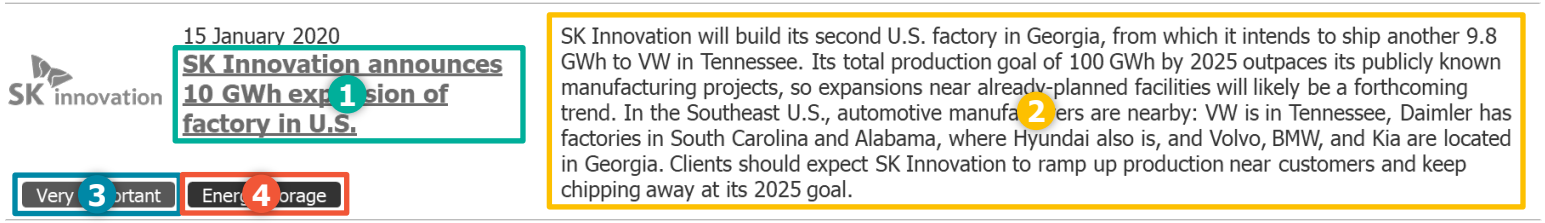
Singapore Battery Consortium

2022 Q1 Newsletter

SINGAPORE BATTERY CONSORTIUM

Understanding curation of recent industry developments and technology news

Recent industry developments and technology news are specifically curated based on the relevance to the progression of the industry. Each news event is categorized based on importance and area of focus (see below for description for both).



1. **Link**: Hyperlink to original news article. Note some news articles may be behind paywall.
2. **Analysis**: Writeup of the news event as it relates to industry development and recommendations for action.
3. **Importance**: Take on the potential importance of the event from "Truly Disruptive" to "Ignore"
4. **Area of Focus**: Category of the news event based on the to the topic.

Importance	Description
Truly Disruptive	A game-changing, landmark development
Very Important	Significant news that will have strong implications
Average Importance	Worth noting, but not likely to be too important or disruptive
Low Importance	An over-hyped development, which is not worth monitoring closely
Ignore	Misleading or irrelevant development, worth being cautious about

Area of Focus	Description
Built environment energy use	Hardware and software technologies for commercial and residential energy consumption
Business models and regulations	Novel business models for energy production, consumption, and distribution, as well as policies with transformational impact on new energy technology development
Energy for mobility	Energy sources for powering road, rail, aviation, and marine – includes movement of goods and people
Energy storage	Various forms electrochemical energy storage, such as Li-ion and solid-state batteries
Stationary storage	Utility-scale and long-duration energy storage for grid services, renewables integration and backup, and microgrid support

RECENT INDUSTRY DEVELOPMENTS AND TECHNOLOGY NEWS

Battery recycling continues to gain momentum as markets seek alternative means for securing battery materials

30 December 2021

RWE and Audi work together on second-life battery storage project in Germany

Average Importance | Stationary storage

RWE and Audi are collaborating on the development of a 4.5-MWh storage system using 60 second-life Li-ion batteries from Audi e-tron vehicles. The system is co-located at RWE's pumped storage hydropower plant in Herdecke, North Rhine-Westphalia in Germany, where the company already has 7 MWh of stationary storage. The partners expect the system to reach a lifetime between one and ten years, depending on usage. RWE plans to start using the second-life system in early 2022, mainly for frequency regulation, but also intends to test other applications "on a flexible basis."

7 January 2022

Reliance New Energy Solar acquires Na-ion developer Faradion

Average Importance | Stationary storage

Earlier in 2021, Reliance announced a battery production facility in Jamnagar, India, that coincided with a USD 144 million investment in Ambri, despite the firm's low commercial readiness. In contrast, Faradion has experience using contract manufacturers and will be more compatible with near-term production for Reliance. Na-ion batteries got a boost of attention when CATL announced it would produce the technology, likely cementing Reliance's choice with Faradion. India would be an ideal location for Na-ion batteries given the absence of a Li-ion value chain in the country but shouldn't expect the move to have much impact on the long-duration energy storage technology landscape.

20 January 2022

Nissan to target U.S. and Europe for new battery recycling capacity by 2025

Very Important | Energy storage

Nissan recently announced plans to build new Li-ion battery recycling facilities in Europe and the U.S. by 2025. This will be its first recycling plants outside Japan since building recycling facilities via 4R Energy Corp., a joint venture with Sumitomo Corp., in its domestic market. The Japanese automaker plans to perform recycling in-house to recirculate critical materials (Li, Ni, Co, Mn) into its battery production, reducing production costs. Europe and the U.S. are increasing battery recycling efforts due to growing electric vehicle adoption as well as to China's continued ban on importing battery "black mass."

RECENT INDUSTRY DEVELOPMENTS AND TECHNOLOGY NEWS

Startups continue to raise funding despite maturation of the battery industry

13 January 2022

Freyr looks to build out European LFP production in deal with Taiwanese battery maker

Very Important | Energy storage

Despite a rapidly growing interest in LFP, China remains the only country that manufactures significant quantities of LFP. Freyr, a battery manufacturer that is licensing 24M's SemiSolid production process for up to 40 GWh of capacity, plans to produce LFP cathode materials in Europe under an agreement with Aleees, a Taiwanese LFP battery producer, using Aleees' plant design. The pact includes 10,000 tonnes of LFP cathode material production capacity by 2024, which can expand to up to 30,000 tonnes by 2025. This is a vital step toward building out LFP production capacity in Europe and should expect other cathode materials producers in Asia to make similar announcements.

14 January 2022

Qnovo's USD 24 million Series C led by BorgWarner provides path to mobility applications

Average Importance | Energy for mobility

Laying the groundwork for a future shift to electric mobility, BorgWarner has invested in fast-charging battery management system (BMS) startup Qnovo. BorgWarner has made other acquisitions, most notably Romeo Power in 2019, as it transitions from combustion power trains to electric. Qnovo's BMS is differentiated by its smart-charging protocols that improve battery health and enable faster charging; implementing this digital solution would give BorgWarner a competitive advantage over other packs using the same cell chemistries. BorgWarner's investment should be viewed as a small but important addition to its technology portfolio.

