energies

Article

An Economic Analysis of Solar Energy Generation Policies in the UAE

Mayyas Alsalman, Vian Ahmed *, Zied Bahroun and Sara Saboor

Department of Industrial Engineering, American University of Sharjah, Sharjah P.O. Box 26666, United Arab Emirates
* Correspondence: vahmed@aus.edu

Abstract: Despite global efforts to reduce greenhouse gas emissions, the energy sector remains a major contributor, with hydrocarbon-based resources fulfilling around 80% of energy needs. As such, there is a growing focus on identifying effective and economically feasible policy mechanisms to promote renewable energy adoption. This study focuses on the theoretical problems surrounding the adoption of renewable energy policies. The study aims to highlight the potential for sustainable growth using renewable energy in the UAE and identify the most viable policy mechanisms for enhancing grid-tied solar energy adoption using qualitative and quantitative data collection methods and the HOMER Grid software. Compared to previous research, this study contributes by identifying a unified renewable energy policy mechanism that could significantly enhance the adoption of grid-tied solar energy generation in the UAE. The study's main findings show that a unified renewable policy mechanism could enhance grid-tied solar energy adoption throughout the UAE's electricity authorities. Net metering emerges as the most efficient and economically viable policy for customers and electricity utilities.

Keywords: greenhouse gas emissions; energy demand; sustainability; energy policy mechanism

check for updates

Citation: Alsalman, M.; Ahmed, V.; Bahroun, Z.; Saboor, S. An Economic Analysis of Solar Energy Generation Policies in the UAE. *Energies* **2023**, *16*, 3165. https://doi.org/10.3390/en16073165

Academic Editor: Seung-Hoon Yoo

Received: 25 February 2023
Revised: 25 March 2023
Accepted: 27 March 2023
Published: 31 March 2023

1. Introduction

Rapid economic growth combined with increasing energy demand is a continuous driving force for economic development, social advancement, and improved quality of life. Thus, the impact of energy demand on the environment has increased the focus of global nations on sustainability efforts that can be achieved by focusing on developing suitable renewable energy policies that address efficient energy consumption and reduce greenhouse gas (GHG) emissions [1]. As such, the Kyoto Protocol introduced in 2005 provided a suitable framework for the developing countries to implement optimal control strategies, which tend to reduce GHG emissions [2]. In addition, nations are motivated by the Paris agreement to reduce the global temperature below the critical level of 2 °C. Addressing this concern, the environmental and energy experts proposed during the Paris COP21 climate change summit that renewable energy (RE) plays an essential role in improving the environmental quality and reducing the effect of climate change on our environment [3]. However, rapid population growth, urbanization, and increased energy consumption result in increased GHG emissions. A number of studies report that the energy sector alone accounts for two-thirds of GHG emissions, as more than 80% of energy needs are satisfied using hydrocarbon-based resources [4].

The GCC countries are globally recognized for their abundant hydrocarbon resources, which include some of the largest oil fields in the world. While the energy sector is a significant source of CO_2 emissions in the region, the UAE has emerged as the 10th-largest oil-producing country in the world with an impressive GDP per capita [5]. The UAE has taken a proactive stance towards environmental protection, driven by its commitment to sustainable economic growth. With rapid economic growth over the past few decades, the UAE's energy demand has soared. In 2010, the country's electricity consumption was estimated to be 85.2 billion kWh, a remarkable 8.5% increase from the previous year [6]. However, in a bid to reduce dependence on conventional energy sources, the UAE has announced a set of policies aimed at promoting renewable energy (RE) sources. As such, the government aimed at ensuring that by 2021, 27% of the energy sector is supplied by RE, which is a significant step towards achieving sustainable development [7,8].

The UAE government has therefore demonstrated its commitment towards sustainability deployment by setting ambitious targets. However, in order to facilitate this transition, it is crucial to establish effective renewable energy (RE) policy mechanisms that would enable a significant share of RE in the national energy mix. Identifying the most feasible and cost-effective policy that aligns with the UAE's unique needs is essential to bridge the gap between policy formulations and their actual implementation. To achieve this, it is necessary to analyze the factors that impact the deployment of renewable energy in the UAE. This paper aims to investigate various renewable energy policy mechanisms and recommend the most appropriate and cost-effective policy for adoption by the UAE electricity authorities while considering the critical factors that impact the deployment of renewable energy in the country.

2. Literature Review

This section aims to provide a literature review on the deployment of renewable energy policies. It will begin by providing an overview of the different types of policy mechanisms, followed by a comparative analysis of their implementation both internationally and within the UAE. The discussion will then delve into the economic, political, and technological factors that impact the deployment of renewable energy. By examining these aspects, this review seeks to provide a thorough understanding of the current state of renewable energy deployment policies and their potential for future growth.

