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Renewable Energy and Its Role in the Environmental Footprint: The Experiences of Egypt and Morocco

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Abstract:

Renewable energy and the environmental footprint form an integrated economic system, leveraging their optimal use to achieve public benefit across various sectors and promote sustainable development. This is accomplished by evaluating the environmental status and determining the capacity of natural ecosystems to regenerate resources depleted by human or natural factors.
The experiences of selected countries, such as Egypt and Morocco, in developing renewable energy systems and addressing environmental footprints have influenced other resource-rich nations. This study employs a descriptive-analytical approach, examining the capabilities and considerations available in the selected countries to explore the potential for establishing a link between renewable energy and the environmental footprint.
The analysis reveals disparities in economic systems within this domain, but both countries have managed to achieve economic balance through the integration of renewable energy with environmental footprint management. Morocco's experience, in particular, has been remarkable, thanks to its substantial resources and robust economic considerations, positioning it as a leader in energy production.

Keywords: Environmental Footprint, Renewable Energy, Sustainable Development, Clean Technology.

Introduction:

The energy crisis has become one of the most pressing global challenges due to the significant increase in population. Researchers have sought new and alternative energy sources to replace traditional ones, turning to renewable energy to achieve the highest levels of environmental footprint efficiency, particularly in countries with diverse energy resources. Since economic activities depend on environmental assets and their capacity to provide raw materials and environmental services that support life, managing these resources has become a critical issue for decision-makers worldwide. This urgency is heightened by the critical state of environmental conditions caused by poor human management of ecosystems and the lack of environmental considerations in development planning. These factors have placed immense pressure on natural resources, especially non-renewable ones, disrupting the natural balance.
Biocapacity and the environmental footprint are used as tools to measure human impact on the environment. These concepts were developed by the Global Footprint Network and are widely used in sustainability studies worldwide. The environmental footprint measures the overall impact of human activity on the environment, encompassing various aspects such as energy consumption, water use, chemical materials, soil and forests, livestock, and greenhouse gas emissions. Renewable energy, on the other hand, refers to energy derived from naturally replenished sources such as sunlight, wind, water, geothermal heat, and biomass. These sources offer a sustainable alternative to fossil fuels, which contribute to pollution through greenhouse gas emissions and exacerbate climate change. Investing in renewable energy provides a sustainable and effective solution to reduce the environmental footprint of energy consumption.
The environmental footprint serves as a key sustainability metric and helps guide decision-making on resource use while identifying areas to reduce environmental pressure.

Study Problem:

Renewable energy holds significant economic and environmental importance, primarily in identifying critical measures and finding alternative solutions to preserve and leverage the environmental footprint. This study focuses on experiences in the Middle East, specifically Egypt and Morocco, which have reaped the benefits of this strategic shift to establish an effective economic system while keeping pace with global advancements in developed countries.
The study poses the following primary question:

How can renewable energy be utilized to protect the environment, and how can it serve as a tool for achieving sustainable development in Morocco and Egypt?
This overarching question branches into the following sub-questions:

- Does the reduction in environmental footprint levels and the associated environmental challenges have economic and environmental implications?
- What is the relationship between renewable energy and the environmental footprint?
- Is it possible to explore the economics of renewable energy and the environmental footprint in Egypt and Morocco?

Study Hypotheses:

- Renewable energy plays a role in the environmental footprint and serves as an alternative to fossil fuels in Egypt and Morocco.
- There is a relationship between energy consumption and environmental footprint indicators represented by renewable energy.
- Renewable energy serves as a specific tool for protecting the environmental footprint.

Study Objectives:

- Demonstrate that the environmental footprint is an accounting tool that makes sustainable development measurable by calculating consumption within its biocapacity and linking it to its regenerative capabilities to achieve sustainability.
- Highlight the major environmental problems and disturbances faced by Egypt and Morocco due to systemic imbalances.
- Examine how Morocco and Egypt benefit from renewable energy and the environmental footprint.
- Show that the environmental footprint is a forward-looking and strategic indicator that must be considered for sustainability and environmental protection simultaneously.

Study Methodology:
To address the research problem, the descriptive-analytical method was employed. This involved reviewing books, reports, and academic studies on the subject, in addition to information gathered from online sources, to describe and explore the academic terms presented and facilitate the study's objectives.
The study is divided into the following sections:

1. The Conceptual Framework of Sustainable Development, Environmental Footprint, and Renewable Energy
2. The Relationship between Renewable Energy, Environmental Footprint, and Sustainable Development
3. The Economics of Renewable Energy and Environmental Footprint in Egypt and Morocco

The study concluded with a set of findings and recommendations that may prove highly beneficial for advancing bioenergy production and environmental performance.

First: The Conceptual Framework of Sustainable Development, Renewable Energy, and Environmental Footprint
1. The Conceptual Framework of Sustainable Development
1.1 The Concept of Sustainable Development:
Sustainable development is a process that harmonizes the exploitation of resources, investment directives, technological advancement, and institutional changes in a way that enhances the potential to meet present and future human needs and aspirations.
The World Commission on Environment and Development (WCED) defined it in 1987 as:
"Meeting the needs of the present without compromising the ability of future generations to meet their own needs" (Al-Aayeb, 2011, p.13) in its report titled *Our Common Future*. This report emphasized economic development while taking environmental considerations into account, asserting that development cannot continue if it harms the environment. This meeting introduced the idea that sustainable development is a concept concerned with ecological balance.
Sustainable development was also defined in the third principle of the Earth Summit held in Rio de Janeiro in 1992 as: *"The management and protection of natural resource bases (forests), quantitative resources, water resources, genetic resources (plant and animal) alongside the orientation of technological and institutional changes that are environmentally appropriate, economically viable, and socially acceptable. This is done in a way that ensures the continuous satisfaction of human needs for present and future generations"* (Amin Sayed, 2005, p.156).

