

GREEN TECHNOLOGY FRAMEWORK FOR HALAL INDUSTRY SUSTAINABILITY AND ECOSYSTEM PROTECTION



Mansur Muhammad and Safiullah Junejo

Abstract: Achieving a sustainable ecological system requires abandoning traditional environmental practices that historically relied on coal and fossil fuels, which release greenhouse gases that contribute to global warming and climate change. This study aims to extend green technological approaches necessary for industries, including the halal sector, to sustain the ecosystem in day-to-day operations. This research offers a novel and comprehensive approach by bringing together green technology, halal industry practices, and ecosystem protection, issues rarely addressed in the existing literature. The study employs qualitative documentary analysis to systematically collect, review, analyse, and interpret documents and texts, gaining insights into this specific phenomenon and its potential for fostering sustainability across various sectors. We extend key aspects of a green technology framework for sustainable halal industry and provide implementation strategies. A handful of international corporations have begun integrating renewable energy sources, such as solar and geothermal, into their operations. These efforts align with national and international calls for emissions mitigation and control. Critical green frameworks for a sustainable halal industry include green buildings, sustainable farming, efficient rendering processes, vermicomposting, waste incineration, and electric vehicle adoption. Moreover, environmental practices should become a criterion for halal certification to ensure future sustainability in the halal sector. Furthermore, policymakers and industry leaders should establish a dedicated Green Innovation Fund to support research and development of green technologies tailored to halal businesses. Implementing these strategies will require collaboration between government agencies, industry stakeholders, and research institutions. By prioritizing sustainability, the halal industry can reduce its environmental impact while meeting the growing demand for halal products and services. As the global community increasingly recognizes the urgency of addressing climate change, the halal industry has a unique opportunity to lead by example. By embracing green technologies and sustainable practices, it can demonstrate that halal industry growth and environmental stewardship can go hand in hand, setting a new standard for responsible business practices across sectors.

Keywords: Halal industry, green technology, sustainable farming, incineration, green fund

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1. Introduction

The halal industry is not confined solely to the food and beverage sector. Its scope and function extend across various sectors, including pharmaceuticals, finance, tourism, fashion, cosmetics, and all other industries that provide goods and services in compliance with Shariah law, catering to both Muslim-majority and non-Muslim-majority countries (Herindar, 2022; Judijanto et al., 2024). The industry has experienced remarkable growth, surpassing expectations over the past decade. The expenditure on halal goods and services has risen from \$1.62 trillion in 2012 to \$2.29 trillion in 2022, and it is projected to reach \$3.1 trillion by 2027, reflecting a 4.8% five-year growth rate (State of Global Islamic Economics, 2024). This rapid expansion underscores the increasing global demand for halal-compliant products and services, transcending religious boundaries and becoming a mark of quality assurance. The trend and development started over 1400 years ago when Allah, through his prophet, ordained halal to be an end to the means. This practice has spread across Europe and America. Non-Muslims have become aware and knowledgeable of their consumption due to Muslim enforcement and regulations on embracing halal in daily endeavours (Rejeb et al., 2021). However, to formalize and standardize the operation of the halal industry, some countries established halal certification institutions. In Singapore for example, halal operation has been managed and controlled under the authority of Majlis Ulama Islam Singapura (MUIS) since 1972 similarly, countries like Indonesia, and Thailand maintained an institution that provides certification to the goods and services that pass the criteria for being categorized as halal.

While this development is appreciable, researchers and policymakers in the sector are baffled by the issue of sustainability and environmental challenges (Abderahman et al., 2021; Abdullah et al., 2018). Issues in Muslims countries such as resource consumption, waste management, and environmental impact. High water usage and extensive land requirements for livestock farming contribute to water scarcity, deforestation, and habitat loss. Additionally, improper disposal of animal waste and by-products leads to pollution and greenhouse gas emissions. The industry's reliance on fossil fuels for production and transportation exacerbates its carbon footprint, while the need for renewable energy adoption remains pressing. Livestock farming's methane emissions and using fertilizers and pesticides for feed production further degrade the environment, and the fishing industry's practices threaten marine ecosystems. Moreover, the lack of standardized sustainability criteria within halal certification processes threatens its sustainability (Maulana et al., 2023). Furthermore, The global nature of the halal supply chain increases carbon emissions due to long-distance transportation and energy-intensive cold chain logistics.

Sustainability in the halal industry is crucial in that, it ensures the responsible use of resources such as water, land, and energy, which are critical for maintaining environmental balance and reducing the industry's ecological footprint (Trimulato et al., 2022). Sustainable practices in halal production can mitigate issues like deforestation, water scarcity, pollution, and greenhouse gas emissions, thereby preserving ecosystems and biodiversity. By adopting renewable energy sources and efficient waste management systems, the halal industry can significantly reduce its impact on climate change and environmental degradation (Nordin et al., 2022).

Green technology adoption is one key innovation towards addressing the challenge of sustainable practices in the industry and protecting the ecosystem. According to (UNCTAD, 2023) Green technology, also known as sustainable

technology or clean technology, refers to using science and technology to create products, processes, and systems that are environmentally friendly and promote sustainability. The primary goal of green technology is to reduce the negative impacts of human activities on the environment, conserve natural resources, and foster a more sustainable and resilient ecosystem. Sustainable halal production, distribution, and consumption can benefit immensely from technology that considers both present and future generations by conserving resources and fostering a sustainable environment. For instance, Boye & Arcand (2013) posited that green technology in food production could be achieved by utilizing small areas of land for farming and rearing animals with sophisticated chemicals and equipment - a form of organic farming that allows for forward and backward integration. Similarly, enzymes have proven to be reliable and sustainable in food processing; they are not only cost-effective and time-saving but also environmentally friendly (Simpson et al., 2012).