27 January 2022

Factorial Energy raises USD 200 million in Series D funding round

Average Importance | Energy storage

Factorial Energy's funding round was led by Mercedes-Benz and Stellantis as part of a joint venture that was announced in November 2021. The money raised will help scale up the company's proprietary solid-state electrolyte (SSE) material known as Factorial Electrolyte System Technology. It is noteworthy that Factorial Energy has been aggressive in its development of SSEs, and the company recently announced a pilot production facility. It also claimed to have tested a 40-Ah battery at room temperature, a temperature at which SSEs tend to have poor conductivity. Factorial's growing partnerships with large automotive OEMs is noteworthy but the company's quick growth should still be viewed skeptically.

RECENT INDUSTRY DEVELOPMENTS AND TECHNOLOGY NEWS

Incumbent aerospace companies continue to play active role in the development of electric aviation

27 January 2022

Embraer's urban air mobility business Eve to go public

Low Importance | Energy for mobility

Following its launch as an independent company in October 2020, Embraer's Eve will be going public via a special purpose acquisition company after partnering with Zanite Acquisition Corp. The company wants to use the funds raised for further R&D of the technology, with a target to certify electric vertical take-off and landing (eVTOL) capabilities by 2025, a timeline that was also predicted by Lux. Embraer has already granted Eve access to company's IP for eVTOL technology, and the partnership provides the company an advantage over others in the market. Further announcements regarding certification should be monitored, as it has been the biggest bottleneck towards commercialization.

31 January 2022

Wisk Aero's USD 450 million cements its position as leader in eVTOL development

Very Important | Energy for mobility

Wisk Aero has received USD 450 million from Boeing, one of the largest nonpublic financing rounds for an electric vertical take-off and landing (eVTOL) company to date. In addition to this investment, Boeing will continue to lend engineering and other aviation expertise to Wisk. The funding will be used for continued development and part certification. Wisk is likely to achieve part certification for its electric aircraft, but certifications to operate aircraft autonomously is still far in the future. Consider Wisk a leader but recognize it won't likely overcome the numerous challenges to the operation of autonomous air taxis and don't be surprised if the company pivots to other applications.

4 February 2022

Li-Cycle establishes first battery recycling plant in Europe through a joint venture

Very Important | Energy storage

The company announced last week that it plans to establish its first European recycling operations in Norway. The rapid increase in electric vehicle (EV) adoption in Norway and expected growth in battery demand is a key driver. Li-Cycle has established a joint venture with ECO STOR and Morrow Batteries, providers of energy storage solutions. While this is Li-Cycle's first "spoke" plant, which will process 10,000 tonnes of manufacturing scrap and end-of-life batteries starting in 2023. Expect Li-Cycle to expand its spoke plants into other European EV markets and announce its first "hub" plant by 2024.

RECENT INDUSTRY DEVELOPMENTS AND TECHNOLOGY NEWS

The industry looks to bolster infrastructure to support growing electrification in vehicle fleet

4 February 2022

Daimler, NextEra, and BlackRock form partnership to boost heavy-duty vehicle infrastructure in U.S.

Average Importance | Energy for mobility

Daimler, NextEra, and BlackRock signed a memorandum of understanding that lays the groundwork for a USD 650 million joint venture to advance high-powered chargers and hydrogen refueling stations for heavy-duty vehicles. As momentum picks up to electrify heavy-duty vehicles, infrastructure investments have thus far failed to materialize, as heavy-duty vehicles require over 1 MW of power compared to the fastest charging vehicles, which use 350-kW chargers. Daimler's "electric island" in Portland, Oregon, was built using light-duty vehicle chargers, while the higher powered 1-MW chargers are in development.

4 February 2022

Momentum Technologies raises USD 20 million for its membrane solvent battery recycling technology

Very Important | Energy storage

Momentum Technologies raised funding from Freestone, a Tailwater Capital portfolio company. Momentum licensed its membrane solvent exchange technology from Oak Ridge National Laboratory and is scaling up in partnership with Haliburton Labs. Its first foray into recycling focused on rare earth oxide recovery from electronics waste at purities greater than 99.5%. The company now uses a combination of hollow fiber membranes and organic solvents to selectively recover critical battery metals. While thermal processes have been in place for decades, we are currently seeing a rise in efficient and sustainable solvent extraction and physical separation technologies.

10 February 2022

Solid-state battery newcomer Soelect raises USD 11 million in Series A

Low Importance | Energy storage

The USD 11 million funding round was led by Lotte Chemical with GM Ventures and KTB Network also contributing. Soelect was founded in 2018 by Dr. Jin Cho, and the company has two main technologies: a Li-metal anode and a solid polymer electrolyte. According to patent activity, the Li-metal anode inhibits dendrite formation by utilizing a protective polymer layer; Soelect claims its Li-metal anode can withstand 4C charge rates. Fast charging remains a key challenge for solid-state batteries; however, without further specifications of testing conditions, the technology value and scalability remain open questions.

RECENT INDUSTRY DEVELOPMENTS AND TECHNOLOGY NEWS

China makes strides towards the "tipping point" as electric vehicles surpass 10% of new vehicle sales to start the year

18 February 2022

New energy vehicle sales in China up 135.8% despite 30% subsidy drop

Very Important | Energy for mobility

New energy vehicle (NEV) sales in China surged in January, far exceeding expectations. NEV sales, which include battery electric, plug-in hybrid, and fuel cell powertrains, typically increase ahead of subsidy drops as buyers rush to take advantage of expiring financial subsidies. In this case, that did happen as sales fell in January 18.6% compared to December of last year, but this is drastically lower than expected, and compared to 2021, sales more than doubled. In total, NEVs captured 17% of all automotive sales in January, a steep increase from the annual average, which was 5.4% for all of 2020.