1.2 Characteristics of Sustainable Development:
The United Nations Conference held in Rio de Janeiro in 1992 outlined the characteristics of sustainable development as follows (Amin Sayed, 2005, p.158):

- A long-term development approach that relies on assessing available resources and planning for the longest possible future period.

- Respecting the rights of future generations to access existing natural resources.
- Improving the quality of human life while considering people's well-being.
- Avoiding the depletion or pollution of natural resources while preserving the biosphere.
- Coordinating policies for natural resource use with investment directions and technological alternatives to achieve mutual development.

1.3 Criteria for Developing Effective Indicators for Sustainable Development:
The criteria include the following (Moschetti, translated by Baha, 2000, p.167):
- Reflecting fundamental and essential aspects of the economic, social, and environmental health of a society over generations.
- Being clear and achievable so that society can understand and accept them.
- Being measurable and predictable.
- Having available, up-to-date values.
- Indicating whether variables are reversible and controllable.
- Identifying methodologies for preparing any indicator clearly, ensuring its precise application, social and scientific acceptance, and reproducibility.
- Being time-sensitive, pointing to indicative trends.

1.4 Sustainable Development Goals (2015-2030):
In 2015, the United Nations General Assembly adopted the 2030 Sustainable Development Goals (SDGs). While sustainable production and consumption patterns intersect with most of the 17 goals outlined in the plan, a distinct goal was dedicated to this matter: Goal 12. This goal comprises a set of targets to be achieved within specific timeframes, including sustainable management and efficient use of natural resources by 2030. Key targets include: (Amira, 2001, p. 132)
- Halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses, by 2030.
- Achieve the environmentally sound management of chemicals and waste throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release into air, water, and soil to minimize their adverse impact on human health and the environment by 2030.
- Substantially reduce waste generation through prevention, reduction, recycling, and reuse by 2030.
- Encourage companies, particularly large and transnational ones, to adopt sustainable practices and integrate sustainability information into their reporting cycles.
- Ensure that people everywhere have access to relevant information and awareness about sustainable development and lifestyles in harmony with nature by 2030.

2. The Conceptual Framework of Renewable Energy
1.2 The Concept of Renewable Energy:
The term "Renewable Energy" refers to energy generated from natural processes without human intervention, which is continuously replenished. James G. Daly defined it as:
"Energy derived from natural sources that are replenished at a rate faster than they are consumed," including sources available ubiquitously around us. Daniel Bargain described it as:
"Clean energy from natural sources or processes that are continuously present," such as sunlight and wind, whose availability depends on time and weather (Moran et al., 2018, p. 189).
The Intergovernmental Panel on Climate Change (IPCC) defined renewable energy as:
"All energy derived from solar, geophysical, or biological sources that replenish in nature at a pace equal to or faster than their utilization rates. This energy is generated from continuous and cyclic natural processes, such as biomass energy, solar energy, geothermal energy, water movement, tidal energy in oceans, and wind energy. Various mechanisms allow for converting these sources into primary energies like heat, electricity, or kinetic energy through multiple technologies, enabling the provision of energy services and abundant electricity" (Atlik, 2018, pp. 26-45).
From these definitions, renewable energy sources include solar radiation, geothermal energy, wind, ocean waves, flowing or falling water, and biomass energy in its various forms. Key advantages of renewable energy are its inexhaustible and free nature, along with its environmental cleanliness.

Alternative Energy:
Alternative energy refers to any energy source that can replace fossil fuels and is often derived from traditional energy sources that have a minimal impact on the environment compared to fossil fuel combustion. Examples include solar, wind, water movement, and geothermal energy. All renewable energy sources originate from non-fossil sources and are

inexhaustible, such as solar energy, wind energy, biomass energy, hydropower, geothermal energy, wave energy, and tidal energy. Thus, renewable energy is a natural resource generated and replenished at a rate equal to or faster than its consumption.

Renewable energy is a strategic consideration for all countries, both developed and developing, as it helps reduce reliance on traditional energy sources and preserves the environmental footprint. It also forms part of future policies aimed at fostering sustainable, long-term investments.

2.2 Elements of Renewable Energy

The main elements of renewable energy include: (Nasif Iman, 2007, p. 20)

- **Solar Energy:** This includes radiant light and heat from the sun harnessed through continually advancing technologies, such as solar heating, photovoltaic cells, concentrated solar power, and artificial photosynthesis.
- **Hydropower:** Derived from hydroelectric dams and large-scale reservoirs, hydropower remains popular in many developing countries.
- **Wind Energy:** Airflow can be used to power wind turbines, with energy capacities ranging widely from approximately 600 kW to 9 MW.
- **Geothermal Energy:** High-temperature geothermal energy comes from the thermal energy generated and stored within the Earth. This energy, which determines a material's temperature, can be sourced from the Earth's depths, including its core.
- **Biomass Energy:** Biomass refers to biological material derived from living or recently living organisms, often plants or plant-derived materials, which serve as a specific energy source.
- **Hydrogen Energy:** Hydrogen is a significant energy source, constituting up to 75% of the mass of the surrounding universe. Its lightweight and clean properties make it an excellent fuel or energy source, with the ability to be converted into various forms of energy.

