The Role of Artificial Intelligence in Supporting Green Economy in GCC: Its economic, managerial and necessary legal framework impact

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Abstract

The overarching objective of this study was to determine the economic and administrative impact of artificial intelligence (AI) on the green economy in the Gulf Cooperation Council (GCC), as well as the legal framework needed to support this impact. This paper used a mixed qualitative methodology consisting of qualitative participant observation, social and cultural analysis and case studies. Study concluded that AI innovations are already being applied across industries to optimize efficiency, reduce waste, enable circularity, and advance renewables. From smart grids to virtual assistants, AI solutions aligned with sustainability goals confer competitive advantage while mitigating environmental harm. The research was also consistent in showing, though, that fully capitalizing on AI's possibilities requires strategic policymaking and implementation oversight. Though AI adoption is increasing, gaps remain in skills, data systems, and supportive frameworks. A clear regulatory agenda must address risks like privacy, equity, and safety to raise AI capabilities responsibly. Partnerships between government, businesses, and academia can promote cutting-edge green AI that serves both prosperity and ecology. In conclusion, the study suggests that AI can play a significant role in supporting the transition to a green economy in GCC .However, the adoption of AI in this context presents significant administrative and legal challenges that need to be addressed. Therefore, policymakers and stakeholders in the GCC should collaborate to develop a comprehensive legal framework that promotes the use of AI in a responsible and sustainable manner.

Keywords: Artificial Intelligence (AI), Green Economy, legal, Efficiency, Data privacy, liability, Intellectual property, Managerial

Introduction

The Gulf Cooperation Council (GCC) is a political and economic alliance formed in ١٩٨١ between six Middle Eastern nations: Saudi Arabia, Kuwait, the United Arab Emirates, Qatar, Bahrain, and Oman. Headquartered in Riyadh, Saudi Arabia, the main goal of the GCC is to foster unity, collaboration, and shared cultural identity among its members, all of whom have comparable historical ties rooted in Arab and Islamic heritage. By promoting alignment on objectives and policies, the GCC facilitates cooperation on key issues impacting its constituent countries (About GCC, ٢٠٢٣). The growing importance of this organization and its potential for contributing to regional stability in the future are directly related to this study's objectives which are discussed below.

Study Objectives:

The overarching objective of this study was to determine the economic and administrative impact of artificial intelligence (AI) on the green economy in the Gulf Cooperation Council (GCC), as well as the legal framework needed to support this impact. This main objective is supported by several additional objectives as described below.

Restructure and More Objectives:

Some additional objectives for this study included the following:

- Assess the current level of AI adoption within green industries in GCC countries and analyze the economic contributions in areas like energy, construction, transportation.
- Identify administrative challenges and opportunities for governments in regulating, supporting, and leveraging AI to promote sustainability goals and green economic growth.

- Evaluate the cost-benefit ratio of investments in AI to support decarbonization, renewable energy expansion, resource efficiency, and environmental protection in the GCC.
- Determine the regulatory frameworks and policy incentives required to accelerate development and adoption of impactful green AI technologies across the GCC.
- Analyze case studies of successful implementation of AI for sustainability initiatives across GCC nations to derive best practices.
- Assess gaps in digital skills, data systems, and technological readiness that may hinder GCC countries from capitalizing on AI's sustainability potential.
- Project future trends in green AI applications and quantify opportunities for economic, environmental, and human benefit for the GCC.

These objectives are achieved through analysis of relevant economic policies, market research, trend forecasting, and case study approaches to derive data-driven insights on maximizing AI's potential for the green economy of the GCC.

Importance of Study

The findings of this study have critical importance at both a practical and strategic level. Practically, these findings can provide a valuable framework to guide efficient policymaking and investment around leveraging AI for sustainability, which are national goals of all GCC members (Khan and Al-Ghamdi, ٢٠٢٣). Likewise, developing an improved understanding of AI's economic contributions and required governance frameworks allows optimizing its current applications while identifying gaps in the existing body of knowledge that require additional research.