This research presents a unique and holistic approach by integrating green technology, halal industry practices, and ecosystem protection areas that are rarely explored together in the existing literature. To the best knowledge of the researchers, this is the first attempt to extend a green technological approach with special attention to the halal industry as the firms in the industry are getting bigger. By integrating these critical issues, there could be a solution to the growing demand for environmentally conscious practices in the halal sector, which has been underexplored in both academic research and industry implementation. The framework also supports broader sustainability goals, offering innovative solutions for reducing environmental impacts while maintaining compliance with halal principles.

The structure of this study is organized as follows: Section 1 provides an introduction to the study, outlining the background. Section 2 presents a comprehensive review of the relevant literature, critically analyzing existing research on green technologies in the halal industry and identifying the research gaps. Section three outlines the research methodology of this study. Section 4 presents the findings of the research and offers a thorough discussion. Finally, Section Five concludes the paper by summarizing key findings, addressing the research objectives, and proposing evidence-based policy recommendations for both industry stakeholders and policymakers. This section also acknowledges the limitations of the study and suggests directions for future research.

2. Literature Review

2.1 Theoretical Underpinnings

This study borrows leave from two major theories of business ethics and organizational management. firstly, stakeholder theory (ST) postulates that Stakeholder Theory posits that organizations should strive to create diverse value for a range of stakeholders. These stakeholders encompass any individuals or groups that can influence or be influenced by the organization's actions. This includes, but is not limited to, civil society organizations, local communities, customers, employees, governmental bodies, shareholders, and suppliers. The theory suggests that by considering and addressing the needs of this broad spectrum of stakeholders, rather than focusing solely on shareholder profits, organizations can achieve more sustainable and ethical success (Mahajan et al., 2023). Stakeholder Theory promotes

organizational value creation for both internal stakeholders (e.g., employees, shareholders) and external stakeholders (e.g., customers, communities, suppliers). Protection strategies include fair compensation, safe working conditions, quality products, environmental stewardship, and regulatory compliance (Friedman & Miles, 2002).

Effective implementation involves regular stakeholder analysis, formal engagement processes, and integrating stakeholder interests into decision-making and performance metrics. This balanced approach, considering all stakeholders rather than just shareholders, leads to more sustainable and ethical business practices (Freeman, 2010). The halal industry being one of the major players in Muslim and non-Muslim countries is not an exception, especially in connection with sustaining the ecosystem. However, implementing green technologies in the operational management of the halal industry is a responsibility fulfilment to diverse groups. Such action can be translated to mean complementing the effort of the government towards achieving a sustainable environment. In this regard, halal industry has stakeholder responsibility on individuals, its employees, society and the government by utilization of human and natural resources in a sustainable manner.

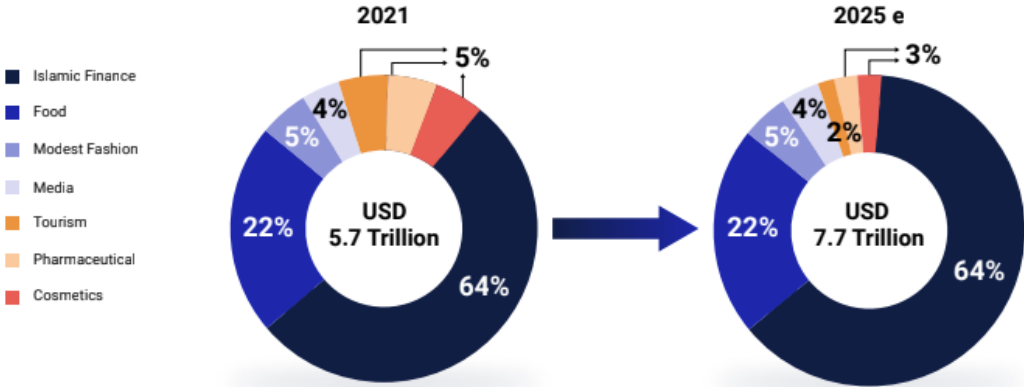
Secondly, according to resource-based theory, a company may gain a competitive advantage over its rivals by possessing strategic resources (Acedo et al., 2006). This theory emphasizes the importance of strategic assets that enable firms to adopt new technologies, invest in research and development, or acquire resources that offer a competitive edge (Olavarieta and Ellinger 1997). Implementing green technology for environmental sustainability can be costly, and not every firm may be able to undertake this as a social responsibility. However, early adoption and a well-planned strategy to integrate such actions into decision-making processes can help organizations achieve their goals of operating green buildings and implementing renewable technologies.

2.2 Economic significance of the Halal industry globally.

The State of the Worldwide Islamic Economy Report (GIE) 2022 portrays a dynamic perspective on the global halal business, anticipating an upward trajectory despite adverse economic backdrops. The halal business has increased dramatically, with an expected 1.9 billion Muslims spending around US\$ 2.0 trillion in 2021, with a compound annual growth rate (CAGR) of 8% between 2015 and 2021 (Shafaki, 2023). The Muslim population's rapid growth and devotion to standards drive the halal industry's expansion. According to the Pew Research Center, the Muslim population is expected to increase at a CAGR of 1.8% between 2020 and 2025, outpacing the world population's 1.1.% (Pew Research Center, 2024). Therefore, demand for halal products/commodities goes beyond Muslim societies globally, with halal items obtaining popularity due to their perceived cruelty-free and environmentally beneficial characteristics.

