Article

Not peer-reviewed version

Saudi Arabia's Circular Economy Path to Global Leadership

Muhammad Usman Akram * , Aamir Iqbal Ghazanvi , Muhammad Abubakar

Posted Date: 4 March 2025

doi: 10.20944/preprints202503.0181.v1

Keywords: Circular Economy; Vision 2030; Renewable Energy; Green Initiative; Sustainable Development; Green Hydrogen; Kingdom of Saudi Arabia

 doi:10.20944/preprints202503.0181.v1

Article

Saudi Arabia's Circular Economy Path to Global Leadership

Muhammad Usman Akram [1] **Aamir Iqbal Ghazanvi and Muhammad Abubakar**

Affiliation 1; aamirghaznavi@hotmail.com; mabubakar180@gmail.com

* Correspondence: m.usmanimtisal@yahoo.com

Abstract: This paper establishes that pursuing a circular economy is central to the success of Vision 2030 whereby Saudi Arabia has laid down its plan to shift from an oil-reliant economy to one that is innovation and sustainability-based. This paper looks at the renewable energy policies of the Kingdom with a special focus on renewable energy and green policies including the Neom project and Saudi Green Initiative. While notable progress has been achieved, certain areas require further enhancement, such as refining legislation, advancing technology integration, and fostering adaptability within organizational cultures. These aspects therefore require policy improvement, increased investment in, and public awareness of innovation. Additionally, given that Saudi Arabia is already leading the world in green hydrogen, with such ongoing visionary projects and effective collaboration across the region and the rest of the world, there is little doubt that the country is a solid part of the sustainability wave. This paper discusses the environmental, economic, and geopolitical impact of Saudi Arabian circular economy active strategies and future recommendations that can be implemented. Thus, Saudi Arabia can obtain economic diversification, keep its environment safe, and have a global impact – all in one century, becoming an example of 21st-century sustainability

Keywords: circular economy; vision 2030; renewable energy; green initiative; sustainable development; green hydrogen and Kingdom of Saudi Arabia

1. Introduction

The global economy is on the brink of changes with an increasing emphasis on solving environmental problems, lack of resources, and the climate. At the centre of this change there's the circular economy, concept that can be seen as a modification of the current linear 'take-make-dispose' business model by implementing equitable sustainable modelling. Within this perspective, Saudi Arabia, a country that for many years relied on its hydrocarbon-based economy, is now one of the countries that most actively promote the principles of the circular economy at the national level. This change is not only a necessity of an environment but also a strategic move to promote more economic revenue and to increase Saudization's position on the international stage, too.

The framework within which this change is taking place is Saudi Arabia's Vision 2030. Initiated in the year 2016 this vision is geared towards the realization of the economic diversification in the Kingdom and the reduction of dependence on oil export. Integral to Vision 2030 is the integration of sustainability into the developmental framework of the nation. The goals of the circular economy concept are directly in line with the Vision 2030 since efforts involve efficient use of resources, reduction of wastes, and innovation. Saudi Arabia pursues circularity in its economic plans to mitigate urgent environmental challenges, launch new technologies, and establish itself as a circular economy pioneer (Abdulaziz AlJaber et al., 2024).

The adoption of circular economy principles presents significant opportunities for Saudi Arabia, particularly in promoting economic diversification and enhancing stability. For many years the

[1] Corresponding Author's Email: m.usmanimtisal@yahoo.com

 doi:10.20944/preprints202503.0181.v1

Kingdom's economy relied extremely much on the oil export and therefore very sensitive to the global oil price trends. In one way, the application of circular principles creates a chance to construct a more stable economy from scratch and support localized value chains. Some of the more promising industries for generating income include renewable energy sources, recycling and industries that are friendly to the environment. In addition, circular economy practices is very relevant in enhancing the resource utilisation since many products are imported with their lifecycle stretched. This is most relevant in a country like Saudi Arabia, where resource management is something beyond a necessity in order to foster sustainable economic development.

Another driving factor behind Saudi Arabia's adoption of the circular economy is its alignment with international standards. Some of the conventions Kingdom has committed itself to include the Paris Agreement which aim at reducing greenhouse gases and climate change. That is why the low-carbon circular economy approach is a perfect solution because it is based on resource efficiency, full circulation, low-carbon technologies, and waste reduction. In this regard, such practices not only help Saudi Arabia demonstrate compliance with the commitments undertaken by the global community, but also contribute to the promotion of the image of the country as a responsible member of the international community. This is especially important given the fact that the Kingdom plans to woo foreign investors and consolidate its relations with dominant world economic players (Yusuf Akinwale, 2024).

2. Literature Review

The circular economy has thus popularized a sustainable approach in tackling global sustainability issues. Based on the principles of resource utilization, waste elimination and ecological responsibility the concept has been researched in different fields and countries. In the case of Saudi Arabia, the adoption of circular economy principles was characterized as the shift in a paradigm and as such, supported the Vision 2030 objectives of the diversification of the economy as well as the minimisation of negative environmental effects. This literature review aims to explore the theory of the circular economy and its practices from global perspectives, and Reginald including Saudi Arabia with its specific context. Moreover, it also investigates policy frameworks and cultural enablers, and technological barriers and innovations that helped the Kingdom of Saudi Arabia to transition towards circular economy.

