Halal with Hydrogen: A Sustainable Energy Paradigm for a Low-Carbon Future

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ABSTRACT

As the world confronts the pressing realities of climate change and energy insecurity, the role of hydrogen, particularly green hydrogen, is becoming pivotal in the global energy transition. Hydrogen holds immense potential as a clean energy carrier that can facilitate the decarbonization of hard-to-abate sectors like industry, transportation, and heavy manufacturing. This paper explores the possibility of integrating hydrogen technologies into the Halal framework, a concept traditionally confined to food and finance. Halal, in the context of energy, entails adherence to Islamic principles of sustainability, responsible resource management, and fairness in production and distribution processes. Muslim-majority countries, particularly members of the Organisation of Islamic Cooperation (OIC), have the potential to lead the hydrogen economy, leveraging their vast renewable energy resources to produce Halal-certified hydrogen. This integration could enable these nations to meet their decarbonization goals while ensuring compliance with Shariah principles. Moreover, the paper explores the role of Islamic finance, particularly Sukuk (Islamic bonds), in funding hydrogen infrastructure, thereby aligning financial investments with Islamic ethical principles. By establishing Halal certification standards for hydrogen, OIC countries can position themselves as leaders in the global energy transition. This paper provides policy recommendations for the development of hydrogen technologies in OIC countries, addressing the challenges of technology, market development, and regulation. It also explores the opportunities for collaboration among OIC nations, which could catalyse the creation of a Halal hydrogen market that aligns with both Islamic values and global sustainability goals.

1. Introduction

As climate change accelerates, with rising global temperatures, extreme weather events, and increasing pressure on natural resources, the urgency for clean energy alternatives has never been greater. The **Paris Agreement** mandates that nations worldwide reduce their carbon emissions to limit global warming to well below 2°C above pre-industrial levels, ideally 1.5°C. Achieving these targets requires a massive shift from fossil fuel-based energy systems toward clean, renewable sources such as solar, wind, and hydrogen.

Hydrogen, especially green hydrogen, is emerging as a critical player in the energy transition. Green hydrogen, produced via electrolysis using renewable energy, is entirely carbon-free and offers a versatile solution for decarbonizing sectors that are challenging to electrify, such as heavy industry,

maritime shipping, and aviation. However, the widespread adoption of hydrogen faces significant technological, economic, and regulatory challenges.

Simultaneously, the Islamic world, comprising 57 member states of the **Organisation of Islamic Cooperation (OIC)**, is seeking ways to integrate sustainable practices into their economic and social systems. Many of these nations are richly endowed with renewable energy resources and have growing ambitions to reduce their carbon footprints in line with global climate targets. However, energy policies in Islamic nations must align with the ethical and legal framework provided by Shariah law, which governs various aspects of Muslim life, including economics, food, and finance.

This paper proposes the integration of **hydrogen energy** within the **Halal** framework. Traditionally associated with food and finance, the concept of Halal can be extended to encompass energy production, ensuring that the hydrogen produced is not only sustainable but also ethically and morally aligned with Islamic principles. This integration provides a unique opportunity for OIC countries to lead the global energy transition while maintaining their adherence to Islamic values.

1.1. Research Questions

a. How can the **Halal framework** support the adoption of **hydrogen** as a clean energy source?
b. Can **Halal-certified hydrogen** become a key driver in the decarbonization efforts of OIC countries?
c. What policy frameworks are necessary to integrate **Islamic ethical principles** into the **global hydrogen economy**?

These questions serve as the foundation for this study, offering insights into how hydrogen technologies can be adapted and certified under the Halal framework, and how Islamic finance can facilitate the funding of clean energy infrastructure.

2. Islamic Ethical Framework and Sustainability

Islamic teachings provide a comprehensive ethical framework that can guide the development and deployment of sustainable energy technologies. Central to this framework is the concept of **Khilafah** (stewardship), which establishes the duty of Muslims to protect and preserve the environment. The Qur'an emphasizes that human beings are entrusted by Allah with the care of the Earth, and they must act as stewards, ensuring that natural resources are managed responsibly. This principle is particularly relevant in the context of energy, where the exploitation of fossil fuels has led to environmental degradation, pollution, and climate change.