Globally, national plans for expanding the halal industry rapidly contribute to the significant development of this sector. Several countries worldwide are aggressively pursuing strategies/plans to increase the production and availability of halal products and services with its required halal legislation. Meanwhile, the halal industries are embracing technology, with a crucial attempt to develop a halal digital ecosystem through online connections, platforms, and services (Harsanto et al., 2024).

Even with the beneficial trend, halal businesses encounter regulatory hurdles, which include complicated standards that vary by country and area. Amendments to regulations may significantly influence economic prospects, especially if they raise production costs or restrict market access. Interestingly, the entire market size of the halal industry, including financial assets, is predicted to expand to US\$ 7.7 trillion in 2025, higher than 5.7 trillion in 2021 (Consultancy. Asia, 2023).



Source: Global Islamic Economy 21/22, Global Islamic Report 16/17

The Organization of Islamic Cooperations (OIC) and its prominent member nations, especially Southeast Asia, significantly influence worldwide halal industry developments. Malaysia has a halal market that contributes roughly 7.5% of its GDP, with a 20.8 million Muslim population (MRI, 2024). It is well known worldwide, ranking first in halal travel and food and second in halal medicines, with US\$ 31.3 million global halal export value. Notably, Indonesia tops the world's halal expenditure at 11%, with 236 million Muslim population. The halal market in Indonesia is valued at US\$ 65.4 billion, and it ranks second in halal food globally and modest fashion third (Yana, 2023). As an emerging player in the halal industry, Brunei specializes in halal food, medicines, and cosmetics, a smaller but still growing company. It adopts digital approaches to get halal certification and considers collaborative agreements with Malaysia and Indonesia (Sulaiman et al., 2023). Globally, the implications of the halal industry landscape have significant consequences.

OIC member nations, which account for 85% of the world's Muslim population, are crucially expected to grow faster than the global average GDP growth. Collaboration and cooperation among OIC member nations, particularly Malaysia and Indonesia, may boost intra-OIC halal trade and capitalize on each country's comparative advantages. As the halal industry continues to grow constantly, these Southeast Asian countries, with their current status/expertise and also strategic positions, are well positioned to overcome trade gaps and capitalize on untapped prospects for such development and cooperation.

2.3 Sustainability in the Halal Industry and Standardization

Sustainability in the halal industry has drawn critical attention as key players comprehend the urgency of aligning halal practices with environmental and ethical

challenges. In this context, the notion of sustainability includes not only environmental stewardship but also social and economic dimensions to ensure that halal commodities and services meet current demands without threatening future generations to meet their own (Talib & Zulfakar, 2023).

Globally, the halal industry is a rapidly growing sector with rising consumer demand, which provides both possibilities and challenges to sustainability. Integrating green technology is critical for promoting sustainability in the halal industry. Dasarathy et al. (2023) emphasized that green technology refers to technologies and practices that decrease environmental impact and efficiently enhance resources. The significant integration of green technology into halal production methods has the potential to drastically lower waste carbon emissions and enhance the overall sustainability of this industry (Junejo et al., 2023). Constructively, consuming renewable energy sources such as solar and wind power in halal-certified farms and companies could help reduce dependency on fossil fuels and greenhouse gas emissions, which are not eco-friendly.

Moreover, Pratikto et al. (2021) highlighted that sustainability in halal industries entails ethical animal care and equitable labor practices. Halal values are strongly aligned with humane animal care, and adopting high animal welfare requirements may boost halal productivity's ethical standards. Fair labor strategies are critical to the industry's societal sustainability, ensuring that workers participating in the production process of halal commodities are treated appropriately and have safe working conditions.

Regulatory frameworks and certification requirements are essential to ensure sustainability in the halal industry. Several governments have established halal certification agencies that include sustainability requirements in their certification procedures. For instance, Malaysia's Halal Industry Development Corporation (HDC) stresses sustainability while providing halal certification, encouraging ecologically friendly and socially appropriate strategies. Such regulations guarantee that halal products/commodities fulfill extensive criteria addressing religious and environmental tensions (HDC, 2023).

Ardiantono et al. (2024) described that the halal industry confronts numerous challenges in reaching recognizable sustainability, including differences in regulatory standards across countries, which may impede global trade and certification procedures. Therefore, integrating sustainable practices and advanced technologies might be prohibitively expensive for small and medium-sized enterprises (SMEs) in halal industries. To address such worries, the industry's key players, governments, and also international organisations must build collaboration to standardized guidelines and provide financial and technical assistance to SMEs. These practices and standards are crucial to the rapid growth of this industry while adhering to the value of ecological stewardship, social accountability, and economic possibility.

Therefore, adopting green production methods is one of the most critical sustainability strategies in the halal industry. Green production entails employing eco-friendly technology and techniques to decrease waste and carbon emissions. According to Ali et al. (2023), most halal-certified farms and food processing industries are adopting renewable energy sources such as solar and wind energies to mitigate the high levels of reliance on nonrenewable energy sources. Also, measures such as efficient irrigation methods and treatment of wastewater to recycle the water are being practised to mitigate water shortage.

However, ethical treatment or animal welfare is, in fact, another fundamental

aspect of sustainability of the industries that mass produce halal products. There are inherent features of Halal that allow for fair care of livestock, and at the moment, these characteristics are being developed, adding new aspects to the animal's welfare. The critical standards help to guarantee that production and processing procedures are put in place to minimize the stress and suffering of the animals before they are slaughtered. Through its Department of Islamic Development (JAKIM) certification authorities, an investigative urge for ethical animal treatment throughout the supply chain (Ali et al., 2021).

