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Renewable energy as a strategic option for achieving sustainable development in Arab economies

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***Abstract*---**The severity of environmental problems has increased due to the excessive consumption of fossil energy sources, making the search for clean and renewable energy alternatives urgent. Global interest in renewable energy sources is rising because of their role in creating a more sustainable energy mix and contributing to sustainable development in its economic, social, and environmental dimensions. Many Arab economies have begun to harness solar and wind energy, achieving significant progress in using these sources efficiently. This study aims to clarify the concepts of sustainable development and renewable energy, examine their role in achieving developmental goals, and highlight the programs implemented in some Arab economies. Through analyzing these concepts and reviewing the adopted programs and policies, the study finds that renewable energy is a clean and environmentally friendly resource, with solar energy being used globally. It also shows that many Arab economies have substantial renewable energy resources and have started integrating them into their local energy mix, enhancing their role in achieving sustainable development.

***Keywords*---**Fossil Energy, Solar Energy, Wind Energy, Sustainable Development, Renewable Energy.

1. Introduction

With the increasing global awareness of environmental issues and the recognition of the need to protect the environment, there has also been a growing awareness of the importance of transitioning to various renewable energy sources. These sources are considered crucial for ensuring a secure energy supply (Takala, 1991). The types of renewable energy sources vary by country and include solar, wind, nuclear energy, among others (Kartal, 2022). All these sources offer

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numerous advantages as they are natural, clean, sustainable, and provide an inexhaustible fuel supply.

Similarly, sustainable development is one of the most significant developments in modern developmental thinking (Adams, 2008). This concept emerged in the 1987 Brundtland Report by the World Commission on Environment and Development of the United Nations and is based on a set of interconnected and integrated dimensions (Tomislav, 2018).

Achieving sustainable development is closely linked to energy services, as the availability of sufficient energy significantly contributes to achieving development goals (Dincer & Rosen, 1999). Consequently, most countries, including Arab economies, have placed great emphasis on renewable energy due to their substantial resources in solar and wind energy. These countries have implemented various programs and developed medium- and long-term plans with varying degrees of advancement.

Based on this, the main issue is: How can renewable energy sources contribute to achieving sustainable development in Arab economies? This main issue gives rise to several sub-questions, including: What is meant by sustainable development? What are renewable energies? What is the relationship between renewable energies and sustainable development?

The study is based on the following hypotheses: Sustainable development is development based on fairness in the distribution of resources between current and future generations. Energy is the capacity to perform work, resulting from the inherent power of an object. The use of renewable energies contributes to achieving the dimensions of sustainable development.

The study aims to clarify the concepts of sustainable development and renewable energies, provide a clear overview of various energy sources and their role in achieving developmental goals, and highlight the major programs implemented in this field across some Arab economies. Due to the nature of the study, a descriptive approach was used to examine the theoretical backgrounds of sustainable development and renewable energy, along with a case study method to explore some Arab economies.

2. Theoretical Framework

The concept of sustainable development emerged in the Brundtland Report by the World Commission on Environment and Development of the United Nations in 1987, and since then, it has gained significant importance due to the efforts of various parties to develop and disseminate this concept. The Brundtland Commission defined sustainable development as: "Development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs."

On the other hand, the FAO (Food and Agriculture Organization) defined sustainable development as: "The management and protection of the natural resource base and the direction of technological and institutional change in a

manner that ensures the continued satisfaction of human needs now and in the future." The United Nations Global Environment and Development Council described sustainable development as: "All coordinated and integrated procedures and processes necessary to alter resource use, investment patterns, technological direction, and institutional gaps to ensure the fulfillment of current and future human needs and activities."(Hoelting, 1994).

Based on these definitions, sustainable development can be comprehensively defined as a process of transforming the prevailing patterns of resource utilization to meet the needs of the present generation while considering the needs of future generations, using clean technologies to protect and minimize environmental degradation. The main characteristics of sustainable development are: ensuring long-term continuity by meeting the needs of both current and future generations, striving for optimal use of natural resources, and supporting the protection of the environment and reduction of its degradation.