2.1. Renewable Energy Deployment Policy Mechanisms

Energy policy is a government strategy that addresses energy development issues, including production, distribution, and consumption. Rissman et al. [9] note that policy attributes include international treaties, investment incentives, legislation, energy targets, conservation guidelines, taxation, and simulation strategies. Developed countries have implemented effective policies, including green labeling, procurement, and target setting, to increase renewable energy use. However, accessibility, affordability, and policy deregulation affect renewable energy integration. This section outlines common global renewable energy mechanisms and recommends relevant policies for UAE electricity authorities.

a. Feed-in tariff (FIT)—This is a widely used renewable energy mechanism that offers a long-term pricing scheme to renewable energy producers and aims to compensate for costs as well as risk-related issues. FIT is defined as a renewable energy policy that pays a guaranteed price for power generated by a renewable energy source for each unit of electricity fed into the grid, usually for a long-term period of about 20 years [10]. The Public Utility Regulatory Policies Act (PURPA) was the first to introduce FIT policies in the USA, whereas the second implementation of FIT was in Denmark and Germany in mid-1990. Tariff mechanisms were successfully applied in 73 countries [11]. The advantage of using the FIT mechanism is that it allows nontraditional developers to participate in the renewable energy market by installing solar panels to generate electricity, as well as reducing investors' risks as generators guarantee a fixed energy price for a fixed duration.

b. Net metering—Net metering enables utility customers to own and operate grid-tied PV systems and profit by offsetting some of their electricity consumption while being paid for excess energy fed into the grid. It is also known as "net feed-in-tariff" [12]. Net metering utilizes a bidirectional meter that measures imported and exported energy, promoting distributed generation with a higher retail rate than conventional generators [12]. Solar energy is produced during peak demand [13], allowing for significant income and long-term savings on utility bills. Net metering focuses on small-scale grid-tied solar projects, avoiding excess energy feedback and fluctuations, and contributing to lower reliance on fossil fuels.

c. Quota—The quota mechanism or renewable portfolio standards (RPS) is a quantity-driven renewable energy policy where the government sets a framework for companies to produce, distribute, or sell a specific quantity of energy products from renewable sources [14]. Noncompliant companies must pay penalties, and market competition creates the lowest renewable energy prices. Although applied in several countries worldwide, RPS has not achieved the success of feed-in tariffs and metering in Germany and Denmark [15].

d. Auctioning—Auctioning, tendering, or bidding is a quantity-driven energy policy where producers bid to produce a specific quantity of energy at a cost per unit. According to Atalay et al. [16], auctions are classified into different forms, such as sealed-bid, descending-bid, or hybrid bids, based on the nature of the bid, the type of RE resource, and the site of energy generation. Auctions foster renewable energy market growth, reduce investor risk, and improve cost efficiency through price competition. Auctions can be part of FITs, but they differ in their use of local content requirements. They have yielded positive developments, including increased renewable energy capacity at a lower price and wind energy industry growth. To prevent underbidding risks, price references can be set before auctions with FIT support [17].

e. Investment tax credits—Investment tax credits are tax incentives, such as income tax credits and production tax credits, that can reduce the cost of renewable energy. Governments worldwide offer various tax-related incentives to encourage renewable energy investment, such as capital, VAT reductions, tax reductions, and property tax incentives. Investment tax credits are widely used to cover the expenses of renewable energy systems and installation costs, particularly in the early stages of deployment when costs are high. They can reduce investment risks and costs in renewable energy technologies [18]. Subsidies or rebates can also make renewables a more attractive investment option despite their high initial costs.

Renewable energy policy mechanisms are used to create competition in the energy market and break the monopoly on energy production. These mechanisms are usually used in combination to increase the amount of renewable energy in the power generation sector. The dominant policy mechanisms include feed-in tariffs, net metering, gross metering, quotas, bidding, tendering, and auctions. Tax incentives and subsidies can also be applied in conjunction with these policy mechanisms to support the development of the renewable energy market. These mechanisms have contributed to mitigating emissions and meeting the needs of the renewable energy sector. The following section examines the current state of renewable energy policies in general and in the UAE in particular.