Strategically, the analysis will delineate pathways for GCC countries to capitalize on green AI for national and regional prosperity, competitive capability, and environmental resilience. With rigorous assessment of the challenges, opportunities and projected benefits of aligning AI

innovation with sustainability, public and private leaders in the GCC can make informed decisions that responsibly harness technology's potential. Given the urgency of progressing sustainability and the power of emerging technologies, evidence-based insights are indispensable for realizing AI's possibilities. This multifaceted study can therefore yield crucial intelligence for steering GCC nations toward becoming pioneers in ethical, prosperous green AI economies as noted in the literature review below.

Literature Review

An analysis by Anisa et al. (٢٠٢٣) reviewed applications of artificial intelligence (AI) in biowaste remediation and valorization for sustainability from ٢٠٠٧-٢٠٢٢. Biowaste refers to discarded organic materials that can be converted into bioenergy. However, feedstock variability and supply chain instability have hindered biowaste's potential. The analysis found AI helps overcome these challenges. Four main techniques were identified: neural networks for predictions, Bayesian networks for probabilistic models, decision trees for decision support, and multivariate regression to relate variables (Aniza et al., ٢٠٢٣).

Neural networks comprised the most common AI approach in the Aniza et al. study which provided more accurate and rapid predictions than conventional methods. Model performance improvements, however, still remain a key opportunity for future iterations. Notwithstanding the challenges that are involved, enabling better data-driven insights and process optimization means that AI is a highly effective tool for improving biowaste-to-bioenergy systems (Aniza et al., ٢٠٢٣). The analysis by Aniza and his colleagues synthesized ١١٨ studies to provide strategic insights on AI's benefits in mitigating, repurposing, and sustaining biowaste at scale and highlighted AI's pivotal role in advancing biowaste circularity to achieve environmental sustainability (Aniza et al., ٢٠٢٣).

Likewise, the results of a bibliometric analysis by Khan and Nasir (٢٠٢٣) also provide significant support for the use of AI applications for predicting, developing, and managing renewable wind and solar energy resources. With environmental pollution a growing global concern, and technology essential for achieving sustainability, this study analyzed AI's role in renewable energy based on patterns in the literature. Findings revealed three research clusters: AI optimization of renewables, smart renewable challenges and opportunities, and forecasting through machine learning (Khan and Nasir ٢٠٢٣).

The study by Khan and Nasir provided valuable strategic insights concerning best practices for leveraging AI across the renewable energy lifecycles, from prediction to efficiency improvements and beyond. Although previous studies linked technology and energy, this seminal study highlighted AI specifically as an impactful tool for developing wind and solar to address environmental issues. Moreover, Khan and Nasier synthesized knowledge and outlined research trajectories to guide effective application of AI in renewable systems. Taken together, the bibliometric analysis emphasized AI's growing significance in sustainable energy advancement (Khan and Nasir ٢٠٢٣).

In addition, a case study by Damoah et al. (٢٠٢١) applied corporate social responsibility theory to examine how an AI-enhanced medical drone program in Ghana can improve healthcare supply chains and support sustainable development goals. The research data for this study was collected via interviews and documents from a major medical drone initiative. The findings that emerged from this study indicated AI optimization of drone logistics significantly boosted supply chain performance and reduced carbon emissions by enabling delivery of emergency medicines without vehicles. Further, by cutting mortality and providing essential supplies, the drone program

aided local socioeconomic outcomes related to health, economic growth, and climate action (Damoah et al., ٢٠٢١).

The findings that emerged from this study shown that the noise-free drones also reduced disruption. As a result, AI-coordinated drone delivery offered environmental benefits while also improving supply chain equity, timeliness, and human welfare, thereby aligning the objectives and outcome of this initiative with corporate sustainability. In sum, the research in Ghana highlighted an AI application that enhanced healthcare supply chains while furthering sustainability, showing technology's promise to jointly address health and development challenges (Damoah et al., ٢٠٢١).