The requirements for sustainable development can be summarized as follows(Davidson, 1996): the efficient use of natural resources and wealth, meeting human needs through wise consumption management by understanding both current and future needs (Laszlo & Laszlo, 2007), fostering human development by building a knowledge-based society that provides knowledge, information sources, and learning opportunities while encouraging innovation, promoting sound economic development through knowledge-based economic programs, preserving the environment with attention to both public and private environmental management, and enhancing internal and external partnerships by strengthening cooperation and information sharing.

Sustainability can be categorized into three levels. The first, **Weak Sustainability**, is based on the idea that different forms of capital can substitute for each other, at least concerning current economic activities and available resources. Under weak sustainability, expansion often occurs at the expense of environmental resources, where ecological and human activities fall within the scope of economic activities. This approach implies that economic growth will continue to accelerate over time, as depicted in the subsequent figure.

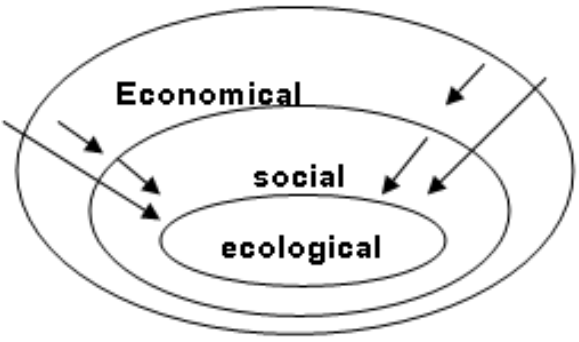

Figure 1: Weak Sustainability (Economic Coverage) (Ghania, 2016, p. 47)

The second type, **Logical Sustainability**, highlights the need to evaluate each component of capital—natural, human, social, and man-made—and determine the critical thresholds for each, where alterations might cause non-substitutability issues. The third type, **Strong Sustainability**, argues that capital components are complementary rather than interchangeable, meaning that economic activities must align with human activities, which should be integrated into the ecological (environmental) sphere. This concept is illustrated in the following figure

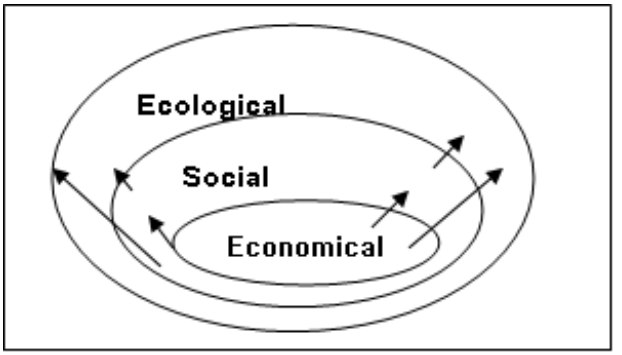

Figure 2: Strong Sustainability (Vegetative Cover) (Ghania, 2016, p. 46)

3. Renewable Energy Sources in Arab Economies – Reality and Potential

The Arab region possesses significant potential in renewable energy (Basha et al., 2021), particularly in solar and wind energy. Given the non-renewable nature of fossil fuels, there is a pressing need to explore alternative sources that support and extend their longevity.

3.1 The Nature of Energy

In linguistic terms, energy is "the literal translation of the word 'Energy' or 'Energie,' which means activity, as it implies that something contains effort or work."(Shove & Walker, 2014). Energy is categorized based on its sources into several types (Iqbal, Azam, Naeem, Khwaja, & Anpalagan, 2014), including fossil energy sources, which are defined as those providing most of the energy needs for modern industrial societies, such as coal and oil, and are considered finite due to their depletion through extraction and use. These include coal, a solid black substance composed of carbon, hydrogen, oxygen, nitrogen, and sulfur; natural gas, which is colorless and odorless and primarily composed of methane, a chemical compound of carbon and hydrogen; and petroleum, a dense, flammable black liquid made up of a mixture of organic compounds, mainly carbon and hydrogen (Ali Lutfi, 2008).

3.2 Fundamentals of Renewable Energy

Renewable energy sources are naturally occurring resources, making them a significant asset that warrants exploitation.

