts revenue for low-cost airlines, enabling them to buy more efficient narrowbody aircraft, while forcing regional operators to reduce their fleet size.

3 | We expect RAM to become a more relevant market in the future. Investments in the sector have already reached USD 2 billion, excluding the urban air mobility segment. However, more investments are needed to exploit the full potential of this new generation of mobility.

4 | Next-generation RAM is attractive due to its ease of implementation. It does not require major new development or landing technology, merely the addition of charging or hydrogen refueling facilities to existing infrastructure.

5 | Whether the factors for RAM's initial decline can be overcome remains to be seen. However, new electric and hydrogen propulsion technology could revitalize the sector by addressing the issues of cost as well as sustainability. RAM will complement research and development for these new propulsion technologies for medium- and long-haul aviation.

6 | We have identified three potential trajectories for the RAM (short- and long-distance) market, which vary according to the development of the macroeconomic environment. The downside case scenario predicts a market of USD 10 bn in 2050; the upside case is almost five times higher, at USD 50 bn. This will depend heavily on whether the industry can drive down costs. Succeed and RAM can become a mass-market form of mobility; fail and it will remain a niche option at a premium price for those seeking greater convenience, comfort or even sustainability.

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