2.1. Theoretical Foundations of the Circular Economy

The circular economy is a move away from the traditional linear 'take-make-dispose' model to an economy that promotes the idea of using as many resources as possible, recycling those and replenishing the resources. Essentially, the circular economy presents a counter view of conventional economic foundations that peg their success on the consumption path, a system that is in fact unsustainable. Similarly, Dam et al., (2020) pointed out that in circular economy, it is important that the flow of goods and materials are closed-loop in order to minimize resource-extraction and maximize the duration of product use. The Ellen MacArthur Foundation (2013), a leading advocate for the concept, identified three primary principles: avoiding waste and pollution, rethinking production and consumption patterns and remaking natural environments. They integrate into the foundation of the global circular economy frameworks.

Kirchherr et al. (2023) offered an overall definition which indicates that it is a trans-disciplinary concept that is associated with environmental science, economics and industrial design. Their work highlighted how circular practices are linked, thus, showed that interacting changes in production, distribution, and consumption can reduce the impacts on the environment and resources. This integrated approach corresponds with the objectives of Saudi Arabia in vision 2030 to transform the economy and at the same time pursue sustainability.

Additional theoretical developments also highlight the importance of innovation in the circular economy. Ghoreishi & Happonen, (2020) posited that digitalization and artificial intelligence for instance are among the key drivers of circularity. It also embraces resource tracking and predicting

 doi:10.20944/preprints202503.0181.v1

equipment's failure rate besides improving recycling resulting to Saudi Arabian dreams of being at the forefront in green technology.

2.2. Global Best Practices in Circular Economy

Globally, with a view of adopting the circular economy, different countries have seemed to succeed in the implementation of the framework, and hence serve as a good reference point for Saudi Arabia. In Europe such a document as the European Union (EU) Circular Economy Action Plan exists, which sets standards for the policies aimed at sustainable development. This broad framework focuses on policies dealing with waste minimization, recycling objectives and the promotion of resource-saving technologies (European Commission, 2020). Other European countries like the Netherlands, Denmark, and Germany have taken the lead in implementing circular economy policies especially in the areas of waste and recycling, green energy, and sustainable farming.

One of the most frequently discussed examples is the Dutch concept of "Circular Holland". This program combines high-tech recycling solutions, sustainable product development, and triangulation between different industries to decrease material consumption substantially and enhance green technology (Walker et al., 2021). In the same manner, Denmark's changed from fossil-based energy to renewable energy especially wind energy can be cited as having adhered to the circular principles when planning their energy policies. It also underscores the need for policy consistency, cooperation with various actors and leveraging of technology to achieve circular economy objectives.

Asian countries such as China have implemented specific legislation like Circular Economy Promotion Law, reveal the policy driven implementation. Fan & Fang (2020) provided a detailed examination of circular economy at the micro (enterprise level), meso (industry park), and macro (regional and national) levels of China. The adoption of circular economy in such industrial parks including the Suzhou Industrial Park shows that this approach has cuts energy use and emissions. These practices give a roadmap to KSA as the country aims to build eco-friendly industrial cities and a circular economy in manufacturing. Australia and New Zealand have also shown good practices regarding circular economy especially in the agricultural sector. Short et al. (2021) explained how the practices of regenerative farming methods, the waste-to-energy systems, and the water technologies correspond to circular economy approaches that can be adopted in Saudi Arabian or other regions facing water scarcity and desertification.

2.3. Regional Applications and Relevance to Saudi Arabia

The Middle East and North Africa (MENA) region has specific sustainability challenges to address, particularly in the areas of water, climate, and energy. Therefore, another way to look at these challenges in the region is through the implementation of circular economy strategies with Saudi Arabia being one of the leading economies in the region. Some studies highlight the importance of incorporating circular principles in the Kingdom benefitting sectors like energy, waste, and water.

Recently, Jahan et al. (2022) focused on the potential of circular economy solutions for alleviating water scarcity in Saudi Arabia. Their research focused on the reuse of wastewater and other water treatment technologies, which is closely related to circular economy because it entails the regeneration of resources. Another important aspect of sustainable food system pointed out in the Kingdom was the investments in water-saving technologies like hydro ponics and vertical farming. These inventions are especially significant because the Kingdom imports a significant part of its food and has scarce cultivable land.

Another important area of interest is the energy from renewable sources. Islam & Ali (2024) analyzed the different renewable energy projects of Saudi Arabia with reference to the National Renewable Energy Program and development of Neom, a completely renewable energy-based city. These concepts demonstrate the application of the circular economy concepts with an emphasis on low-carbon technologies, energy efficiency, and sustainable urban planning. The author was right in

 doi:10.20944/preprints202503.0181.v1

his opinion that initiatives of the Kingdom put Saudi Arabia on the map of countries actively working to advance the energy transition and global decarbonization.

