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# Examining the Utilization of Clean Energies for Sustainable Development: A Case Study of Saudi Arabia, United Arab Emirates, and Qatar

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**Abstract:** In recent years, sustainable development has emerged as a cornerstone of global development efforts, emphasizing ecological preservation alongside economic growth. Developed countries have long prioritized sustainable practices, integrating environmental conservation, resource management, and social equity into their policies. This commitment addresses critical global challenges, including climate change and resource depletion, while striving to balance growth and ecological preservation. Oil-rich nations in the Persian Gulf, such as Saudi Arabia, the UAE, and Qatar, are also advancing sustainability by diversifying their economies and reducing reliance on fossil fuels. These countries are leveraging their renewable energy potential to transition towards cleaner energy systems. Saudi Arabia's Vision 2030 aims to generate 50% of its energy from renewable sources by 2030, with significant investments in solar and wind projects. The UAE leads with initiatives like the Mohammed bin Rashid Solar Park and Barakah Nuclear Power Plant, while Qatar invests heavily in solar technologies. These efforts highlight how clean energy technologies and sustainable strategies foster innovation, environmental preservation, and economic diversification. By adopting renewable energy, Gulf nations exemplify how sustainability can drive a greener future. Together, global efforts underscore the shared responsibility of ensuring a sustainable world for future generations.

**Keywords:** Sustainable development, Development studies, Environmental preservation, Developed countries, Policy frameworks, National agendas, Environmental protection.

## 1. Introduction

Development stands as one of the highest priorities for any nation. Once fundamental survival and security concerns are addressed, countries seek to foster prosperity and progress, aiming for a dynamic and positive state that ensures a high quality of life for their citizens. Development is a multifaceted concept, encompassing political, economic, social, and environmental aspects, all of which should ideally progress cohesively across all sectors. However, in the aftermath of the industrial revolution, development became mistakenly synonymous with mere economic growth. As a result, any activity yielding economic gain was perceived as contributing to development, leading to the exploitation of the environment and finite resources. This shortsighted approach resulted in severe consequences, such as

environmental degradation, climate crises, water scarcity, and depletion of finite resources like oil and gas.

In response to these challenges, researchers and scholars have been determined to discover solutions that prevent development from causing environmental crises and endangering future generations. Thus, the concept of sustainable development emerged, seeking to address the needs of both current and future generations simultaneously. Initially formulated by developed countries, the principles, objectives, components, and prerequisites for achieving sustainable development led to the transfer of polluting industrial facilities to developing countries, ostensibly to protect the environment of the developed nations. As globalization took hold and more developing countries joined this process, oil-rich Gulf nations recognized the importance of environmental preservation and the risks associated with over-relying on revenue from hydrocarbon exports. Consequently, they embarked on environmentally conscious strategies, pursuing economic diversification and embracing clean energy sources. Various measures were undertaken in the realm of sustainable development to achieve these goals. Among the nations that invested significantly in sustainable development, Saudi Arabia, the United Arab Emirates, and Qatar emerged as notable examples. In addition to long-term planning, these countries entered into agreements with multinational corporations to enhance their capacity for utilizing renewable energy sources, accelerating the shift away from hydrocarbon energies. Their success in employing clean energies serves as a commendable model for realizing sustainable development.

This research endeavors to explore the endeavors and initiatives undertaken by Saudi Arabia, the United Arab Emirates, and Qatar in their pursuit of sustainable development. The paper's hypothesis posits that these countries have steered towards sustainable development through economic diversification, moving away from their reliance on income from oil and gas exports, and instead embracing clean energy sources. The article primarily focuses on analyzing the programs and actions of these Arab nations in adopting renewable energies for sustainable development, while subsequent research will delve further into the aspect of economic diversification.

## **2. The theoretical framework**

Before we delve into the topic of advancement, let's grasp its fundamental constituents using straightforward language. The term "development" comprises two parts: "De," which implies opposing or changing, and "Envelop," which signifies structure and protection. When we combine these elements, it conveys the idea of moving from an unfavorable situation to a positive and transparent state that everyone acknowledges. In essence, development entails progressing from one stage to another, enhancing efficiency to meet emerging needs. When improvements are made that bring happiness to people's lives, we refer to it as advancement. Presently, after extensive study and analysis of advancement, experts unanimously agree that it is a dynamic process that impacts all facets of our existence. Different individuals hold diverse notions about the meaning of advancement. Some assert that it involves producing more and increasing productivity, while others perceive it as enhancing life in both quantity and quality—such as improving healthcare, reducing unemployment, and fulfilling economic and social requirements. The advancement entails granting equal access to education and culture and encouraging active participation in various spheres of life. The theoretical framework of advancement revolves around comprehending its foundational elements and how

it drives progress in multiple aspects of our lives. It is akin to transitioning from an undesirable condition to a superior and widely acknowledged state, thereby fostering happiness and contentment among individuals in their lives. Different aspects of advancement are connected, including economic, social, political, and cultural dimensions. It's important to look at all of them together. For example, if a country's economy grows, but people are still poor, jobless, and facing inequality, it's not real advancement [10].

Experts have different views on advancement, depending on their knowledge and field of study. Generally, advancement includes various aspects such as:

- **Economic development:** Economic growth signifies enhancing the workforce's productivity, diminishing the significance of agriculture in overall production, adopting technology, and undergoing rapid urban expansion. This is one of the earliest theories of progress, proposing that developed Western countries offer the most exemplary model for advancement in third-world nations. It aligns with the notion of development through modernization.
- **Economic and social development:** In this perspective, not only economic capabilities are highlighted, but also consideration is given to social equity factors, encompassing resource redistribution, poverty alleviation, access to sufficient nutrition, fostering optimism for a better life, guaranteeing a minimum standard of living, and tackling social class disparities.
- **Political, economic, and social development:** In this dimension of development theories, which is more comprehensive than the previous two, progress is assessed based on factors such as a deeper understanding of political, economic, and social processes, proficiency in resolving everyday challenges, enhancement of practical skills, improved management of economic resources, focus on human dignity, and promotion of mutual respect and equality within societal relationships.