2.2. United Arab Emirates Renewable Energy Policy Mechanisms

This section compares the deployment of renewable energy policy mechanisms from an international perspective and the UAE's perspective. Mezher et al. [19] found that approximately 70% of countries worldwide use feed-in tariffs and metering mechanisms to encourage renewable energy adoption due to their investment security and market stability benefits, mainly from wind and solar energy. The study also revealed that 50% of renewable energy projects were European, followed by Asian, American, and African. The UAE government announced its first renewable energy policy in 2009, aiming to generate 27% of energy from renewables by 2021 [20]. To achieve this goal, to support renewable energy deployment, while Abu Dhabi set a quota mechanism for a 10 MW solar plant installed in Masdar City connected to the existing electricity grid [3]. However, some companies faced challenges due to the lack of a taxation system, which prevented full adoption of auctions penalties [20]. Nonetheless, the UAE remains committed to promoting renewable energy and has made significant progress towards achieving its targets and has the potential to become a trailblazer in renewable energy adoption.

In 2016, the UAE signed the Paris Agreement and committed to adopting a renewable energy mix, making climate change a top priority. The Ministry of Climate Change and

Environment was created to lead this effort. The National Climate Change Plan was introduced in 2017 as a roadmap for sustainability adaptation up to 2050. Both Abu Dhabi and Dubai have implemented net metering policies to address climate change issues, and as a result, have become top sustainable cities. The UAE aims to achieve sustainable growth by pursuing renewable energy deployment to meet the increasing demand for electricity [21].

The UAE leads the GCC in solar growth, with solar PV accounting for 83% of installed renewable energy capacity. Dubai's Shams Dubai net metering initiative, launched in 2014, allows customers to generate and feed excess energy back into the grid. Dubai Electricity and Water Authority (DEWA) operates the legislation and guidelines for connecting solar to the grid, installing bidirectional meters during the initiative. DEWA will transfer excess energy to the next month's bill, with no payment for surplus energy. As of 2021, 900 MW of solar PV rooftop projects has been installed under the net metering mechanism [22].

The UAE has, therefore, made a commendable commitment towards sustainability, and it is actively working towards deploying renewable energy sources. While there are some challenges that may hinder the UAE's adoption of renewable energy policy mechanisms, the upcoming section will provide valuable insights to identify the most viable options. By exploring these mechanisms and carefully selecting the ones that are best suited to the UAE's unique circumstances, the country can further advance its efforts towards a more sustainable future.

2.3. Factors Impacting Renewable Energy Deployment

This section highlights the main factors that impact renewable energy deployment to support the UAE's adaptation of grid-tied solar energy generation, which include:

Environmental protection—Environmental protection ensures sustainable deployment by taking various actions to reduce environmental problems such as pollution and GHG emissions. By lowering the consumption of fossil fuels and addressing pollution contributors, GHG emissions and environmental impacts can be reduced [23].

Economic development—The most visible barrier to renewable energy deployment is the high installation cost of renewable energy, which tends to reduce renewable energy projects. This is primarily due to the high cost of technologies, making them prohibitively expensive for consumers to adopt clean energy [24]. Thus, the economic benefits of renewable energy projects are directly related to the developer's enthusiasm and their willingness to develop projects. Therefore, due to the lack of social acceptance from investors and the lack of public financial support for renewable energy installation, this becomes a hurdle to renewable energy deployment.

Technological advancement and energy security—Achieving a sustainable and affordable supply of renewable energy is essential for a brighter future, and it can be achieved through stable energy systems and technological advancements. To successfully implement renewable energy projects, it is important to have access to sufficient resources and a reliable energy supply. By raising public awareness and investing in the necessary infrastructure and grid connectivity, the UAE can overcome the challenges and enjoy the benefits of renewable energy adoption. With the right support and incentives, investors can see the tremendous potential in renewable energy and contribute to a cleaner and more sustainable energy future for all [25].

Policy framework—Legal frameworks and policy systems have the potential to serve as key drivers for the deployment of renewable energy, promoting fairness and justice in the energy market. Effective and well-structured policies can play a crucial role in encouraging the adoption of renewable energy sources, while reducing regulatory barriers and increasing the overall effectiveness of national efforts towards renewable energy deployment [26]. To further boost renewable energy investments and deployment in the UAE, policymakers can work to develop more coordinated and supportive regulatory frameworks, such as a unified policy on mandatory renewable energy implementation, to promote clean energy across all seven emirates. By implementing these changes, the UAE can unlock the full potential of renewable energy and help build a more sustainable future.

Geographical location—The geographical location plays a significant role in determining the feasibility of RE projects, as it impacts the availability of key resources. The amount of rainfall, intensity of the sun, and scarcity of fossil fuels are some of the key factors that determine the suitability of a location for RE. However, unfavorable weather conditions, limited sunshine hours, and an uneven distribution of solar radiation can all result in interruptions in the supply of RE [27].

Thus, Table 1 shows a summary of the significant factors and their subfactors that play a critical role in hampering the renewable energy deployment as discussed in this section, with 18 of their subfactors.