Furthermore, the petrochemical sector that remains to be the cornerstone of the Saudi Arabian economy has vast potential in terms of circular economy strategies. For instance, Dong et al. (2022) have emphasized that chemical recycling and waste-to-energy as whole can help in avoiding excessive accumulation of industrial waste and dependence on virgin feedstock. These advancements are crucial in transforming the industrial sector towards sustainability in the Kingdom.

2.4. Saudi Arabia's Circular Economy Initiatives

Almost all the circular economy activities in Saudi Arabia are closely related to Vision 2030 as it seeks to diversify the economy, decrease dependence on oil, and increase the sustainability of the natural environment. Some of the significant projects and programmes reflect that circularity ethos is integrated into the Kingdom's development plans. Neom is the Vision 2030 project which is a $500 billion smart city project that has many features that core to circular economy. Built with the goal of being 100% reliant on renewable energy sources, Neom has incorporated advanced solutions in the spheres of water and waste recycling and green transportation. In a recent research study by Madakam and Bhawsar (2021), the author reviewed Neom as a circular city proposed for the evaluation of crucial global optimums as the city planned to work on only renewable energy and the automation of closed-loop resource procedures. The work showed how Neom aligns with sustainability principles and can be seen as exemplar city to others in the region The Saudi Green Initiative introduced in 2021 is a plan that seeks to reforest Saudi Arabia, which is a desertification process, cut on carbon emission and enhance waste management. As stated by Alshathri, (2022), waste recycling remains one of the integral parts of the strategy, with the intention to build new complex recycling facilities and enhance the circular economy adoption by various sectors. The authors also pointed out that the strategies like using biofuel derived from municipal waste in the Kingdom fall under circular economy and help in achieving the sustainable development goals of the Kingdom.

Therefore, Saudi Arabia has adopted circular economic approach and is committed to producing green hydrogen. Most recently, Dong et al. (2022) sought to understand if the Kingdom is capable of spearheading the international hydrogen market due to its rich solar and wind energy. An important focus was made on the application of hydrogen in achieving near-zero carbon intensity in energy sector and in developing circular economy processes in the petrochemicals and transport sectors. Nevertheless, supported by its hydrocarbon-focused recovery plan, Saudi Arabia initially introduced circular economy principles into its oil and gas industry. In this regards, Al-Rashed et al. (2023) pointed out that the industry has stepped into emission reductions with the action of Carbon capture, utilization, and storage (CCUS), as well as enhanced oil recovery (EOR).

2.5. Challenges in Implementing Circular Economy Principles

When it comes to applying the circular economy principles in Saudi Arabia, several issues are evident while there is a massive step that has been made. These are policy and regulatory constraints, technology restrains, and culture restraints. Alqarni (2022) study underlined the importance of the wide-ranging policies meant to encourage circular behaviours as well as practices among firms. Also, most existing environmental policies have poor mechanisms of implementing these measures, especially on waste disposal and efficient use of natural resources.

State of the art recycling processes, and renewable energy systems are capital intensive, making it hard for developing nations to adopt. Mahboub & Fawaz (2022) discussed that Saudi Arabia still has much technological potential for increasing circulation economy efficiency, though it may only request expensive and advanced creations. The authors suggested more fund allocations toward research and development, and acquisitions from foreign technology vendors. The success of circular economy initiatives is closely linked to fostering consumer awareness and proactive engagement. He also established while conducting a study that Almulhim, (2022) revealed that Saudi citizens have

 doi:10.20944/preprints202503.0181.v1

very little knowledge about recycling and sustainable consumption. The authors proposed giant campaigns, which raise concern and spread knowledge about circularity at the personal and community levels.

2.6. Future Directions and Opportunities

However, the prospects of circular economy in Saudi Arabia promise a lot of innovation and global leadership amid challenges. International cooperation, funding in circular economy technologies, creation of regional sustainability networks could help the Kingdom to improve the process of circular economy shift. In addition, Saudi Arabia strategy of leveraging on the geographical advantage and access to renewable energy resources places the country as a favorable destination for sustainable development.

However, while the Kingdom presses on with Vision 2030's strategies for promoting the circular economy, it is necessary for more research to be conducted to assess its subsequent effects. Policies and effects of this nature make it possible to carry out evaluations of a particular project like Neom and the Saudi Green Initiative. The fact maintaining the circular economy in Saudi Arabia is of transformative nature, one can conclude its impact is beyond the scope of local economic activity. If the Kingdom actively fills the policy gaps, encourages innovation and raises awareness, it can easily become a world reference in sustainability. With more Vision 2030 projects rolled out, Saudi Arabia's sustainable solutions will set a trend for countries who want sustainable economic development.

3. Methodology

In this section, it defines the methodological approach employed to investigate Saudi Arabia's circular economy strategies and their significance for obtaining global supremacy. The research uses both qualitative and quantitative research methods due to the need to capture a broader picture of the topic under discussion. Research was conducted using document analysis, case studies, policies, and statistics along with the qualitative data from interviews with stakeholders and policymakers.

3.1. Research Design

Mixed research design was adopted to integrate both qualitative and quantitative data to achieve the aims and objectives of the study in exploring the circular economy in Saudi Arabia. The qualitative approach involved the analysis of policies, projects, and strategies related to the topic under study, while the quantitative approach involved analyzing statistical data on waste management, renewable energy, and economic diversification. This dual approach helped to gain a more detailed understanding of the dynamics of the circular economy's journey and obstacles in the Kingdom.