Yet another case study, this one by Zaheer et al. (٢٠٢٣), combined lean principles and machine learning to improve energy efficiency for flexographic printing machines. Flexographic printing is widely used in packaging and labeling due to its versatility, cost-effectiveness, speed, image quality, and eco-friendliness, but optimizing energy usage presents challenges. By applying root cause analysis and continuous improvement processes, the research reduced idle time by ٣٠٪ for two machines, yielding over ٣٤٪ in energy savings per meter printed (Zaheer et al., ٢٠٢٣). In addition, these researchers also used a multi-linear regression model which succeeded in accurately predicting energy consumption using machine parameters, enabling optimized job scheduling. The integrated lean and machine learning approach decreased energy use and costs while maintaining print quality. By increasing sustainability, this method can help printing companies meet environmental objectives. In sum, this study demonstrated an effective solution to a key efficiency issue in flexographic printing using modern AI techniques combined with lean management philosophy (Zaheer et al., ٢٠٢٣).

A case study by Pawlicka and Monika (٢٠٢٢) examined implementing sustainable supply chain finance supported by AI in the Omni channel retail sector. Given limited research on

intersection of sustainable supply chain finance, AI, and Omni channel logistics, the study aimed to identify opportunities to enhance sustainability through this approach. These researchers gathered data from two international clothing companies via documents, observation, and interviews (Pawlicka and Monika, ٢٠٢٢).

The findings that emerged from this study indicated that AI-enabled sustainable supply chain finance could significantly improve sustainability across supply chains, especially strategically by fostering partnerships for value-added eco-friendly materials conferring competitive advantages. AI increased SSCF efficiency, service quality, and supply chain transparency (Pawlicka and Monika ٢٠٢٢). This study contributed timely insights on leveraging AI-supported sustainable supply chain finance to progress sustainability in omnichannel retail, while improving productivity, consistency, and resilience. Further, the stud also provided useful guidance for apparel and other industries pursuing responsible omnichannel expansion. In sum, the study highlighted the promise of AI-powered financing to strengthen sustainable, ethical omnichannel supply chains (Pawlicka and Monika ٢٠٢٢).

Finally, as the use of AI continues to increase, the GCC member-states are exploring legal frameworks to govern its responsible and ethical use. These frameworks primarily focus on data privacy, cybersecurity, and transparency to ensure the responsible development and deployment of AI technologies (Berglind et al., ٢٠٢٣). In addition, other legal considerations that must be taken into account include fairness and non-discrimination which should be validated across citizen demographics through testing. Further, extensive and ongoing testing must validate consistent safety and performance aligned to design intentions. Taken together, developing legal frameworks for the use of AI that protect privacy, security, equity, transparency, safety, and

accountability across the AI lifecycle and ecosystem represent foundational best practices for ethical, trustworthy artificial intelligence.

Methodology

This paper used a mixed qualitative methodology consisting of qualitative participant observation, social and cultural analysis and case studies. The participant observation portion was conducted within a GCC-related organization using AI for sustainability to gain on-the-ground insights about implementation. The researcher was embedded to directly observe AI integration processes, workflows, relationships, and challenges. Concurrent hands-on participation in AI testing, training, and application added crucial contextual understanding which are shared in the findings that follow below.

Although no overall cultural dimension data exists for all six member-states of the GCC, some indication of their overall cultural preferences, values, norms, expectations and workplace behaviors can be discerned from the breakdown in Figure ١ below for Kuwait, Qatar and Saudi Arabia, the only three member-states for which data is available from noted sociologist, Geert Hofstede. Nevertheless, as the graphic representation of the cultural dimension data for these three countries depicted in Figure ١ below indicates, all three rate comparably on the four cultural dimensions of interest (e.g., power distance, individualism, masculinity and uncertainty avoidance).

Fig. ١. Cultural Dimensions of GCC Members

As shown in Figure ١ above, the GCC scores high on power distance, indicating acceptance of hierarchical orders with centralized authority and expectations for subordinates to follow directions from benevolent autocratic superiors. The GCC's low individualism score reflects a collectivist society with strong in-group loyalty and mutual responsibility among members prioritized over societal rules. As a relatively feminine culture, the GCC values cooperation, quality of life, and well-being over status with conflicts solved through compromise (Hostede, ٢٠٢٣).

