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A Study on Decarbonizing Commercial Kitchens through Hydrogen Fuel: Challenges, Opportunities and a Way Forward

Nikhil Devrao Wankhede

Assistant Professor, Bharati Vidyapeeth College of Hotel & Tourism Management Studies, Navi Mumbai

Saurabh Singh Chandel

Assistant Professor, Bharati Vidyapeeth College of Hotel & Tourism Management Studies, Navi Mumbai

Abstract

Decarbonizing commercial kitchens is increasingly becoming one of the most important areas that need attention as part of the wider effort to promote sustainability and respond to the climate change challenge. This paper seeks to investigate the viability and suitability of using hydrogen as an environmentally friendly substitute for traditional fossil fuels used for cooking. In particular, this investigation will explore some of the issues surrounding the use of hydrogen fuel in commercial kitchens. Some of the key obstacles that will be highlighted include prohibitive infrastructure costs, health and safety concerns, storage difficulties, and regulatory hurdles. However, the study will also uncover some new possibilities such as the role of the government in providing incentives, availability of clean hydrogen fuels, and recent improvements in fuel cell technology. Through the analysis of successful strategies employed in other parts of the world, a set of recommendations will be formulated for adoption.

Keywords: *Hydrogen Fuel; Decarbonization; Commercial Kitchens; Clean Energy Transition; Green Hydrogen; Sustainable Hospitality; Energy Efficiency*

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1. Introduction

The increasing urgency of climate change mitigation has intensified the global focus on decarbonizing energy-intensive sectors, including the hospitality and food service industry. Commercial kitchens, which predominantly rely on fossil fuels such as liquefied petroleum gas (LPG) and natural gas, are significant contributors to greenhouse gas emissions and indoor air pollution. The transition toward low-carbon alternatives is therefore critical to achieving global sustainability goals, particularly those aligned with clean energy and climate action frameworks. Hydrogen fuel, especially green hydrogen produced through renewable energy sources, has emerged as a promising solution due to its zero-carbon combustion characteristics, emitting only water vapor during use. Recent technological advancements have demonstrated the feasibility of hydrogen-based cooking systems, including pilot projects and prototype commercial kitchen equipment, indicating a paradigm shift in energy utilization within the sector (Gupta, 2024). Hydrogen can be seen as a solution that would contribute to achieving goals of sustainable development in terms of access to clean energy, environmental protection, and positive health effects (Mukelabai et al., 2022). Despite the obvious advantages of hydrogen as a future source of energy, it

should be noted that transitioning to hydrogen fuel involves certain challenges related to techno-economic factors. In practice, the implementation of hydrogen fuel in commercial kitchens is increasingly becoming a reality through various trial runs and initial commercialization ventures. The deployment of hydrogen-fueled burners and cooking appliances has shown lower emissions of carbon monoxide and nitrogen oxides, promoting environmental sustainability. Moreover, the creation of hydrogen-fueled commercial kitchen models and pilot plants signifies the increasing willingness of industry players to explore alternative sources of energy. Nevertheless, the integration of hydrogen technology in commercial kitchens is faced with obstacles, such as potential safety risks due to hydrogen's high combustion capabilities, the requirement for dedicated storage and delivery networks, and unclear regulations. In addition, the financial feasibility of hydrogen-fueled systems depends on the declining price of green hydrogen generation and favorable policy environments. Nevertheless, technological advancements and government policies, such as hydrogen mission plans and clean energy initiatives, create immense opportunities for hydrogen uptake in commercial kitchens (Galan, 2023).

2. Background of Study

The adoption of sustainable energy systems to reduce carbon emissions has become a pressing global priority in light of the rapidly worsening effects of climate change and the high levels of greenhouse gases emitted by energy-intensive industries. The hydrogen fuel has gained widespread recognition as an alternative clean energy technology that could effectively address the carbon footprint issue since it does not emit any carbon during combustion. Recent research underscores that hydrogen-fuel-powered systems could significantly contribute to emission reductions in multiple end-use sectors, including the cooking and heating sector (Zhao et al., 2025). Scientific literature shows that the harmful effect of gaseous combustion cooking can still be experienced despite attempts at mitigation through the installation of ventilation systems, indicating the necessity for cleaner alternatives (Ecostandard, 2024). Cooking solutions that use hydrogen as an energy source, and specifically catalytic combustion technology, represent an innovative option that results in water vapor release only. Therefore, the reduction of emissions and improvement of indoor air quality makes hydrogen-based cooking methods relevant to the problem (Kozhukhova et al., 2025). However, at the same time, it should also be acknowledged that hydrogen usage in kitchens entails both opportunities and threats, which must be understood to harness hydrogen's true potential (Vidal-Durango et al., 2024).