3.2.1 Concept of Renewable Energy

The International Energy Agency (IEA) defines renewable energy as "energy derived from natural processes that replenish themselves at a rate faster than

their consumption." Renewable energy refers to "energy derived from natural resources that are replenished and cannot be exhausted, characterized by being perpetual and environmentally friendly. This contrasts with non-renewable energy sources, which are often found in finite reserves and require human intervention to extract. Unlike fossil fuels, renewable energy does not have detrimental effects on the environment when utilized."(Sofiane, Mohamed, & Mohamed). It is also described as "electricity generated from sources such as solar, wind, biomass, geothermal, and hydro, as well as biofuels and hydrogen extracted from renewable sources." (Farhat)

Based on these definitions, a comprehensive definition of renewable energy is: "Energy obtained from nature, which is constantly available and characterized by its renewability (non-exhaustibility) and environmental friendliness. Its sources include solar, wind, hydro, biomass, geothermal energy, among others, contrasting with non-renewable energy which is typically found in finite reserves in the earth."(Moufid & Rabia El-Adawiya, 2014).

3.2.2 The motivations for seeking renewable energy sources

There are various motivations driving countries to turn towards renewable energy sources. One of the main reasons is the need to ensure energy security, as the increasing consumption of energy leads to a decline in traditional reserves, prompting the search for sustainable alternatives (Hao & Shao, 2021). Climate change is also a significant factor, as the shift to renewable energy helps reduce greenhouse gas emissions in the atmosphere(Olabi & Abdelkareem, 2022). Additionally, the decreasing costs of renewable energy make it an attractive option for countries to adopt. This is coupled with the necessity to diversify energy sources to alleviate the pressure on petroleum usage. It is also worth noting the growing global interest in renewable energy, as evidenced by the numerous studies and international conferences, such as the one held in 2001, which emphasized the urgent need to exploit these sources due to the ever-increasing demand for energy.

3.2.3 Renewable Energy Sources

- **Solar Energy:** Solar energy is a clean, renewable source that is inexhaustible as long as the sun exists. In fact, all energy sources on Earth originated from solar energy (Foster, Ghassemi, & Cota, 2009). The sun provides the Earth with energy that exceeds the world's total energy needs by about 5000 times (Abbott, 2009). For instance, the energy that can be obtained from sunlight in just 105 minutes is sufficient to meet the world's energy needs for an entire year. Arab countries have significant potential in the field of solar energy, with high levels of total solar radiation ranging between 4-8 kWh/m²/day and 1700-2800 hours of solar radiation per year (Mana, 2021). Solar energy is commonly used in Arab economies for domestic water heating and in some pilot projects for water desalination. Electricity production using solar energy has also been achieved in Algeria, Morocco, and Egypt, with the establishment of three solar power plants with capacities of 150, 140, and 470 megawatts, respectively.

- **Wind Energy:** Wind energy is derived from the movement of air and wind, and it has been used for various purposes since ancient times (Johnson, 1985), such as powering sailing ships and operating windmills. Wind energy has several

advantages, including its well-developed technology and the fact that it does not produce carbon dioxide emissions. Wind turbines operate autonomously and do not require constant maintenance or fuel. In the Arab world, wind energy is concentrated in some countries, but it is possible to transport it from generation sites to areas where it is needed. For example, Morocco, Egypt, and Oman have locations with an average annual wind speed of 9 to 11 meters per second, with capacity factors exceeding 30% annually.

- **Hydropower:** Hydropower is associated with electricity generation stations located on river waterfalls and is defined as energy derived from the continuous movement of water, which is inexhaustible (Kaygusuz, 2016). Hydropower is obtained from several sources, including large and small hydropower plants, as well as energy derived from water movement without the use of dams. The Arab world is characterized by a scarcity of water resources, as most of its land lies in arid and semi-arid regions, and this scarcity is exacerbated by continuous demographic and economic growth. Rivers are the primary source of surface water in the Arab region, with total surface water resources estimated at around 205 billion cubic meters, of which 26% originates within the Arab world, while the remainder comes from outside.