## 2.1. Sustainable development

Resilient growth emerged as a response to the limitations of the traditional advancement paradigm, which focused on enriching social, cultural, and political aspects alongside economic expansion. However, the unsustainable use of limited natural resources raised concerns about the long-term continuity of advancement [20]. Researchers introduced the concept of sustainable development to address these issues and ensure the achievement of development goals while conserving the environment and ensuring its enduring viability. Sustainable development necessitates considering more than just economic aspects and human activities. It should also take into account factors like population, resource utilization, and environmental impacts [13]. One of the most widely accepted definitions of sustainable development is provided by the Brundtland Commission, which states that sustainable development meets the needs of the current generation without compromising the ability of future generations to meet their own needs.

In general, three features have played a major role in promoting the concept of sustainable development:

- a) The negative consequences of implementing structural adjustment policies aimed at tackling the global economic crisis.

- b) The ongoing and unavoidable increase in poverty, hunger, and inequality on a global scale.
- c) Disturbing environmental degradation and depletion of natural resources resulting from the application of various technologies.

Sustainable development involves responsibly using limited natural resources by replenishing and restoring them naturally. Failing to do so results in a negative impact on the availability of these resources and makes the development process unsustainable. Essentially, sustainable development policies can be divided into four key areas :

Sustainable growth comprises two fundamental concepts. Firstly, it emphasizes the importance of prioritizing the basic requirements of the world's impoverished. Secondly, it acknowledges the limitations imposed by the ecosystem in meeting both present and future needs. However, fulfilling the immediate needs of the destitute may not always align with the needs of future generations. It is evident that access to crucial resources like power, pure water, pure air, political liberties, and community safety from crime and war varies among nations worldwide [23]. As a result, sustainable development establishes interconnections between three vital domains: the environment (covering water and waste management), society (encompassing employment, human rights, gender parity, peace, and human security), and the economy (addressing poverty reduction, corporate responsibility, and accountability).

Here are some instances of sustainable development:

- Utilizing wind energy
- Harnessing solar energy
- Implementing sustainable construction practices
- Efficiently managing water resources
- Promoting sustainable green spaces and forests (such as the BYJUS educational center)

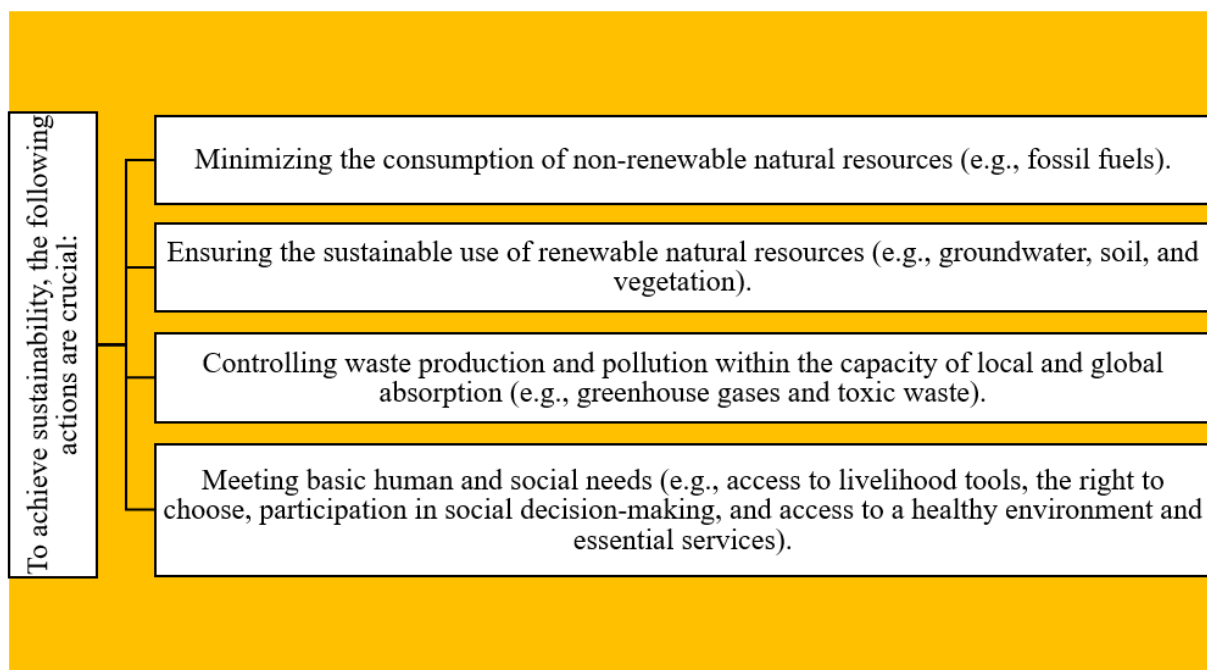


Fig .1: Crucial actions to achieve sustainability [2][3].

This text highlights the significance of renewable energy sources, and it aims to examine Saudi Arabia, Qatar, and the United Arab Emirates as examples of countries embracing clean energy for sustainable development. The initiatives and programs taken by these three nations to shift from fossil fuels to clean energy can be analyzed using the theoretical framework of sustainable development.