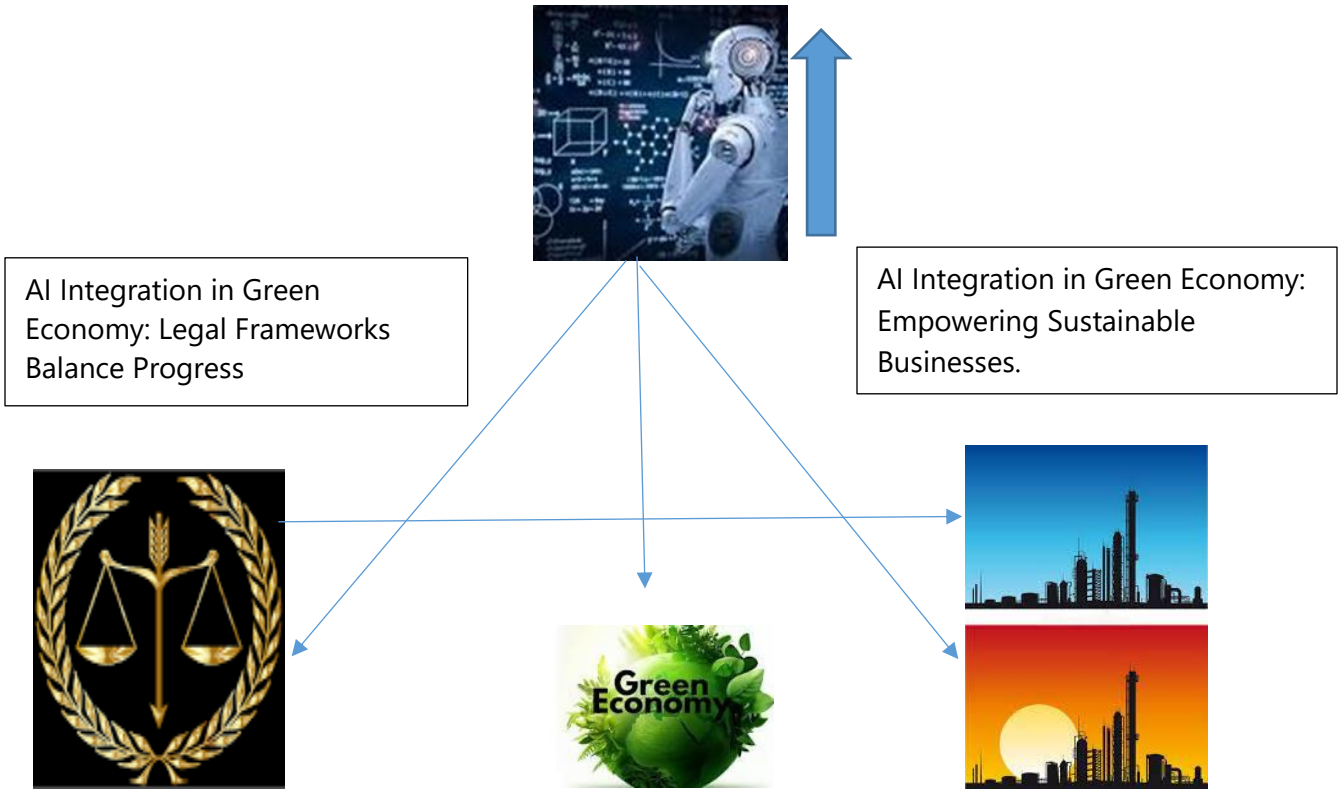
The high uncertainty avoidance score shows a preference for rigid codes of behavior and intolerance of unorthodox ideas, with a strong need for rules and busy work ethic driven by inner urges for precision, punctuality and security. Taken together, the GCC exhibits cultural dimensions of hierarchy, collectivism, femininity and uncertainty avoidance that shape workplace norms, relationships and motivations in distinct ways (Hofstede, ٢٠٢٣).