3.2. Data Collection

The secondary data were collected from reports of several departments like the Saudi Vision 2030 report, publications from the Ministry of Environment, Water, and Agriculture, the Saudi Green Initiative, etc. Other data were gathered from international bodies like the Ellen MacArthur Foundation which has detailed information on circular economy and practices across the globe. Therefore, in the process of this study, a comprehensive literature review was undertaken to search for scholarly articles that cover various circular economy (CE) activities and studies around the world and in Saudi Arabia in particular. This involved gathering and reviewing of articles from scholarly and peer-reviewed journals, policy briefs, and industry reports.

Five key informants comprising of the policymakers, sustainability consultants, and academic researchers with expertise in circular economy practices were interviewed. The interviews themselves were semi-structured, where the interviewer could deviate from the general questions and focus on certain elements such as the implementation of relevant policies or the role of technology or culture in circularity within Saudi Arabia. The circular economy strategies of Neom,

 doi:10.20944/preprints202503.0181.v1

the Saudi Green Initiative, and the Nation Renewable Energy Program were taken as case studies to determine their effectiveness and compliance with circular economics.

3.3. Data Analysis

Data analysis was conducted in three phases: The information gathered was analyzed using thematic analysis which involved the identification of frequently discussed issues like waste disposal, green energy, and policy coherence. This process included analysis of the data and use of coding to determine patterns in the context of Implementing circular economy in Saudi Arabia.

In the quantitative analysis, descriptive statistics was used in analyzing statistical data on waste generated, recycling efficiency, renewable energy installed, and economic diversification efficiency. The absolute values and the comparison with other countries offered more understanding of Saudi Arabia's advancement. The findings from the case studies were analyzed to assess the implementation of circular economy practices in Saudi Arabia. This process entailed evaluating the effectiveness of certain projects and their potential for further enhancement.

3.4. Ethical Considerations

Ethical approval was obtained for the expert interviews, and participants provided informed consent. Confidentiality was maintained by anonymizing responses, and data were stored securely to prevent unauthorized access. The study adhered to principles of academic integrity and transparency in data collection and analysis.

4. Findings

Therefore, the findings of the present study offer a clear revelation of the circular economy situation in Saudi Arabia, including its advancements, concerns, and prospects for winning the globally competitive position. The discussion is arranged under subcategories that emerged from the analysis of the data collected.

4.1. Progress in Circular Economy Implementation

Saudi Arabia has demonstrated great progress in implementing circular economy concepts in different sectors. The research also shows that these initiatives are responsive to the objectives outlined in Vision 2030 particularly on economic development and conservation of our natural environment. One of the greatest accomplishments is the Kingdom's commitment to sustainability through generation of clean power. The National Renewable Energy Program has made it possible for the country to achieve large scale PV and wind facilities like Sakaka Solar Plant and Dumat Al-Jandal Wind Farm. These policies have enhanced renewable electricity generation capacity in Saudi Arabia to nearly 10 GW in 2023 and turned it into a reference for green innovations (Al-Gahtani, 2024).

The smart city project known as Neom is an example of the kingdom's interest in sustainable urbanism. It was established that Neom utilizes circular system such as renewable energy solutions, waste to energy solutions and smart water management. These features show that Neom has the possibilities to become a model of circular urban planning globally. The Saudi Green Initiative has brought about the proper management of waste within the country. Recycling rates have risen from 5% in 2015 to around 30% in 2023, thanks to modern recycling plants and advertising. Other waste management initiatives include the renewable energy projects which have helped in minimizing the utilization of landfills for disposal as seen in the Riyadh Municipal Waste Treatment Plant project (Almulhim & Al-Saidi, 2023).

4.2. Challenges in Implementing Circular Economy Principles

However, the following difficulties obscure the general advancement of circular economy approaches to the kingdom of Saudi Arabia. The results reveal fragmentation of regulatory systems

 doi:10.20944/preprints202503.0181.v1

to address circular economy practices. As much as Vision 2030 offers a strategic framework, staunch policies that will encourage business entities or compel them into compliance are lacking appreciably in terms of policy frameworks. This was further echoed by the following stakeholders with the compliance of recommending waste minimization, resource management and circular designing of products through legislation. Use of the advanced recycling system as well as implementation of renewable energy systems consequently necessitates the use of capital. The results show that the requirement for significant initial investments and access to advanced technologies poses challenges, particularly for SMEs. Also, the lack of local production infrastructure for renewable energy equipment makes import dependency a problem for cost effectiveness (Aya Abdelmeguid et al., 2022).

4.3. Opportunities for Global Dominance

Saudi Arabia boasts of its proximity to other countries, rich sources of renewable energy, and large-scale development plans that make it a plausible key player in the circular economy. Thus, the investment of the Kingdom in green hydrogen production such as Neom's Hydrogen Plant provides a great chance to control the hydrogen market. Thus, according to the findings, the unique selling proposition for Saudi Arabia can be derived from the availability of solar and wind resources necessary to produce affordable hydrogen.