22 February 2022

Amprius ships first commercial batteries for high-altitude pseudo satellites

Average Importance | Energy for mobility

After securing funding from Airbus for the development of the high-capacity silicon nanowire anodes in 2019, Amprius has announced the commercial shipment of 450 Wh/kg Li-ion cells. The batteries will be used in high-altitude pseudo satellites (HAPS). It is noteworthy that Airbus had deployed Amprius' silicon anode Li-ion batteries in the first successful flight of Zephyr HAPS. Despite the promising metrics, silicon nanowires are costly to produce and are unlikely to find their way into electric vehicles. Given the weight restrictions and the requirement for high energy density, Amprius' technology will be more useful in high-cost defense and aerospace applications.

22 February 2022

Volta Trucks raises USD 260 million in Series C funding round

Average Importance | Energy for mobility

The round for Volta Trucks was led by Luxor Capital along with Byggmästare Anders J Ahlström, Agility, and B-Flexion. The capital raised will be used by Volta Trucks to fund its engineering and business operations, which also include the company's 16-tonne Volta Zero, whose prototype was unveiled in 2021. It is noteworthy that Volta Trucks has already received a large order of electric trucks from logistics company DB Schenker; the company claims to have an order value of USD 1.3 billion. With the planned production of Volta Zero in 2022, Volta Trucks is well positioned to deliver an electric truck and look out for further announcements regarding its four new models.

RECENT INDUSTRY DEVELOPMENTS AND TECHNOLOGY NEWS

Establishing a domestic battery value chain is emerging as a national security concern in the U.S.

23 February 2022

New Li-S research from Drexel University claims to solve polysulfide shuttling challenge

Very Important | Energy storage

Dr. Vibha Kalra's group at Drexel University created a stable form of sulfur, γ-sulfur. This work is notable because the battery uses a carbonate electrolyte, and the method of depositing sulfur on carbon nanofiber results in a rare, stable form of sulfur at room temperature. The battery exhibited a cycle life of 4,000 cycles, much higher than other available Li-S cells. Clients interested in Li-S batteries should recognize that this research forms a very specific form of sulfur through high-temperature processes; this piece of research is an important step toward understanding the chemistry, but high-temperature synthesis processes may challenge commercialization prospects.

23 February 2022

U.S. Department of Energy to fund USD 3 billion in scaling up domestic battery industry

Very Important | Business models and regulations

Funding from the U.S. Department of Energy (DOE) will be made available for raw materials extraction and refining, battery manufacturing, and battery end-of-life handling. The U.S. has consistently funded novel energy storage technologies through the DOE, but the new funding specifically calls out raw materials and manufacturing support. Following the National Blueprint for Lithium Batteries, the U.S. has followed through on substantial grant and loan programs that will make a substantial impact on the country's battery value chain.

25 February 2022

U.K. government announces awards of GBP 6.7 million for long-duration energy storage projects

Very Important | Stationary storage

As part of the U.K.'s Net Zero Innovation Portfolio, the Department for Business, Energy, & Industrial Strategy has awarded GBP 6.7 million in funding across two programs to accelerate energy storage deployment. Divided into two streams, Stream 1 focuses on commercializing near-term technologies, while Stream 2 provides opportunities for demonstrating early-stage technologies. Among the technologies chosen are vanadium redox flow batteries, compressed air energy storage, thermal energy storage, and gravity-based energy storage. This funding round provides insight into the U.K.'s budding storage strategy: its particular focus on flow batteries and mechanical energy storage indicate a long-term opportunity for larger and longer duration systems.

RECENT INDUSTRY DEVELOPMENTS AND TECHNOLOGY NEWS

Automakers continue to move upstream with direct collaboration with battery material producers

7 March 2022

Envision AESC says it will have an EV battery with a 1,000-km range by 2024

Low Importance | Energy for mobility

Nissan Motor- and Envision Group-owned Envision AESC has made several bold statements, including that it will produce EV (electric vehicle) batteries with a 1,000-km range in the manufacturing facility it is building near Tokyo. Although the headline looks impressive, without a reduction in costs, achieving this longer range will require a larger and more expensive battery pack. The company did not disclose any specific achievements in battery technology but did target reducing charging time and eventually producing solid-state batteries at the facility. The vague claims leave room for suspicion until we see the cost and volume benefits over the incumbent Leaf EVs.

9 March 2022

BASF and POSCO choose Quebec, Canada, for a new cathode materials production site

Very Important | Energy storage

BASF and POSCO both announced that they would build a cathode active materials production facility in Bécancour, Quebec. POSCO will build the site in a joint venture with GM to supply batteries for electric vehicles. Quebec's government has been actively working to build an attractive location for the battery industry by funding startups, offering incentives for manufacturing, and touting its natural resources like hydropower and battery raw materials. BASF has taken it a step further and mentioned it could potentially expand to precursor material production, which has historically been contained within Asia.

23 March 2022

Suzuki Motor Corporation signs JPY 150 billion MOU with India to produce BEVs and EV batteries

Average Importance | Energy for mobility

The Japanese automaker Suzuki, which occupies about half of India's car market, has signed a memorandum of understanding (MOU) with the State of Gujarat, India, to invest approximately JPY150 billion for local manufacturing of electric vehicles (EVs) and batteries. The proposed manufacturing site, which could have a 15-GWh capacity as funding suggests, will supply 30% of capacity output to supply the growing domestic battery EV (BEV) market, while 70% of output will go to Suzuki's global sales. The facility is strategically located to establish itself in India's growing BEV market while also supplying other regions. Three years after pulling out of their aggresive commercial launch of the battery-powered WagonR, this longer-term MOU will be pivotal as the Indian market offers immense growth potential.

ELECTRIC AVIATION

The Future of Electric Aviation

As governments and societies continue to push policies that support decarbonization, efforts aimed at curbing transportation emissions have similarly led to a push to decarbonize the aviation sector, which currently accounts for 11% of the transportation sector's total emissions.

Multiple decarbonization solutions and players exist across the technology landscape, although specific attention should be paid to those manufacturers developing aircrafts with battery-electric or hybrid-electric powertrains.