3. The Conceptual Framework of the Environmental Footprint

1.3 The Concept of the Environmental Footprint

In 2003, Mathis Wackernagel and others established the "Global Footprint Network," aiming to enhance the measurement of the environmental footprint and elevate its importance to that of GDP. The organization currently collaborates with 22 countries.

William Rees defined the environmental footprint as:

"The productive land area and energy-driven ecosystems required to produce the resources and materials consumed and to absorb the waste generated by a community living at a specific standard of living on Earth."

In essence, it is an indicator to measure the impact of society on natural resources and the sustainability level of the population's lifestyle and its effects on the planet (Mohammed Ali Sayed, 1998, p. 69).

The **environmental footprint** is defined as:

"A calculative mechanism of resources, dividing the amount of biologically productive land and water areas used by an individual, city, country, or region to produce the resources consumed and absorb the carbon dioxide generated. In other words, it is the total resources consumed by a nation, whether domestic or imported, and the environmental damage caused by utilizing these resources. This consumption is measured in global hectares per capita and includes agricultural land, forests, and fishing areas necessary for food production, clothing, and pollution absorption caused by energy consumption, as well as the infrastructure required for human activities." (Mohammed Ali, 2009, p. 250).

From the above, we can conclude that the environmental footprint is a measure of human impact on ecosystems. It represents the influence of human activities measured in terms of the biologically productive land and water required to produce consumed goods and manage generated waste. The footprint calculation takes into account everything we do—how we eat, travel, live, and our daily habits involving water usage and other resources.

2.3 Measuring the Environmental Footprint and Its Mechanism of Operation:

The environmental footprint essentially measures the supply and demand on nature. On the supply side, biocapacity represents the productive natural land areas, including forests, fisheries, grazing lands, and agricultural lands. These areas, when intact and uninterrupted, have the capacity to absorb nearly all waste generated by humans, especially carbon emissions (Ramadan Mohammed, 2001, p. 369).

The environmental footprint accounts for the productive areas required to provide renewable resources and absorb some waste generated. Additionally, it includes productive areas occupied by human infrastructure such as buildings, roads, and pathways.

3.3 The Environmental Footprint as a Composite Environmental Indicator for Measuring Sustainability:

A study by the World Economic Forum on sustainability development indicators included 20 main indicators divided into 68 sub-indicators. It relied on a methodological framework based on five key sustainability pillars: (Dariz, 2002, p. 10):

1. **Ecosystems:** The extent to which countries can maintain their natural systems at healthy levels and improve rather than degrade them.
2. **Reducing Environmental Pressures:** The degree to which human pressures on the environment are minimized to avoid significant negative impacts on ecosystems.
3. **Reducing Human Vulnerability:** The extent to which social systems and populations are safeguarded from direct exposure to environmental degradation.
4. **Social and Institutional Capacity:** A nation's ability to establish institutional and social systems capable of addressing environmental challenges.
5. **International Leadership:** The extent to which a nation collaborates internationally to achieve shared goals for global environmental protection and reduces transboundary environmental impacts.

Global Movement to Address Environmental Challenges:

International efforts to address environmental issues have followed two primary directions:

1. **Establishing Binding Environmental Agreements:**

This began with key milestones such as the United Nations Conference on the Human Environment in *Stockholm* (1972), resulting in the Stockholm Declaration, which outlined principles and recommendations serving as a foundation for environmental preservation. Additionally, the United Nations Environment Programme (UNEP) was established.

2. **The 1992 Earth Summit in Rio de Janeiro:**

This conference resulted in the adoption of three major agreements:

- The United Nations Framework Convention on Climate Change (UNFCCC).
- The Convention on Biological Diversity (CBD).
- The United Nations Convention to Combat Desertification (UNCCD).

The first set of agreements reflects the current status, while the second focuses on performance and action, aiming to address environmental challenges at the international level.

A. Indicators of the Current Situation:

These indicators include: (Sabah and Al-Zein, 2022, pp. 741–744)

1. **Driving Force Indicators:**

These indicators highlight social, demographic, and economic progress within societies and their relationship to changes in lifestyle, production patterns, and consumption habits. They encompass a wide range of factors influencing major environmental changes, such as population growth, increasing individual needs and activities, and economic indicators.

2. **State Indicators:**

These indicators represent the quantity and quality of physical characteristics (e.g., temperature), biological characteristics (e.g., fish stock levels), and chemical phenomena (e.g., atmospheric carbon dioxide concentration).

3. **Pressure Indicators:**

These indicators measure the stress placed on the environment and its components due to harmful emissions—physical, biological, or otherwise—as well as the use of natural resources and land. Such pressures cause damage to the environment and natural resources. A notable example of these indicators is the carbon dioxide emissions index.

4. **Impact Indicators:**

Environmental pressures lead to changes in its state, which in turn result in social and economic impacts within society. Impact indicators are used to describe these effects, such as biodiversity loss.

5. **Response Indicators:**

These indicators address the extent to which individuals and governments respond to prevent, protect, compensate, improve, mitigate, or adapt to environmental changes. They act as driving forces for redirecting prevailing consumption and production trends.