2.1. Maqasid al-Shariah and Environmental Ethics

The **Maqasid al-Shariah** (objectives of Islamic law) offer a moral compass for addressing contemporary challenges, including those related to environmental sustainability. The five primary objectives of Shariah—protection of life, intellect, religion, lineage, and property—are all directly or indirectly linked to environmental health. By preserving natural resources and promoting clean energy, Muslims fulfill their duty to protect life (Hifz al-Nafs) and property (Hifz al-Mal), while ensuring that future generations inherit a habitable planet.

In his work on environmental ethics, **Seyyed Hossein Nasr** highlights the importance of spiritual and ethical awareness in confronting ecological crises. Nasr argues that modern environmental problems stem from a disconnection between humanity and the natural world, a relationship that Islam seeks to restore through the principles of Khilafah and Amanah. **Ibrahim Ozdemir** echoes this sentiment, noting that Islamic teachings offer a moral foundation for sustainable development, including the responsible use of energy resources.

2.2. Amanah and Resource Management

Amanah (trust) is another key principle that guides the Islamic approach to sustainability. As trustees of the Earth, Muslims are required to manage resources prudently, avoiding waste (Israf) and ensuring that their actions do not harm future generations. This concept aligns with the goals of the **circular economy** and **zero-waste initiatives**, which aim to minimize resource depletion and reduce environmental harm.

In the context of energy, Amanah requires that Muslims seek out clean, renewable sources that minimize environmental impact and contribute to long-term sustainability. Hydrogen, particularly **green hydrogen**, aligns with this principle as it produces no greenhouse gas emissions and offers a sustainable alternative to fossil fuels. Moreover, the production of green hydrogen using renewable energy sources such as wind and solar ensures that resource consumption is kept within sustainable limits, in line with the Islamic mandate to avoid excess (Ghuluw).

2.3. Sustainability and Halal Energy

The Islamic world has traditionally applied the concept of Halal to food and finance, but there is growing recognition that Halal principles can extend to other sectors, including energy. In the context of hydrogen, **Halal certification** would ensure that the production process adheres to Islamic ethical standards, including sustainability, responsible resource use, and the protection of public welfare. **Halal hydrogen** would need to be produced using clean, renewable energy sources and must minimize harm to the environment and human health.

The development of a Halal-certified hydrogen industry could position OIC countries as leaders in the global energy transition. By integrating Islamic ethical principles into hydrogen production, Muslim-majority nations can ensure that their energy strategies align with both global sustainability goals and the values of Shariah.

3. The Role of Hydrogen in a Low-Carbon Future

The design of official non-halal labels is carried out to ensure that Muslim consumers receive clear and reliable information regarding the halal status of food and drinks in restaurants. The following are the stages of the concept for designing an official non-halal label based on three categories: Non-Halal, Halal in Registration, and Halal Be Confirmed.

Hydrogen is increasingly recognized as a key solution for decarbonizing sectors that are difficult to electrify. Unlike battery-electric technologies, which are suitable for short-distance transportation and low-energy applications, hydrogen offers a higher energy density and can be used in a wide range of applications, from heavy industry to long-haul transport.

3.1. Hydrogen Production Pathways

There are several methods of hydrogen production, each with varying levels of carbon intensity:

- **Green hydrogen**: Produced via electrolysis powered by renewable energy sources (e.g., solar, wind, hydropower), green hydrogen is the most environmentally sustainable option. It emits no carbon dioxide (CO_2) during production or use, making it ideal for decarbonizing the energy sector.
- **Blue hydrogen**: Produced from natural gas with the application of **carbon capture and storage (CCS)** technology. While blue hydrogen reduces emissions, it still relies on fossil fuels, making it less sustainable than green hydrogen.

- **Grey hydrogen**: Produced from fossil fuels (usually natural gas) without any emissions mitigation. Grey hydrogen is the most carbon-intensive form of hydrogen and is inconsistent with the goals of a low-carbon future.

Of these, **green hydrogen** offers the greatest potential for reducing global carbon emissions. According to the **International Energy Agency (IEA)**, green hydrogen has the potential to play a significant role in achieving net-zero emissions by 2050, particularly in sectors that are difficult to decarbonize, such as steel production, cement manufacturing, and heavy transportation (IEA, 2022).

