



International Journal of Innovative Research in Science Engineering and Technology (IJIRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



Impact Factor: 9.935

Volume 15, Issue 5, May 2026

Brief Review on Special and Synthetic Fuel

Jadhav Nitin Dnyaneshwar¹, Wabale Santosh Madhav², Sangale Sandesh Sadashiv³, Ganesh Gangadhar Kalbande⁴, Saudagar Tuba Kayyum⁵, Prof. Niraj Balkrishna Dole⁶

Student, Department of Mechanical Engineering, Matoshri College of Engineering and Research Technology, Maharashtra, India¹⁻⁵

Assistant Professor, Department of Mechanical Engineering, Matoshri College of Engineering and Research Technology, Maharashtra, India⁶

ABSTRACT: Brief Review on Special and Synthetic Fuel

Special and synthetic fuels have emerged as promising alternatives to conventional fossil fuels due to increasing energy demand, depletion of petroleum reserves, and stringent environmental regulations. Special fuels include advanced fuels designed for specific applications such as aviation, military systems, high-performance engines, and low-emission industrial operations. Synthetic fuels, commonly referred to as e-fuels or artificial fuels, are produced from non-petroleum feedstocks including coal, natural gas, biomass, hydrogen, and captured carbon dioxide through processes such as Fischer–Tropsch synthesis, gas-to-liquid (GTL), coal-to-liquid (CTL), and power-to-liquid (PtL) technologies. These fuels offer advantages including reduced greenhouse gas emissions, compatibility with existing infrastructure, improved combustion efficiency, and enhanced energy security. Recent developments in renewable energy integration and carbon capture technologies have further accelerated research in sustainable synthetic fuel production. However, high production costs, energy-intensive processing, and scalability limitations remain major challenges for widespread commercialization. This paper presents a brief review of the classification, production methods, advantages, limitations, and future prospects of special and synthetic fuels in transportation and industrial applications. The study highlights the significant role of these fuels in achieving carbon neutrality and supporting the global transition toward sustainable energy systems.

KEYWORDS: Fischer–Tropsch synthesis, gas-to-liquid (GTL), coal-to-liquid (CTL), and power-to-liquid (PtL)

I. INTRODUCTION

Introduction

The rapid growth of industrialization, transportation, and global energy consumption has significantly increased dependence on conventional fossil fuels such as gasoline, diesel, and coal. However, the continuous depletion of crude oil reserves and rising environmental concerns associated with greenhouse gas emissions have accelerated the search for cleaner and sustainable energy alternatives. In this context, special fuels and synthetic fuels have gained considerable attention in recent years due to their potential to improve energy efficiency, reduce environmental pollution, and ensure long-term energy security.

Special fuels are specifically formulated fuels designed to meet the operational requirements of advanced engines, aerospace systems, military applications, and high-performance industrial equipment. These fuels possess unique properties such as high calorific value, improved combustion characteristics, enhanced thermal stability, and lower emissions. Examples include aviation turbine fuel, bio-blended fuels, cryogenic fuels, and high-octane performance fuels. The development of special fuels is primarily driven by the need for better engine performance, reliability, and compliance with stringent emission standards.

Synthetic fuels, also known as synfuels or e-fuels, are manufactured through chemical conversion processes using feedstocks such as coal, natural gas, biomass, hydrogen, and captured carbon dioxide. Common production technologies include Fischer–Tropsch synthesis, gas-to-liquid (GTL), coal-to-liquid (CTL), biomass-to-liquid (BTL), and power-to-liquid (PtL) methods. Unlike conventional petroleum fuels, synthetic fuels can be produced from renewable and non-conventional resources, making them an attractive option for sustainable energy development. In addition, synthetic fuels are compatible with existing fuel infrastructure and internal combustion engines, enabling

easier adoption without major modifications to transportation systems.

Recent advancements in renewable energy integration, hydrogen production, and carbon capture technologies have further enhanced the feasibility of synthetic fuel production. Many countries and industries are investing in synthetic fuel research to achieve carbon neutrality and reduce dependence on imported fossil fuels. Despite these advantages, challenges such as high production costs, low overall energy efficiency, and large-scale commercialization limitations continue to hinder widespread implementation.