B. Performance Indicators:

Performance indicators allow for a comparison between the current environmental state and the desired or target state. They include:

1. **Environmental Footprint:**

As previously discussed, the environmental footprint measures Earth's biocapacity to meet human needs while absorbing the waste they generate. This can be assessed at the city, regional, national, group of countries, or global levels.

2. **Biological Capacity (Biocapacity):**
This relates to the supply side of resources, reflecting the health of Earth's biological systems. It measures changes in Earth's biodiversity.

3.4 Estimation of the Environmental Footprint:
The estimation process involves the following steps:
- **Converting Consumed Quantities into Global Hectares:** For instance, to calculate the global hectares required for flour consumption in a specific country, the amount of wheat necessary to produce the flour is first calculated. Then, the agricultural land required to grow the wheat (in hectares) is determined. This value is converted into global hectares by multiplying it by a specific conversion factor.
- **Calculating the Land Needed to Absorb Pollution from Industrial Products:** This includes emissions from imported goods. For example, the carbon dioxide emitted during the production of imported cars is calculated, and these pollutants are added to the importing country's footprint. This increases the environmental footprint of the importing country while reducing that of the exporting country.

Global analyses of the environmental footprint reveal that the human consumption pattern exerts immense pressure on available natural resources. Resource consumption exceeds nature's capacity to replenish those resources. Ideally, biocapacity should equal the environmental footprint. If the biocapacity is lower than the footprint, the country experiences a natural resource deficit (Salim, 2010, p. 95). The environmental footprint is calculated as follows:

Environmental Footprint – Biocapacity = Environmental Deficit
Where:
- **Biocapacity = Area × Productivity**
- **Environmental Footprint = Population × Per Capita Consumption × Resource/Waste Intensity**

Second: The Relationship Between Renewable Energy, Environmental Footprint, and Sustainable Development
1. Integrating the Environmental Footprint with Sustainable Development:
Economic policies play a significant role in increasing natural resource depletion and environmental pressures. Development policies and programs affect natural resource bases in many areas (Karshif and Khaza, 1999, p. 175). Many instances of excessive pollution and overexploitation of resources are linked to market failures or policy deviations. These deviations can lead to increased unemployment and poverty.
The economic crisis of the 1980s forced many developing countries to resort to external borrowing or deficit financing, with unexpected effects on their environmental footprint (Salem Tawfiq, 1999, p. 43). Rising prices of manufactured goods in developed countries reduced incomes in developing nations, prompting deforestation as the poor resorted to firewood and animal dung for heating, lighting, and pumping water (Mahmoud and Nasr Mohammed, 2001, p. 200).
Shifting to a low-carbon world through technological innovations and institutional reforms must begin with immediate partial actions by high-income countries to reduce their unsustainable carbon emissions. These countries must commit to substantial reductions in emissions. Sustainable development, as a rational development model, focuses on preserving resources and ensuring an environmentally clean footprint for future generations. It incorporates non-economic variables such as education, health, clean air, and water, which are valued for their intrinsic benefits (Shukran, 2023, p. 39).
Sustainable development is an integrated service involving international, regional, national, and local perspectives and collective actions. It includes contributions from international institutions, governments, civil society organizations, and individuals, aiming to ensure better living conditions for the present and future generations.

2. The Relationship Between Renewable Energy and Environmental Footprint
2.1 Aligning Renewable Energy with Environmental Footprint:
Countries worldwide have begun aligning renewable energy with environmental footprints by redesigning their environmental and energy policies through 2050. Renewable energy sources are promoted as key options for reducing carbon dioxide emissions and other pollutants contributing to global warming.
Economic experts in 2020 identified that renewable energy, nuclear energy, and energy efficiency improvements have strong potential to reduce carbon dioxide emissions, though not necessarily other emissions or resource consumption. The growing relationship between energy and the environmental footprint indicates that increasing renewable energy use may impact the footprint itself. Conversely, exceeding renewable energy demand could lead to potential adverse effects.
Different environmental footprint metrics (e.g., water footprint vs. carbon footprint) allow for comprehensive assessments of sustainability and fair comparisons of alternatives, such as air pollution versus climate change. However, consistent evaluation requires unifying indicators into a standard framework.

2.2 Renewable Energy in the Context of Sustainable Development:
The energy sector is a key driver of economic development, with a strong correlation between economic growth and energy consumption. Renewable energy plays a fundamental role in ensuring a reliable and sustainable energy supply for current development needs. By relying on a diversified economic base, countries can extend the lifespan of investments in resources such as oil and gas, increase the contribution of renewable energy sectors to GDP, maintain their position in global energy markets, and enhance the growth of their national economies, particularly in developing countries.
Renewable energy offers cost-saving opportunities, as renewable energy technologies have become relatively affordable. Lower borrowing costs in developing countries have further facilitated this shift. In advanced economies, the establishment of renewable energy facilities is often cheaper than fossil fuel-based energy sources, even in regions with limited sunlight. Government incentives, such as feed-in tariffs for solar energy, accelerate the transition to renewable energy in these nations. However, in many developing countries, renewable energy technologies remain costly due to high interest rates, which increase the overall costs of transitioning to renewable energy.