### **3. Utilizing Clean Energy: A Step Towards Sustainable Development**

The restricted access to energy resources and their transmission systems poses a predicament to both economic and human progress. Within our environment, we find diverse sources of energy, both sustainable and non-sustainable, such as solar, wind, tidal, geothermal, biofuels, coal, oil, natural gas, and uranium. Overlooking action to diminish greenhouse gas emissions resulting from the escalated use of fossil fuels will have unfavorable repercussions on global climate change. Enhancing energy efficiency and maximizing the utilization of sustainable resources play crucial roles in combating climate change and mitigating the hazards of natural disasters. To safeguard natural ecosystems, it is vital to explore and develop further renewable and plant-based resources. An astounding 3 billion people worldwide still depend on wood, coal, or animal waste for heating and cooking. Energy consumption remains the primary contributor to climate change, accounting for approximately 65% of total greenhouse gas emissions (The United Nations Environment Programme). Since 1990, global CO<sub>2</sub> emissions have surged by more than 43%. At present, sustainable energy stands as the largest source of electricity generation, providing 16% of the world's electricity at competitive prices [19]. This form of energy significantly contributes to electricity generation in many developing countries, and bioenergy or biofuels account for 15% of the world's primary energy supply.

#### **3.1. Global environmental objectives**

- By 2030, ensure global access to affordable, reliable, and modern energy services.
- Significantly increase the share of renewable energy in the global energy mix by 2030.
- Improve energy efficiency at a rate twice the global average by 2030.
- Strengthen international cooperation by 2030 to facilitate access to clean energy technologies and research, including renewable energy, energy efficiency, and advanced technologies to reduce fossil fuel pollution.
- Enhance investment in energy infrastructure and clean energy technologies to provide modern and sustainable energy services in all countries, including less developed countries, developing countries, and small islands, in alignment with their individual plans by 2030 (The United Nations Environment Programme) [21].

The growth and expansion of sustainable energy play crucial roles in achieving economic, social, and environmental development objectives, making them fundamental factors in accomplishing sustainable progress in every country. The adoption of sustainable energy sources like wind, solar, and geothermal can diminish dependence on fossil fuels and decrease pollutant emissions. While sustainable energy sources necessitate significant initial capital investment, their maintenance and repair costs are generally low compared to non-renewable energy production methods. Additionally, sustainable energy offers advantages such as abundance, reliability, reduced pollutant production, enhanced energy supply security, and increased access to sustainable and dependable energy resources for decentralized utilization in rural and less developed regions. They contribute to mitigating global warming, fostering

economic growth, creating employment opportunities in underprivileged regions, increasing per capita income, and safeguarding the environment across all domains. Notably, the current water conditions favor the use of waterless methods in these types of power plants compared to thermal power plants, making them a viable and renewable option. Table 1 shows the key insights on clean energy for sustainable development.

**Table 1: Key Insights on Clean Energy for Sustainable Development**

Aspect	Details
<b>Energy Sources</b>	Solar, wind, tidal, geothermal, biofuels, coal, oil, natural gas, uranium.
<b>Global Challenges</b>	<ul style="list-style-type: none"> <li>- 3 billion people rely on wood, coal, or animal waste for heating and cooking.</li> <li>- Energy consumption accounts for 65% of greenhouse gas emissions.</li> <li>- CO2 emissions have increased by 43% since 1990.</li> </ul>
<b>Renewable Energy Contribution</b>	Provides 16% of global electricity, competitively priced. Bioenergy accounts for 15% of primary energy supply.
<b>Global Environmental Objectives</b>	<ul style="list-style-type: none"> <li>- Ensure global access to affordable, reliable energy by 2030.</li> <li>- Increase the share of renewables in the energy mix.</li> <li>- Improve energy efficiency at twice the global rate.</li> <li>- Strengthen international cooperation on clean energy research.</li> <li>- Invest in energy infrastructure and technologies globally.</li> </ul>
<b>Benefits of Sustainable Energy</b>	<ul style="list-style-type: none"> <li>- Reduces reliance on fossil fuels and pollutant emissions.</li> <li>- Low maintenance costs compared to non-renewables.</li> <li>- Enhances energy security and decentralization.</li> <li>- Promotes economic growth and job creation in underprivileged areas.</li> <li>- Mitigates global warming and safeguards ecosystems.</li> </ul>
<b>Water-Saving Advantage</b>	Waterless methods in renewable energy plants are more sustainable than traditional thermal power plants.

#### 4. Renewable, clean energies in Saudi Arabia

Sustainable and eco-friendly energies have surfaced as a crucial emphasis for Saudi Arabia in recent years, as the nation aims to diversify its energy mix and shift towards a more sustainable and environmentally conscious future. Despite being one of the globe's largest producers of oil and gas, Saudi Arabia acknowledges the significance of diminishing its reliance on fossil fuels and embracing sustainable energy sources to tackle the challenges of climate change and secure a long-term energy supply.

Solar energy is at the forefront of Saudi Arabia's sustainable energy initiatives due to the country's abundant sunshine and vast desert regions. The government has initiated numerous ambitious solar projects, including the world's largest solar park, to exploit the potential of solar power. These projects aim to utilize advanced technologies and extensive solar installations to produce clean electricity and decrease the nation's carbon emissions. The objective is not only to fulfill domestic energy requirements but also to export sustainable

energy to neighboring countries, improving energy security and regional collaboration. Wind energy is another pivotal player in Saudi Arabia's sustainable energy landscape. The nation has substantial wind resources, particularly along its Red Sea coast and in specific inland regions. Saudi Arabia has been actively investigating the establishment of Wind farms to capitalize on its wind potential and diversify its energy portfolio. By harnessing the power of wind, the country can further diminish its dependence on fossil fuels and progress towards a greener and more sustainable energy future [16]. Hydropower is also being examined as a prospective sustainable energy source in Saudi Arabia. While the country is not conventionally linked with substantial water resources, it has been investigating the viability of hydropower projects, particularly in regions with natural water flow or through the use of desalinated water. These initiatives aim to utilize water resources efficiently and generate clean electricity, contributing to the country's sustainable energy goals.