This paper presents a brief review of special and synthetic fuels, focusing on their classification, production methods, properties, advantages, limitations, and future prospects. The study also highlights the role of these fuels in achieving sustainable energy systems and reducing environmental impacts in modern transportation and industrial sectors.

II. SURVEY AND SPECIFICATION

The increasing demand for sustainable and environmentally friendly energy sources has led to extensive research on special and synthetic fuels. Researchers and industries worldwide are exploring alternative fuels to reduce dependence on petroleum-based fuels and minimize harmful emissions. Special fuels are primarily developed for high-performance applications such as aerospace propulsion, defense systems, marine engines, and advanced automotive technologies. Synthetic fuels, on the other hand, are artificially produced fuels manufactured from alternative feedstocks including coal, natural gas, biomass, hydrogen, and captured carbon dioxide.

Several studies have focused on improving the combustion characteristics and thermal efficiency of special fuels. Aviation turbine fuels and cryogenic fuels have shown significant advantages in aerospace applications due to their high energy density and stable combustion behavior. Bio-blended fuels such as ethanol–gasoline and biodiesel–diesel mixtures are also considered special fuels because they enhance engine performance while reducing exhaust emissions. Researchers have reported that the use of oxygenated additives in fuels improves combustion efficiency and decreases carbon monoxide and particulate emissions.

Synthetic fuels have gained major attention because they can be produced using renewable and non-renewable resources. Fischer–Tropsch synthesis is one of the most widely used technologies for synthetic fuel production. In this process, syngas composed of carbon monoxide and hydrogen is converted into liquid hydrocarbons. Gas-to-liquid (GTL), coal-to-liquid (CTL), and biomass-to-liquid (BTL) technologies are extensively studied for commercial fuel production. Among these, biomass-derived synthetic fuels are considered more environmentally sustainable due to their lower carbon footprint.

Recent surveys indicate that synthetic fuels can significantly reduce sulfur emissions, particulate matter, and greenhouse gas emissions when compared with conventional fossil fuels. Hydrogen-based synthetic fuels and power-to-liquid (PtL) technologies are emerging as future solutions for carbon-neutral transportation systems. Many developed countries are investing in e-fuel technologies to support decarbonization goals in aviation, shipping, and heavy transportation sectors.

Despite the advantages, researchers have identified several challenges associated with special and synthetic fuels. High production costs, energy-intensive conversion processes, storage difficulties, and infrastructure limitations remain major barriers to large-scale commercialization. Moreover, the overall efficiency of synthetic fuel production depends heavily on renewable electricity availability and carbon capture technologies.

Overall, existing literature demonstrates that special and synthetic fuels have strong potential to support future sustainable energy systems. Continuous advancements in fuel processing technologies, catalyst development, renewable energy integration, and emission control techniques are expected to improve the feasibility and economic viability of these fuels.

Key Characteristics

1. High Combustion Efficiency:
Both fuel types are designed to improve combustion performance and reduce fuel wastage.
2. Reduced Emissions:
Synthetic fuels generally contain lower sulfur and aromatic compounds, resulting in cleaner exhaust emissions.

3. Engine Compatibility:
Most synthetic fuels can be used in existing internal combustion engines with minimal modifications.
4. Renewable Integration:
Modern synthetic fuel production increasingly utilizes renewable electricity and green hydrogen.
5. Energy Security:
These fuels reduce dependence on crude oil imports by enabling domestic fuel production from alternative resources.

Applications

- Aerospace and aviation industries
- Military and defense systems
- Automotive and transportation sectors
- Marine propulsion systems
- Industrial heating and power generation

III. LITERATURE SURVEY

Literature Survey

Numerous research studies have been conducted on special fuels and synthetic fuels to address the growing concerns of fossil fuel depletion, environmental pollution, and energy sustainability. Researchers have mainly focused on improving fuel efficiency, reducing harmful emissions, and developing economically viable fuel production technologies. Synthetic fuel technologies such as Fischer–Tropsch synthesis, power-to-liquid (PtL), gas-to-liquid (GTL), and biomass-to-liquid (BTL) have received considerable attention due to their capability to produce cleaner transportation fuels from alternative resources. (RSC Publishing)