3. Renewable Energy's Role in Environmental Footprint Reduction:
Amid the decline in global oil and natural gas prices, energy experts view investment in clean and renewable energy as the most favorable option.
Governments worldwide have signed a global agreement to set ambitious goals for addressing climate change. This includes limiting the increase in global average temperatures to below 2°C above pre-industrial levels and achieving net-zero greenhouse gas emissions by the second half of the 21st century (Sheikh, 2007, p. 31).
Maximizing the use of renewable energy sources, such as solar, wind, and hydrogen extracted from seawater (expected to see technological advancements within the next two decades), can significantly enhance the environmental footprint. Additionally, renewable energy contributes to reducing greenhouse gas emissions and mitigating climate change. Many countries in the region rank among the highest per capita emitters of greenhouse gases globally.
Renewable energy can also address other pressing environmental issues in the region, such as rapidly increasing pollution levels, high associated costs, and declining quality of life. The region currently experiences the world's second-highest level of air pollution, with particulate matter concentrations exceeding 50% of the global average, causing damages equivalent to approximately 0.9% of GDP. When comparing energy sources, the cost of carbon dioxide emissions from fossil fuels must also be considered. Countries in the region can benefit financially from carbon credits through the United Nations Clean Development Mechanism (CDM).
Although it is challenging to estimate the value of other emissions due to their indirect effects, they often harm public health and the environment. Renewable energy, by contrast, does not pollute the environment, air, or seas (Malik, 2019, p. 144).
Energy plays a critical role in driving economic growth and fostering development, making it a priority in national development plans and strategies. Investment plans and programs for energy have increasingly transcended national boundaries. The diversity of renewable resources—such as wind, oil shale, solar, hydropower, and nuclear energy—enables the global economy to adopt policies that support the environmental footprint in developing countries. However, these policies require updates to previously enacted laws to align with modern economic strategies.
Despite frequent calls to enhance reliance on alternative energy sources, renewable energy remains a cornerstone for securing energy supply and supporting sustainable development.

4. The Link Between Renewable Energy, the Environmental Footprint, and Its Future Effectiveness:
The global focus on the environmental footprint has grown significantly, integrating environmental concerns with economic development within the concept of sustainable development. Trends in environmental footprints over the past decades have shown significant degradation across various sectors, with direct impacts on human development, particularly for millions of people relying on natural resources for their livelihoods.
The integration of renewable energy and the environmental footprint provides the following benefits: (Sanaa Shaker, 2023, p. 19)

- **Enhancing Well-being:** Renewable energy is linked to the environmental footprint and positively contributes to human welfare through services such as heating, lighting, cooking, transportation, leisure, and recreation. While energy is essential for economic production, energy costs reduce part of this welfare. The availability of the environmental footprint (raw materials) is critical as production elements like minerals, water, oxygen, and genetic resources are essential for production processes.
- **Providing Suitable Living Conditions:** The environmental footprint determines the quality of life, which is heavily influenced by the surrounding environment. Additionally, the environmental footprint supports habitats for other living species.
- **Supporting Ecosystem Functions:** Especially metabolic capabilities, as increasing human consumption of goods and materials heightens the need for a robust environmental footprint. This role is crucial in most countries worldwide to

achieve a sustainable ecosystem, ensuring sustainable development and fostering economic and financial structures for future generations.

- **Linking the Environmental Footprint with Sustainable Development:** This enhances its connection with renewable energy, which plays a vital role in improving the economies of poor countries. The experiences of Egypt and Morocco are notable examples. The UNDP defines sustainable development as development for people, jobs, and nature, prioritizing poverty reduction, productive employment, social integration, and environmental regeneration while balancing human populations, societal capacities, and nature's immense resources (Sanaa Shaker, 2023, p. 45).
- **Providing a Balanced Basket of Raw Materials:** Ensuring balanced intergenerational access to production elements within the investment process requires thoughtful management.

Renewable energy has constraints and influencers in maintaining the environmental footprint to reduce human consumption levels. This has prompted several Gulf countries, Algeria, Morocco, Egypt, and African nations to launch initiatives focused on solar, wind, and ocean energy projects. These initiatives aim to reduce dependence on conventional energy and establish economic projects under the title of *Clean Energy Economies.* These projects reflect a clear shift toward core programs for global economic growth amidst the globalization of electronic economies. Consequently, many economists advocate for clean energy as a way to maintain market structures, secure international support, and uphold the global market.

Third: Renewable Energy Economics and Environmental Footprints in Egypt and Morocco

1. Renewable Energy Economics and Environmental Footprints in Egypt

1.1 Conventional Energy Resources and Potential:

Egypt has significant capabilities for energy generation, with 24.70 MW of energy generated in 2010, and 99% of its population had access to national electricity. Key conventional resources include:

- **Fossil Fuels:** Egypt is a significant producer of non-OPEC energy sources, with the sixth-largest confirmed oil reserves in Africa. More than half of these reserves are offshore (Asman, 2021, pp. 22–25). Although not an OPEC member, Egypt's oil consumption reached 766,000 barrels per day in 2020, marking a 1.98% annual increase. The following table illustrates Egypt's fossil fuel consumption, specifically oil, from 2016 to 2020.

Table 1: Fossil Fuel Consumption in Egypt (2016–2020)

Years	Barrels Per Day
2016	840,000
2017	786,000
2018	731,000
2019	734,000
2020	766,000

Source: Economic and Social Commission for Western Asia, *Renewable Energy: Legislation and Policies in the Arab Region*, Beirut, United Nations, 2021, p. 172.