In addition to solar, wind, and hydropower, Saudi Arabia is exploring other renewable energy sources, such as geothermal and biomass, to expand its clean energy portfolio. Geothermal energy, in particular, shows promise in certain regions of the country, where underground heat can be tapped to produce electricity. Biomass, on the other hand, utilizes organic waste and agricultural residues to generate energy, contributing to waste reduction and a circular economy.

The transition to renewable and clean energies in Saudi Arabia is not just an environmental imperative; it also presents significant economic opportunities. The country's Vision 2030, a comprehensive roadmap for economic diversification and social development, places a strong emphasis on renewable energy as a key driver of economic growth. By investing in clean technologies and renewable projects, Saudi Arabia aims to create new industries, generate job opportunities, and attract foreign investment. Embracing renewable energy aligns with the country's commitments to global climate initiatives, such as the Paris Agreement. By reducing its carbon emissions through the adoption of clean energies, Saudi Arabia is contributing to the global effort in mitigating climate change and addressing its environmental responsibilities as a major energy producer. To accelerate the transition towards renewable and clean energies, Saudi Arabia has implemented various policy measures and incentive programs. The government has introduced renewable energy targets, aiming to achieve a certain percentage of its energy mix from renewables within a specified timeframe. This has encouraged private sector investments in renewable projects and facilitated international collaborations with leading companies and technology providers.

The Saudi government has been proactive in developing regulations and frameworks to support renewable energy deployment, including power purchase agreements and net metering schemes. These mechanisms provide stability and predictability for investors and consumers, making the transition to renewable energy more attractive and financially viable. Saudi Arabia's pursuit of renewable and clean energies signifies a bold and forward-thinking approach to addressing the challenges of the 21st century [18]. By capitalizing on its abundant renewable resources and embracing clean technologies, the country is diversifying its energy mix, reducing its carbon footprint, and promoting sustainable economic growth. The commitment to renewable energy aligns with the country's broader vision for economic transformation and social development, making Saudi Arabia a leading player in the global shift towards a greener and more sustainable energy future. As the world faces the urgent need to combat climate change, Saudi Arabia's efforts in renewable and clean energies serve as an



inspiration for other nations, demonstrating that economic prosperity and environmental stewardship can go hand in hand. Through continued investments, policy support, and international collaborations, Saudi Arabia is poised to become a global leader in the renewable energy transition and contribute significantly to a more sustainable and resilient planet for future generations. Table 2 summarized the section.

**Table 2:** Renewable and Clean Energy Initiatives in Saudi Arabia

Renewable Energy Source	Initiatives and Efforts	Benefits and Impacts
<b>Solar Energy</b>	<ul style="list-style-type: none"> <li>- Development of the world's largest solar park.</li> <li>- Advanced solar technology adoption.</li> <li>- Large-scale solar installations.</li> </ul>	<ul style="list-style-type: none"> <li>- Reduces carbon emissions.</li> <li>- Meets domestic energy demands.</li> <li>- Enables energy export and regional collaboration.</li> </ul>
<b>Wind Energy</b>	<ul style="list-style-type: none"> <li>- Exploitation of substantial wind resources, especially along the Red Sea coast.</li> <li>- Establishment of wind farms.</li> </ul>	<ul style="list-style-type: none"> <li>- Decreases reliance on fossil fuels.</li> <li>- Diversifies the energy portfolio.</li> <li>- Progresses towards a sustainable future.</li> </ul>
<b>Hydropower</b>	<ul style="list-style-type: none"> <li>- Exploration of natural water flow and desalinated water for energy.</li> <li>- Feasibility studies in select regions.</li> </ul>	<ul style="list-style-type: none"> <li>- Efficient utilization of water resources.</li> <li>- Contributes to clean electricity production and sustainability goals.</li> </ul>
<b>Geothermal Energy</b>	<ul style="list-style-type: none"> <li>- Tapping underground heat in specific regions.</li> <li>- Research and development in geothermal applications.</li> </ul>	<ul style="list-style-type: none"> <li>- Provides a reliable and sustainable energy source.</li> <li>- Expands renewable energy options.</li> </ul>
<b>Biomass Energy</b>	<ul style="list-style-type: none"> <li>- Utilization of organic waste and agricultural residues.</li> <li>- Promotes circular economy practices.</li> </ul>	<ul style="list-style-type: none"> <li>- Reduces waste and carbon emissions.</li> <li>- Contributes to renewable energy supply.</li> </ul>
<b>Policy Measures</b>	<ul style="list-style-type: none"> <li>- Renewable energy targets.</li> <li>- Incentive programs for private investments.</li> <li>- Frameworks like power purchase agreements.</li> </ul>	<ul style="list-style-type: none"> <li>- Encourages private sector engagement.</li> <li>- Facilitates international collaborations.</li> <li>- Attracts foreign investments.</li> </ul>
<b>Economic Opportunities</b>	<ul style="list-style-type: none"> <li>- Vision 2030 initiative emphasizing renewable energy.</li> <li>- Creation of new industries and job opportunities.</li> </ul>	<ul style="list-style-type: none"> <li>- Drives economic diversification.</li> <li>- Boosts sustainable economic growth.</li> <li>- Aligns with global climate commitments.</li> </ul>

## 5. Neom City: The Vision for a Futuristic Megacity

Neom City is a groundbreaking and ambitious project launched by Saudi Arabia with the vision of creating a futuristic megacity that sets new standards for urban living, sustainability, and innovation. The name "Neom" is a combination of two words: "Neo" meaning new and "M" representing the first letter of the Arabic word for future. Spanning across three countries—Saudi Arabia, Egypt, and Jordan—Neom is strategically positioned along the Red Sea coast, promising a new era of economic growth and development. This article delves into the grand vision, key objectives, potential challenges, and expected impact of the Neom City project.