With large-scale projects like Neom and the Saudi Green Initiative, the Kingdom can offer lessons to other countries intending to establish circular economy systems. In this way, through exporting acquired skills and technologies within the frameworks of these endeavors, the Kingdom can further cement its role as a global sustainability champion (Al-Gahtani, 2024). Currently, Saudi Arabia is the largest economy in the Middle East, so this country has high chances to initiate circular economy strategies in the region. In this sense, it is possible to identify the need to strengthen links with other neighbouring countries in order to establish regional sustainability networks as well as shared resources.

4.4. Impact of Circular Economy Practices

The research findings show that circular economy integrates environmental and economic value with regard to the kingdom of Saudi Arabia. Actions on circular economy have cut down on greenhouse gases, optimized waste and resource utilization. The case of the integration of renewable energy and sustainable urban planning in Neom depict how a circularity practice does have environmental impacts.

Circular economy projects as a strategy would fit well in Vision 2030 due to its goal of de linking the economy from oil revenues. This study shows that spending in the renewable power sources, waste management, and green technologies has opened up new economic ventures that promote innovation and employment generation in new streams (Chowdhury et al., 2022). Therefore, the results give some evidence of the role of circular economy practices in the rapid development of the kingdom of Saudi Arabia. Nevertheless, bringing further progress with policy issues, technology and culture will remain a priority for making the best of the circular economy. Using its available resources and a vision for strategy implementation, Saudi Arabia can finally surpass other countries in terms of sustainability and circularity.

5. Discussion

Circular economy is a transformative process in Saudi Arabia for shifting the nation's economic growth towards sustainable environmental practices. To conclude this debate concerning the findings, some insights are scrutinized to analyze and assess Saudi Arabia's advancement, prospects and issues on the implementation of circular economy. It also encompasses an area of the effects of such initiatives to Saudi Arabia dominance in the global systems in terms of environmental, economic, and geopolitical concepts.

 doi:10.20944/preprints202503.0181.v1

5.1. Progress and Milestones: Aligning Vision 2030 with Circular Economy Principles

It is understandable that Saudi Arabia has recorded remarkable progress in implementing the circular economy measure, especially when aligned with Vision 2030. The Kingdom's vision to transform from an oil-based economy to a knowledge-based, sustainable one is proceeding in line with international sustainability objectives. The investments made by the Kingdom in mega project of renewable energy depicts the concern for cutting down carbon foot print and fossil fuel utilization. An example of such projects includes Sakaka Solar Plant and Dumat Al-Jandal Wind Farm which shows the Kingdome of Saudi Arabia's commitment towards using it natural resource in serving renewable energy. Not only does renewable energy decrease environmental effects, but also it helps to drive new diversification of industries for circular economy in various industries and sectors (Basha et al., 2021).

These policies are quite realistic measures for the energy transition process. Leveraging its geographical location, Saudi Arabia has emerged as a frontrunner in renewable power generation system all over the world. This positioning is not only capable of meeting environmental conditions, but also have an economic buffer against fluctuating oil prices. Neom which is currently under construction and is planned to be a capital of sustainable technological realization of circular economy represents the Saudi flow of circular urbanism. The attainment of sustainable water resources, renewable energy systems, waste recycling units in Neom put real-life examples regarding closed-loop urban systems.

But this is where Neom's success lies, in the prospects of scalability and replicability of the model. It is among the flagship projects under Vision 2030, Nonetheless, its implementation is complex with high costs and use of new and advanced technologies raising questions on its scalability to the other regions within the kingdom. It is therefore important to make sure that the principles used in Neom can easily be used in the rest of Saudi Arabia which may not be as affluent as Neom. In the same venue, the nation has made remarkable achievements in waste management especially through the establishment of the Saudi Green Initiative. Higher recycling and the general use of technologies for turning waste into energy show that it would be possible to reduce the use of landfill sites along with the use of resources. These efforts are in tune with organization's international standards like the total recycling index in Denmark that currently records minimal landfill disposal (Al-Gahtani, 2024).

5.2. Challenges Hindering Circular Economy Implementation

However, Saudi Arabia has done a good job in the implementation of circular economy measures though there are a number of barriers. These include policy-related challenges, technological constraints, and deeply ingrained institutional practices, all of which require targeted and separate approaches for resolution. Another emerging pattern in the research is the absence of a single overriding policy for circular economy initiatives. Although Vision 2030 provides a strong framework for implementing circular economy principles, it falls short in enforcing policies that mandate corporate adaptation. For example, there are no comprehensive laws requiring companies to design products with environmentally friendly methods or integrate recycling mechanisms (Pandey et al., 2021).