Notably, the aerospace industry's attitude toward electrification has evolved significantly. While the fire of a Li-ion battery in Boeing's 787 Dreamliner in 2013 led regulators and other aerospace companies to reconsider the use of Li-ion batteries in aircrafts, startup activity have swarmed into the flying car space in the past decade with numerous companies working on developing airplanes today.

Image Source: Bye Aerospace

ELECTRIC AVIATION

The rise of electrification in road transportation is quickly drawing interest towards the aviation industry

WHY IT MATTERS

As the entire transportation industry is under scrutiny for carbon emissions, and aviation's share is expected to grow, more and more aircraft manufacturers are looking at the possibility of electric aviation for applications that range from air taxis and flying cars to regional aircraft and, most ambitiously, commercial airliners.

HOW IT WORKS

Electric aviation requires replacing the existing combustion engine with batteries, electric motors, and in some cases fuel cells for extended range. Many developers are also investigating new aircraft designs, as the lack of hot exhaust in all-electric planes enables more aerodynamic designs.

KEY PLAYERS

The electric aviation space has historically been driven more by small developers focused on regional and urban aircraft, but in recent years, large companies – notably Airbus, Rolls-Royce, and even some automakers – have started to make moves in the space using internal projects, partnerships, and acquisitions.

CHALLENGES TO OVERCOME

Electric powertrains are heavier than combustion counterparts, limiting the range of electric aircraft. Beyond the technical challenges, regulations for certifying electric aircrafts remain arduous and have thus far prevented commercial sales for most companies – limiting deployments to demonstration flights.

Electric aviation can be segmented into three target applications that each have a distinctly different use case

FLYING CARS, AIR TAXIS

Application: Flying cars, air taxis, and VTOL target intraurban transit applications with the goal of reducing commuting times and ground transportation congestion.

Aircraft Design: Developers primarily pursue vertical takeoff and landing (VTOL) configurations that utilize distributed electric propulsion (DEP) systems rather than more traditional fixed-wing architectures. Most are targeting single- to four-passenger arrangements.

FIXED-WING AIRCRAFT

Application: Passenger planes with less than 20 passenger seats and small cargo planes typically used for island hopping, fjord hopping, and access rural locations.

Aircraft Design: Fixed-wing architectures to increase efficiencies at higher cruising altitudes and to leverage existing airport infrastructure. The use of electric powertrains also enable more aerodynamic aircraft designs due to lack of hot exhaust.

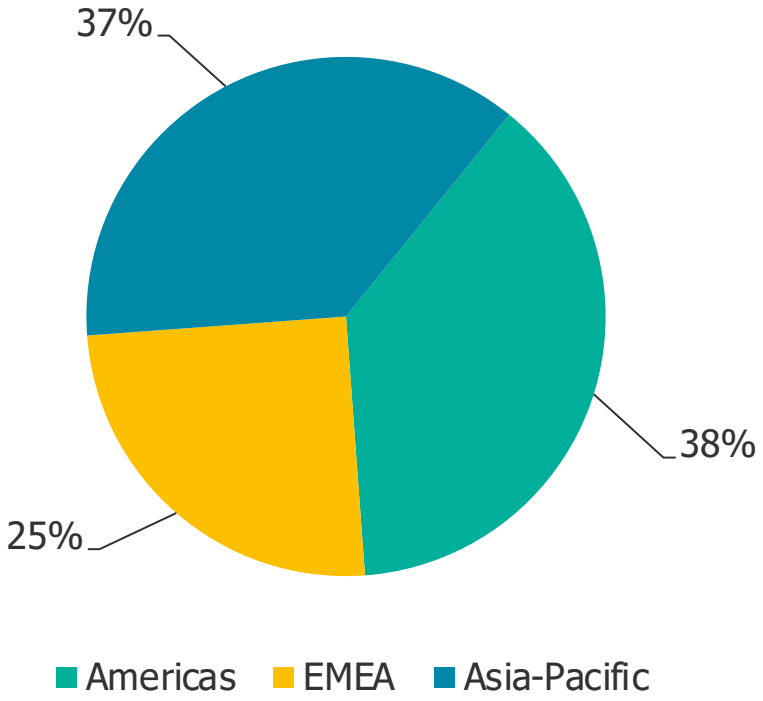
COMMERCIAL AIRLINER

Application: Passenger planes with more than 100 passenger seats and designed for long-distance – regional or international – routes.

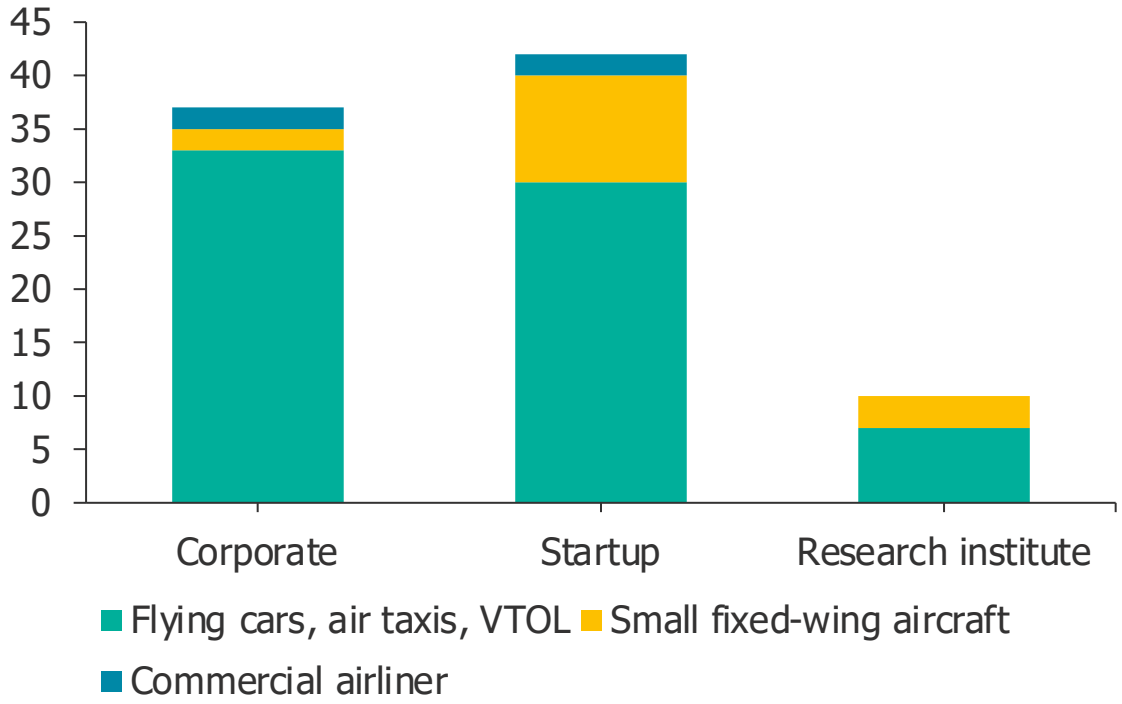
Aircraft Design: While powertrain choices vary between hybrid electric and all-electric designs, all developers are focused on fixed-wing configurations to replicate incumbent commercial airlines.