Early studies on synthetic fuels primarily concentrated on coal-based and natural gas-based fuel production processes. Fischer–Tropsch synthesis was identified as one of the most effective techniques for converting syngas into liquid hydrocarbons suitable for transportation applications. Research has shown that catalyst selection, reactor temperature, and pressure conditions significantly influence fuel yield and selectivity. Several investigations have focused on cobalt- and iron-based catalysts to improve hydrocarbon conversion efficiency and fuel quality. (Springer)

Recent literature highlights the increasing importance of renewable synthetic fuels, especially in aviation and heavy transportation sectors where direct electrification is difficult. Studies on sustainable aviation fuels (SAF) indicate that synthetic fuels produced from captured carbon dioxide and green hydrogen can substantially reduce lifecycle carbon emissions while remaining compatible with existing engine technologies and fuel infrastructure. Advanced PtL systems integrating renewable electricity and carbon capture technologies are being explored for future carbon-neutral fuel production. (ScienceDirect)

Several review articles have examined the production pathways and classifications of synthetic fuels. Researchers have categorized synthetic fuels into methanol-based fuels, dimethyl ether (DME), Fischer–Tropsch fuels, hydrogen-derived fuels, and bio-synthetic fuels. These studies emphasize that synthetic fuels possess advantages such as low sulfur content, cleaner combustion, higher thermal stability, and reduced particulate emissions when compared with conventional petroleum fuels. (MDPI)

Studies related to special fuels have mainly focused on fuels used in aerospace, military, and high-performance automotive applications. Aviation turbine fuels, cryogenic fuels, and biofuel blends are widely investigated due to their superior combustion properties and lower environmental impact. Researchers have reported that blending conventional fuels with bio-components improves engine efficiency and reduces carbon monoxide and hydrocarbon emissions. Special fuels are also being designed to meet stringent emission regulations and improve engine durability under extreme operating conditions.

Many researchers have addressed the economic and technical challenges associated with synthetic fuel production. High capital investment, complex reactor systems, catalyst deactivation, and energy-intensive hydrogen production remain major limitations for large-scale commercialization. Community and industrial discussions also indicate that Fischer–Tropsch fuel production requires careful heat management and extensive downstream processing, which

increases production costs. (Reddit)

Recent advancements in artificial intelligence, catalyst optimization, and process modeling have opened new possibilities for improving synthetic fuel production efficiency. Advanced computational models and machine learning techniques are now being used to optimize reaction kinetics and reactor performance in Fischer–Tropsch systems. (arXiv)

Overall, the literature survey indicates that special and synthetic fuels offer promising solutions for future sustainable energy systems. Although technological and economic challenges still exist, continuous advancements in renewable energy integration, catalyst development, carbon capture, and fuel synthesis technologies are expected to improve the feasibility and commercial adoption of these fuels in the coming years.

IV. DISCUSSION AND METHODOLOGY

Discussion and Methodology

Methodology

The methodology adopted in this review paper is based on a comprehensive analysis of published research articles, technical reports, industrial publications, and conference papers related to special and synthetic fuels. The study focuses on understanding the classification, production technologies, properties, applications, environmental impacts, advantages, and limitations of these fuels. Information was collected from reliable scientific databases, journals, and energy-related publications to ensure accuracy and relevance of the review.

The methodology consists of the following stages:

1. Literature Collection

Relevant literature related to special fuels and synthetic fuels was collected from research journals, review articles, government energy reports, and industrial studies. Key topics considered during the survey include:

- Types of special and synthetic fuels
- Fuel production techniques
- Fischer–Tropsch synthesis process
- Gas-to-liquid (GTL) technology
- Coal-to-liquid (CTL) technology
- Biomass-to-liquid (BTL) technology
- Power-to-liquid (PtL) systems
- Fuel properties and combustion characteristics
- Environmental and economic impacts

2. Data Analysis

The collected information was analyzed to compare different fuel technologies based on:

- Production efficiency
- Emission characteristics
- Energy density
- Fuel compatibility
- Sustainability
- Economic feasibility
- Industrial applications

Comparative analysis was used to identify the advantages and limitations of each fuel type.