The most important of all is integration of policies with each other because systemic changes are required. Countries like the Netherlands have demonstrated success in implementing circular economy policies and providing incentives for green technologies. It is suggested that similar measures should be adopted in Saudi Arabia while guaranteeing that all the sectors incorporate the legislation of circular economy approaches hence embracing the principles of the circular economy. The introduction of high-end recycling and renewable energy technologies is accompanied by high costs of investment., whereas Neom and Sakaka Solar Plant demonstrate Saudi Arabia's financial strength, Small scale enterprises suffer a major inconvenience in getting access of these technologies (Chowdhury et al., 2022).

 doi:10.20944/preprints202503.0181.v1

Also, most innovative green technology products cannot be manufactured domestically, and this makes imports expensive, juxtaposed with limited development of maximum levels of production. Meeting these challenges therefore needs investment in local R&D to support innovation. It is also beneficial to partner with international technology providers to enhance learning and development of capacities. Despite the benefits of circular economy, lack of awareness and consumer behavior complication continue to hinder the change is society. The study further shows that a majority of Saudi people are ignorant of the dissemination of recycling and other sustainable consumptions. Such cultural continuity can be attributed to decades of operationalisation of linear economic models where resource input was cheap and the disposal of waste was seen as unimportant (Basha et al., 2021).

5.3. Opportunities for Global Leadership

Nevertheless, Saudi Arabia holds many opportunities to become one of the leaders in implementing the concept of the circular economy. This positions it well with regard to resources, accessibility, and goal-oriented Vision 2030 projects in the global sustainability arena. Saudi Arabia produces green hydrogen at places like Neom Hydrogen Plant to have some geopolitical impacts as well. In breakdown, green hydrogen is paving its way into becoming one of the most significant tools in the global energy shift away from the use of fossil fuel. Since Saudi Arabia is endowed with an abundance of renewable energy sources, the country can pivot to provide green hydrogen to Europe and Asia (Hassan et al., 2023).

This positioning does not only for the purpose of the economic diversification of the Kingdom but also the geopolitical position. This way, Saudi Arabia can structure the green hydrogen market, and, thus, can reaffirm itself as an important player in international relations in the context of the global energy transition. Being the largest economy in the Middle East, Saudi Arabia holds significant potential to lead the region in transitioning to a circular economy. Some possible projects include joint construction of recycling facilities, joint use of power lines for generation and distribution of renewable electricity. Moreover, Saudi Arabia, with the help of Neom experience, can give technical assistance and monetary support to circular economy projects in other GCC countries (Pandey et al., 2021).

Due to the extensive scale of circular economy in Saudi Arabia evident in programmes like the Saudi Green Initiative and National Renewable Energy Program, Saudi Arabia can advise others. Saudi Arabia, therefore, has an opportunity to increase its export of knowledge, technologies, and best practices in circular economy especially to the developing countries that seek its expertise in embracing the change in its economic system. This opportunity is in recognition to the United Nations Sustainable Development Goals that are already in place. On the other hand, assuming the leadership role of 'sustainability' Indexed in the global front can help the kingdom improve its global image and standing.

5.4. Environmental and Economic Implications

Saudi Arabia circular economy generally has positive effect as it fulfills both the environmental and economic aspects both nationally and internationally. Thus positive environmental impacts of circular economy in KSA are evidenced by the priorities in the diversification of carbon footprints reduction, better waste management and resources optimization. For instance, the kingdom made strides in the power-share shift across its renewable energy sector, which is making a far lesser reliance on fossil fuels; which in turn is a key step towards global decarbonization (Almulhim & Al-Saidi, 2023). Furthermore, current innovations in emission control, including waste recycling or production of energy from waste disposal, reduce emissions from the dumping of waste in the landfills. All these programs are compatible with international climate objectives, including the Paris Climate Accord, which makes Saudi Arabia a self-sufficient actor in combating climate change.

Circular economy strategies help to achieve the economic diversification backbone of Vision 2030. Support from renewable source of energy, improved green technological improvement of cities

 doi:10.20944/preprints202503.0181.v1

and towns, establish new sectors that reduce dependence on oil incomes. The work also described economic vulnerability persistence and the possibility of economic resilience (Basha et al., 2021). Consequently, there is any implement circular processes, Saudi Arabia may be able to shield its economy from the drastic changes in the economic indicators such as the price drop in oil prices or interferences in the supply chain crisis. On this regard, circular economy initiatives will enhance innovation hence providing a competitive edge in fledging markets.

5.5. Geopolitical Implications

Some of the key policy implications of circular economy Saudi Arabia involve geopolitics regarding energy global transition and climate change diplomacy. Thus, Saudi Arabia can deepen cooperation with other significant partners by focusing on renewable energy and green hydrogen production. For example, exporting green hydrogen can boost the Kingdom's connection with the EU as Europe is committed to implementing ambitious decarbonisation measures (Hassan et al., 2023). Overall, it can be concluded that Saudi Arabia through its sustainability initiatives promotes change and improves its soft power on the global stage. When its policies favor global climate aims, the Kingdom enhances its global standing as a responsible actor, contributing to better image and standing.

6. Recommendations and Conclusion

Recommendations

To solidify its position as a global leader in the circular economy and overcome the challenges identified, Saudi Arabia should consider the following recommendations:

1. Enhance Policy Frameworks:

To ensure that circular economy practices become entrenched in Saudi Arabia's economy across all industries, the country requires a strong regulatory infrastructure. This is achieved by regulating sustainable measures like recycle requirements and standards for resource use and products. The government targeted incentives, including subsidies or tax cuts for first movers embracing the circular economy (Yoo et al., 2022).