Neom City aims to be a global showcase of modernity and innovation—a place where cutting-edge technologies, sustainable practices, and forward-thinking governance converge to create an unparalleled urban experience. Crown Prince Mohammed bin Salman unveiled the Neom project in 2017 as part of Saudi Arabia's ambitious Vision 2030, which seeks to diversify the kingdom's economy and reduce its reliance on oil revenues. The vision for Neom encompasses several key pillars, including technological advancement, renewable energy, sustainable living, and economic diversification. It seeks to attract top talent from around the world, promote research and development, and serve as a catalyst for economic growth in the region. Neom City is envisioned as a global economic powerhouse, facilitating trade and business across Asia, Europe, and Africa [22].

### - Key Objectives

- a) **Sustainability and Renewable Energy:** One of the core objectives of Neom City is to be a leader in sustainability and renewable energy. The project aims to be powered entirely by renewable sources, utilizing solar and wind energy to reduce carbon emissions and combat climate change.
- b) **Smart and Connected City:** Neom City will incorporate state-of-the-art smart technologies, including AI-driven infrastructure, IoT connectivity, and autonomous transportation systems. These innovations aim to enhance efficiency, reduce energy consumption, and improve the overall quality of life for residents and visitors.
- c) **Economic Diversification:** As part of Vision 2030, Neom City seeks to diversify the Saudi economy beyond oil and petrochemical industries. It will serve as a hub for various sectors, including tourism, entertainment, healthcare, biotechnology, and advanced manufacturing.
- d) **Quality of Life:** Neom City aspires to be a place where people can thrive and lead fulfilling lives. It will offer a mix of cultural, recreational, and entertainment amenities, making it an attractive destination for both residents and tourists.

- **Challenges and Considerations:** While the Neom City project promises substantial benefits, it also faces significant challenges and considerations. Some of the key challenges include:

- a) **Funding:** Building a city from scratch requires substantial financial investment. Neom City's success hinges on attracting investors and securing sustainable funding for its long-term development.
  - b) **Environmental Impact:** Despite its focus on sustainability, constructing a megacity on a pristine coastline may still have environmental repercussions. Mitigating and minimizing such impacts will be crucial.
  - c) **Social and Cultural Integration:** Neom City's multicultural nature and progressive outlook may encounter resistance from conservative elements in the region. Striking a balance between modernity and preserving cultural values will be essential for social cohesion.
  - d) **Infrastructure and Logistics:** Developing an area as vast as Neom City requires robust infrastructure and efficient logistics to ensure seamless connectivity and accessibility [7].
- **Expected Impact:** The successful realization of Neom City could have far-reaching impacts, not only for Saudi Arabia but also for the broader Middle East and the world:
- a) **Economic Growth:** Neom City has the potential to become a significant economic contributor to Saudi Arabia, attracting investment, creating jobs, and stimulating various industries.
  - b) **Technological Advancement:** As a global innovation hub, Neom City may drive technological advancements, attracting research and development projects, and fostering a culture of creativity and entrepreneurship.
  - c) **Sustainability Inspiration:** Neom City's commitment to sustainability and renewable energy could inspire other cities and nations to adopt similar practices and accelerate the global transition towards green technologies.
  - d) **Diplomatic Relations:** Neom City's multi-national scope could strengthen diplomatic ties and foster cooperation between participating countries.

Neom City represents an audacious endeavor that aims to redefine the concept of urban living in the 21st century. With a vision that encompasses sustainability, innovation, and economic diversification, Neom has the potential to be a pioneering model for future cities worldwide. While challenges abound, the outcomes of this visionary project could herald a new era of progress and prosperity for Saudi Arabia and the broader region [12]. As Neom City continues to take shape, the world awaits to witness its transformative impact on the landscape of modern urbanization

## 6. Clean Energy in the United Arab Emirates

The United Arab Emirates (UAE) has emerged as a significant player within OPEC, making substantial investments in various energy sectors in recent years. While focusing on increasing oil production capacity, the UAE has also placed significant emphasis on the development of renewable energy, particularly solar power.

With a population of ten million, the UAE ranks among the world's largest producers of carbon dioxide. In response, the country has unveiled an ambitious plan to reduce carbon emissions comprehensively by 2050 [14]. Despite decades of efforts to diversify its economy, the UAE

remains heavily reliant on oil and gas exports, accounting for about 30% of its gross domestic product. Unfortunately, this reliance has also resulted in the UAE being one of the highest emitters of greenhouse gases, trailing only Australia and the United States.

Embracing soft power, the UAE is keen to portray itself as a nation dedicated to environmental conservation. As part of its strategic planning, it has heavily invested in renewable energy. This not only helps mitigate environmental impacts but also serves to facilitate the expansion of oil and petroleum product exports. The UAE has set its sights on hosting the United Nations Climate Change Conference in 2023, a move that reflects its commitment to environmental initiatives and public diplomacy. With over 170 countries expected to participate, this hosting endeavor is considered one of the UAE's most significant steps in this direction.