Green packaging is also receiving vast adoption in applying the halal system at an expanding rate. Abdullah et al. (2018) have noted that, from a global perspective, most of the related halal industries are now adopting biodegradable and recyclable packaging materials due to their environmental impact. This integration serves the customer's concern regarding plastic waste in the market while adhering to global sustainability standards. Some halal food producers have proceeded even further by ensuring they use environmentally friendly biodegradable plant-based packaging material, reducing the amounts of packaging waste that goes to landfills.

Some organizations have adopted sustainability standards concerning the all-halal sector, the sustainability strategy formulated for the global halal industries is an environmentalist perspective of sustainability enhanced by social justice and economic progress. This framework encourages halal firms to adopt plans that preserve resources to offer decent working conditions while supporting communities' financial issues. Therefore, associations like the Islamic Chamber of Commerce, Industry, and Agriculture (ICCIA) promote sustainable standards by providing training to the halal industries and the resources needed to implement such practices effectively (ICCIA, 2022).

It is also a fact that national initiatives are essential in the context of setting up and sustaining the long-term standards of the halal sector worldwide (Islam et al., 2023). For instance, Indonesia's Halal Product Assurance Agency (BPJPH) added sustainability standards to the requirements for halal certification. Such standards include ecological standards that require a firm production process to be ecologically friendly or sustainable social responsibility standards. Such activities boost the legitimacy of halal commodities and guarantee that they fulfill global sustainability standards (BPJPH, 2021).

Despite these advances, the halal industry faces critical challenges in fully integrating environmental standards. Changes in legislative systems among countries might result in sustainability requirements. Moreover, the cost of implementing sustainable practices can be prohibitive, especially for SMEs in the halal industry. Therefore, to address these challenges, stronger and broader international collaboration and support are required in terms of financial incentives and technical assistance for SMEs to integrate robust technology into the halal industry.

2.4 Case studies of sustainable Halal businesses.

In recent years, numerous halal businesses have emerged as trailblazers in incorporating sustainability into their operations, showing that economic success can be balanced with environmental and social accountability. The following case studies demonstrate practical techniques and strategies that not only adhere to halal standards but also encourage sustainability. One significant example is Halal Farms USA, which

established a sustainable meat production standard. Halal Farms USA specializes in organic agricultural practices, which guarantee that livestock are produced without the use of antibiotics or synthesis hormones. Additionally, solar panels power the firm's activities, significantly lowering its carbon footprint (Hashom et al., 2020). This comprehensive approach to sustainability improves the quality of their products and appeals to environmentally aware consumers.

Kurniawati & Cakravastia (2023) highlighted that Halal Cosmetics is also a key emerging player in the cosmetics or beauty industry, which has embraced sustainability by focusing on natural and ethically produced products/commodities. The industry has eliminated toxic ingredients from its products to reduce environmental effects and utilizes recycling packaging. Halal Cosmetics also assures that its supply chain is transparent and that all suppliers employ ethical labor standards. Likewise, Halal Cosmetics has also developed a devoted client base that values responsible beauty products by contemplating on environmental and social sustainability.

Saffron Road stands out in the food business for its focus on sustainable sourcing and production. This halal food firm collaborates with farmers who practice sustainable agriculture, such as crop rotation and organic farming, ensuring that the ingredients are both halal and ecologically beneficial. Saffron Road also invests in eco-friendly packaging solutions that are biodegradable and compostable; the corporation actively promotes fair trade policies, which ensure that farmers are fairly compensated for goods. Saffron Road's comprehensive approach to sustainability has earned it a reputation for excellence and accountability (Doyle, 2022).

Green Hajj, a program launched by Hajj and Umrah travel agencies, provides a new viewpoint on the sustainability of religious tourism. Green Hajj recognizes significant pilgrimages' environmental effects and offers eco-friendly travel preferences, such as carbon offset programs and waste reduction techniques throughout the pilgrimage. The campaign encourages all pilgrims to develop or adopt ecological habits, such as utilizing reusable water bottles and reducing plastic waste (Qutubuddin, 2024). Green Hajj has effectively raised pilgrims' understanding of sustainability by encouraging environmental stewardship within frameworks of religious observance, inspiring other travel agencies to follow suit.

According to Sovacool et al. (2021), another inspiring case is Halal Diary, which produces halal-certified dairy products using sustainable agricultural practices. Halal Diary adopts rational grazing to keep the land healthy and minimize erosion. The organization also uses water recycling techniques to preserve water and renewable energy sources to fuel its practices. Halal Diary also eliminates food waste by benevolent surplus goods to local food banks. This holistic approach to sustainability benefits both the environment and the local community by establishing Halal Diary as a model for other firms in the sector.

These case studies emphasize how sustainability and halal standards may flourish together. These firms have effectively integrated sustainability into their operations by utilizing new techniques and considering ethical standards first. They serve as role models for other firms in the halal industry, demonstrating that economic achievement can be attained while benefiting the environment.

2.5 Applications of green technology in various industries

Green technology, also known as clean technology, is critical to industry transformation because it promotes sustainable practices that reduce carbon footprints. Green technology applications are paving the way for more sustainability in various domains or sectors of a region, including renewable energy solutions and waste management technological innovations.

In the energy sector, renewable energy technologies like solar, wind, and hydroelectric power are transferring how we produce electricity. For example, solar panels convert sunlight into clean energy, dramatically decreasing fossil fuel dependency and limiting carbon emissions. Countries like Germany and China have invested extensively in solar energy, resulting in significant carbon footprint reduction, and establishing worldwide milestones for renewable energy adoption (IEA, 2023). Wind energy is another essential component of the energy sector which utilizes wind turbines to transform wind into power. In Denmark, Offshore wind farms have proved the practicality of wind energy on a large scale, providing a considerable portion of the country's energy demands and demonstrating the promise of green or clean technologies (Gielen et al., 2019).

