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Review Article

# Green Propulsion Technologies in the Aviation Industry and its Challenges

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## I N F O

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## A B S T R A C T

As the global community grapples with the urgent need to address climate change and reduce environmental impact, the field of propulsion technologies is undergoing a transformative shift towards sustainability. This abstract explores the latest developments in green propulsion technologies, focusing on their applications in the aerospace industry. Green propulsion encompasses a spectrum of innovative solutions designed to minimise carbon emissions, energy consumption, and environmental footprints. Various propulsion systems, such as electric propulsion, biofuels, hydrogen fuel cells, and advanced hybrid systems, are at the forefront of the paradigm shift. This book chapter examines the key principles and engineering behind green propulsion technologies, highlighting their potential to revolutionise traditional flying and space exploration. The abstract also discusses the challenges and obstacles associated with the widespread adoption of green propulsion technologies, as well as any potential environmental impacts they may have on a large scale. In conclusion, this abstract provides a comprehensive overview of the latest advancements in green propulsion technologies, emphasising their potential to reshape the future of flying and the aviation industry in general. As nations and industries continue to prioritise sustainability, the integration of these innovative propulsion solutions is poised to play a pivotal role in achieving a greener and more sustainable future.

**Keywords:** Green Propulsion, Sustainability, Aerospace, Propulsion Technologies, Environmental Impact, Carbon Emissions, Energy Efficiency, Biofuels, Hydrogen Fuel Cells, Aviation, Space Exploration, Innovation, Hybrid Systems, and Global Sustainability

## Introduction

A paradigm shift in the field of propulsion technologies has been sparked by the urgent need to address climate change and lessen the environmental impact of human activities. In light of global sustainability goals, traditional transportation and space exploration systems that depend on fossil fuels and produce significant carbon emissions are becoming less and less viable. A crucial solution to this dilemma is the development of green propulsion technologies, which seek to completely transform how we move vehicles and traverse our environment. Propulsion technologies have been reevaluated in light of the environmental effects of conventional propulsion systems, particularly in the aviation and aerospace industries. Green propulsion technologies, sometimes referred to as sustainable or environmentally friendly propulsion, are a broad category of cutting-edge approaches intended to reduce the environmental impact of space missions and transportation.[1,4] The need to slow down global warming is becoming more pressing, and this has led to developments in materials science and engineering as well as energy efficiency and emissions reduction in propulsion systems.

Green propulsion technologies aim to reduce the environmental impact of conventional propulsion systems, enhance sustainability, and stimulate innovation in space exploration and transportation.[4,8]

The principal goals consist of:

- Greenhouse Emission Reduction
- Enhancing energy efficiency
- Promoting renewable energy sources
- Adopting alternative fuels
- Encouraging electrification
- Improving air quality
- Enhancing sustainability in aerospace
- Meeting regulatory standards
- Encouraging and developing research and development
- Addressing economic viability

**Scope:** Green propulsion technologies have a broad range of applications in different industries, all of which contribute to the overall objective of promoting sustainability and minimising environmental impact. The following two are some important areas of green propulsion technology in the aerospace industry:

**Aviation:** The development and application of environmentally friendly aircraft solutions is the main goal of green propulsion technologies in the aviation industry. In order to lower carbon emissions and improve fuel efficiency, this includes the use of electric propulsion, alternative aviation fuels (such as biofuels), and sophisticated hybrid systems.

**Space Exploration:** Green propulsion technologies are intended to increase the sustainability and efficiency of spacecraft and satellite propulsion systems. Advanced propulsion techniques, such as solar sails and ion thrusters, are being investigated to reduce the ecological footprint of space missions. The pictorial representation of the conversion from conventional green propulsion technology has been shown as a graphical abstract in Figure 1.


**Figure 1.The Electric propulsion and Bio-Fuels used in space industry**

## Advancements Made Towards Green Propulsion Technology by Industries

In 2018, ISRO started working on developing green propulsion technology. In 2018, they created a sustainable solid propellant using ammonium di-nitramide as the oxidant and glycidyl azaide polymer (GAP) as the fuel. [9] ISRO has been executing technology demonstration projects with green propellant mixes like methanol-water, glycerol-water, liquid oxygen, kerosene, and hydrogen peroxide. Liquid oxygen and liquid hydrogen-based launch vehicle propulsion system testing has started at ISRO. Green propulsion technologies are already being used by them in their operations. Nevertheless, the mission only partially makes use of the technologies. Liquid oxygen and liquid hydrogen propulsion, for example, are employed in the cryogenic upper stages of the GSLV Mk-III launch vehicle.