- **Biomass Energy:** Biomass energy refers to energy derived from photosynthesis, burning wood, or biological conversion (Sofer & Zaborsky, 2012). It also includes energy obtained from municipal waste, paper, and some organic digestion waste. Biomass energy has several advantages, such as moderate production costs and its availability in large quantities. Energy can be extracted in small facilities, and burning biomass does not release carbon dioxide. The use of advanced technological methods can improve its production process. Methane gas utilization also reduces its release into the atmosphere, thereby mitigating its impact on global warming. In the Arab world, biomass resources are relatively limited due to the semi-arid nature of most lands. Agricultural waste, wood, and animal waste are the primary sources, while industrial use remains limited and mainly associated with the private sector.

- **Geothermal Energy:** Geothermal energy refers to the thermal energy stored in the Earth's interior(Dickson & Fanelli, 2013), generated by the friction between hot rocks and nearby water, or by water that is introduced by humans. The resulting steam is used to generate electricity. Geothermal energy has several advantages, including being clean and non-polluting, not requiring fossil fuel consumption, which reduces reliance on it and its harmful emissions. Geothermal power plants can operate continuously for 24 hours, a capability that other energy sources like oil or coal cannot match. In the Arab world, geothermal energy resources are limited, and geological exploration is still incomplete, with no significant exploitation to date, especially in Algeria, Egypt, Jordan, Yemen, Syria, Saudi Arabia, Morocco, and Tunisia. The only recorded project in this field is the geothermal project at Lake Assal in Djibouti, supported by the African Development Group in cooperation with the Danish government.

- **Nuclear Energy:** Nuclear energy is generated by controlling nuclear fission and fusion reactions (Glasstone, 1968). It has several advantages, including being a reliable energy source with predictable and nearly constant supply in a specific

location, not affected by weather conditions. Nuclear fuel preparation is abundant, as uranium is found throughout the Earth's crust. Its price remains relatively stable, as do its sources. Nuclear power plants have a low environmental impact. In the Arab world, countries like Egypt, Iraq, and Algeria have strongly pursued nuclear programs, and Arab nations have expressed their intention to include electricity generation and water desalination in their strategies to diversify energy sources. The UAE, Saudi Arabia, Jordan, and Egypt have made significant progress toward their goals of establishing and operating local nuclear reactors for peaceful purposes.

- **Shale Gas:** Shale gas is natural gas generated within shale rocks that contain oil due to heat and pressure, and it remains trapped within the cavities of these solid rocks (Wang, Chen, Jha, & Rogers, 2014). Shale gas has several characteristics, including the short time required for its production, and its exploitation relies on advanced and extensive drilling techniques. Its availability provides large quantities of natural gas to the global resource base.

In the Arab economies, Algeria ranks first in terms of shale gas reserves, with approximately 707 trillion cubic feet, equivalent to about 58% of the total shale gas resources in the Arab economies (Fix, 2015). The UAE follows in second place. It is worth noting that these two countries alone hold nearly 75% of the total technically recoverable resources. The following table illustrates this:

Table 1. Estimates of Technically Recoverable Shale Gas Resources in Arab Economies (Ali, 2013, p. 43)

Country	Wet shale gas (trillion cubic feet)
Algeria	706.9
Egypt	100
Libya	121.3
Morocco	11.9
Tunisia	22.7
Jordan	6.8
Oman	48.3
United Arab Emirates	205.3
TOTAL	1223.5

It can be observed from the table above that Algeria ranks first in terms of shale gas quantities, followed by the UAE in second place with an estimated 205.3 trillion cubic feet. Libya ranks third with 121.3 trillion cubic feet, while other countries follow with varying amounts.

4. Arabic programs outlined in the field of renewable energies and their role in achieving sustainable development

Given the abundance of renewable energy sources in most Arab economies, their utilization is a significant support and effective contribution to achieving sustainable development goals.

4.1 Arabic Programs in the Field of Renewable Energies

Many Arab economies have made significant strides towards using renewable energies and improving efficiency in their use. They have developed future strategies and policies in the energy sector to ensure that renewable energy contributes between 5% and 20% over various long-term periods. Arab economies place great importance on establishing laws related to the renewable energy sector. Numerous laws, regulations, and decisions have been issued, varying from general framework laws that regulate the sector as a whole to laws focusing on specific areas, such as the building sector. The following presents the experiences of some Arab economies concerning the most important programs and projects planned and implemented in the field of renewable energies.