Interestingly, the transportation sector is likewise experiencing a green transformation as electric vehicles (EVs) have gained popularity in this era. EVs provide a greener alternative to regular automobiles, which are powered by electricity rather than gasoline or diesel. Companies like Tesla and Nisan are leading the way by developing EVs that reduce pollution and reliance on fossil fuels. Also, the improvement in the battery technology improved the efficiency and the mileage of the EVs, thus making them more appealing to their respective populations. Modern technological advancements like electric buses/trolleys and trains are being adopted into public transport to reduce the concentration of the population in urban areas and encourage environmentally friendly transport systems (Shah et al., 2021).

Despommier (2020) also notes that green technologies are already being applied in the agricultural field to enhance sustainability and the level of agricultural yield. Smart farming, which uses localization techniques such as GPS and IoT implements, helps the farmers have better control of crops, reducing the use of chemical fertilizers and pesticides. This not only brings positive effects on the reduction of the adverse impacts on the environment but also brings a positive effect on the increment of agricultural productivity as well as food security. Another such innovation is vertical farming, which is an approach to commercial farming in layers that is normally used in populous cities. It utilizes less water as well as space compared to traditional farming, which may yield fresh crops all year round, reducing the emission of greenhouse gases by food transport.

The construction sector is also incorporating innovation and technologies referred to as green or clean technologies for the production of better construction in the future. They are building constructions that are friendly to the environment, characterized by such features as like solar systems, energy-efficient glasses, and enhanced insulation materials. Such structures may use bamboo, which is environmentally friendly, and recycled steel to minimize the impact on the environment. Also, facilities that include enhanced lightning and temperature control systems help attain more efficient energy consumption and strengthen operating costs (Ademilade et al., 2020).

Tanveer et al. (2022) have also mentioned that green technology is advancing very well in waste management. Here, recycling and composting advances are on the right track to take the waste off the dumpsite and decrease environmental destruction.

Therefore, enhanced recycling methods can transform items such as electronic waste into functional products, thus reducing the assessment for new raw materials. On the other hand, composting recycles and turns unwanted scrap, such as organic wastes, into fertile soil, boosting the agricultural sector while at the same time helping in the reduction of methane content in landfills.

In terms of securing water, water conservation technology is necessary for solving these issues based on worldwide water scarcity. Desalination plants are on the rise in arid countries – these are plants that filter seawater to become drinkable. Technological advancement in desalination technologies such as the reverse osmosis process has made this facility more efficient and cheaper, providing a sustainable solution to the provision of drinking water. Finally, water recycling technologies in commercial buildings and households help reduce water implementation and enhance sustainability (Esmaeilion et al., 2021).

Integrating green technology in these sectors also shows that achieving sustainable development and eradicating environmentally induced problems is attainable. The given technologies are expected to be used more and more as these advance and become more accessible, which in turn drives advancement in sustainability.

2.6 Integration of green technology in the Halal industry

The integration of green technology in the halal industry is assess rational that employs strategic values in halal-purity, cleanliness, halal, and ethical sense to address modern environmental issues. This integration also benefits the sustainability of halal products and, at the same time, increases consumers' propensity to purchase environmentally friendly and ethically manufactured products.

Renewable energy can indeed be classified as one of the major sectors in which green technology remains relevant to the halal industry. In Malaysia for example, many farms and food processing facilities have been given halal certifications to use solar and wind energy. This transition decreases reliance on nonrenewable energy sources and reduces gas levels, which has adverse effects on the climate and, hence, creates a cleaner world. Many halal meat industries have installed solar plants in farms and factories, thus reducing carbon prints and costs. Such a critical change is socially responsible since it is profitable for the environment, as well as for customers who are concerned with the usage of products and services that are environmentally friendly.

Moreover, water preventing is another significant segment of green technology that is applied to the halal industry. Thus, it is substantial that halal production manufacturing, particularly in the food chain industry, does require a large amount of water during the manufacturing process. Implementing advanced water recycling and purification systems may reduce water waste and consumption to deficient levels. A few dairy farms have halal certification, and few have closed-loop water systems where water used in cleaning and milk production is recycled. They help to optimize the usage of water and minimize wastage, hence enhancing the aspect of environmental sustainability; it also conforms to the concept of halal technologies and standards (Tseng et al., 2022).

Green technology enhances the implementation of better waste management systems that benefit the halal business. Residues from halal food production may be

identified and recycled through composting and anaerobic digestion to generate more valuable items. These processes produce compost and biogas, which are recyclable valuable products such as a renewable energy source in the form of biogas and organic fertilizer in the form of compost. Apart from this, it reduces the amount of waste that is being processed and supports sustainable farming. Some industries in Indonesia Halal Organic Waste Solutions have embarked on using such technologies whereby the circle or loop is completed to ensure the conservation of all the resources and reduced waste is examined.

Another business segment that is increasingly adopting green technologies is the aspect of packaging. Interestingly and globally, Halal food producers might adopt sustainable packaging options for their products, such as biodegradable and compostable packaging materials. Such a change relates to the increasing concerns regarding plastic pollution and seems reasonable to the environmentalist ideas of many purchasers. Halal cosmetics companies are leading the way by using non-GMP and non-ISO plant-based packaging material that is also approved for halal use and has a positive ecological impact. This approach helps lessen the level of packaging waste that is affecting the environment, and at the same time, the trend facilitates more appeals to consumers who are conscious of their impact on the environment (Sugibayashi et al., 2019).