The UAE stands as the first country in the Middle East to sign the Paris Agreement on climate change and hosts the International Renewable Energy Agency. By doing so, the UAE underscores its commitment to global cooperation and domestic policies aimed at achieving a low-carbon future. To combat the carbon impact arising from heavy industries and energy exports, the UAE has strategically made solar power plant construction more cost-effective than natural gas plants. Additionally, the country boasts one of the world's largest carbon capture systems and is the first in the region to commit to an absolute reduction in emissions of 23.5% by 2030 [24].

With a clear vision for its energy security, the UAE has set a target of securing 44% of its total energy supply from renewable sources by 2050. To achieve this ambitious goal, Abu Dhabi has allocated a substantial budget of 163 billion dollars for investment. The UAE plans to fulfill the remaining 38% of its energy needs through natural gas, a more environmentally friendly option compared to coal and oil, by the same target year. Electricity generation from coal and nuclear energy will occupy the second and third positions, contributing 12% and 6%, respectively.

Aligned with its formulated plans, the UAE aims to achieve a 70% reduction in carbon dioxide emissions by 2050, a shared objective among Abu Dhabi and its associated emirates. As per reports from the UAE's Ministry of Industry and Energy, the country's total renewable energy capacity reached 2,300 megawatts by the end of 2020.

Looking ahead, the UAE's ambitions extend further, intending to quadruple its renewable energy production capacity by the end of 2025, reaching an impressive 9,000 megawatts. To realize this objective, the UAE currently has several ongoing projects in progress, firmly establishing its commitment to transitioning towards clean and sustainable energy solutions [16].

## **7. Solar Energy in the UAE**

Solar energy, due to its abundance in most parts of the world, is one of the most reliable energy sources globally, especially in countries like the United Arab Emirates where it enjoys high popularity. The UAE holds a significant position in concentrated solar energy production, ranking third in the world with an annual electricity generation capacity of 140 megawatts.

- **Solar Power Stations in Abu Dhabi:** The Shams Power Station, located in the city of Madinat Zayed, is the first and largest renewable energy power plant in the United Arab Emirates (UAE), boasting an annual electricity generation capacity of 100 megawatts.

This remarkable project accounts for 7% of Abu Dhabi's total energy needs, equivalent to supplying energy for around 20,000 households in the UAE through renewable solar energy.

**Table 3: Clean Energy Initiatives and Solar Power Developments in the UAE**

Aspect	Details
<b>Emphasis on Clean Energy</b>	UAE's strategy includes reducing carbon emissions by 2050 and diversifying the energy portfolio.
<b>Carbon Emission Goals</b>	Reduce emissions by 23.5% by 2030 and 70% by 2050.
<b>Paris Agreement</b>	First Middle Eastern country to sign the Paris Agreement and hosts the International Renewable Energy Agency.
<b>Target for Renewable Energy</b>	Achieve 44% of total energy from renewable sources by 2050, supplemented by 38% from natural gas.
<b>Investment in Renewables</b>	Allocated \$163 billion to achieve renewable energy targets.
<b>Carbon Capture Systems</b>	Hosts one of the world's largest carbon capture systems to combat industrial emissions.
<b>Renewable Energy Capacity</b>	Reached 2,300 MW by the end of 2020, targeting 9,000 MW by 2025.
<b>Solar Power Stations</b>	Shams Power Station, Mohammed bin Rashid Al Maktoum Solar Park, Al Dhafra Solar Farm.
<b>Shams Power Station</b>	Largest renewable plant in Abu Dhabi, generating 100 MW, supplying energy to 20,000 households.
<b>Mohammed bin Rashid Solar Park</b>	World's largest concentrated solar power station, targeting 5,000 MW by 2030.
<b>Al Dhafra Solar Farm</b>	2,000 MW capacity, expected to power 160,000 households, doubling Noor Abu Dhabi's capacity.
<b>Impact of Noor Abu Dhabi</b>	Reduces CO <sub>2</sub> emissions equivalent to 1 million metric tons annually, comparable to removing 200,000 vehicles.
<b>Vision 2050</b>	Transitioning towards clean energy to achieve sustainability and energy security.

- **The Mohammed bin Rashid Al Maktoum Solar Park:** The Mohammed bin Rashid Al Maktoum Solar Park, planned as part of Dubai's clean energy strategy until 2050, was finally commissioned in 2012. This ambitious project is expected to be completed by 2030, and it stands as a unique utilization of renewable energy. Also known as the Dubai Solar Park, it is the world's largest concentrated solar power station. By 2030, it is estimated that this project will generate up to 5,000 megawatts of electricity annually [15].
- **The Al Dhafra Solar Farm:** The Al Dhafra Solar Farm, located near the Al Dhafra military base, has a capacity of 2,000 megawatts. This project is a collaboration between Abu Dhabi National Energy Company with a 40% share and UAE-based companies, EDF and JinkoPower China, each holding a 20% stake. It is expected to become operational in late 2022, and with its launch, Abu Dhabi's solar energy capacity

will increase to 3,200 megawatts. The Al Dhafra Solar Farm is set to provide enough energy to power around 160,000 households in Abu Dhabi, nearly twice the capacity of the Noor Abu Dhabi project.

Currently, Abu Dhabi's active solar energy capacity stands at approximately 1,300 megawatts, collected from projects like Shams and Noor Abu Dhabi, and it accounts for the majority share of renewable energy in the UAE. For instance, the Noor Abu Dhabi project alone reduces carbon dioxide emissions by the equivalent of one million metric tons, equivalent to removing 200,000 vehicles from the streets of the UAE [17]. Table 3 outlines the UAE's clean energy initiatives and major solar power projects, emphasizing their contributions to sustainable energy and carbon emission reduction goals.