3. Scope and Significance of Study

The study involves an elaborate study on the use of hydrogen fuel as a renewable form of fuel in replacing fossil fuels in the process of decarbonizing commercial kitchen operations in particular the hospitality industry. The study focuses on the aspects involved in hydrogen fuel use from a technical point of view, environmentally as well as economically. The study delves into the processes involved in hydrogen production especially the production of green hydrogen, storage, combustion, and whether it is compatible with the existing commercial kitchen operations. The study analyzes the applications of hydrogen fuel in different types of operations such as hotels, restaurants, industrial kitchens, and caterers, all of which have high demand for energy and continuity of operations (IEA, 2023). Through the incorporation of both international and Indian points of view, the study assesses policy, initiatives by governments, and readiness of the industry to adopt hydrogen-based cooking practices. Besides the above, the study assesses the environmental impact of hydrogen fuel from a lifecycle perspective as compared to the traditional fossil fuels (IRENA, 2024).

The importance of this study is reflected not only in its contribution to the academic field but also in its practical applications in making policies within the sphere of sustainable energy and green hospitality practices. In terms of research contributions to the academic world, this study bridges an important research gap by exploring the specific issue of decarbonization of commercial kitchens, which is currently relatively poorly explored within the scope of energy transition researches. Moreover, by combining theories related to clean energy adoption with real-world knowledge about hydrogen technologies, the present study adds to the development of interdisciplinary research in such fields as energy studies, environmental management, and hospitality operations. Such solutions are especially important given the growing interest of many nations in achieving the goals of zero-net emissions and overall transition to clean energies (Staffell et al., 2024). (World Economic Forum, 2024).

4. Objectives of Study

- To examine the role of hydrogen fuel as a sustainable energy alternative for decarbonizing commercial kitchen operations
- To analyze the environmental impact of hydrogen-based cooking systems in comparison with conventional fossil fuel-based kitchen practices
- To evaluate the technological feasibility and operational efficiency of hydrogen fuel in commercial kitchen applications
- To identify the key challenges associated with the adoption of hydrogen fuel, including cost, infrastructure, safety, and regulatory barriers
- To explore emerging opportunities and innovations in hydrogen-based cooking technologies within the hospitality and food service sector
- To provide the better insights for the effective implementation of hydrogen fuel in achieving sustainable and low-carbon commercial kitchen operations

5. Review of Literature

Recent research about hydrogen as an energy source has brought to light the possibility of hydrogen being a transformational tool that could help decarbonize various industries with high energy requirements, such as commercial kitchens. It has been stated that hydrogen is a promising energy source in terms of being a zero-emission fuel source that would help replace existing fossil-based energy sources and serve for thermal purposes. Utilization of hydrogen in cooking equipment has been identified as one of the promising areas that require more exploration and research due to the potential energy savings and emissions reduction that this approach would allow. In addition, hydrogen possesses high energy density and low emissions from burning, which makes it suitable for continuous high-temperature cooking activities common in commercial kitchen environments (IEA, 2024).

Another research by IRENA (2023) analyzed the environmental impacts as well as health risks linked to conventional cooking fuels along with the benefits of hydrogen fuel alternatives. Research has shown that the use of conventional fuels for cooking results in significant indoor as well as outdoor air pollution caused by toxic substances including carbon monoxide, nitrogen oxides, and other particulates. As for the hydrogen-fuelled system, combustion yields water vapor only thus providing zero-emission technology and greatly improving indoor air quality. This technology can be especially useful in commercial settings where staff and guests are regularly exposed to such gaseous emissions. From an environmental perspective, hydrogen fuel systems can help reduce the overall carbon footprint of the hospitality industry.

The feasibility of hydrogen for use in cooking from a technological perspective has been widely studied, with particular emphasis on the issues associated with burner design, combustion process control, and safety considerations. According to recent scientific research, it is feasible to create burners compatible with hydrogen in order to guarantee proper flame characteristics, energy-efficient heat transfer processes, and reduction in pollutants emissions. Nevertheless, the problems of flame invisibility, extremely high diffusivity, and greater danger of leaking pose additional technical and safety concerns that need to be addressed through further engineering innovations. Several experiments proved that adjustments made in the burner designs and combustion setups help avoid the mentioned threats without compromising efficiency. (Kobayashi et al., 2023).

According to the economics literature, the expense of generating, storing, and distributing hydrogen is still considered a major hindrance to its large-scale utilization in business settings. While green hydrogen may be eco-friendly, it is more costly compared to other forms of fuel because of the huge capital requirement for building electrolyzers and renewable energy generators. Moreover, the absence of efficient channels of distribution and refueling stations is another impediment to hydrogen's utilization in kitchens (Staffell et al., 2023). The financial incentives and policies have been cited as important factors in facilitating hydrogen use in the energy sector.