Furthermore, green technology is also being incorporated into managing the halal supply chain. High-tech tracking and monitoring mechanisms through IoT and a chain, integrated system that enhances the level of visibility. Such systems guarantee that the procured, processed, and delivered merchandise conforms to the halal standards and is sustainable. The above kind of transparency helps enhance trust with the customers and helps the organization solve the problems of inefficiency in the supply chain, which contributes to improving sustainability.

3. Methodology

The key contribution of this study is to identify a green technological framework for the halal industry's sustainable operations, and its impact on the ecosystem. We employ qualitative documentary analysis. The documentary research method is a qualitative research approach that involves the systematic collection, review, analysis, and interpretation of documents and texts to gain insights and understanding about a specific topic. These documents can be written texts, electronic documents, audio-visual materials, and other forms of recorded information (Ahmed, 2010; Bowen, 2009; Scott, 2014). According to (Bohnsack, 2014) narrates that documentary analysis involves identifying the documents or studies relevant to the research topic. These studies or documents are reviewed and analyzed to identify the key themes, patterns and insights. In the next step, findings from the document are interpreted, and synthesized to gain an insight and deep understanding of the research. The documentary method is justified in this study due to its resource efficiency, ethical considerations, data availability, data quality, time efficiency, data protection, data validity, and data accessibility. These factors make document analysis a valuable approach for qualitative research. furthermore, Document analysis follows a structured methodology that includes preparing materials, extracting data, analyzing content, and distilling findings. This systematic approach ensures rigor in qualitative research and helps manage biases that may arise during analysis (Dalglish et al., 2020)

4. Development of the Green Technology Framework by Identifying Key Green Technologies

1. Renewable Energy Sources:

Renewable energy sources are crucial for reducing carbon emissions and sustaining the environment, though price competitiveness remains a challenge. Many corporations can afford to adopt these sources. According to IRENA, (2018), about one-third of countries have embraced corporate renewable energy. These entities are aligning with global calls for green sustainability and complementing government efforts. Figure 1 shows the trend of renewable energy adoption by companies: 2410 large companies have incorporated renewables in their operations, especially for electricity generation. Over 50 companies now source all their power from renewables, while 200 use 50% renewables (WEF, 2024). Halal industries are not an exception in this regard, this is due to the huge market with the high prospect for expansion, effort could be made to adopt renewable sources like solar, geothermal, bioenergy, and wind for electricity generation. In the halal food industry, electric chillers are currently used for cooling, but solar systems or gas-powered absorption chillers are considered cleaner and safer alternatives.



Figure 1. Market and Industry Trend of Renewable Energy Source.

Source: IRENA (2018)

2. Waste Management Technologies.

Negative externalities that affect the lives of individuals are cautioned against in industrial practice globally (Kusuma et al., 2022). As we know before reaching the end user, halal breeding starts the cycle of halal resource utilization and waste management. Insani et al., (2019) highlighted that food and livestock waste can be an

environmental pollutant. Therefore, the halal industry must show its social corporate responsibility to manage and respond to the resulting waste problems. The halal industry, like other industries, can adopt existing technologies or develop new technologies to handle waste. Some major waste management technologies such as rendering, vermicomposting, incineration, and biogas could be utilized. Rendering for instance involves a process of converting the by-products into high valuable ingredients for instance the conversion of meat and bone meal, poultry meat meal, feather meal, blood meal and tallow. This process highly supports sustainability by transforming waste into valuable resources. On the other hand, vermicomposting is a process that utilizes earthworms and microorganisms to convert organic waste into a valuable soil amendment and nutrient-rich fertilizer. Furthermore, incineration is a thermal waste treatment technology that involves the combustion of waste materials at high temperatures to reduce their volume and mass. This process typically reduces waste by 80-85% in mass and 95-96% in volume, making it a widely used method for managing municipal solid waste and hazardous waste (Makarichi et al., 2018). In addition, Biogas has been identified as a sustainable waste management technique that involves anaerobic digestion of the organic waste to produce a renewable source. The process occurs in the absence of oxygen, it is typically a controlled experiment as it uses an anaerobic reactor as a digester. It could be applied to various waste streams, including agricultural, municipal and industrial waste (Babu et al., 2022).

These waste management technologies create waste products that are not necessarily pollutants and can generate future economic values for the industry, including animal feed, fertilizer, energy, and other resources. Harnessing these technologies by the halal industry could significantly sustain the ecological system and complement the government's effort to have a clean environment.

3. Agricultural Innovation: this concerns sustainable farming practices and technologies that increase food production while reducing environmental impact. For instance, organic farming, precision agriculture, vertical farming, and hydroponics. In recent time, the role of farming in environmental degradation is considerably large. The system contributes up to 12% annually to the GHG. The current traditional practice with a huge impact on the environment is not sustainable, however, a modern approach as suggested by Niggli et al., (2009) at guarantees low GHG farming is inevitable. Starting with the assessment report of the IPCC (2007) highlighted four major areas through which sustainable agriculture could lead to low carbon emissions: crop rotation and farming system design, nutrient and manure management, livestock management, pasture and fodder supply improvement, fertile soil maintenance and finally the restoration of degraded land.

4. Sustainable Transportation: This is a crucial component of halal industry logistics and a major concern in the halal food supply chain. The distribution network from producer to consumer can benefit the environment by adopting technologies and practices that reduce ecological impact. Such practices may include using electric or hybrid vehicles, optimizing route planning to reduce fuel consumption, and implementing reverse logistics for waste reduction. Additionally, the use of blockchain technology can enhance traceability and transparency in the supply chain, ensuring halal compliance while promoting sustainability (Abderahman et al., 2021; Kurniawati & Cakravastia, 2023).