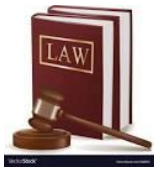
These findings suggest that the acceptance of the use of AI in workplace settings depends on organizational culture established from the top-down, meaning that leaders must make this a priority in their day-to-day activities as well as their long-range planning.

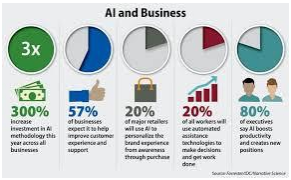
Findings, Analysis and Discussion

Creating a study model figure to show the impact of AI on the green economy from legal and business perspectives can be a visually effective way to present the research relations and impact.

Synergy between Legal and Business Perspectives: Accelerating Green AI Innovations







One of the more noteworthy findings that quickly emerged from the research was the fact that the opportunities to use of AI to support a greener economy in the GCC are virtually infinite, limited only by the imaginations and technological expertise of practitioners. Indeed, the literature search revealed the use of AI in almost every enterprise imaginable, and these practices are consistently contributing to improved sustainable and greener operations in their own unique ways. In other words, AI today is creating a new paradigm where automation and machine learning can reduce humanity's carbon footprint and perhaps just save the world for future generations.

Some of the ways that AI has been used for these purposes include so-called "fuzzy logic" circuits that automatically monitor operations and make adjustments to optimize efficiencies. For instance, smart power grids which optimize transmission efficiency, seamlessly integrate renewables, and reduce distribution losses through machine learning algorithms that balance loads and stabilize intermittent solar/wind generation. Likewise, automated monitoring leverages predictive analytics on usage data to identify anomalies and ensure preventative maintenance for water, gas, electricity, and manufacturing infrastructure before leaks or excess consumption occur. AI digital platforms can map byproduct and waste flows to close regional circular economy loops, like directing desalination brine to produce minerals or matching plastic waste to refinement processes.

Computer vision and AI-guided robotic disassembly foster higher-value materials recovery from complex products at end-of-life by automating complex disassembly. Renewables like solar panels and wind farms can maximize productive lifetime through AI-assisted predictive

maintenance. At the consumer level, virtual assistants provide personalized resource conservation recommendations based on analyzing usage patterns in homes and offices. Through optimized systems, circular synergies, and accelerated renewable uptake, thoughtfully implemented AI can enable GCC countries to decouple economic expansion from fossil fuel dependence and waste generation.

AI-optimized smart power grids improve efficiency, integrate renewables, and reduce transmission losses through data-driven load balancing and stabilization. Automated monitoring via predictive analytics prevents leaks, emissions, and unnecessary usage across infrastructure. Digital platforms map circular economy synergies between regional byproduct and waste flows. Computer vision and robotic disassembly enable higher-value materials recovery from complex end-of-life products. AI predictive maintenance maximizes the productive lifetime of green infrastructure like solar arrays. In addition, virtual assistants provide personalized resource conservation recommendations based on analyzing consumption patterns. Carbon accounting tools accurately track emissions across value chains to inform climate targets. Geospatial analytics and simulation modeling powered by machine learning enhance siting and design of renewable projects and energy-efficient buildings. Furthermore, AI also has applications in carbon removal techniques, blockchain supply chain tracing, and predictive climate risk modeling. Taken together, thoughtfully implemented AI can empower GCC nations to decouple economic growth from fossil fuel dependence by improving efficiency, circularity, and sustainable development (Truby, ٢٠٢٣). AI technologies hold immense promise in mitigating the environmental impact of these developments. To foster the growth and widespread adoption of impactful green AI technologies across the GCC, it is crucial to establish effective regulatory frameworks and policy incentives.

This analysis explores the necessary measures that can promote the development and adoption of green AI technologies in the region.