Table 1. Main Factors Impacting Renewable Energy Deployment.

No.	Factors Affecting Renewable Energy Deployment	Critical Subfactors
1	Environmental protection	Lower the reliance on fossil fuels. Reduce environmental problems such as pollution, CO_2, and GHG emissions. Minimize the impact on the ecological environment [23].
2	Economic development	The high installation cost of RE technologies. The low cost of conventional energy resources. The lack of financial support. Extended period of RE return on investment. Economic growth. An increase in power consumption [24].
3	Technological advancement and energy security	Stable and uninterrupted RE supply. Grid reliability. Sufficient infrastructure [25].
4	Policy framework	Well-structured policies and strategy. Legal framework to attract investors in RE development. Discrepancies in setting regulations due to having different entities. Grid-connection standards for RE power generation [26].
5	Geographical location	Unfavorable weather conditions. Renewable energy resource availability [27].

The purpose of this study is to identify the most significant factors impacting the deployment of renewable energy in the UAE by adopting the five categories of factors outlined in Table 1, along with their 18 corresponding subfactors identified from the literature. This will be achieved by seeking expert opinions to highlight the most impactful factors. In addition, the study aims to evaluate the impact of these factors on the utilization of the most relevant renewable energy generation in the UAE. To accomplish this, a technoeconomic analysis will be conducted using a case study of a building operated by the Dubai Electricity and Water Authority (DEWA). By analyzing the impact of these factors, we aim to provide insight into how the UAE can more effectively deploy renewable energy and achieve its sustainable development goals.

3. Methodological Approach

The following section outlines the main methodological steps utilized in this study and offers a theoretical overview of both the AHP approach and the main inputs and outputs of the HOMER Grid software.

3.1. Methodological Steps in Assessing Renewable Energy Deployment in the UAE

Figure 1 depicts the methodology used in this study to assess the factors influencing renewable energy deployment in UAE electricity authorities and propose the most viable and economically efficient RE policy for the country.

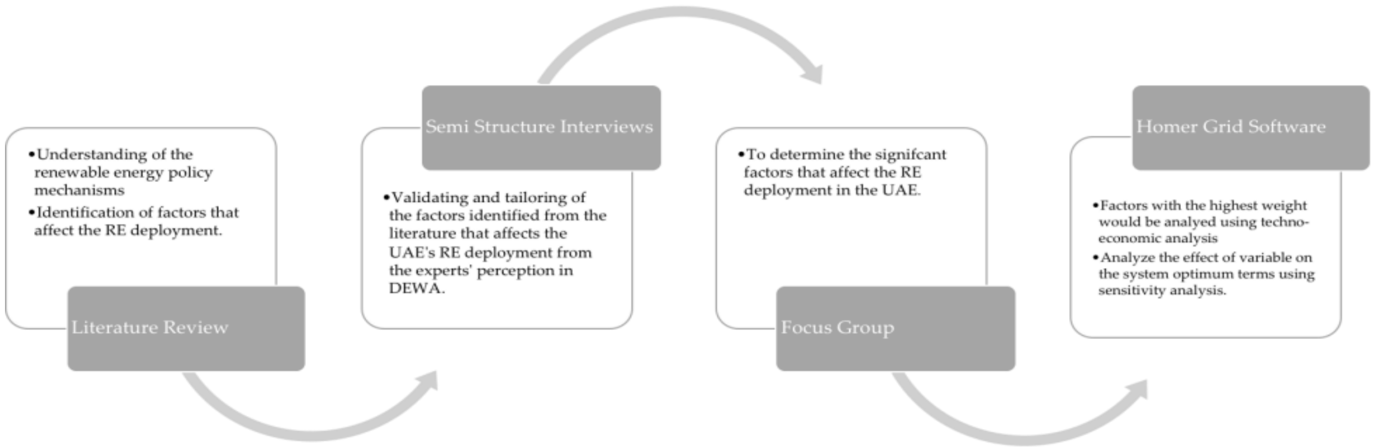


Figure 1. Methodological Steps.

As such, the data collection and analysis were conducted in the following stages.

Stage I: Literature review—the literature review aided the study in developing an understanding of the most popular renewable energy policy mechanisms and factors that impact the successful implementation of RE energy deployment around the world and especially in the UAE.

Stage II: Semistructured interviews—semistructured interviews (Appendix A) were conducted with sustainability experts from Dubai Electricity and Water Authority (DEWA) to evaluate the factors identified in Table 1 and gain an in-depth understanding of their perceptions of the most critical factors affecting renewable energy deployment in the UAE, as well as the most valuable renewable energy policy mechanisms to be promoted by the UAE's electricity authorities.