3.2. Hydrogen in Industry

Hydrogen is particularly valuable in the industrial sector, where it can be used as a feedstock for chemical production, as a reducing agent in steelmaking, and as a fuel for high-temperature processes. The decarbonization of industries like steel and cement is crucial to achieving global climate targets, as these sectors are responsible for a significant portion of global CO_2 emissions. **Green hydrogen** offers a pathway for reducing emissions in these sectors by replacing carbon-intensive fuels and feedstocks.

In the steel industry, for example, hydrogen can be used as a reducing agent in place of coke (a form of coal) in the production of **direct reduced iron (DRI)**. This process emits significantly less CO_2 than traditional methods of steel production, making it a key technology for decarbonizing the sector. Similarly, hydrogen can be used as a fuel in cement kilns, reducing the carbon footprint of cement production.

3.3. Hydrogen in Transportation

The transportation sector is another key area where hydrogen can play a transformative role. While battery-electric vehicles (BEVs) have gained popularity for short-distance transport, hydrogen fuel cells offer advantages for long-distance, heavy-duty transport, such as trucks, buses, and ships. **Fuel cell electric vehicles (FCEVs)** powered by hydrogen can travel longer distances on a single charge and can be refueled quickly, making them suitable for applications where battery-electric vehicles may not be practical.

According to the **Hydrogen Council**, a global initiative of leading energy, transportation, and industrial companies, hydrogen could account for up to 18% of total global energy demand by 2050, with the potential to reduce CO_2 emissions by 6 gigatons annually (Hydrogen Council, 2021). The deployment of hydrogen in sectors such as heavy transport, shipping, and aviation is essential to achieving these emission reductions.

3.4. Challenges in Hydrogen Adoption

Despite its potential, the adoption of hydrogen faces significant challenges. **Storage** and **transportation** of hydrogen are technically complex and costly due to its low energy density and highly flammable nature. Hydrogen must be stored under high pressure or in liquefied form, which requires specialized infrastructure that is not yet widely available.

Transporting hydrogen over long distances also presents challenges, as it is less energy-dense than other fuels. Pipelines designed for natural gas may need to be retrofitted or replaced to accommodate hydrogen, and new refueling infrastructure will need to be developed for hydrogen-powered vehicles.

Addressing these challenges requires substantial investment in **research and development**, as well as the establishment of **clear regulatory frameworks** to govern the production, storage, and distribution of hydrogen. Technological advances in **hydrogen storage** and **transport**, such as solid-state storage or ammonia-based storage, may help overcome some of these obstacles, but these technologies are still in the early stages of development.

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4. Halal Certification for Hydrogen Technologies

The concept of **Halal certification** has traditionally been applied to food and finance, ensuring that products and financial instruments comply with Islamic principles. However, the Halal certification process can be expanded to include energy production, particularly hydrogen, to ensure that energy sources are ethically produced and environmentally sustainable.

4.1. Defining Halal Hydrogen

Halal hydrogen would be produced using renewable energy sources, such as wind, solar, or hydropower, in a manner that aligns with Islamic ethical standards. This includes adherence to principles of environmental stewardship (Khilafah), responsible resource management (Amanah), and the avoidance of harm to future generations. The use of green hydrogen, which emits no greenhouse gases, would be consistent with these principles, as it minimizes harm to the environment and promotes long-term sustainability.

A Halal-certified hydrogen industry would also ensure that the entire value chain, from production to distribution, adheres to Islamic ethical standards. This would include ensuring that workers are treated fairly, that resources are managed responsibly, and that the production process minimizes waste and environmental harm. In this way, Halal certification can serve as a tool for promoting ethical energy production in line with both Islamic values and global sustainability goals.

4.2. Developing Halal Certification Standards

The development of **Halal certification standards** for hydrogen technologies will require collaboration between **Islamic scholars**, **scientists**, and **industry leaders**. Islamic scholars will need to work with energy experts to understand the technical aspects of hydrogen production and to ensure that the certification process is scientifically rigorous. Industry leaders, meanwhile, will need to engage with regulatory bodies and certification agencies to establish best practices for Halal hydrogen production.