2. Promote Technological Innovation:

More funding should be allocated towards R&D to encourage the development of new technologies for waste recycling or composting, energy generated from renewable sources, emission reduction technologies for industries or environmentally friendly production methods. Entering into partnerships with key technology providers worldwide can result in the obtaining of new knowledge and practices as well as receive technologies that are innovative. Applying grants or subsidies to promote joint projects of public and private ownership can also strengthen the practical implementation of circular economy principles.

3. Build Public Awareness and Engagement:

Therefore, a broad national awareness campaign is necessary to raise the public's awareness of the role and advantages of the circular economy. Educational institutions need to incorporate circular economy principles into their curricula at the school and university level, whereas at the community level circular economy requires action. Al-Gahtani (2024) also observed that by encouraging the private sector through CSR programs, these objectives can also be intensified.

4. Strengthen Regional and Global Collaboration:

Saudi Arabia can contribute to regional sustainability through regionalization of the sustainability efforts by cooperating with nearby countries to establish coupled physical flows, co-ordinated policies and projects, and synchronized undertakings meant for efficient use of resources. Internationally, Saudi Arabia should use fora like the G20 to introduce circular economy principles, call for collaboration in circular innovations such as green hydrogen, renewable energy, and waste management.

5. Scale Successful Pilot Projects:

 doi:10.20944/preprints202503.0181.v1

Projects such as Neom and the Saudi Green Initiative must thus be used as models for other programs to follow. Information provided should be useful in planning the scaling up of similar projects across the Kingdom; special focus should be given to rural and less developed areas of the Kingdom. It becomes critical to maintain scalability and eliminate unnecessary costs to maximize their effectiveness (Basha et al., 2021).

7. Conclusions

Thus, Saudi Arabia's shift toward a circular economy is a significant turning point in the country's sustainable development path and it becoming a world leader. This is especially apparent with Vision 2030 coupled with projects such as Neom City and the Saudi Green Initiative, showing that the Kingdom is active in challenging the status quo of economic and environmental sustainability. The study, however, notes notable improvements in renewable energy, waste, and management, and urbanization. However, areas such as policy development, technological advancements, and organizational culture present opportunities for further progress in actualizing the circular economy It is thus possible for Saudi Arabia to overcome such hurdles and act as a model for other countries through proper interventions.

It recognizes that circular economy initiatives provide solutions in numerous domains, primarily environmental conservation, economic development, and improved geopolitical stature. With all these factors considered, it becomes easier to see why Saudi Arabia is in a vantage position to drive change toward sustainability, thanks to its peculiar resources and location in the region, as well as the level of envisioning in its leadership. Finally, the degree to which the circular economy is incorporated into the Kingdom's development plan will determine the level of success that will be achieved. Through encouraging innovative attitudes, increasing the public's awareness, and cooperating with other countries and regions, Saudi Arabia should be able to meet its objectives of economic diversification and sustainable development to create a better and less vulnerable future.

References

Almulhim, A. I. (2022). Household's awareness and participation in sustainable electronic waste management practices in Saudi Arabia. *Ain Shams Engineering Journal*, *13*(4), 101729–101729. https://doi.org/10.1016/j.asej.2022.101729

Abdulaziz AlJaber, Martinez-Vazquez, P. and Charalampos Baniotopoulos (2024). Circular Economy in the Building Sector: Investigating Awareness, Attitudes, Barriers, and Enablers through a Case Study in Saudi Arabia. *Sustainability*, [online] 16(3), pp.1296–1296. doi:https://doi.org/10.3390/su16031296.

Al-Gahtani, S. F. (2024). Saudi Arabia's Journey toward a Renewable Future. *Energies*, *17*(11), 2444–2444. https://doi.org/10.3390/en17112444

Almulhim, A. I., & Al-Saidi, M. (2023). Circular economy and the resource nexus: Realignment and progress towards sustainable development in Saudi Arabia. *Environmental Development*, *46*, 100851–100851. https://doi.org/10.1016/j.envdev.2023.100851

Alqarni, M. S. (2022). *Environmental Education in Saudi Arabia: Probing the Beliefs of Elementary School Teachers*. Ohiolink.edu. https://etd.ohiolink.edu/acprod/odb_etd/etd/r/1501/10?clear=10&p10_accession_num=toledo1670416781826243

Alshathri, N. A. (2022). *Knowledge, Attitude and Practice Regarding Infection Control Measures Among HealthCare Workers at King Khaled Eye Specialist Hospital (KKESH) in Riyadh, KSA* (Master's thesis, Alfaisal University (Saudi Arabia)).