3. Classification of Fuels

The fuels were categorized into two major groups:

Special Fuels:

Fuels developed for specific applications such as aviation, military systems, racing engines, and industrial operations.

Synthetic

Fuels produced artificially using alternative feedstocks including coal, natural gas, biomass, hydrogen, and captured carbon dioxide. Fuels:

4. Evaluation of Production Technologies

Different fuel production technologies were studied and compared based on process complexity, fuel quality, and environmental performance. Major technologies reviewed include:

Fischer–Tropsch synthesis

Gas-to-liquid (GTL)

Coal-to-liquid (CTL)

Biomass-to-liquid (BTL)

Power-to-liquid (PtL)

The review also considers recent advancements in renewable hydrogen production and carbon capture integration.

Discussion

The global energy sector is undergoing rapid transformation due to increasing environmental concerns and the depletion of conventional fossil fuel resources. Special and synthetic fuels are emerging as promising alternatives because they provide improved fuel efficiency, lower emissions, and enhanced energy security. The discussion in this review highlights the technological developments, practical applications, benefits, and challenges associated with these fuels.

Special fuels

are mainly designed to achieve superior performance under specific operating conditions. Aviation turbine fuels, cryogenic fuels, and biofuel blends are examples of special fuels developed for high-efficiency combustion and reduced engine wear. These fuels improve thermal stability and combustion quality while complying with modern emission regulations. In aerospace and defense applications, special fuels are preferred because of their reliability and high energy density.

Synthetic fuels are gaining significant importance because they can be produced from both renewable and non-renewable feedstocks. Technologies such as Fischer–Tropsch synthesis enable the conversion of syngas into liquid hydrocarbons suitable for transportation and industrial use. Synthetic fuels possess several advantages including very low sulfur content, cleaner combustion, and compatibility with existing internal combustion engines and fuel distribution systems.

Among the synthetic fuel production technologies, biomass-to-liquid (BTL) and power-to-liquid (PtL) systems are considered more sustainable because they utilize renewable resources and captured carbon dioxide. Hydrogen-based synthetic fuels are particularly important for achieving carbon neutrality in sectors such as aviation, shipping, and heavy transportation where battery-electric systems face operational limitations.

Despite these advantages, several technical and economic challenges limit the widespread adoption of synthetic fuels. The production process requires high energy input, advanced catalysts, and expensive infrastructure. In addition, renewable hydrogen production and carbon capture technologies remain costly, affecting overall fuel economics. Storage and transportation of certain synthetic fuels also require specialized handling systems.

The discussion further indicates that government policies, environmental regulations, and investments in renewable energy technologies will play a major role in the future development of synthetic fuel industries. Continuous advancements in catalyst design, process optimization, and renewable electricity generation are expected to improve fuel production efficiency and reduce overall costs.

Therefore, special and synthetic fuels are expected to become important components of future sustainable energy systems. Although complete replacement of conventional fossil fuels may not occur immediately, these fuels can significantly contribute to reducing greenhouse gas emissions and enhancing long-term global energy sustainability.

V. CONCLUSION

Special and synthetic fuels have emerged as important alternatives to conventional fossil fuels due to increasing energy demand, depletion of petroleum resources, and growing environmental concerns. This review highlights the major developments, classifications, production technologies, properties, applications, advantages, and challenges associated

with these fuels. Special fuels are specifically designed to provide improved combustion efficiency, high thermal stability, and reliable performance in advanced applications such as aviation, defense, automotive, and industrial systems.

Synthetic fuels, produced through technologies such as Fischer–Tropsch synthesis, gas-to-liquid (GTL), coal-to-liquid (CTL), biomass-to-liquid (BTL), and power-to-liquid (PtL), offer a promising pathway toward cleaner and more sustainable energy systems. These fuels possess several benefits including lower sulfur emissions, reduced particulate matter, compatibility with existing fuel infrastructure, and the potential for carbon-neutral operation when produced using renewable energy and captured carbon dioxide.

