ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jul1653

The Future of Electric and Hybrid Aircraft in South Asia: Opportunities, Challenges and the Path Toward Sustainable Aviation

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Publication Date: 2026/08/05

Abstract: The aviation industry is undergoing a major technological transformation as it seeks sustainable alternatives to conventional fossil-fuel-powered aircraft. Growing concerns over climate change, rising fuel costs, and international commitments to reducing greenhouse gas emissions have accelerated the development of electric and hybrid-electric aircraft. While Europe, North America, and parts of Asia have made significant progress in adopting these technologies, South Asia remains at an early stage despite its rapidly expanding aviation market. This review paper examines the current status of electric and hybrid-electric aircraft technologies and explores their future potential in South Asia, with particular emphasis on Bangladesh. It reviews recent academic studies, industry developments, and reports from international aviation organizations to evaluate technological progress, infrastructure readiness, regulatory challenges, and environmental benefits. The paper highlights key issues such as battery technology, hybrid-electric propulsion systems, airport charging infrastructure, and certification requirements. The review identifies several barriers to the adoption of electric aviation in South Asia, including limited research and development, inadequate infrastructure, high investment costs, and evolving regulatory frameworks. However, increasing passenger demand, expanding airport networks, renewable energy development, and opportunities for international collaboration provide a strong foundation for future growth. The study concludes that hybrid-electric aircraft are likely to serve as the most practical transition technology for regional aviation, while fully electric aircraft may become increasingly viable as battery technology advances. Strategic investment in research, infrastructure, education, and supportive policies will be essential for enabling South Asia to participate in the global transition toward cleaner and more sustainable air transportation.

Keywords: *Electric Aircraft; Hybrid-Electric Propulsion; Sustainable Aviation; South Asia; Bangladesh; Battery Technology; Green Aviation; Regional Air Transport; Aviation Decarbonization; Future Aerospace Technologies.*

How to Cite: Abrar Haque Bhuiyan Nahal (2026) The Future of Electric and Hybrid Aircraft in South Asia: Opportunities, Challenges and the Path Toward Sustainable Aviation. *International Journal of Innovative Science and Research Technology*, 11(7), 2885-2890. https://doi.org/10.38124/ijisrt/26jul1653

I. INTRODUCTION

The aviation industry is essential for global connectivity, economic development, and international trade, but it also contributes approximately 2–3% of global carbon dioxide (CO_2) emissions. As concerns about climate change continue to grow, the aviation sector is under increasing pressure to adopt cleaner and more sustainable technologies. Electric and hybrid-electric aircraft have emerged as promising alternatives to conventional fossil-fuel-powered aircraft, offering the potential to reduce greenhouse gas emissions, noise pollution, and operating costs while improving energy efficiency.

Recent advancements in battery technology, electric propulsion systems, lightweight materials, and power electronics have accelerated the development of electric aviation. Leading aerospace organizations and manufacturers are actively investing in these technologies to support the transition toward sustainable air transportation. South Asia, one of the fastest-growing aviation markets, presents significant opportunities for adopting electric and hybrid-electric aircraft due to rising passenger demand, expanding airport infrastructure, and increasing renewable energy capacity. However, challenges such as limited research and development, inadequate infrastructure, and evolving regulatory frameworks remain.

This review paper examines the current state of electric and hybrid aircraft technologies and evaluates their potential application in South Asia, with particular emphasis on Bangladesh. It also discusses the opportunities, challenges, and prospects of integrating sustainable aviation technologies into the region's aviation sector.

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II. ELECTRIC AND HYBRID AIRCRAFT TECHNOLOGIES

The aviation industry is currently experiencing one of the biggest technological changes since the introduction of jet engines. As governments and aviation companies work to reduce carbon emissions and improve fuel efficiency, electric and hybrid-electric aircraft have become important areas of research and development. Unlike conventional aircraft that rely entirely on aviation fuel, these new aircraft use electric power either as the primary source of energy or in combination with traditional engines.