## **8. Green hydrogen in the UAE**

Green hydrogen has emerged as a key player in the United Arab Emirates' (UAE) ambitious plans for sustainable development and the transition towards a green economy. Green hydrogen, often referred to as "hydrogen of the future," is produced through the electrolysis of water using renewable energy sources, such as wind, solar, or hydro power. This process involves splitting water molecules into hydrogen and oxygen, and when the electricity used in the process comes from renewable sources, it is considered green or renewable hydrogen.

The UAE, known for its abundant oil and gas reserves, has recognized the importance of diversifying its energy mix and reducing its carbon footprint. Embracing green hydrogen is a strategic move towards achieving these objectives while simultaneously fostering economic growth and environmental stewardship. The country's leaders have grasped the potential of green hydrogen as a game-changer in the global energy landscape, and they are leveraging their expertise in energy production and technology to position themselves as pioneers in this emerging industry.

One of the most significant initiatives in the UAE's green hydrogen journey is the partnership between Engie, a French company, and Masdar, a renewable energy company based in Abu Dhabi. Together, they have invested approximately 5 billion dollars in establishing green hydrogen-related projects in the Emirates. This substantial investment reflects the UAE's commitment to becoming a leading player in the green hydrogen market and underscores the potential of this renewable resource to transform the nation's energy sector.

The versatility of green hydrogen has also captured the UAE's attention, as it can be used across a wide range of industries. From transportation and energy storage to industrial processes and power generation, green hydrogen has the potential to revolutionize how the country meets its energy needs. In transportation, for instance, green hydrogen can power fuel cell electric vehicles, offering a clean and efficient alternative to traditional fossil fuel-powered vehicles.

The UAE's commitment to green hydrogen is a manifestation of its forward-looking vision for sustainable development. By embracing this transformative energy solution, the country aims to reduce its carbon emissions, mitigate the impacts of climate change, and contribute to the global effort in achieving net-zero carbon emissions. Investing in green hydrogen also aligns with the UAE's commitment to the United Nations Sustainable Development Goals, particularly in areas such as affordable and clean energy, climate action, and industry innovation.

The country's pursuit of green hydrogen is not just an environmental endeavor; it also holds promising economic prospects. As the global demand for clean energy increases, green hydrogen can become a valuable export commodity for the UAE. By capitalizing on its abundant renewable resources, the country can position itself as a major exporter of green hydrogen to international markets, potentially diversifying its revenue streams and securing a more sustainable future for its economy. The UAE's tactical emphasis on green hydrogen is not without obstacles. While the country boasts plentiful sustainable resources, incorporating and expanding greenhydrogen production and distribution infrastructure necessitates significant investments and coordinated endeavors. Additionally, technological progress and cost reductions are vital to make green hydrogen competitive with traditional fossil fuels. However, the UAE's resolute dedication to creativity and partnerships with prominent firms and research establishments globally bode well for surmounting these challenges. To strengthen the advancement of green hydrogen, the UAE has established research and innovation centers, promoting partnerships with industry pioneers and research establishments from across the world. Such collaborations are crucial in propelling the technology and encouraging knowledge transfer, cultivating an atmosphere of creativity and advancement in the green hydrogen domain. The UAE's adoption of green hydrogen signifies a forward-thinking approach to sustainable progress and a dedication to addressing climate change. By investing in green hydrogen projects and harnessing its sustainable energy potential, the country is not only diversifying its energy mix but also positioning itself as a significant participant in the global green hydrogen market. As the world transitions towards a greener and more sustainable future, the UAE's commitment to green hydrogen sets a potent example for other nations to follow, inspiring joint action in tackling the urgent challenges of our time. Fig 2 shows a demo of the Green Hydrogen Ecosystem in the UAE.



**Fig 2:** The Green Hydrogen Ecosystem in the UAE.



## 9. Clean energies in Qatar

Qatar, despite its abundance of oil and natural gas, has taken a significant step since 2017 to decrease its dependence on these natural resources and shift towards renewable energy sources. As part of this broader strategy, the country has renamed its state-owned oil and gas company from Qatar Petroleum to Qatar Energy, signifying a focus on energy efficiency and environmentally-friendly technologies like carbon dioxide capture and storage [21].

- **Solar Energy:** Qatar's weather, favored with abundant sunlight, enables the generation of electricity from solar energy. Thorough research on Qatar's solar energy potential has been ongoing since the 1980s, approximating global horizontal solar radiation, direct normal irradiance, and diffuse horizontal irradiance at approximately 2163 kilowatt-hours per square meter, 1855 kilowatt-hours per square meter, and 897 kilowatt-hours per square meter, respectively, over a 10-year average. To decrease reliance on fossil fuels, Qatar has taken the initiative to implement Tesla's renowned "Powerpack" batteries in its initial solar energy storage project. This experimental endeavor, in cooperation with the "Al-Attiyah Group" and "Tesla," aims to store electric energy using batteries to ensure a stable power supply during peak consumption periods, enhance energy efficiency, and fortify the grid's resilience. Additionally, Qatar has successfully launched an impressive 800-megawatt solar project, hastening the adoption of solar energy [4].
- **Wind Energy:** Qatar also owns a wind energy potential, with estimations from Doha between 1976 and 1989 showing an average wind speed of 4.4 meters per second at 10 meters above ground level and around 7.1 meters per second at 100 meters above sea level. Amusingly, 80% of the time, wind speeds in Qatar go beyond the critical threshold of 3 meters per second. Leveraging this wind potential, Qatar is actively contributing to achieving its renewable energy objectives. Nevertheless, the country's heavy reliance on hydrocarbon energy exports renders its economy susceptible to fluctuations in energy prices and global events that impact the value of hydrocarbon resources. Since these resources are non-renewable, depending only on their exports poses the risk of the government facing a lack of alternative income sources in the event of depletion, potentially leading to economic instability [8].