National hydrogen programs, such as those of India, Germany, and Japan, seek to encourage production, distribution, and application of green hydrogen in different sectors, including cooking and heating. Policy frameworks stress the need for public-private collaboration and research, as well as infrastructure development that is necessary for encouraging hydrogen adoption. In addition, international cooperation and financial strategies are implemented to support the transfer of information and knowledge related to hydrogen fuel technology. Consequently, policy actions result in an enabling framework that facilitates integration of hydrogen fuels in commercial kitchens for sustainable energy shifts (World Economic Forum, 2023).

The introduction of hydrogen technology and fuels into cooking and heating is not just a matter of introducing new technologies but also requires organizational changes, personnel training, and changes in stakeholders' attitudes to new opportunities. For the safe use of hydrogen fuel in the kitchen, the manager of the business kitchen needs to know about the risks and opportunities of hydrogen fuel. It should also be noted that the implementation of hydrogen fuel into commercial kitchens necessitates the creation of a set of norms and standards that will help avoid any safety problems (Van Renssen, 2024).

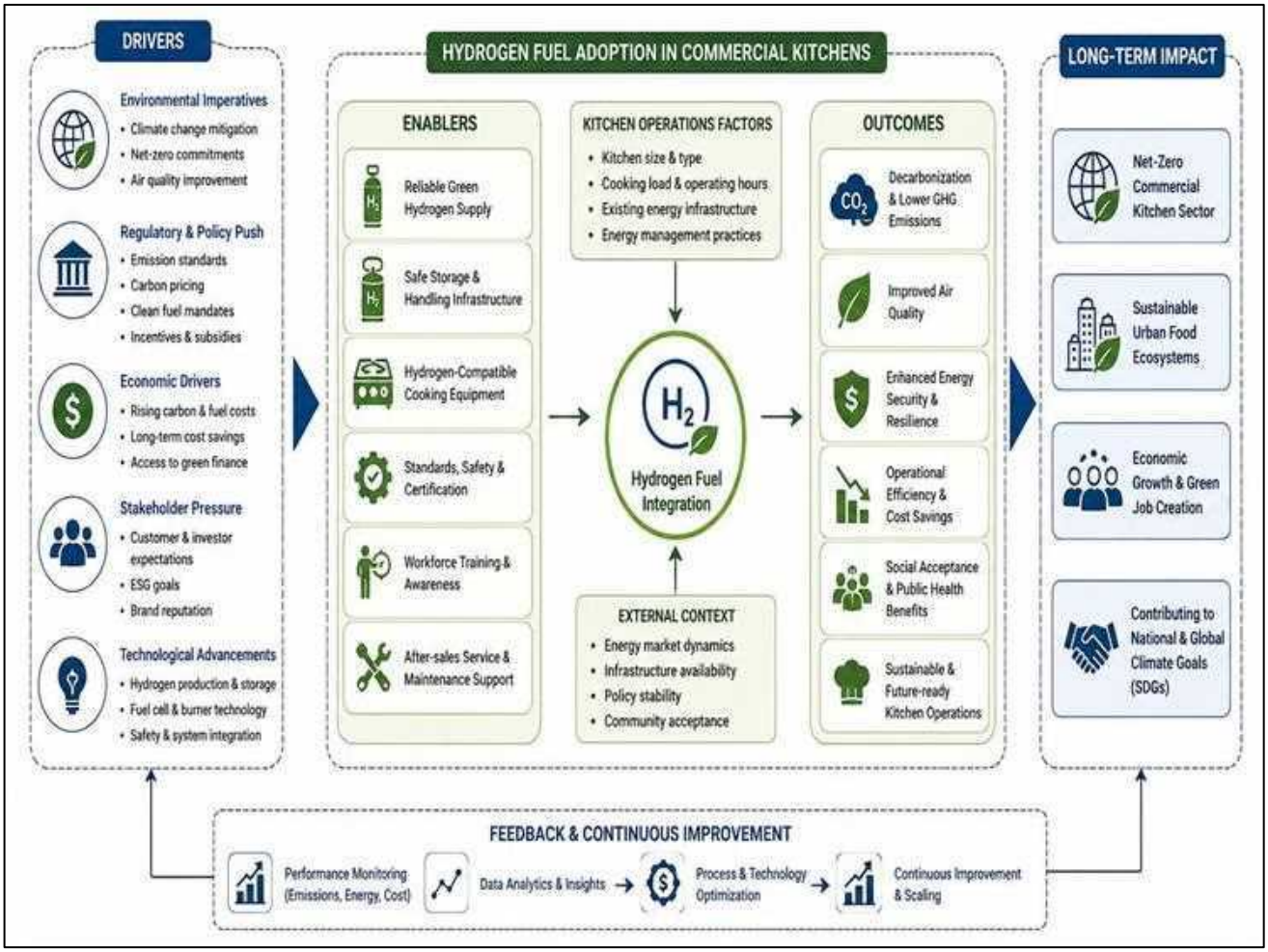
6. Discussion and Analysis

Analysis of hydrogen fuel as an alternative technology for decarbonization in commercial kitchens shows remarkable compatibility with worldwide climate change mitigation approaches and energy transition processes. The energy demands characteristic of commercial kitchens create favorable conditions for using hydrogen energy in such facilities. As is mentioned above, modern studies on energy transition prove that hydrogen may be effectively used for decarbonization of energy-consuming processes (IEA, 2025). Technologically speaking, hydrogen-fired cooking devices have demonstrated considerable development regarding improvements in their combustion efficiency, lower emission levels, and operational capabilities. Technical solutions related to new hydrogen burners, catalytic combustors, and fuel cell power sources make hydrogen usage more feasible at high temperatures. According to current studies, innovative burner designs and advanced safety controls help cope with these problems successfully and enable reliable and efficient use of hydrogen for combustion purposes (Balat, 2024). The

use of hydrogen fuel in commercial kitchens will face challenges in the short term while providing numerous opportunities in the long term (BloombergNEF, 2024).

It is pertinent to mention here that policy and regulation have a pivotal role to play in ensuring that hydrogen fuel technology can be widely adopted within commercial kitchen settings. Countries around the world are increasingly realizing the importance of hydrogen fuel technology in their efforts to make the energy transition, which is why they are enacting various policies to encourage the development of hydrogen technologies. The development of national hydrogen strategies, funding schemes, and regulatory frameworks is helping countries overcome various obstacles such as infrastructure, safety regulations, and market development. (IEEFA, 2024). While the implementation of hydrogen fuel in commercial kitchens is highly beneficial, its adoption will require an integrated strategy combining technology and economics among other aspects (IRENA, 2025)