The electric aviation landscape offers a geographically diverse set of organizations

Electric Aviation Players
By region



Electric Aviation Players
Count of organizations by technology



Note: The figures above are a non-exhaustive representation of the landscape for players with innovation activity in technologies for electric aviation. Analysis by organization type and technology segmentation is non-exclusive with several organizations active in more than one technology area. Organizations with minor activity were removed from the analysis.

Electric aviation activity is heavily concentrated in flying cars, air taxis, and VTOLs and led by corporates and startups

- **Innovation in electric aviation is occurring across regions.** The Asia-Pacific and Americas regions account for similar levels of innovation activity within the industry. While startups are mostly responsible for the activity in the Americas, Asia-Pacific's activity is largely driven by research institutes. Although EMEA has lower levels of electric aviation activity, the region has some of the more impressive corporates and startups in the industry.
- **Corporates have the largest share of flying cars, air taxis, and VTOL patents across the industry.** While corporations have patented more vertical-lift aircraft designs and technologies than startups and research institutes, they have made little progress developing and scaling electric aircraft compared to startups. Most large players are happy to simply invest in and partner with companies pursuing technology development, as it is difficult, time-consuming, and costly for corporates to allocate resources to ground-up development. Additionally, the near- to mid-term capabilities and use cases of electrified aircraft represent an extremely small fraction of the available market for incumbent manufacturers like Airbus, Boeing, and other general aviation companies.
- **Research institutes are less focused on full aircraft development compared to corporates and startups.** This is likely due to the high capital costs associated with novel aircraft development. Research institutes play a much larger role in underlying systems development and seldom strive to developing full aircrafts. Those engaged in research and development of systems that support electrified flight (i.e., novel powertrains, novel battery chemistries) are not captured in this analysis.

ELECTRIC AVIATION: TECHNOLOGY LANDSCAPE

Growing interest in electric aviation has spawned numerous startups looking to differentiate their solutions

Note: The market map above is an alphabetical representation of the landscape by technology and organization type. Organizations were selected by, but not exclusively, patent activity, venture capital funding, and academic publications. Inclusion in the above market map is only an assessment of the activity by each organization and not a measurement of technology quality or leadership position.

Despite growing momentum, hype and technical immaturity plague all three technology segments in electric aviation

- **Flying cars, air taxis, VTOL.** This represents the most crowded segment in electric aviation, featuring the largest number of corporate and startups players. While corporates like Airbus, Bell, and Boeing have the experience and resources to develop these systems, as evidenced by successful demonstrators and prototypes, startups are leading the way with billions of dollars in venture funding and, in some cases, 10 years of development under their wings. Companies like Joby, Lilium, and Volocopter are expecting commercial operations to begin before 2025, while Chinese developer EHang has already sold dozens of units and is currently expanding production and manufacturing.
- **Small fixed-wing aircraft.** The landscape for small fixed-wing aircraft is dominated by startups, although corporate player Embraer and government research and space agency NASA have both developed electric fixed-wing demonstrators. Current players offer a range of solutions, including hybrid-electric powertrains from the likes of Ampaire, Zunum Aero, and Faradair and all-electric aircraft developed by Eviation and Bye Aerospace. While competition exists, each aircraft will ultimately service unique market needs dependent on passenger capacity and trip length requirements.
- **Commercial airliner.** While each technology segment intends to operate commercially, this category assumes high-volume passenger transport akin to traditional commercial airlines, capable of carrying 100 or more passengers. This is expectedly the smallest market segment, as the difficulty of electrifying aviation scales with aircraft size. The players engaged in electrifying commercial airliners must wait for advancements in battery technologies, which they expect will occur by 2030. However, the most high-profile project – E-Fan X – led by Rolls-Royce and Airbus launched in 2017 was cancelled in 2020 before test flights were scheduled to begin in 2021.

ELECTRIC AVIATION: VTOL

EHang

EHang, founded in 2014, has evolved into one of the more notable companies in the VTOL space, touting its work via global demonstrations. EHang has proposed early applications that span medical supply and patient transport, tourism, and general commercial passenger transportation, though an additional use case has presented itself in Norway's oil and gas industry that sees eVTOLs potentially replacing helicopters currently used for transporting personnel, spar parts, supplies, and samples to and from offshore drilling platforms and mainland operational sites.

While traditional helicopter use incurs high fuel and labor costs, EHang's autonomous eVTOL can provide 24-hour autonomous service with its zero-emissions alternative. There is further potential for these aircraft to assist with tasks including oil and gas delivery, maintenance and inspection, wind power plant servicing, and transportation of radioactive materials.


Image Source: EHang

LUX TAKE

EHang's proposal of its vehicles supporting Norway's oil and gas sector may prove an even more suitable fit for the technology. While VTOLs will likely not operate as affordable, equitable urban air taxis in the desired high-capacity use case, the technology has potential for specialized low-carbon transportation applications and logistics, medical, tourism, military, and oil and gas sectors. EHang may potentially prove the commercial viability of replacing incumbent vehicles for reducing emissions in one of the potential operations in the industrial sector.