## 10. The Fossil Fuels Impact in Saudi Arabia, the UAE, and Qatar, and the Advantages of Sustainable Energies

The usage of fossil fuels has been dominant in powering the economies of Saudi Arabia, the UAE, and Qatar for many years, owing to their abundant reserves of oil and natural gas. However, this heavy reliance on fossil fuels has brought about environmental challenges and economic vulnerabilities. As a result, these nations are now looking towards a more sustainable energy future by exploring the benefits of renewable and sustainable energies. In Saudi Arabia, oil has been the backbone of the economy, contributing significantly to government revenue and GDP. Nevertheless, the country acknowledges the need to reduce dependence on oil exports to safeguard its economy from fluctuations in global oil prices.



Similarly, the UAE and Qatar have experienced rapid economic growth driven by their natural gas and oil resources. However, this dependence on hydrocarbons has made their economies susceptible to global energy market fluctuations and concerns about finite resource depletion. The extraction and burning of fossil fuels also contribute to environmental degradation and greenhouse gas emissions, posing challenges in combating climate change and protecting the region's delicate ecosystems.

To address these issues, Saudi Arabia, the UAE, and Qatar are actively exploring renewable energies such as solar, wind, and hydro power. Emphasizing sustainability and reduced carbon emissions, these renewable sources offer several advantages. Firstly, sustainable energies produce minimal to zero greenhouse gas emissions, making them environmentally friendly and essential in combating climate change. Transitioning to renewable sources can help reduce the region's carbon footprint and improve air quality. Secondly, diversifying their energy mix with sustainable sources enhances energy security and resilience, reducing the vulnerability to global energy market fluctuations and depletion of finite resources. Thirdly, investing in renewable energy projects fosters economic diversification. The clean energy sector creates new economic opportunities, attracting investments and generating employment.

The region's abundant renewable resources, including sunlight, wind, and hydro potential, offer a reliable and sustainable energy supply for domestic consumption and the possibility of export to neighboring countries. Advancements in sustainable technologies and cost reductions make renewable energies increasingly competitive with traditional fossil fuels. Furthermore, relying on domestic sustainable resources can enhance energy independence, reducing the dependence on energy imports. Overall, Saudi Arabia, the UAE, and Qatar are taking significant steps towards a more sustainable energy future. By embracing renewable and sustainable energies, these countries can mitigate the environmental impact of fossil fuels, diversify their economies, and lead in the global transition towards cleaner and more resilient energy systems.

## **11. Conclusion**

In recent years, the notion of sustainable development has garnered substantial attention and interest among researchers and scholars globally. This escalating interest can be attributed to the distressing observation of environmental deterioration, prompting intellectuals to seek effective solutions to preserve a livable and unspoiled planet for future generations. Developed European countries, notably, have been at the forefront of advocating sustainable development. They have not only expressed profound concerns about environmental contamination and the adverse impacts of greenhouse gas emissions on the planet but have also taken proactive measures to present viable strategies for achieving sustainability. One of the pivotal strategies that have been put forth involves transitioning from traditional hydrocarbon-based energy sources to embracing greener and more renewable alternatives.

Similarly, countries in the South of the Persian Gulf have not remained idle in the pursuit of sustainable development. They have initiated efforts and actions to move towards a more sustainable future. However, these nations face specific challenges due to their economies being heavily reliant on oil and gas revenues, a situation known as "rent-based economies." This dependence creates an additional layer of complexity when attempting to adopt eco-friendly energy solutions, as it may conflict with the established economic models and present

difficulties in altering the energy landscape. The necessity for action is particularly pronounced for oil-rich Gulf countries due to the inherent vulnerabilities associated with their reliance on hydrocarbon revenues. Not only does this dependency impede their ability to fully embrace sustainable development, but it also renders their economies susceptible to the fluctuations in global oil and gas prices, potentially leading to long-term economic crises. Hence, it becomes imperative for these nations to diversify their energy mix and reduce their reliance on hydrocarbon revenues to secure a more stable and resilient future. In response to these challenges, Gulf countries in the South of the Persian Gulf have proactively undertaken long-term visioning exercises. Through these comprehensive initiatives, they have emphasized the significance of environmental preservation and the necessity of utilizing renewable energy sources for sustainable development. By charting a course towards clean and sustainable energy, they seek to safeguard their economies, protect the environment, and ensure a sustainable future for their citizens.

Saudi Arabia, the United Arab Emirates, and Qatar have emerged as pioneers in the region, showcasing their strong commitment to sustainability. These countries have integrated the principles of sustainable development into their medium and long-term planning, demonstrating their determination to decrease dependence on hydrocarbon revenues and steer their nations towards a more sustainable future. These pioneering nations have not merely confined themselves to theoretical commitments but have translated their vision into practical actions. Investments in renewable energy infrastructure, research and development, and the deployment of clean energy projects are clear indications of their unwavering dedication to sustainable development. By spearheading the transition towards cleaner energy sources, these nations are setting a positive example for the rest of the world. Their efforts serve as a beacon of hope and inspiration for other countries, encouraging them to follow suit and prioritize sustainability as a key aspect of their development agendas. The mounting global interest in sustainable development has been driven by the alarming state of environmental deterioration. Developed European countries, as well as countries in the South of the Persian Gulf, have shown their commitment to this cause, with the latter facing unique challenges due to their rent-based economies and dependence on hydrocarbon revenues. Despite these challenges, visionary initiatives and practical actions have been undertaken by pioneering nations like Saudi Arabia, the UAE, and Qatar, demonstrating their resolute dedication to embracing clean energy and achieving sustainable development. Through their efforts, they pave the way for a greener and more sustainable future for their nations and the world at large.

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