4.1.1 Algeria has developed a comprehensive program in the field of renewable energies (Stambouli, Khiat, Flazi, & Kitamura, 2012), focusing on three main areas: Firstly, in photovoltaic solar energy, the plans include accelerating the development of projects with a capacity of 800 megawatts by 2020, along with additional projects reaching 200 megawatts from 2021 to 2030 (Khaider, Mohammed, & Meriem, 2018). Secondly, in solar thermal energy, the program involves executing two projects with a capacity of 150 megawatts each, establishing four solar thermal plants with a capacity of 1200 megawatts between 2016 and 2020, and increasing annual production to 600 megawatts until 2030. Thirdly, in wind energy, the program includes setting up a 10-megawatt wind farm, creating two wind farms with a capacity of 20 megawatts each, and conducting studies to identify suitable sites for additional projects with a capacity of 1700 megawatts. Additionally, the energy efficiency program aims to promote responsible energy use by improving building thermal insulation, developing solar water heaters, introducing solar-powered air conditioning technologies, promoting the use of energy-efficient lighting, enhancing energy efficiency in the industrial sector, and improving public lighting efficiency.

4.1.2 Morocco has outlined ambitious renewable energy programs, including the development of five solar plants with a total capacity of 2000 megawatts, covering 14% of electricity needs, reducing CO2 emissions by 3.7 million tons annually, and saving 1 million tons of oil equivalent, with a total cost of 70 billion dirhams, with the first plant operational since 2015 (Boulakhbar et al., 2020). In wind energy, Morocco aims to achieve 14% of its total electrical capacity, equivalent to 2000 megawatts, with an estimated cost of 31.5 billion dirhams, saving 1.5 million tons of oil equivalent and reducing CO2 emissions by 5.6 million tons, with the first plant starting in 2014. Additionally, the National Irrigation Water Conservation Program targets modernizing irrigation systems on 550,000 hectares by 2020, having already reached 330,000 hectares by 2013. The energy efficiency program aims for a 12% reduction in energy use by 2020 and 15% by 2030, with an investment of over 21 billion dirhams and the creation of around 40,000 jobs by 2020.

The United Arab Emirates has initiated significant renewable energy programs, starting with the Shams 1 project in 2013 (Nanath, Kaitheri, & Samdani, 2022), the country's first renewable energy project and the world's largest concentrated solar power plant with a 100-megawatt capacity, followed by the Noor 1 plant and plans for a new 350-megawatt solar plant in Abu Dhabi. Aiming for 1000

megawatts by 2020 and 5000 megawatts by 2030, the Dubai Supreme Council targets solar energy to make up 7% of Dubai's energy mix by 2020, 25% by 2030, and 75% by 2050. In nuclear energy, four plants have been completed in Abu Dhabi since 2012, contributing 5.6 gigawatts, or about 26% of the emirate's energy mix. Additionally, the UAE has embraced waste-to-energy projects to tackle pollution and waste management while generating more energy.

Sudan has implemented renewable energy programs that focus on solar power installations, with around 2 megawatts set up in rural and remote areas to benefit the service sector (Saeed, 2020). The strategic renewable energy development plan aims to significantly contribute to efficiency, sustainability, and economic and social development by assessing and utilizing renewable sources. Key objectives include achieving 1.943 megawatts of renewable energy by 2031, providing 5,160 gigawatt-hours of clean energy, improving social conditions in rural areas with a 30% coverage of renewable energy services, reducing lighting consumption by replacing one million bulbs with compact fluorescents, cutting electricity use in government buildings by 15% by 2014, and enhancing the power factor in the industrial sector from 0.6 to 0.95 by December 2014.