ELECTRIC AVIATION: SMALL FIXED-WING

Ampaire

Ampaire is developing a scalable electric-hybrid powertrain platform for small passenger and cargo aircrafts. Currently the company is focusing on six to nineteen passenger aircrafts and plans to for flights to be fully electric, only carrying fuel for emergency reserves. Its six-seater plane, the Electric EEL, is currently capable of all-electric flight routes of less than 160 kilometers and is targeting 450+ kilometers with its hybrid powertrain.

In addition, the company is designing its aircrafts with the battery in the belly of the plane, so battery swapping is a potential alternative to traditional charging. For its current six-seater planes with smaller battery packs, charging times are short enough to use fast charging at levels between 30 kW and 60 kW. The company is also working with Electro.Aero for the development and construction of fast charging infrastructure at regional airports.

Image Source: Ampaire

LUX TAKE

In December 2020 Ampaire completed its first all-electric trial flight in Hawaii – a 20-minute flight from Maui's Kahului Airport across the island to Hana and back on a single charge. Ampaire's successful test flights and strategy of using existing aircraft designs will be an advantage for reducing design and certification times as the company seeks Federal Aviation Administration approval for commercial use in small, regional aviation markets.

ELECTRIC AVIATION: SMALL FIXED-WING

Eviation

Eviation designs a nine-passenger all-electric commuter plane called Alice. The plane is powered by 9,400 Li-ion (NMC) cells in a battery system that weighs 3,600 kg and stores roughly 920 kWh of usable energy. The modules and packs are equipped with the company's proprietary liquid coolant thermal management system. The Alice has an unpressurized cabin enabling a cruising altitude of 3,000 meters and a maximum range of 1,000 kilometers with a required 45-minute battery reserve.

The Alice will cost approximately $3.5 million and is expecting Federal Aviation Administration (FAA) certification in 2023. Test flights will begin in 2021 with plans to deliver its first production plane in 2023, coinciding with FAA certification. While the Alice is the primary focus, the company has long-term goals of developing a 70-passenger aircraft for the international market.

Image Source: Eviation

LUX TAKE

With a focus on the U.S. regional flight market, Eviation is targeting the most appropriate application given the current limitations of all-electric flight. The company has an extensive list of development partners including GKN Aerospace and Honeywell and is well-positioned to deliver a certified aircraft in the coming years. However, a prototype fire in early 2020 will likely cause delays before the company's first successful test flight and highlights the potential barriers for electric aviation.

Technical and regulatory challenges related to range and safety affect all market segments

TECHNICAL CHALLENGES

Depending on the market segment, the significances of these issues ranges from those that can be overcome in less than a year's time to those that are insurmountable without technological breakthroughs.

Li-ion batteries, which have been successfully commercialized for electric vehicles, may not necessarily be the right energy storage technology for electric aviation.

Aerospace companies are therefore continually searching for the right energy storage technology that meets both safety and performance needs, and they have the budget to pay a premium to develop alternative chemistries that promised increased safety over Li-ion batteries.

REGULATORY CHALLENGES

The aviation space is highly regulated globally across all market segments, and some countries have made advancements in permitting aircraft to be electrified, while others have developed close working relationships with leading startups.

The first fatalities from an electric airplane occurred in 2018 when a prototype, all-electric aerobatic flyer made by Siemens and Magnus Aircraft caught fire and crashed in Hungary.

While this lone incident did not impact the momentum for electric aviation, technical malfunctions will likely cause regulators to retreat from their relative enthusiasm and support for electric aviation.

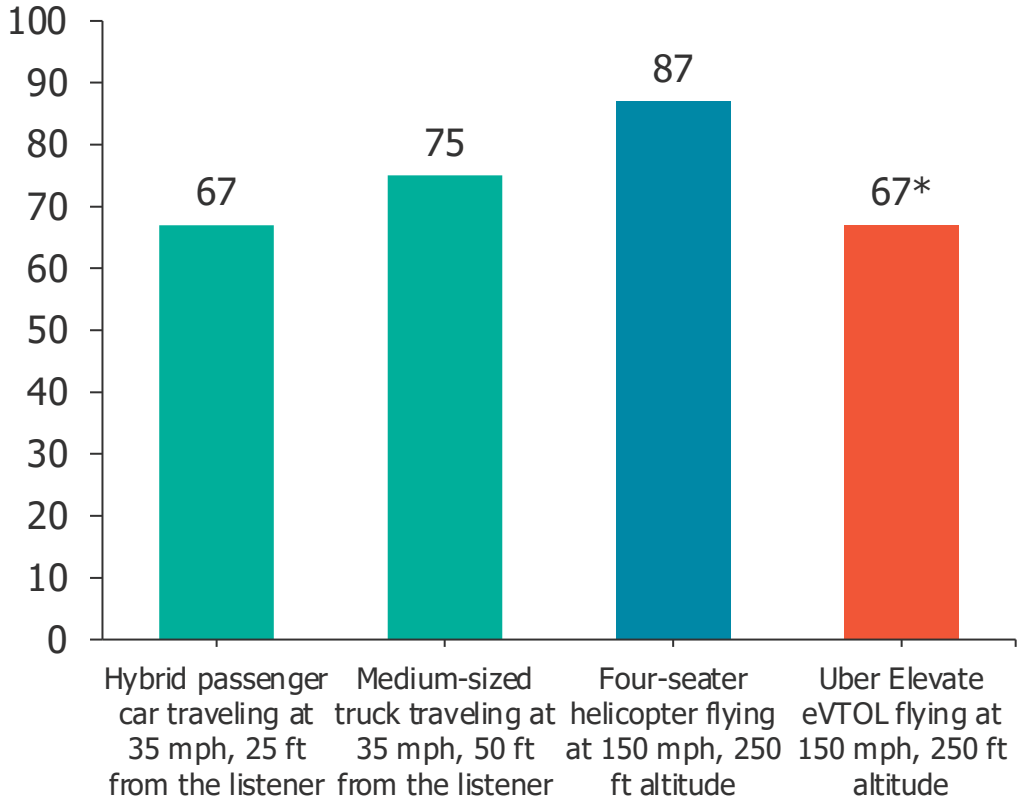
Air taxis, flying cars, and VTOLs face significant technical hurdles related to noise, autonomy, and infrastructure