From the data, Egypt recorded its highest oil consumption rate in 2016, reaching 840,000 barrels per day. This figure then dropped to 786,000 barrels in 2017 and further to 731,000 barrels in 2018. However, oil consumption in Egypt began to rise again, recording 734,000 barrels per day in 2019 and slightly increasing to 766,000 barrels in 2020.
The historical data on fossil fuel consumption in Egypt reveals a fluctuating trend due to various factors, including environmental conditions like temperature drops and economic factors such as changes in fuel prices.

Natural Gas Consumption in Egypt

Reforms in Egypt's energy sector have significantly transformed the industry, attracting investments, particularly in natural gas discoveries. Major natural gas discoveries in the Eastern Mediterranean have elevated Egypt's status in the region as a gas production hub. These developments have created new opportunities for regional integration, positioning Egypt as the third-largest natural gas producer in Africa, following Algeria and Nigeria (Rajaa, 2021, p. 85).

Table 2: Natural Gas Consumption and Decline Rates in Egypt (2022)

Years	Consumption Rates	Billion Cubic Meters	Decline Rate
2013–2015	49.5	Billion m³	3.5%
2016	46.1	Billion m³	
2017	35.3	Billion m³	

Years	Consumption Rates	Billion Cubic Meters	Decline Rate
2018	59.6	Billion m³	
2019	58.6	Billion m³	
2020–2022	75.8	Billion m³	

Source: Organization of Petroleum Exporting Countries (OPEC), *Annual Report 66*, Issue 2138, pp. 100–103.

The table above illustrates consumption rates, showing that during 2013–2015, the rate reached 49.5 billion cubic meters. However, it decreased in 2016 to 46.1 billion cubic meters and further declined in 2017 to 35.3 billion cubic meters. Consumption increased in 2018 to 59.6 billion cubic meters, according to international data on fossil fuels in Egypt. The annual natural gas consumption remained stable at 59.6 billion cubic meters. However, between 2020–2022, Egypt's annual natural gas consumption rose to 75.8 billion cubic meters compared to the 59.6 billion cubic meters in 2018.

1.2 Indicators of Renewable Energy, Environmental Footprint, and Sustainable Development Dimensions in Egypt

Solar energy is one of the key pillars of development in Egypt. Economic experts have indicated that Egypt faces challenges in securing sufficient energy resources, particularly oil and natural gas, which account for 95% of its total energy needs. Despite Egypt's reserves of these resources (Reich, 2021, p. 378), studies suggest that balance between oil and gas production and consumption may return within three years, following resolution of the economic difficulties faced by the oil and gas sector. According to Egypt's energy strategy for 2030, which is currently being updated, the target is to achieve this balance by 2035.

Table 3: Estimated Capacities and Annual Energy Generation from Solar Thermal Power Plants (CSP) and Photovoltaic (PV) Plants (2015–2026)

Year	PV Annual Energy Generation (TWh)	PV Annual Added Capacity (MW)	CSP Annual Energy Generation (TWh)	CSP Annual Generated Capacity (MW)
2026/2025	0.9	600	10.785	2400
2025/2024	0.15	100	1.38	350
2024/2023	0.15	100	1.38	350
2023/2022	0.12	80	1.585	350
2022/2021	0.12	80	1.29	250
2021/2020	0.21	80	1.29	250
2020/2019	0.06	40	1.12	250
2019/2018	0.06	40	1.005	150
2018/2017	0.045	30	0.685	150
2017/2016	0.045	30	0.65	350
2015/2016	0.03	20	0.4	250

Source: Egyptian Ministry of Electricity and Renewable Energy, Renewable Energy Authority Publications, 2021, p. 183.

The situation presents an additional challenge for the Egyptian economy, exposing it to unpredictable and uncontrollable price fluctuations in global energy markets. This also leads to the depletion of Egypt's foreign currency reserves, adversely affects the trade balance, and reduces the competitiveness of the national economy.

1.3 The Role of Energy in Supporting the Environmental Footprint in Egypt

Energy in Egypt is centered around four main factors: new offshore natural gas discoveries, financial reforms, renewable energy development, and grid interconnections. These developments have collectively transformed the energy landscape. During the same timeframe as the development of new gas fields, Egypt installed gas-powered energy plants and built a massive solar energy park near Aswan, which is considered the world's largest operational photovoltaic solar park with a capacity of 1.8 GW (Al-Tariq, 2020, p. 37). The $4 billion solar complex consists of about 40 solar plants developed by over 30 foreign companies from 12 countries. It is projected to prevent approximately 2 million tons of annual CO2 emissions (Faroukhi, 2020, pp. 84–112).

The integration of Egypt's renewable energy capacity with Europe, Africa, and the Middle East has driven increased investments in renewable energy generation between 2019 and 2023. Renewable sources, including solar and wind, accounted for 38% of Egypt's installed capacity, amounting to 2.23 GW.

Egypt's Integrated Sustainable Energy Strategy for 2035 aims to increase renewable energy production tenfold, representing 42% of the installed capacity by 2035. Additionally, reducing the carbon footprint by transitioning to green hydrogen is expected to contribute positively to combating climate change. Egypt now targets installing 61 GW of renewable energy capacity by 2035.