This collaboration could result in the creation of **Halal energy certification bodies**, which would oversee the certification process and ensure that hydrogen producers adhere to the ethical and environmental standards outlined in the Halal framework. These bodies could also provide guidance to OIC countries on how to integrate Halal-certified hydrogen into their national energy strategies.

The certification process would likely involve **audits** of hydrogen production facilities, assessments of the energy sources used, and evaluations of the overall environmental impact of the hydrogen production process. By ensuring that hydrogen is produced in a manner consistent with Islamic values, OIC countries can differentiate their hydrogen products in the global market, positioning themselves as leaders in the production of clean, ethical energy.

5. Hydrogen Economy and the Islamic World

The **Organisation of Islamic Cooperation (OIC)**, which represents 57 member states, many of which are rich in renewable energy resources, has the potential to play a leading role in the global hydrogen economy. Several OIC nations, including **Saudi Arabia**, **Malaysia**, and the **United Arab Emirates**, are already investing in hydrogen technologies, making them key players in this emerging sector.

5.1. Saudi Arabia's NEOM Project

One of the most ambitious hydrogen projects in the world is **Saudi Arabia's NEOM** project, a $500 billion futuristic city that aims to be powered entirely by renewable energy, including **green hydrogen**. The NEOM project, part of **Saudi Vision 2030**, seeks to diversify the Kingdom's

economy away from oil dependence and toward renewable energy sources. NEOM's hydrogen production will rely on Saudi Arabia's vast solar and wind resources to produce green hydrogen via electrolysis, which can then be used to power vehicles, industries, and even entire cities.

The Kingdom's **Public Investment Fund (PIF)**, along with international partners, is financing the development of NEOM's green hydrogen infrastructure. The project is expected to produce 650 tons of green hydrogen per day by 2025, making it one of the largest hydrogen projects in the world. This positions Saudi Arabia as a global leader in the hydrogen economy and demonstrates the potential for OIC countries to leverage their renewable energy resources for hydrogen production.

5.2. Malaysia's Hydrogen Strategy

Malaysia, a global leader in **Halal certification**, is also positioning itself as a key player in the hydrogen economy. The Malaysian government's **National Hydrogen Economy Strategy**, launched in 2020, focuses on promoting the production of **green hydrogen**, particularly in the state of **Sarawak**. Sarawak, which has abundant hydropower resources, is using its renewable energy capacity to produce green hydrogen via electrolysis.

The Sarawak government has already established partnerships with international companies, including **Linde** and **Sumitomo**, to develop hydrogen infrastructure. These partnerships aim to scale up the production of green hydrogen for both domestic use and export, positioning Malaysia as a regional hub for hydrogen production and distribution.

5.3. Islamic Finance and Hydrogen

Islamic finance offers a unique opportunity to fund hydrogen projects in a manner that aligns with Shariah principles. Instruments such as **green Sukuk** (Shariah-compliant bonds) have already been used to finance renewable energy projects in OIC countries, and they could also be used to fund hydrogen infrastructure. **Green Sukuk** provide an ethical alternative to conventional bonds, ensuring that investments are made in projects that promote environmental sustainability and social welfare.

By issuing green Sukuk to fund hydrogen projects, OIC countries can attract ethical investors who are looking to support clean energy initiatives while adhering to Islamic values. In 2017, **Malaysia** issued the world's first **green Sukuk** to finance renewable energy projects, setting a precedent for other OIC countries to follow. **Indonesia**, **Saudi Arabia**, and the **United Arab Emirates** have since followed suit, issuing green Sukuk to fund solar, wind, and other renewable energy projects.

The use of Islamic finance to fund hydrogen projects could help OIC countries overcome the financial barriers to hydrogen adoption, while ensuring that investments are made in a manner consistent with Islamic ethical principles.

6. Challenges and Policy Recommendations

While the integration of hydrogen technologies into the Halal framework offers significant opportunities for OIC countries, it also presents several challenges. These challenges include the high cost of green hydrogen production, the lack of hydrogen infrastructure, and the need for regulatory frameworks to govern the production, storage, and distribution of hydrogen.