➢ *Electric Aircraft*

Electric aircraft are powered entirely by electric motors instead of conventional combustion engines. The electricity is usually stored in rechargeable lithium-ion batteries, which supply power to the aircraft throughout the flight. Since electric motors do not burn fossil fuels during operation, they produce zero direct carbon dioxide (CO_2) emissions while flying. In addition, electric motors generate much less noise than traditional aircraft engines, making them suitable for airports located near urban areas.

Another important advantage of electric aircraft is their lower maintenance requirements. Electric motors contain fewer moving parts compared to conventional jet engines, reducing maintenance costs and improving reliability. They also convert electrical energy into mechanical energy more efficiently than internal combustion engines.

Despite these advantages, electric aircraft still face several technological challenges. The biggest limitation is battery energy density, which refers to the amount of energy that can be stored in a battery compared to its weight. Current batteries are significantly heavier than aviation fuel for the same amount of usable energy, limiting both flight range and passenger capacity. Charging time and battery lifespan also remain important challenges for commercial operations. As a result, today's electric aircraft are mainly designed for pilot training, short regional flights, and small passenger aircraft.

➢ *Hybrid-Electric Aircraft*

Hybrid-electric aircraft combine electric propulsion systems with conventional fuel-powered engines. Instead of relying entirely on batteries, these aircraft use both electricity and aviation fuel to provide power during different phases of flight. This combination allows aircraft to reduce fuel consumption while maintaining longer flight ranges than fully electric aircraft.

During take-off, electric motors can provide additional power, reducing the workload of conventional engines. During cruising, both systems work together to improve fuel efficiency. In some hybrid designs, batteries can even be recharged during flight using onboard generators. This flexible power management makes hybrid-electric aircraft more practical for commercial aviation in the near future.

Hybrid systems offer several important benefits. They reduce greenhouse gas emissions, lower fuel costs, decrease engine noise, and improve overall energy efficiency without requiring the extremely large batteries needed for fully electric aircraft. For these reasons, many aviation experts believe hybrid-electric aircraft will serve as an important transition technology before fully electric commercial aircraft become widely available.

One of the leading examples is the Heart Aerospace ES-30, a regional aircraft designed to transport approximately 30 passengers using hybrid-electric propulsion. Another important project is Airbus Eco Pulse, which is testing distributed electric propulsion technology to improve aircraft efficiency and reduce emissions. These projects demonstrate that hybrid-electric technology is progressing rapidly and could become commercially available within the next decade.

➢ *Comparison Between Electric and Hybrid Aircraft*

Although both technologies aim to reduce aviation's environmental impact, they differ in terms of performance, range, and commercial readiness. Fully electric aircraft produce zero direct emissions during flight but are currently limited to shorter distances because of battery technology. In contrast, hybrid-electric aircraft still use aviation fuel but consume significantly less fuel than conventional aircraft while offering greater operational flexibility and longer range.

For South Asia, where regional air travel continues to grow and airport infrastructure is still developing, hybrid-electric aircraft may provide the most practical solution during the early stages of sustainable aviation. As battery technology continues to improve over the coming decades, fully electric aircraft are expected to become increasingly suitable for regional commercial operations. Overall, electric and hybrid-electric aircraft represent two complementary approaches to achieving sustainable aviation. Continued advancements in battery technology, lightweight materials, electric propulsion systems, and renewable energy integration will determine how quickly these technologies can be adopted across South Asia and the rest of the world.

Table 1 Comparison between Conventional, Hybrid-Electric, and Fully Electric Aircraft

Feature	Conventional Aircraft	Hybrid-Electric Aircraft	Fully Electric Aircraft
Energy Source	Aviation Fuel	Aviation Fuel + Battery	Battery Only
CO_2 Emissions	High	Moderate	Zero (during flight)
Noise Level	High	Medium	Low
Flight Range	Long	Medium–Long	Short
Maintenance Cost	High	Moderate	Low
Commercial Readiness	Fully Commercial	Near Commercial	Emerging

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III. OPPORTUNITIES AND CHALLENGES IN SOUTH ASIA

South Asia is one of the fastest-growing aviation markets in the world. Countries such as India, Bangladesh, Pakistan, Sri Lanka, and Nepal have experienced a steady increase in air travel over the past two decades due to population growth, economic development, tourism, and international trade. As more people choose air transportation for business, education, healthcare, and leisure, the demand for efficient and environmentally friendly aircraft is expected to continue increasing. This growth creates an opportunity for South Asian countries to adopt new aviation technologies, including electric and hybrid-electric aircraft, as part of their long-term transportation strategies.