2 Renewable Energy Economics and the Environmental Footprint in Morocco
2.1 Renewable Energy Resources in Morocco

- **Solar Energy:**

Morocco receives abundant solar energy, which is harnessed directly or converted into electricity through solar panels. Renewable energy sources in Morocco contribute as follows: 19.6% hydropower, 7.3% wind, 8.1% other sources, and 4.2% solar energy. Morocco's solar energy plan includes five solar power plants in Ouarzazate, Ain Beni Mathar, Foum El Oued, Boujdour, and Sebkha Tah, with a financial investment of $9 billion. By 2023, these plants aim to produce around 2,000 MW of electricity (Al-Hussein, 2019, p. 40). This project will save Morocco 1 million tons of fossil fuel annually and prevent 3.7 million tons of CO_2 emissions per year.

- **Wind Energy:**

Morocco focuses on transitioning to a sustainable economy as a developing country grappling with poverty and high unemployment. Wind energy has been a strategic choice to manage rising energy demand and promote structural sustainability. In 2019, Morocco exported part of its energy to sub-Saharan Africa as part of the United Nations' development programs to preserve the environmental footprint. Morocco's clean energy policy targets 43% renewable energy by 2020 (Enrtich, 2020, p. 75). Reports indicate wind energy constituted 10% of Morocco's total capacity in 2019 and is expected to reach 28% by 2030.

- **Hydropower:**

Renewable hydropower accounted for 0.4% of Morocco's national energy portfolio and about 10% of electricity production in 2007. Hydropower and wind energy have significantly supported renewable energy in Morocco, with a current capacity of 147 MW. Plans to install additional hydropower plants aim to produce 975 MW, with a combined capacity of 1,200 MW from integrated plants and dams, averaging over 2,000 million kWh in high-rainfall years. These facilities save around 700,000 tons of fuel for other purposes (Shamran, 2021, pp. 78–79).

Water resource exploitation in Morocco is estimated at 12.6 km³ annually, ranking 41st globally. Agriculture accounts for 87% of water usage, followed by domestic use at 10% and industrial use at 3%. Overexploitation of groundwater for industrial purposes has been noted in areas such as Souss-Massa. Morocco's 2008 National Renewable Energy Plan aimed to meet 15% of household energy needs through renewable energy, creating 400,000 jobs and attracting over €4.5 billion in investments by 2020 (Lee, 2021, pp. 154–155).

Morocco's total area is approximately 44.6 million hectares, with 4.4 million hectares of forests, 9 million hectares of agricultural land, and 21 million hectares of grazing land. Its built infrastructure spans 889,000 hectares. While agricultural crops, grazing land, and forests in Morocco fall below the global average, fishery yields exceed it.

Morocco's total biocapacity is 7.27 million global hectares, which is less than its consumption-based environmental footprint of 41.3 million global hectares. Production-related environmental footprints (excluding carbon) amount to 23 million global hectares, below the local biocapacity. This suggests Morocco has not yet begun depleting its natural capital reserves.

The per capita environmental footprint in Morocco is 1.3 global hectares, which is below both the global average and the global per capita biocapacity. This indicates that Morocco's consumption rate can serve as a global model for sustainability.

Agricultural land constitutes about 68.1% of Morocco's total land area as of 2020, with much of it suitable for permanent crops.

2.2- Indicators of Renewable Energy, Environmental Footprint, and Dimensions of Sustainable Development in Morocco

The transition to a renewable energy-based system in the Middle East and North Africa (MENA) region requires increasing efforts at all levels. This transition will not only necessitate the development of large-scale renewable energy projects but also the advancement of relevant infrastructure. Table () illustrates Morocco's population growth rate, the implementation of legal and regulatory frameworks, increased community participation, and the opening of new markets and industries. This highlights the importance and clarity of social and technical interconnectedness within the energy system and the critical dynamics of system innovation.

Table: Morocco's Population Distribution According to IMF Data (2014-2021)

Country	Population Growth Rate (up to 2021)	Annual Growth Rate (%)	Growth Rate 2021 (%)	Growth Rate 2025 (%)
Morocco	10.7 million	11.96	1.2	12.1

Source: (Sanaa, 2023, p. 65)

The population growth in Morocco is increasing amidst low individual income levels. The population growth rate reached 11.96% by 2021 and is projected to reach 12.1% by 2025, exceeding expectations. By 2050, the population is anticipated to reach 12.2 million, potentially increasing the consumption of all natural resources.

Renewable energy constitutes a cornerstone of Morocco's energy strategy, leveraging the significant renewable energy resources available in the country. This approach will enable Morocco to cover a substantial portion of its rising electricity needs. The strategy aims to increase the share of renewable energy in the electricity mix to over 52% by 2030.

Morocco has adopted a new approach by introducing an additional program to support all scheduled seawater desalination plants with renewable energy production units. This ensures self-sufficient energy production and availability. The new strategy includes initiatives such as waste-to-energy (biomass) conversion in major Moroccan cities and maximizing the use of renewable energy. This aligns with the state's overarching energy program from 2004 to 2022.

Table: Indicators of Programmed Production Capacity in Morocco (2022)

Production Capacity	Growth Indicator
Electricity generated from renewable sources (MW)	3950
Electricity generated from wind energy (MW)	1430
Electricity generated from hydropower (MW)	1770
Electricity generated from solar energy (MW)	750
Share of renewable energy in total installed capacity (%)	37
Share of wind energy in total installed capacity (%)	13.40
Share of hydropower in total installed capacity (%)	16.57

Source: Economic Report, Ministry of Mines and Energy, Moroccan Statistics Authority, 2022, Moroccan Periodical Indicators, p. 138.