Ab Talib & Zulfakar, (2023) conducted a comprehensive study on sustainable halal food supply chain management, focusing on the government of Brunei. Their research identified four key pillars of sustainable supply chain management:

responsible sourcing, environmental purchasing, green transportation, and sustainable packaging. Responsible sourcing involves selecting suppliers who adhere to ethical and environmental standards. Environmental purchasing emphasizes procuring eco-friendly materials and products. Green transportation, as discussed earlier, focuses on reducing the carbon footprint of logistics operations. Lastly, sustainable packaging involves using biodegradable or recyclable materials to minimize waste. These findings provide a framework for halal industries to integrate sustainability into their supply chain operations, aligning with both Islamic principles and environmental stewardship.

4. Green Building: Green building also known as sustainable building is a recent development in the fight against climate action. It refers to the structure and application of environmentally responsible processes and resource-efficient processes throughout the building life cycle. It ensures that from the planning to design, construction, operation, maintenance, renovation and demolition are carried out carefully considering the consequential impact on the environment. Some of the key principles of these buildings entail energy efficiency, water efficiency, sustainable materials, waste reduction, and lastly, site and community integration. (Yudelson, 2010; Zuo & Zhao, 2014). As world is becoming complex with urbanization expansion, a key approach that sustain the environment is identifying in ensuring that buildings including industrial estates are green. In 1990 for instance, Building Research Establishment Environment Assessment Methods became the first building certification body, and several green building rating tools were developed to guide the architectural process, similarly, leadership in environmental and energy design leadership perform a similar function of certifying the building for environmental protection (Ding et al., 2022). Green buildings could be integrated into halal certification in the initial face, this will ensure that the existing building gradually transits to a sustainable building while the subsequent halal industry could a hundred per cent go green for a sustainable environment.

5. Pollution Control: Since the Industrial Revolution began in the late 18th century, industrial activities have been a major source of atmospheric pollution. The industrial sector's impact on climate has become increasingly apparent and concerning over the past few decades, prompting global efforts to reduce emissions and transition to more sustainable practices. However, industries in this regard are at the center of pollution control measures and policies for mitigation (Fatta et al., 2004; Sell, 1992). Adopting pollution control measures in the halal industry is essential to ensure environmental sustainability while maintaining compliance with halal standards. This involves implementing practices such as waste reduction through efficient resource management, utilizing eco-friendly materials, and employing advanced waste treatment technologies to minimize water and air pollution. Integrating renewable energy sources and energy-efficient processes can further reduce the industry's carbon footprint. By adhering to these practices, the halal industry can not only meet the ethical and environmental expectations of consumers but also contribute to the global effort of preserving the environment for future generations.

4.1 Steps for adopting green technologies in the Halal Industry.

In this section, we discussed the step-by-step implementation of green technology in

the halal industry by drawing insights from UNIDO (2023), Fageh, (2022), and (Razalli et al., 2012).

1. **Assess current operations:** To implement sustainable practices, halal industries should conduct a comprehensive audit of their current environmental performance. This systematic evaluation enables organizations to identify and critically examine key sustainability issues that have yet to be addressed, facilitating the integration of environmentally sustainable practices into daily operations. The audit should quantify the environmental impact associated with current processes, including emissions, resource consumption, and waste generation. Furthermore, it should propose strategies to mitigate these impacts in alignment with global best practices and regulatory standards. The assessment should also identify significant environmental deficits within the organization and propose targeted interventions to address these gaps, thereby enhancing overall sustainability. Additionally, the audit should encompass an evaluation of occupational health and safety measures across all operational levels, ensuring that environmental mitigation strategies do not inadvertently compromise worker well-being. This holistic approach to sustainability assessment provides a robust foundation for developing and implementing effective green technologies and practices within halal industries.

2. **Set sustainability goals:** At this stage, halal industries must establish clear, quantifiable objectives aligning with Islamic principles and environmental sustainability standards. This process involves developing a comprehensive strategic framework that delineates the necessary steps for achieving successful and sustainable operations. These goals should articulate the desired level of environmental integrity and specify the standards that must be adhered to for optimal performance. The framework should encompass the identification and procurement of appropriate environmental technological equipment, as well as the delineation of achievable short-term and long-term objectives. This strategic planning process should be underpinned by rigorous analysis, incorporating key performance indicators (KPIs) that allow for objectively measuring progress towards sustainability targets. By establishing this robust set of goals and metrics, organizations can effectively guide their transition towards more environmentally responsible practices.

3. **Research Green Technologies:** Research into green technologies constitutes a critical phase in the sustainable transformation of halal industries. This stage involves a comprehensive investigation of environmentally sustainable solutions tailored to each industry sector's specific needs and constraints. Such solutions may encompass renewable energy systems, energy-efficient equipment, or advanced waste reduction technologies. The selection of appropriate green technologies in halal industries is contingent upon multiple factors, including cost-effectiveness, durability, and operational continuity. Given the heterogeneity of industrial processes and organizational structures within the halal sector, each entity must conduct a thorough analysis to identify and adopt technologies that optimally align with its unique operational parameters and sustainability objectives. This process necessitates a rigorous evaluation of available alternatives, considering not only their environmental impact but also their compatibility with halal principles and long-term economic viability.