Green Propellant Infusion Mission: The main payload supplier of a demonstration propulsion system for the Green Propellant Infusion Mission (GPIM) is Aerojet Rocketdyne, a division of L3 Harris Technologies. On a NASA mission, green propellant was successfully demonstrated. [10,12] CubeSat Propulsion Systems: By utilising its additive manufacturing efforts and the knowledge gained from the GPIM programme, Aerojet Rocketdyne is creating a low-cost propulsion system for CubeSats that runs on green propellants. Today's Cube Sats usually have no propulsion, which limits their ability to move around and stay in orbit. The modular propulsion systems offered by Aerojet Rocketdyne span a range of propulsion module sizes, from 1U to 8U, with a maximum delta-v capability of 750 m/sec. In a significant milestone, space transportation company Bellatrix Aerospace has successfully tested India's first high-performance green propulsion system for

satellite propulsion, a greener alternative to conventional hydrazine-based satellite propulsion systems. The firm, which is based in Bengaluru, has developed a proprietary high-performance green monopropellant with valuable guidance from Prof. Charlie Oommen, Department of Aerospace Engineering at IISc Bengaluru. Propellers are required for launch vehicles. And one of them is hydrogen peroxide. And an extremely unique one at that: PROPULSE by Evonik Active Oxygens was created especially for rocket propulsion systems.[13,16] ISRO is developing green propulsion for its ambitious human flight space mission, and figure 2 represents the advances in new oxidizers.

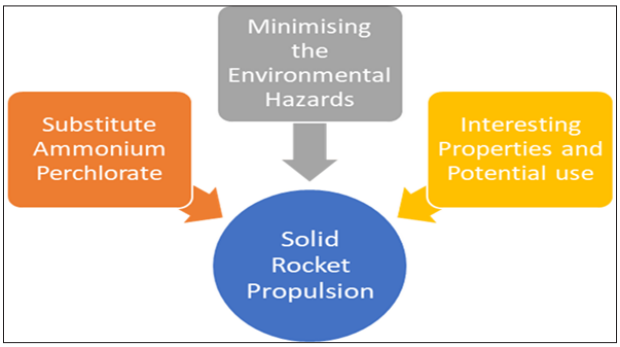


**Figure 2.Recent Advances in New Oxidizers for Green Propulsion (ISRO Source)[12]**

In contrast to conventional propellants, the breakdown of hydrogen peroxide produces only oxygen and water—no substances that are hazardous to people or the environment; consequently, PROPULSE is closely associated with green rocketry. The phrase refers to space travel that is environmentally friendly. In keeping with this slogan, the space industry is putting more and more emphasis on environmentally friendly propulsion technologies for the next generation of rockets to lessen their negative effects on people and the environment. Here, highly concentrated hydrogen peroxide works well as a resource- and environmentally-friendly propellant. It is applicable to hybrid rockets as well.

1. **Challenges and Obstacles:** Green propulsion technology, which seeks to create sustainable and ecologically friendly ways to power cars and spacecraft, has a number of difficulties. Among the principal difficulties are:
2. **Energy Density:** It's common for green propulsion technologies to fall short of traditional propulsion systems in terms of energy density. Concerns regarding the overall efficiency and range of vehicles arise from the possibility that many alternative fuels and energy sources won't produce the same amount of power.
3. **Infrastructure and Adoption:** Adopting green propulsion necessitates major modifications to supply chains, refuelling stations, and charging infrastructure. The high costs and requirement for extensive infrastructure development are the main reasons for the sluggish adoption of green propulsion technologies.
4. **Costs and Affordability:** The development and application of green propulsion technologies can be costly. Widespread adoption may be hampered by high upfront costs as well as the expense of producing and maintaining new systems, especially in businesses with narrow profit margins.
5. **Restricted Endurance and Range:** The endurance and range of certain green propulsion systems may be restricted. For instance, the range of electric vehicles is often limited when compared to conventional internal combustion engine vehicles due to issues with battery technology and charging infrastructure.
6. **Materials and Resource Availability:** Because the development of some green propulsion technologies may require the use of rare or limited materials, there are questions regarding the availability of these resources in light of geopolitical issues. It can be difficult to establish a reliable supply chain for these materials.
7. **Technological Readiness:** Compared to conventional systems, some green propulsion technologies are still in the early phases of development and may not be as dependable or mature. Reaching the same degree of technological preparedness is essential to being accepted in sectors where dependability is critical.
8. **Regulatory Barriers:** New green propulsion technologies might not be well-suited for the rules and standards that are currently in place. The complicated process of changing regulations to guarantee fair competition, safety, and interoperability can impede the adoption of cutting-edge technologies.
9. **Public Perception and Acceptance:** The success of green propulsion technologies is greatly influenced by consumer attitudes and perceptions. The public's confidence in the security, dependability, and usefulness of these technologies must be increased in order for them to be widely adopted.
10. **Interdisciplinary Challenges:** Knowledge in chemistry, materials science, engineering, and other fields is frequently needed to develop green propulsion technologies. Although it can be difficult, cooperation between these many fields is necessary for successful development.
11. **Increase in size Obstacles:** Transitioning from lab-scale prototypes to large-scale execution presents a unique set of difficulties. It is crucial to make sure that green propulsion technologies can be effectively scaled up to satisfy the needs of different industries.