- *Opportunities*

One of the biggest opportunities for South Asia is the rapid increase in regional passenger traffic. Many domestic flights within countries such as Bangladesh, Nepal, and Sri Lanka cover relatively short distances. Since fully electric aircraft are currently best suited for short-haul operations, they could become an environmentally friendly alternative for these regional routes in the future. Hybrid-electric aircraft could also improve fuel efficiency on medium-distance flights while reducing greenhouse gas emissions.

Another important opportunity is the expansion of airport infrastructure across the region. Governments are investing in new airports and upgrading existing facilities to accommodate increasing passenger demand. Bangladesh has recently expanded Hazrat Shahjalal International Airport, while India continues to develop several new regional airports under its aviation development programmes. As airport infrastructure improves, it becomes easier to plan for future charging stations, renewable energy systems, and maintenance facilities required for electric aviation.

South Asia also has growing potential in renewable energy production. Countries such as India and Bangladesh are increasing investments in solar and wind energy. Since electric aircraft require electricity instead of conventional aviation fuel, integrating renewable energy into airport operations could significantly reduce the overall environmental impact of aviation. Clean electricity would allow future electric aircraft to operate more sustainably while reducing dependence on imported fossil fuels.

In addition, electric aviation creates opportunities for research, innovation, and employment. Universities and research institutions across South Asia could establish new aerospace engineering programmes focusing on electric propulsion, battery technology, aircraft design, and sustainable aviation. Such investments would help develop a skilled workforce while encouraging collaboration between academic institutions, governments, and the aviation industry.

- *Challenges*

Despite these promising opportunities, several challenges must be addressed before electric and hybrid-electric aircraft can be widely adopted in South Asia.

The most significant challenge is the lack of charging infrastructure. Unlike conventional aircraft, electric aircraft require high-capacity charging systems at airports. Most airports in South Asia are currently designed to support traditional aviation fuel and do not yet have the electrical infrastructure necessary for large-scale electric aircraft operations. Developing this infrastructure will require significant investment and long-term planning.

Another major challenge is the limited availability of aerospace research and development within the region. Although countries such as India have made progress in aerospace engineering, many South Asian nations still depend heavily on foreign technology and imported aircraft. Research on electric propulsion systems, advanced battery technology, and aircraft certification remains limited, slowing technological development.

Financial constraints also present an important obstacle.Many airlines operating in South Asia face financial limitations, making it difficult to purchase new aircraft or invest in advanced technologies. Governments may need to provide financial incentives, research grants, or tax benefits to encourage the transition toward sustainable aviation.

Aviation authorities will need to establish new certification standards for electric propulsion systems, battery safety, charging procedures, and maintenance requirements. Developing these regulations requires close cooperation with international organizations such as the International Civil Aviation Organization (ICAO), the European Union Aviation Safety Agency (EASA), and the Federal Aviation Administration (FAA).

- *Bangladesh: A Special Perspective*

Bangladesh has made significant progress in expanding its aviation sector over the past decade, but the country remains at an early stage of adopting sustainable aviation technologies. Ongoing investments in airport modernization, including the expansion of Hazrat Shahjalal International Airport, demonstrate the government's commitment to improving national aviation infrastructure. However, electric aviation research, battery technology development, and aerospace manufacturing remain limited.

To prepare for the future, Bangladesh should strengthen collaboration between universities, government agencies, and international aerospace organizations. Expanding aeronautical engineering education, supporting scientific research, and developing policies that encourage sustainable aviation technologies would help the country become better prepared for the transition toward electric and hybrid-electric aircraft. Although commercial implementation may still be several years away, early investment in education, infrastructure, and research will

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jul1653

position Bangladesh to benefit from future technological advancements.