Although there are many significant challenges when it comes to building an air taxi or flying car, such as form factor and unit cost, three key issues affect all developers regardless of aircraft design:

- **Noise:** Existing VTOL aircraft, such as helicopters, are restricted in their ability to fly over densely populated areas due to the loudness of their propellers and engine. In order to operate on-demand air taxi services for intraurban transportation, developers need to consider noise constraints in designing their aircraft.
- **Autonomy:** Driverless passenger vehicles are under development, but pilotless passenger planes are significantly more challenging, with different technical problems, different user capabilities, and different worst-case scenarios.
- **Infrastructure:** Current air traffic management systems were not built to allow autonomous air taxis; a new digital traffic management system developed specifically for autonomous aircraft is needed.

Sound Pressure Level

dB(A) experience by ground listener



*Represents target sound pressure level. Source: Uber Elevate

Civil aviation authorities around the world support testing, but do not yet have firm operational frameworks

Although many countries today explicitly forbid public use of fully autonomous manned aircraft, a few countries are leading the way on vetting air taxi and flying car technologies:

- **Dubai, United Arab Emirates:** The city is eager to implement a public on-demand air taxi service as soon as possible and has announced several partnerships with startups in the industry.
- **New Zealand:** Due to its favorable drone policies, New Zealand has emerged as a favorable testing ground for companies developing autonomous air taxis and flying cars.
- **United States:** The U.S. has lagged behind in implementing drone use regulations, and although the Federal Aviation Administration (FAA) has been vocally supportive of the air taxi industry, its policies must change significantly to allow these aircraft to operate autonomously.

Dubai's Road and Transport Authority (RTA) is looking to air taxis to address road congestion and catalyzed by its Crown Prince's goal for 25% of the city's transportation to be autonomous by 2030. Despite strong support, Dubai has a harsh aviation climate with winds up to 58 mph and frequent sandstorms and has yet to launch an official process for certifying autonomous air taxis. (Image Source: Reuters)

The barriers to growth for small fixed-wing aircraft are minor compared to those for the other market segments

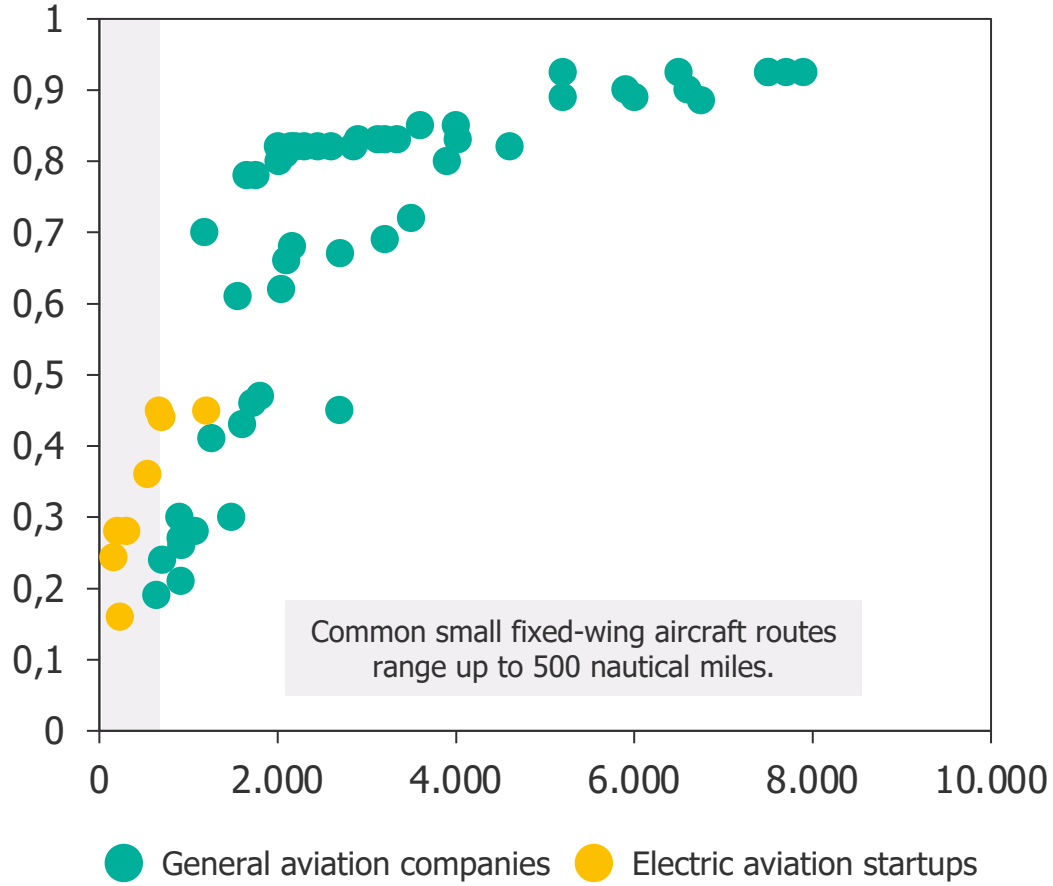
Developers of small fixed-wing aircrafts are not creating a new aircraft design from scratch, nor are they attempting to invent a new urban mobility solution, nor do they require incorporating autonomous capabilities in order to address a broad market.

As such, the most significant barriers to growth for companies developing all-electric regional aircraft are flight testing their planes and encouraging consumers to transition from powering planes with fossil fuels to electricity. Two key issues affecting these barriers to growth are:

- **Range:** Small planes are best suited for short flights, such as island hopping, fjord hopping, and accessing rural locations.
- **Infrastructure:** While small aircraft will be able to use the same air traffic control systems that exist today and do not need additional digital infrastructure, the requisite charging infrastructure does not yet exist, and charging schemes vary from company to company.