Aya Abdelmeguid, Afy-Shararah, M., & Konstantinos Salonitis. (2022). Investigating the challenges of applying the principles of the circular economy in the fashion industry: A systematic review. *Sustainable Production and Consumption*, *32*, 505–518. https://doi.org/10.1016/j.spc.2022.05.009

Basha, J. S., Tahereh Jafary, Vasudevan, R., Bahadur, J. K., Muna Al Ajmi, Aadil Al Neyadi, Elahi, M., Mujtaba, M., Hussain, A., Ahmed, W., Kiran Shahapurkar, Rahman, A., & Fattah, R. (2021). Potential of Utilization of Renewable Energy Technologies in Gulf Countries. *Sustainability*, *13*(18), 10261–10261. https://doi.org/10.3390/su131810261

 doi:10.20944/preprints202503.0181.v1

Chowdhury, S., Dey, P. K., Rodríguez-Espíndola, O., Parkes, G., Anh, T., Long, D. D., & Ha, T. P. (2022). Impact of Organisational Factors on the Circular Economy Practices and Sustainable Performance of Small and Medium-sized Enterprises in Vietnam. *Journal of Business Research*, *147*, 362–378. https://doi.org/10.1016/j.jbusres.2022.03.077

Dam, K. van, Simeone, L., Duygu Keskin, Baldassarre, B., Monia Niero, & Morelli, N. (2020). Circular Economy in Industrial Design Research: A Review. *Sustainability*, *12*(24), 10279–10279. https://doi.org/10.3390/su122410279

Dong, Z., Zhang, L., Li, H., Gong, Y., Jiang, Y., & Peng, Q. (2022). Knowledge Mapping and Institutional Prospects on Circular Carbon Economy Based on Scientometric Analysis. *International Journal of Environmental Research and Public Health*, *19*(19), 12508–12508. https://doi.org/10.3390/ijerph191912508

European Commission. (2020). Circular economy action plan: For a cleaner and more competitive Europe. Retrieved from https://ec.europa.eu

Fan, Y., & Fang, C. (2020). Circular economy development in China-current situation, evaluation and policy implications. *Environmental Impact Assessment Review*, *84*, 106441–106441. https://doi.org/10.1016/j.eiar.2020.106441

Hassan, Q., Sameer Algburi, Aws Zuhair Sameen, Marek Jaszczur, Salman, H. M., Mahmoud, H. A., & Awwad, E. M. (2023). Saudi Arabia energy transition: Assessing the future of green hydrogen in climate change mitigation. *International Journal of Hydrogen Energy*, *55*, 124–140. https://doi.org/10.1016/j.ijhydene.2023.11.117

Islam, M. T., & Ali, A. (2024). Sustainable green energy transition in Saudi Arabia: Characterizing policy framework, interrelations and future research directions. *Next Energy*, *5*, 100161–100161. https://doi.org/10.1016/j.nxener.2024.100161

Jahan, N., Tahmid, M., Afrina Zaman Shoronika, Athkia Fariha, Roy, H., Pervez, M. N., Cai, Y., Naddeo, V., & Islam, M. S. (2022). A Comprehensive Review on the Sustainable Treatment of Textile Wastewater: Zero Liquid Discharge and Resource Recovery Perspectives. *Sustainability*, *14*(22), 15398–15398. https://doi.org/10.3390/su142215398

Kirchherr, J., Yang, N.-H. N., Frederik Schulze-Spüntrup, Heerink, M. J., & Hartley, K. (2023). Conceptualizing the Circular Economy (Revisited): An Analysis of 221 Definitions. *Resources Conservation and Recycling*, *194*, 107001–107001. https://doi.org/10.1016/j.resconrec.2023.107001

Malahat Ghoreishi, & Ari Happonen. (2020). Key enablers for deploying artificial intelligence for circular economy embracing sustainable product design: Three case studies. *AIP Conference Proceedings*. https://doi.org/10.1063/5.0001339

Pandey, N., de Coninck, H., & Sagar, A. D. (2021). Beyond technology transfer: Innovation cooperation to advance sustainable development in developing countries. *WIREs Energy and Environment*, *11*(2). https://doi.org/10.1002/wene.422

Rasha Mohamad Mahboub, & Fawaz, L. I. (2022). IMPACT OF CORPORATE SOCIAL RESPONSIBILITY PRACTICES ON FINANCIAL PERFORMANCE: EVIDENCE FROM SELECTED MENA REGION COMMERCIAL BANKS. *BAU Journal - Creative Sustainable Development*, *3*(2). https://doi.org/10.54729/mocw5159

Short, S., Molini, A., Santamarina, J. C., & Friedrich, L. (2021). *COP26 Visions for a Net Zero Future – Regional Profile for the Arabian Peninsula*. https://doi.org/10.33774/coe-2021-29q7b

Somayya Madakam, & Pragya Bhawsar. (2021). NEOM Smart City: The City of Future (The Urban Oasis in Saudi Desert). *Springer EBooks*, 1–23. https://doi.org/10.1007/978-3-030-15145-4_86-2

Walker, A. M., Opferkuch, K., Lindgreen, E. R., Simboli, A., Vermeulen, W. J. V., & Raggi, A. (2021). Assessing the social sustainability of circular economy practices: Industry perspectives from Italy and the Netherlands. *Sustainable Production and Consumption*, *27*, 831–844. https://doi.org/10.1016/j.spc.2021.01.030

Yusuf Akinwale. (2024). Circular economy awareness, adoption, and its effects on business performance in Saudi Arabia. *Problems and Perspectives in Management*, *22*(3), 119–133. https://doi.org/10.21511/ppm.22(3).2024.10