Overall, South Asia possesses considerable potential to participate in the global transition toward sustainable aviation. By addressing existing technological, financial, and regulatory challenges, the region can gradually integrate electric and hybrid-electric aircraft into its aviation sector while supporting economic growth and environmental sustainability.

Table 2 Opportunities and Challenges for Electric Aviation in South Asia

Opportunities	Challenges
Growing passenger demand	Limited charging infrastructure
Expanding airport infrastructure	High initial investment costs
Renewable energy development	Limited aerospace research
Regional short-haul routes	Battery technology limitations
Skilled workforce development	Regulatory and certification challenges
International collaboration	Dependence on imported technology

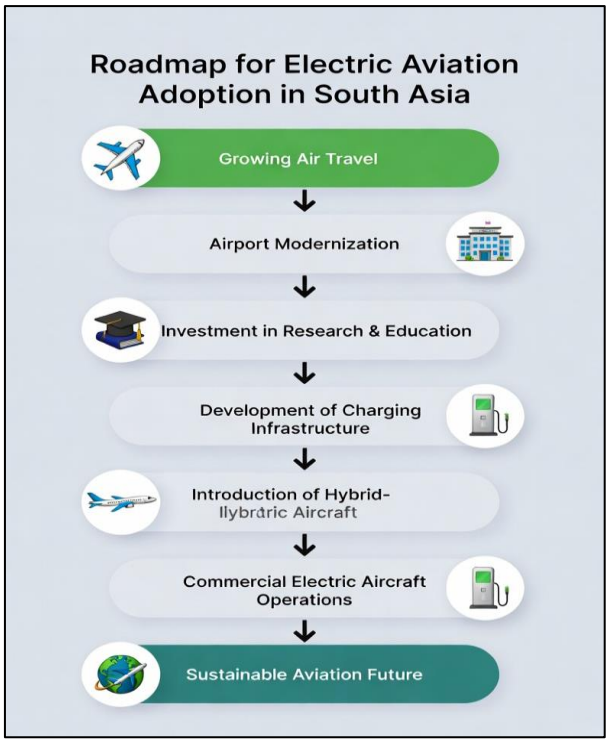

Fig 1 Roadmap for Electric Aviation Adoption in South Asia

IV. FUTURE OUTLOOK AND RECOMMENDATIONS

The future of aviation is expected to be shaped by technological innovation, environmental responsibility, and the growing demand for sustainable transportation. Electric and hybrid-electric aircraft are no longer considered experimental concepts but are becoming an important part of long-term aviation planning around the world. Although significant technical and economic challenges remain, continuous improvements in battery technology, electric propulsion systems, lightweight materials, and renewable energy are expected to accelerate the adoption of cleaner aircraft over the coming decades.

Most aviation experts believe that hybrid-electric aircraft will become the primary solution for regional aviation during the 2030s. Since hybrid aircraft combine conventional engines with electric motors, they provide greater flight range while consuming less fuel and producing fewer greenhouse gas emissions than traditional aircraft. This makes them particularly suitable for South Asia, where many airlines operate short- and medium-distance routes between major cities. Hybrid-electric technology can serve as an effective transition toward fully electric aviation while battery technology continues to improve.

Fully electric aircraft are expected to become more practical in the future as battery energy density increases and charging technology becomes more efficient. Advances in solid-state batteries, lightweight composite materials, and high-efficiency electric motors may allow electric aircraft to carry more passengers over longer distances than is currently possible. Initially, these aircraft are likely to be used for pilot training, domestic flights, and regional commuter services before expanding into larger commercial operations.

South Asia has the opportunity to become an active participant in this technological transformation. Countries such as India and Bangladesh are already investing in airport expansion, renewable energy projects, and improvements in transportation infrastructure. If these developments are combined with investments in electric aviation technologies, the region could gradually reduce aviation emissions while supporting economic growth and improving regional connectivity. However, achieving this goal will require long-term planning, strong government support, and close cooperation between universities, research institutions, airlines, and aircraft manufacturers.