We observe from the above table that the electrical capacity generated from profitable energy sources has exceeded an average of 1,770 MW, confirming the rapid development of renewable energy sources. These accounted for about 37% of the total installed capacity, a share that is expected to increase according to Moroccan economic reports. Profitable energy sources have contributed approximately 13.40% of the total capacity, highlighting the economic considerations and potentials in this domain. When compared to the share of hydropower, which achieved a total installed capacity exceeding profitable energy by a margin of 16.57%, a strong relationship becomes evident between renewable energy and environmental footprint, supported by Morocco's available resources and active policies.

The environmental footprint index in Morocco indicates that protected marine areas constituted approximately 0.7% of territorial waters in 2021. These marine protected areas encompass regions within tidal zones, or beneath them, including water, plant, and animal life, along with associated historical and cultural features preserved by legal or other effective measures to safeguard part or all of their ecosystems.

For built land, protected terrestrial areas in Morocco accounted for 2.2% of the total land area in 2021, as officially documented by national authorities. Permanent croplands constituted 3.9% of the total land area in 2020, referring to lands dedicated to crops like cocoa, coffee, and rubber, which occupy the land for extended periods without requiring replanting after each harvest.

3.2 The Role of Energy in Supporting Morocco's Environmental Footprint:

Morocco has significant potential in solar and wind energy, a fact recognized through the adoption of strategies to develop these sectors. Morocco aims to support renewable energy and environmental footprints by 80% by 2050, with advancements in energy storage technology and green hydrogen while reducing energy costs.

The swift movement toward developmental energy is motivated by increasing the share of national and local electricity and integrating it with solar energy at affordable costs. Morocco's new objectives build on the progress made in expanding wind and solar energy during the initial phase of energy transition. Morocco plans to achieve renewable energy targets for 2030, 2040, and 2050 through advancements in energy storage technology, green hydrogen, and cost reductions in renewable energy (Ahmed, 2019, p.182). This demonstrates that the country is on track to meet its 2030 renewable energy capacity goals, reduce reliance on thermal sources like coal and oil, and decrease the share of coal-installed capacity from

38.8% in 2020 to 22% by 2030. Morocco’s installed capacity reached 39 GW in 2020 and was estimated to rise to 43 GW by 2021, an increase of 9% (Khan Shah, 2020, pp. 26–29). It is expected that Morocco's renewable installed capacity will reach 9.6 GW by 2030, with a compound annual growth rate of 93% over the period 2020–2030.

Conclusion:

Estimates show that the information and communications technology (ICT) industry will represent 3.6% of the global carbon footprint. These statistics have raised international concern and attention to reducing carbon emissions in data centers. Consequently, many companies have sought to minimize energy consumption, adopt artificial intelligence as a carbon reduction alternative, and transition toward environmentally friendly data centers, a concept known as "cleaner technology."

Excessive exploitation of energy, especially conventional energy, climate change impacts, high population growth, and uncontrolled economic and urban development exacerbate environmental challenges in Egypt and Morocco. These challenges include water scarcity, land degradation, improper waste management, marine and coastal environmental deterioration, and air and water pollution. These factors increase the environmental footprint and threaten sustainable development in these countries.

Thus, reducing the environmental footprint is essential to support their economies. This can be achieved by encouraging decision-makers and the public to incorporate environmental accounting into their daily practices, enabling the region to maintain a competitive and viable economy and a healthy environment for the long term.

Results:

- Egypt directed its 2030 vision towards building a competitive, balanced, and diversified economy focused on sustainable development, where renewable energy plays a pivotal role.
- The Integrated Sustainable Energy Strategy (ISES) for 2035 aimed to diversify energy sources, ensure energy security, and guarantee sustainability.
- Egypt aims to generate 20% of its electricity from renewable energy sources by 2035.
- Egypt's experience with renewable energy and its environmental footprint represents an important and effective endeavor to develop the necessary capacities to achieve these goals.
- Morocco’s renewable energy and environmental footprint initiatives ranked it among the top five countries globally in renewable energy production and carbon emissions reduction.
- Morocco's renewable energy and environmental footprint initiatives have enabled it to rely on national energy sources by 8.6%, with expectations to reach 35% by 2035–2040.
- Morocco's achievements in renewable energy projects and a 75% reduction in carbon emissions have also encouraged energy exports to neighboring countries.

Recommendations:

Arab countries can benefit from Egypt and Morocco’s renewable energy and environmental footprint experiences by:
1. Developing a plan to expand renewable energy usage and implementing a master transport plan focusing on identifying and upgrading substations to meet growing demand rates.
2. Overcoming or reducing legal and political legislative obstacles to attract investments in renewable energy by addressing energy market measures.
3. Enhancing energy efficiency measures, especially in buildings, to reduce carbon emissions and protect the environment from ongoing vitality depletion.
4. Adopting renewable energy laws and establishing specialized institutions.
5. Educating consumers on sources of pollution and methods of addressing them based on their consumption of manufactured goods and food products. This requires collaboration between governmental institutions, environmental protection bodies, and consumer protection organizations.
6. Improving infrastructure and energy efficiency in renewable energy usage can help achieve environmental and economic goals.

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