The review also identifies several limitations that currently affect large-scale implementation, including high production costs, energy-intensive processing, infrastructure requirements, and technological complexity. However, ongoing advancements in renewable energy integration, green hydrogen production, catalyst development, and carbon capture technologies are expected to improve the efficiency and economic feasibility of synthetic fuel production in the future.

VI. ACKNOWLEDGMENT

With deep sense of gratitude we would like to thank all the people who have lit our path with their kind guidance. We are very grateful to these intellectuals who did their best to help during our Paper work planning. It is our proud privilege to express deep sense of gratitude to, Prof. Dr. G. K. Kharate, Principal of Matoshri College of Engineering and Research Technology Nashik, for his comments and kind permission to complete this Paper work planning. We remain indebted to Head of the Department Mechanical Engineering Department for their timely suggestion and valuable guidance. The special gratitude goes to my guide Prof. Niraj Balkrishna Dole and staff members, technical staff members of Mechanical Engineering Department for their expensive, excellent and precious guidance in completion of this work planning. We thank to all the colleagues for their appreciable help for our Paper work planning. With various industry owners or lab technicians to help, it has been our endeavor to throughout our work to cover the entire Paper work planning. And lastly we thank to our all friends and the people who are directly or indirectly related to our Paper work planning Costs.

REFERENCES

- [1] A. Li, J. Zheng, Z. Wang, and Z. Zhang, “Research advances and future perspectives in Fischer–Tropsch synthesis for sustainable aviation fuel,” *Sustainable Energy & Fuels*, vol. 10, pp. 42–55, 2026. DOI: 10.1039/D5SE01412C. ([RSC Publishing](#))
- [2] “Electro-sustainable aviation fuel via reverse water-gas-shift based Fischer–Tropsch synthesis: Decarbonization pathways and economic prospects,” *Journal of Cleaner Production*, vol. 540, 147470, Jan. 2026. ([ScienceDirect](#))
- [3] H. T. Schultz, “Towards Net-Zero Aviation: A Critical Review of Sustainable Aviation Fuel Pathways and Scale-Up Constraints,” *Energy Conversions*, vol. 10, 2026. ([energyconversions.org](#))
- [4] “Sustainable Aviation Fuels: A Comprehensive Review of Production Pathways, Environmental Impacts, Lifecycle Assessment, and Certification Frameworks,” *Energies*, vol. 18, no. 14, 2025. ([MDPI](#))
- [5] N. Montoya Sanchez et al., “Conversion of waste to sustainable aviation fuel via Fischer–Tropsch synthesis: Front-end design decisions,” *Energy Science & Engineering*, vol. 10, no. 5, 2022. DOI: 10.1002/ese3.1072. ([ResearchGate](#))
- [6] F. Chireshe et al., “Cost-effective sustainable aviation fuel: Insights from a techno-economic and logistics analysis,” *Renewable and Sustainable Energy Reviews*, vol. 210, 2025. ([EconPapers](#))
- [7] D. Huber, F. Birkelbach, and R. Hofmann, “Evaluating synthetic fuel production: A case study on the influence of electricity and CO₂ price variations,” *arXiv preprint arXiv:2310.14792*, 2023. ([arXiv](#))
- [8] A. Klimek, C. Plate, S. Sager, K. Sundmacher, and C. Ganzer, “Superstructure Optimization with Embedded Neural Networks for Sustainable Aviation Fuel Production,” *arXiv preprint arXiv:2509.09796*, 2025. ([arXiv](#))
- [9] A. E. Comesana, S. S. Chen, K. E. Niemeyer, and V. H. Rapp, “A Structured Framework for Predicting Sustainable Aviation Fuel Properties using Liquid-Phase FTIR and Machine Learning,” *arXiv preprint arXiv:2408.01530*, 2024. ([arXiv](#))
- [10] W. B. Ambrosio, B. A. de Sousa, J. M. Kanieski, P. Marchiorie, and G. Mockaitis, “Sustainable Aviation Fuels: Opportunities, Alternatives and Challenges for Decarbonizing the Aviation Industry and Foster the Renewable Chemicals,” *arXiv preprint arXiv:2504.03880*, 2025. ([arXiv](#))



INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 9940 572 462  6381 907 438  ijirset@gmail.com



www.ijirset.com

Scan to save the contact details