Palestine has outlined renewable energy programs in its strategic plan aiming to achieve 240 gigawatt-hours of electricity from renewable sources by 2020 (Qutaina, Shehada, Yasin, & Alsayed, 2023), which represents 10% of locally produced electrical capacity. The plan estimates that thermal renewable sources will account for around 18% of total energy consumption, particularly for water heating and heating purposes, with a goal of 25% reliance on renewable electricity. The strategy includes using ground-mounted solar photovoltaic systems with a capacity of 25 megawatts, rooftop solar photovoltaic systems with a capacity of 20 megawatts, concentrated solar thermal systems with a capacity of 20 megawatts, biogas from animal waste with a capacity of 18 megawatts, small wind turbine systems with a capacity of 4 megawatts, and wind farms with a capacity of 40 megawatts, all by 2020. Additionally, the National Energy Efficiency Plan, approved by the Cabinet on March 14, 2012, aims to achieve a 5% reduction in total electrical demand across various sectors by 2020 through energy audits and reducing greenhouse gas emissions from energy use.

4.2 The role of renewable energies in achieving sustainable development dimensions within Arab economies

4.2.1 The role of renewable energies in achieving the economic dimensions of sustainable development: Renewable energy significantly contributes to the economic dimensions of sustainable development by transforming unsustainable production and consumption patterns, which is crucial for reducing wastage and improving efficiency in the energy sector. It helps diversify energy sources, reducing dependence on fossil fuels and extending the life of reserves while decreasing import costs for non-oil-producing countries. Renewable energy also addresses desalination needs in water-scarce regions at a lower cost and improves living standards by enhancing energy access in impoverished areas, promoting job creation, and providing better health and education conditions. This holistic approach supports economic growth and sustainable development, particularly in regions heavily reliant on fossil fuels (Hannan et al., 2021).

4.2.2 The role of renewable energy in achieving the social dimensions of sustainable development is significant, as there is a clear link between human development and energy. This relationship is evident in the strong correlation between per capita energy consumption and the Human Development Index, particularly in developing countries. Individual energy consumption plays a crucial role in improving human development indicators by impacting various aspects such as education, health services, and overall living standards. Electricity, in particular, provides a clear example of this, as it is irreplaceable for many essential uses, including lighting and cooling, which directly contribute to enhancing quality of life.

4.2.3 The role of renewable energy in achieving the environmental dimensions of sustainable development is highlighted by the 2002 Johannesburg Declaration on Sustainable Development, which emphasized the need for joint actions and enhanced efforts at all levels to improve access to affordable and reliable energy services for sustainable development and achieve the Millennium Development Goals (Hannan et al., 2021). Agenda 21 also addressed the relationship between energy and the environmental dimensions of sustainable development, particularly regarding atmospheric pollution protection. It called for the implementation of goals related to atmospheric protection and the reduction of negative impacts from the energy sector while considering equitable resource distribution and national conditions. This involved developing energy policies and programs, supporting necessary research to improve energy efficiency, and ensuring integration between energy policies and other economic sectors, especially transportation and industry.

The agenda discussed the relationships between energy and environmental dimensions, focusing on protecting the atmosphere from pollution caused by energy use in various economic and social activities, particularly in industry and transportation. Arab economies have held meetings to address global environmental issues and reach a unified stance. The Arab report on energy, industry, air pollution, and climate change was adopted in New York in 2005 (Djoundourian, 2021). The UN Environment Programme Ministerial Forum was held in the UAE in 2006 (Sinha, Lehmann, & Djankov, 2023), where the Arab Environmental Facility for project financing was established. Morocco hosted the seventh Conference of the Parties to the Climate Change Convention in 2001, while Algeria marked World Environment Day with a focus on "World Deserts and Combating Desertification.

5. Conclusion

This study underscores the critical role of transitioning to renewable energy as a valuable asset for all nations, aiding in achieving sustainable development goals. Sustainable development hinges on meeting the needs of both current and future generations through interconnected economic, social, and environmental dimensions. Renewable energy, derived from natural sources, is clean and eco-friendly, with solar and wind being particularly significant. Energy services are essential for sustainable development, impacting social, economic, and environmental aspects. Many countries, including Arab economies, have

substantial renewable resources and are integrating them into their energy mixes, especially for electricity generation. Recommendations include gradually phasing out energy subsidies to promote renewable energy, raising awareness, providing financial mechanisms, enacting supportive laws, encouraging investment, enhancing international cooperation, ensuring rigorous program implementation, promoting research, and supporting Arab economies in developing energy use for sustainable development.

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