Aircraft Range and Speed Comparison

Mach speed (Y-axis); Nautical miles (X-axis)



There are no remaining regulatory hurdles in Europe and the U.S. for small fixed-wing electric aircrafts

In 2017, both the European Aviation Safety Agency (EASA) and the FAA in the U.S. amended their regulatory frameworks to permit the electrification of small aircraft. The rule changes are very similar and forego technical design specifics in favor of objective-driven requirements.

This enables increased design flexibility, allowing developers to more easily incorporate new technologies like battery electric powertrains. Thus, regulatory barriers for small electric aircraft no longer exist in these locations.

- **Europe:** Norway looks to lead the world in adopting electric aircraft and aims for domestic flights to be fully electrified by 2040.
- **United States:** According to GAMA's 2017 annual report, North America is the largest market for piston airplanes, turboprops, and business jets.

Norway has long been a proponent of electric transportation, consistently topping the charts in plug-in electric vehicle sales. By 2025, the country looks to offer its first commercial route to be flown with a 19-seat electric plane, and by 2040, aims for all of its domestic routes to be flown with electric planes. This is a reasonable goal, as all of these flights are under 1.5 hours, and many are short hops over fjords.(Image Source: Avinor)

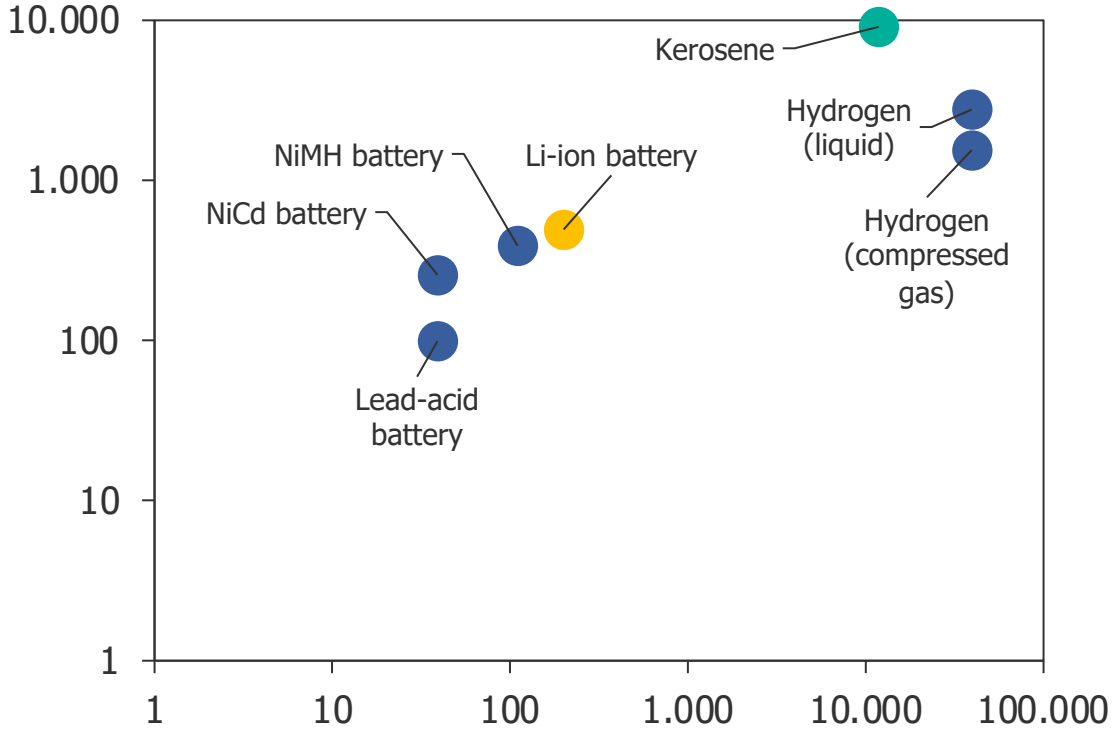
ELECTRIC AVIATION: COMMERCIAL AIRLINERS

The barriers to growth for all-electric commercial airliners are insurmountable without technological breakthroughs

The most notable technical hurdle to commercializing electric aircraft of this size is the energy storage system itself. For ground-based transportation, the system mass is relevant but of relatively low importance; for aerospace applications, weight is a key issue. Battery weight scales poorly, as bigger batteries provide more power but also add weight.

The battery system required to fully electrify a commercial airliner would be so heavy that the plane would need to carry less cargo or fewer passengers in order to remain under weight limits. Airbus estimated that its hybrid electric E-Fan X would require a 2 MW electric motor and a 2,000 kg battery pack to replace only one of the aircraft's four gas turbine engines. In addition to needing to pay for a large, expensive energy storage system, reducing the amount of cargo and passengers would cut into airliners' profits per flight.

Aircraft Range and Speed Comparison
Volumetric specific energy, Wh/L (Y-axis)
Gravimetric specific energy, Wh/kg (X-axis)



ELECTRIC AVIATION

While significant challenges remain, electrification will truly disrupt the aerospace industry landscape

The air taxi and flying car market will be the most difficult segment to succeed in.

Air taxi companies face more significant barriers to growth than either regional aircraft or commercial airliners, as the industry is working to create an entirely new market. The safety and security concerns with these aircraft cannot be understated, and limitations in cost effectiveness compared to other mass transit options will restrict long-term growth.

Electrifying small planes offers the highest and most immediate market growth opportunities.

The regional aircraft market may be the easiest of the three segments for electric aviation companies to break into, as technical and regulatory barriers are minimal. If electric aircraft developers can match the upfront costs of incumbent planes and still achieve operational expenditure reductions, widespread electrification could drive market growth.

Hybrid electric commercial airliners will only become more feasible with advancements in batteries.

Even considering pending commercialization of innovative technologies like lithium-sulfur and solid-state batteries, electrification of commercial airliners will likely still focus on hybrid electric rather than all-electric architectures. There is unlikely to be significant electrification of this market segment before 2035.

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