In order to address these issues, industries, governments, engineers, and researchers must work together to develop supportive regulatory frameworks, encourage innovation, and allocate funds for research and development.[4,14,17,20]

## Environmental Impacts

Green propulsion technologies take the environment into account, even though their goal is to have less of an impact than traditional propulsion systems. Depending on the particular technology and how it is developed, different green propulsion technologies may have different effects on the environment. The following are some broad environmental factors to consider:

- **Resource Extraction and Production:** Obtaining raw materials may have an impact on the environment when producing parts for green propulsion systems. For example, habitat disruption, water pollution, and other environmental issues may arise from the mining of metals and minerals for batteries or fuel cells.
- **Energy Intensity of Manufacturing:** It frequently takes a substantial amount of energy to produce green propulsion technologies, like hydrogen fuel cells or electric cars. If non-renewable resources are used to produce this energy, the manufacturing process may contribute to greenhouse emissions.
- **End-of-Life Management:** Recycling and disposing of parts at the end of a technology's lifecycle are important factors to take into account. For instance, the materials found in electric car batteries need to be properly recycled in order to prevent environmental contamination. Reducing the negative effects of waste on the environment requires efficient recycling systems.
- **Impact on Land Use and Wildlife Habitats:** The implementation of large-scale renewable energy projects, like wind and solar farms, may have an effect on nearby ecosystems and wildlife habitats. Variations in land use can cause biodiversity disruption and habitat fragmentation.
- **Water Usage:** The production of some green propulsion technologies, like biofuels or specific kinds of batteries, may call for a large amount of water resources. In order to avoid detrimental effects on nearby water supplies and ecosystems, sustainable water management is essential.
- **Pollution of Air and Water:** Improper management of the extraction, processing, and manufacturing stages of green propulsion technologies can lead to pollution of air and water. Reducing the pollution that results from these processes is necessary in order to achieve the desired environmental benefits.
- **Source of Electricity:** The environmental impact of charging electric vehicles is contingent upon the source of electricity used. There may be less of a reduction in greenhouse gas emissions overall if the electricity is generated using fossil fuels. When electricity is generated from renewable sources, the environmental benefits are maximised.
- **E-Waste Management:** The handling of electronic waste, or "e-waste," is becoming more and more important as electronic components find their way into green propulsion technologies. Electronic component recycling and disposal must be done correctly to prevent risks to the environment and public health associated with e-waste.
- **Land Use for Biomass Production:** The production of biomass feedstocks, which is necessary for biofuels, which are regarded as a green form of propulsion, may need a sizable amount of land. Deforestation, habitat loss, and competition with food crops for arable land can result from this.
- **Impacts on the Global Supply Chain:** The environmental effects of the global supply chain for essential materials required for green propulsion technologies may be felt. This covers problems with transportation, resource extraction, and geopolitical tensions around resource-rich areas.

Research, innovation, and the creation of sustainable procedures for the manufacture and disposal of green propulsion technologies are being done in an effort to address these environmental issues. To completely comprehend the environmental implications of these technologies and minimise adverse effects, it is crucial to take into account their entire lifecycle.[20,23]

## Future Prospects[15, 16, 22, 23]

Green propulsion technologies have bright futures because environmental preservation, sustainability, and the need to slow down climate change are becoming more and more important worldwide. Positive outlooks for the future of green propulsion are suggested by a number of trends and developments:

- Increasing regulatory support
- Advancements in battery technology
- Growing renewable energy infrastructure
- Innovations in Sustainable Aviation
- Integration of artificial intelligence (AI) and smart technologies
- Circular Economy Practices (Reusing and Recycling Practices)
- Space exploration with sustainable propulsive systems

## Conclusions

In conclusion, as more and more people adopt sustainable approaches to address environmental issues and lower carbon footprints, the future of green propulsion technologies looks bright. Green propulsion is becoming more and more popular due to a confluence of factors, including regulatory support, continuous technological advancements, the integration of renewable energy sources, and consumer preferences shifting towards eco-

friendly options. But issues like developing infrastructure, budgetary constraints, and technological hurdles need to be carefully considered. A more sustainable future for transportation will be facilitated by the combined efforts of industries, governments, and research institutions, as well as a dedication to circular economy principles. This will allow for the full advancement of green propulsion technologies.

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