➢ *Recommendations*

To support the successful adoption of electric and hybrid-electric aircraft in South Asia, several strategic actions should be considered.

- *Investment in Research and Innovation:*

Governments should increase funding for aerospace research, battery technology, electric propulsion systems, and sustainable aviation projects. Universities should be encouraged to establish research centres dedicated to future aircraft technologies and collaborate with international research organizations.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jul1653

- *Modernization of Airport Infrastructure:*

Airports should gradually prepare for electric aviation by developing high-capacity charging systems, upgrading electrical networks, and integrating renewable energy sources such as solar and wind power. Planning these improvements today will make future aircraft operations more practical and cost-effective.

- *Strengthening Engineering Education:*

Educational institutions should expand programmes in aeronautical engineering, electrical engineering, renewable energy, and aviation management. Providing students with knowledge of emerging aviation technologies will help create a skilled workforce capable of supporting future industry demands.

- *International Collaboration:*

South Asian countries should strengthen partnerships with international organizations such as the International Civil Aviation Organization (ICAO), the International Air Transport Association (IATA), the European Union Aviation Safety Agency (EASA), and leading aircraft manufacturers. These collaborations can support technology transfer, research opportunities, professional training, and the development of international safety standards.

- *Development of Supportive Government Policies:*

Governments should introduce policies that encourage sustainable aviation by providing research grants, tax incentives, and financial support for companies investing in electric aviation technologies. Clear regulatory frameworks will also be essential for aircraft certification, battery safety, charging infrastructure, and maintenance procedures.

- *Public and Industry Awareness:*

Airlines, airport authorities, educational institutions, and policymakers should work together to increase awareness of sustainable aviation technologies. Public understanding and industry support will help encourage investment and accelerate the adoption of cleaner aircraft in the future.

Overall, the future of electric and hybrid-electric aircraft in South Asia depends on technological progress, government commitment, and regional cooperation. While fully electric commercial aviation may still require further technological development, hybrid-electric aircraft offer a realistic pathway toward reducing emissions and improving energy efficiency over the next decade. By investing in research, education, infrastructure, and international partnerships today, South Asian countries can position themselves to benefit from the next generation of sustainable aviation technologies.

Table 3 Key Recommendations for Electric Aviation Development

Recommendation	Expected Benefit
Increase aerospace research funding	Accelerates technological innovation
Modernize airport infrastructure	Supports future electric aircraft operations
Expand engineering education	Develops a skilled workforce
Promote renewable energy at airports	Reduces environmental impact
Strengthen international partnerships	Encourages technology transfer and research collaboration
Develop supportive government policies	Attracts investment and ensures safe implementation

V. CONCLUSION

Electric and hybrid-electric aircraft represent an important step toward building a more sustainable aviation industry. Although these technologies are still developing, they offer significant potential to reduce carbon emissions, improve fuel efficiency, and lower operating costs. This review has shown that hybrid-electric aircraft are likely to become the most practical solution for regional aviation in the near future, while fully electric aircraft may become increasingly viable as battery technology continues to improve.

South Asia has considerable opportunities to benefit from these advancements due to its rapidly growing aviation market, expanding airport infrastructure, and increasing investment in renewable energy. However, several challenges, including limited aerospace research, inadequate charging infrastructure, high investment costs, and evolving regulatory requirements, must be addressed before large-scale adoption becomes possible.

For countries such as Bangladesh, early investment in research, engineering education, airport modernization, and international collaboration will be essential to prepare for the future of sustainable aviation. By developing supportive policies and encouraging innovation, South Asia can gradually integrate electric and hybrid-electric aircraft into its aviation sector.

In conclusion, the transition toward cleaner aviation will require long-term commitment from governments, industry, and academic institutions. With continued technological progress and strategic investment, South Asia has the potential to become an active participant in the global movement toward safer, greener, and more sustainable air transportation.

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