١. Establishing Regulatory Frameworks:

a. Environmental Standards and Guidelines:

- Developing and enforcing stringent environmental standards and guidelines will ensure that green AI technologies adhere to sustainability principles.
- Governments can work with relevant experts and stakeholders to set emission limits, energy efficiency benchmarks, and waste reduction targets for AI applications.

b. Data Privacy and Security:

- To encourage the implementation of green AI technologies, a robust data privacy and security framework must be in place.
- The GCC countries should adopt data protection laws to safeguard the collection, storage, and usage of sensitive data required for AI applications while addressing concerns related to citizen privacy.

c. Technology Testing and Certification:

- Establishing an independent certification body to evaluate and certify green AI technologies will boost public trust and encourage adoption.
- This body can evaluate the environmental impact and efficiency of AI solutions, providing a clear indication of their ecological benefits.

d. Collaborative Research and Development:

- Governments can facilitate collaboration between public and private sectors to support research and development efforts in green AI technologies.

- Offering grants, subsidies, and tax incentives for R&D activities can promote innovation in this domain.

٢. Policy Incentives for Green AI Adoption:

a. Financial Incentives:

- Governments can offer financial incentives such as tax breaks, subsidies, and low-interest loans to organizations adopting green AI technologies.
- Implementing energy pricing policies that favor clean and sustainable technologies can further encourage the adoption of green AI.

b. Procurement Policies:

- Governments and public institutions can lead by example by adopting green AI technologies in their operations.
- Introducing procurement policies that prioritize environmentally-friendly AI solutions can create a significant market for these technologies.

c. Capacity Building and Training:

- Investing in training and capacity building programs for AI professionals, researchers, and policymakers will foster expertise in green AI development and deployment.
- Educational initiatives can help build a skilled workforce capable of developing and managing green AI technologies.

d. Public Awareness Campaigns:

- Governments can run public awareness campaigns highlighting the benefits of green AI technologies for the environment and the economy.
- This can help overcome resistance to change and generate support for the adoption of eco-friendly AI solutions.

To accelerate the development and adoption of impactful green AI technologies across the GCC, a comprehensive approach combining regulatory frameworks and policy incentives is essential. By implementing stringent environmental standards, promoting data privacy, encouraging collaborative research, and offering financial incentives, the GCC countries can create a conducive environment for green AI technology growth. Additionally, adopting green AI in public institutions and raising public awareness will further drive the demand for sustainable AI solutions, leading to a more sustainable and environmentally responsible future for the region.

Conclusions and Recommendations

This research highlights the immense potential of AI to accelerate sustainable development and green economic growth in the GCC region. As demonstrated through the literature review and participant observations, AI innovations are already being applied across industries to optimize efficiency, reduce waste, enable circularity, and advance renewables. From smart grids to virtual assistants, AI solutions aligned with sustainability goals confer competitive advantage while mitigating environmental harm.

The research was also consistent in showing, though, that fully capitalizing on AI's possibilities requires strategic policymaking and implementation oversight. Though AI adoption is increasing, gaps remain in skills, data systems, and supportive frameworks. A clear regulatory agenda must address risks like privacy, equity, and safety to raise AI capabilities responsibly. Partnerships between government, businesses, and academia can promote cutting-edge green AI that serves both prosperity and ecology.

Based on the study findings, the following recommendations are offered:

- Develop a coordinated GCC-wide AI strategy and governing body to align technological innovation with sustainability priorities.
- Increase investments in skills training, digital infrastructure, data governance, and R&D to maximize green AI advances.
- Implement targeted incentives and policies to accelerate AI adoption for environmental initiatives across sectors.
- Create frameworks regulating responsible AI development and deployment, including cybersecurity, transparency, and environmental impact reviews.
- Foster collaboration between industry, government, and academia through joint projects, shared research, and AI technology exchanges.
- Conduct further studies quantifying AI benefits and assessing long-term impacts on green economic growth.
- Develop GCC-specific AI auditing tools and standards to verify environmental benefits and ethics.

In the final analysis, it is reasonable to conclude that responsibly leveraging AI's potential is indispensable for realizing national visions aligned with sustainability. This research provides insights and guidance for strategically harnessing AI innovation to advance both human progress and ecological health across the GCC and beyond.

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