4. **Develop an implementation plan:** In this stage, the company creates a phased approach for integrating green technologies, taking into account budget, timeframes, and potential disruptions to its operations. This stage is critical because feedback is essential to ensure that the short-term objectives align with the deliverables.

Furthermore, collaboration with stakeholders is vital to the success of the implementation plan. Engaging with suppliers, customers, and regulatory bodies (halal certification, environmental protection etc.) can help identify potential challenges and opportunities early on. Regularly reviewing and adjusting the plan based on stakeholder input can lead to more efficient and effective integration of green technologies, ultimately supporting the company's sustainability goals and enhancing its reputation in the halal industry.

5. **Secure Funding:** The question of who should be responsible for funding efforts to mitigate environmental degradation has been a significant one, even at the global level. However, the halal industry can explore various financing options, including company profits, green loans, government incentives for sustainable business practices, and international donors. Moreover, companies need to develop a clear financial strategy that outlines how these funds will be allocated and managed. This includes setting aside a portion of the budget specifically for green technology initiatives and establishing a monitoring system to track expenditures and returns on investment. Transparency in financial planning and reporting can build trust among stakeholders and demonstrate the company's commitment to sustainability.

6. **Train Staff:** Training staff is essential because the halal industry employs a large number of personnel. Educating employees on new technologies and sustainable practices is crucial for effective implementation. This training should be an ongoing process, as new technologies continue to emerge and adjustments are necessary to align with global best practices. Moreover, developing a comprehensive training program that includes workshops, hands-on training sessions, and regular updates can ensure that employees are well-equipped to handle the integration of green technologies. Encouraging a culture of continuous learning and innovation within the organization will help staff stay informed about the latest advancements and best practices in sustainability. This not only enhances operational efficiency but also fosters a sense of responsibility and commitment towards environmental stewardship among employees.

7. **Implement Changes:** at this stage Industries adopt a phased approach to implementing green technologies, beginning with pilot projects or small-scale implementations before proceeding to full-scale adoption. This strategic methodology allows for a gradual and controlled integration of new sustainable practices into existing operations. Pilot projects serve as valuable testing grounds, enabling organizations to assess the efficacy of new technologies, identify potential challenges, and refine implementation strategies in a low-risk environment.

8. **Monitor and Measure:** Monitor and measure: Rigorous monitoring and evaluation of newly implemented green technologies are imperative for assessing the efficacy of environmental investments in the halal industry. Organizations must establish comprehensive monitoring systems to track the performance of these technologies and quantify their impact on key sustainability metrics.

9. **Certify and Communicate:** In the final stage, a company is expected to obtain certification for achieving the milestone of integrating green technologies in the production and operation of halal products. Additionally, companies need to communicate their sustainability efforts to stakeholders and the international community through media outlets and environmental forums. Effectively sharing these achievements not only enhances the company's reputation but also sets a benchmark for industry peers. Transparent communication can build trust and inspire confidence among consumers, investors, and other stakeholders. By actively

participating in environmental forums and leveraging various media channels, companies can highlight their commitment to sustainability and contribute to the global discourse on sustainable business practices.

5. Conclusion and Recommendations

Efforts to sustain the environment rest on the shoulders of households, firms, and governments, as environmental pollution is a direct result of human activities. However, inventions and innovations have provided effective ways to interact with the environment without necessarily damaging the ecosystem. While the halal industry has recorded remarkable growth over time, future demand is inevitable as the population grows, with non-Muslims also becoming interested in halal products. Similarly, global efforts towards a clean and sustainable environment are increasing daily, though coordinated and combined cooperation from industries is imperative.

In this study, we developed a green technology framework necessary for the halal industry and ecosystem sustainability. Renewable energy sources have been identified as key to reducing environmental degradation and achieving net zero emissions, as envisioned by the Intergovernmental Panel on Climate Change. The growth of renewable energy sources has been significant, with eight countries achieving 100% renewable energy sources, while 69 countries use 50% renewable energy, according to a report from the International Renewable Energy Agency in 2021. In another similar report, 2,410 corporate companies have integrated renewable energy for electricity generation. Some of the key renewable technologies proposed for the halal industry include solar energy, geothermal, and wind energy, among others.

Another key area of concern in the operation of the halal industry, especially the halal food industry, is waste management, which constitutes a significant part of environmental pollution. The halal industry will benefit from adopting rendering, vermicomposting, incineration, and biogas technologies in waste management. Furthermore, innovations and sustainable inventions in agricultural practices that ensure high productivity while sustaining the ecosystem are detailed for adoption and experimentation by the halal industry. Sustainable transportation is another green technology that will mitigate the effects of carbon emissions. This includes the utilization of electric vehicles for halal supply chains and the use of bioenergy for fueling logistics. Additionally, we propose the use of green buildings in the design of factories and companies, along with pollution control technologies.

Having identified the potential green technologies for adoption by the halal industry, we propose implementation strategies. The implementation process begins with assessing the current status of green technology adoption by halal businesses, setting sustainability goals, and then searching for the required green technology for adoption in the business and operations. In the next phase, the industry develops an implementation plan and secures funding for implementation. Subsequently, the industry trains the staff, implements changes, and conducts monitoring and certification.

We strongly recommend integrating environmental sustainability practices as a criterion for halal process certification. Secondly, a special Green Innovation Fund should be established to support research and development of green technologies tailored to production. Lastly, the halal industry should develop international

cooperation with bodies responsible for emissions mitigation, such as the IPCC and UNFCCC, by showcasing their commitment and ambition to balancing religious requirements with environmental sustainability. Future studies should focus on the use of mixed methods, in addition to qualitative studies, quantitative data could be gathered for trend analysis.

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