6.1. Challenges in Scaling Hydrogen

High Production Costs: Green hydrogen is currently more expensive to produce than blue or grey hydrogen, due to the cost of renewable energy and the inefficiency of electrolysis technologies. Governments will need to provide financial incentives, such as subsidies or tax breaks, to make green hydrogen cost-competitive with fossil fuels.

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Lack of Infrastructure: The widespread adoption of hydrogen requires the development of new infrastructure, including pipelines, storage facilities, and refueling stations. Building this infrastructure will require significant investment and collaboration between governments, industry, and international partners.

Regulatory Frameworks: Clear regulatory frameworks are needed to govern the production, storage, and distribution of hydrogen. These frameworks should ensure that hydrogen is produced in a manner consistent with environmental and ethical standards, while also providing guidance on safety and security.

6.2. Policy Recommendations

To overcome these challenges, the following policy recommendations are proposed:

1. **Subsidies for Green Hydrogen**: Governments in OIC countries should provide financial support for green hydrogen projects, including subsidies for renewable-powered electrolysis plants and tax incentives for companies that invest in hydrogen infrastructure.
2. **Development of Hydrogen Infrastructure**: OIC governments should collaborate with the private sector and international partners to develop hydrogen storage, pipelines, and refueling stations. This will require significant investment in research and development, as well as public-private partnerships.
3. **Halal Hydrogen Standards**: Islamic scholars, industry leaders, and regulatory bodies should work together to develop Halal certification standards for hydrogen technologies. These standards should ensure that hydrogen is produced in a manner consistent with Islamic ethical principles, while also promoting environmental sustainability.
4. **Islamic Finance for Hydrogen**: OIC countries should leverage Islamic finance instruments, such as green Sukuk, to fund hydrogen projects. This will attract ethical investors and provide a Shariah-compliant alternative to conventional finance.

7. Conclusion

To successfully navigate the path towards a low-carbon future, it is essential to adopt innovative solutions that address the challenges posed by hard-to-decarbonize sectors. Hydrogen, particularly green hydrogen, presents itself as a transformative force in achieving global net-zero emissions goals. For OIC (Organization of Islamic Cooperation) countries, this transition carries even greater significance as it provides an avenue to integrate cutting-edge technology within the Halal framework, aligning economic growth with Islamic ethical values. By developing Halal-certified hydrogen, these nations can address global energy demands in an environmentally responsible manner, while ensuring compliance with religious principles. Islamic finance, known for its principles of risk-sharing and ethical investment, can serve as a robust financial engine to fund hydrogen infrastructure and innovation. Green bonds, Sukuk, and other Shariah-compliant financial instruments offer attractive mechanisms to pool resources for the development of a hydrogen economy, fostering cross-border collaborations and partnerships among OIC nations.

Moreover, the investment in hydrogen production, distribution, and storage infrastructure will not only contribute to energy security but will also create economic opportunities, foster industrial growth, and provide a sustainable future for generations to come. The early adoption of hydrogen technologies by OIC countries can position them as leaders in the emerging global hydrogen market, offering Halal-certified solutions that meet both ethical and environmental standards.

However, this transition is not without its challenges. Significant investments are required in research and development and ensuring cost competitiveness remains crucial for large-scale hydrogen deployment. Additionally, the development of clear regulatory frameworks, standardization of Halal

certification for hydrogen, and fostering international partnerships will be pivotal. OIC countries must also overcome technical hurdles, build human capital, and create policies that incentivize innovation in hydrogen technology. Despite these challenges, the integration of hydrogen into the energy mix represents a profound opportunity for OIC countries. With the right strategic vision, policy support, and a focus on sustainable development, these nations can not only contribute significantly to the global low-carbon economy but also assert their leadership on the global stage. Hydrogen offers a pathway for the OIC to embrace a future that is not only technologically advanced but also ethically aligned, paving the way for a more sustainable and inclusive world.

In conclusion, the path toward a hydrogen-driven, low-carbon future presents both challenges and unparalleled opportunities for OIC countries. By combining Islamic finance, Halal certification, and investment in hydrogen infrastructure, the Islamic world is well-positioned to lead the charge in the global energy transition. With thoughtful policies, robust collaborations, and a commitment to ethical and sustainable practices, OIC nations can play a pivotal role in shaping a more sustainable, equitable, and carbon-neutral future for the world.

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