Figure 1: Commercial Kitchens through Hydrogen Fuel



(Source: Author's Self-Interpretation)

7. Findings of Study

- It is revealed that there is great potential for reducing carbon dioxide emissions in commercial kitchens through the use of hydrogen as fuel due to its emission-free characteristics and lower greenhouse gases when produced using renewable energy. The findings show that hydrogen burning has no carbon emissions, and the amount of greenhouse gas emissions is significantly minimized when hydrogen is used compared to LPG and natural gas, which makes hydrogen an ideal fuel for realizing the sustainability goals of the industry.
- One of the most important conclusions from the study is that hydrogen fuel cooking technology is technically feasible despite needing many technological innovations. It is established that hydrogen cookers have been found to be able to generate heat with minimum pollutant emissions. Nevertheless, issues such as difficulty controlling the hydrogen flames, leakages, and material compatibility continue to pose challenges to this technology.
- The study further emphasizes the role of economic feasibility as a key deciding factor when it comes to the use of hydrogen fuel in commercial kitchens. This is because there currently exist some barriers with regard to cost due to expensive green hydrogen production and the inadequacy of its infrastructure.
- The presence of policy support is revealed as yet another key element affecting the use of hydrogen fuel. It is shown by the study that government policies related to national hydrogen missions and clean energy policies are highly important when it comes to the promotion of hydrogen energy generation and consumption.
- The socio-technical readiness becomes one of the critical elements contributing to successful hydrogen transition in commercial kitchen operations. Hydrogen fuel adoption requires certain shifts to be made in operational processes and employee training.

8. Conclusion

This research shows that hydrogen fuel has an immense potential in the decarbonization of commercial kitchens, especially in industries that are considered energy-intensive, including the hospitality industry and institutional food service facilities. The shift from the existing fossil fuel systems towards hydrogen fuel systems could help in cutting down carbon emissions, improving indoor air quality, and making the commercial sector work in accordance with the international climate change agenda. It becomes clear that hydrogen can become a very effective and efficient option for providing heat in commercial kitchens due to its high thermal capacity. Nevertheless, it is important to understand that the success of the process depends on various factors, such as the application of sustainable production techniques, efficient delivery methods, and innovative cooking equipment. Collaboration between private companies and governments, conducting pilot projects, and developing demonstration programs would be critical for promoting hydrogen as an innovative technology in commercial kitchens. Furthermore, the role of national policies regarding hydrogen fuels and the implementation of clean energy strategies should be recognized since these factors could facilitate the development of hydrogen fuel applications in commercial settings. The hydrogen fuel could become a viable long-term strategy for decarbonizing commercial kitchens effectively.

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