Stage III: Focus group—A focus group was conducted (Appendix B), adopting the analytical hierarchy process (AHP) and targeting the experts from DEWA to identify the most critical factors that act as barriers to the deployment of RE in the UAE.

Stage IV: HOMER Grid software—This stage of the study uses hybrid optimization of multiple energy resources (HOMER) Grid software to identify the most feasible renewable energy policy mechanisms that can be promoted in the UAE. In order to do so, the technoeconomic analysis of the factors affecting the UAE's renewable energy deployment is considered. Moreover, a sensitivity analysis is conducted to analyze the future projections of the variations in the input variables and their effect on the output variables that would affect the selection of the feasible RE policy mechanism. A list of abbreviations used in this paper is included in Abbreviations.

3.2. Analytical Hierarchy Process (AHP)

The analytical hierarchy process (AHP) is a powerful tool for multicriteria decision-making, used to assign weights and compare specific criteria [28]. Below, the main steps of the AHP analysis are summarized.

Step 1: Pairwise matrix—The pairwise comparison matrix is formulated using the chosen criteria, with comparative judgments being converted into group decisions by applying the geometric mean to form the comparison matrix. The geometric mean [28] is obtained by taking the square root of the product of a set of positive values a_i, where $i = 1,2,3 \ldots\ n$, as shown in the equation below:

$$\mathrm{GM} = \sqrt[n]{a_1.a_2.a_3 \ldots \ .a_n} \tag{1}$$

Using an average factor in a pairwise matrix is more convenient when different factors contribute to a product. This makes the geometric mean matrix a suitable approach for conducting an AHP analysis and obtaining the weight of the chosen criteria.

Step 2: Normalizing the comparison matrix—To ensure the compatibility of the matrix, it is necessary to normalize the pairwise comparison matrix using Equations (2) and (3).

$$\overline{W}_i = \frac{1}{n} \sum_{j=1}^{n} a_{ij}(\ i = 1, 2, 3, \ldots n) \tag{2}$$

$$W_i = \frac{\overline{W}_i}{\sum_{j=1}^{n} \overline{W}_j(\ j = 1, 2, 3, \ldots n)} \tag{3}$$

Step 3: Calculating the weight percentage—After obtaining the normalized comparison matrix, the priority vector eigenvector is computed to obtain the different weights of the factors along with λ_{max}, the maximum eigenvector. The weight and eigenvector of each critical factor are calculated using the following equations:

$$Aw = \lambda_{max} \times w \tag{4}$$

$$\lambda_{max} = \frac{1}{n} \sum_{i=1}^{n} \frac{(AW)_i}{W_i} \tag{5}$$

Step 4: Consistency check—During the final stages of the analytic hierarchy process (AHP) analysis, the degree of consistency is determined using Equation (7). In this equation, CI represents the consistency index and RI represents the random index. The consistency index is calculated using the following equation:

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{6}$$

If $CI = 0$, the values are perfectly consistent, but small inconsistencies may be acceptable depending on the nature and objectives of the study [29]. The random index (RI) values are used as an indicator of consistency and are obtained from the AHP approach [28].

Step 5: Consistency ratio—The last step is to calculate the consistency ratio (CR) to determine whether the pairwise comparison matrix is consistent. In order to ensure good consistency, the CR should be less than or equal to 0.1.

$$CR = \frac{CI}{RI} \tag{7}$$

3.3. HOMER Grid

The technoeconomic assessment of energy systems is a critical analysis to assess the feasibility of grid-connected renewable energy systems. To conduct this analysis more efficiently, the hybrid optimization of multiple energy resources (HOMER) Grid software from the National Renewable Energy Laboratory (NREL) can be used as an alternative to lengthy algorithms [30]. The software is user-friendly and allows for the prefeasibility, simulation, optimization, and sensitivity analysis of various renewable energy configurations for both stand-alone and grid-connected systems [31]. Additionally, the software can perform sensitivity analysis to investigate changes in variables and evaluate the economic and technical analysis of the system.

To identify the most feasible and cost-effective renewable energy policy mechanism for the UAE, this research employs the HOMER grid software to analyze the behind-the-meter system. The software takes into account the critical factors affecting renewable energy deployment, such as the location, solar radiation, PV system components, and the grid connection scheme. The schematic diagram presented in Figure 2 shows the primary inputs used in the software, which mainly relate to electrical demand. Furthermore, to design and simulate the system's output, additional information is used to provide the best technoeconomic output based on the levelized cost of energy (LCOE), net present cost (NPC), and initial capital cost.

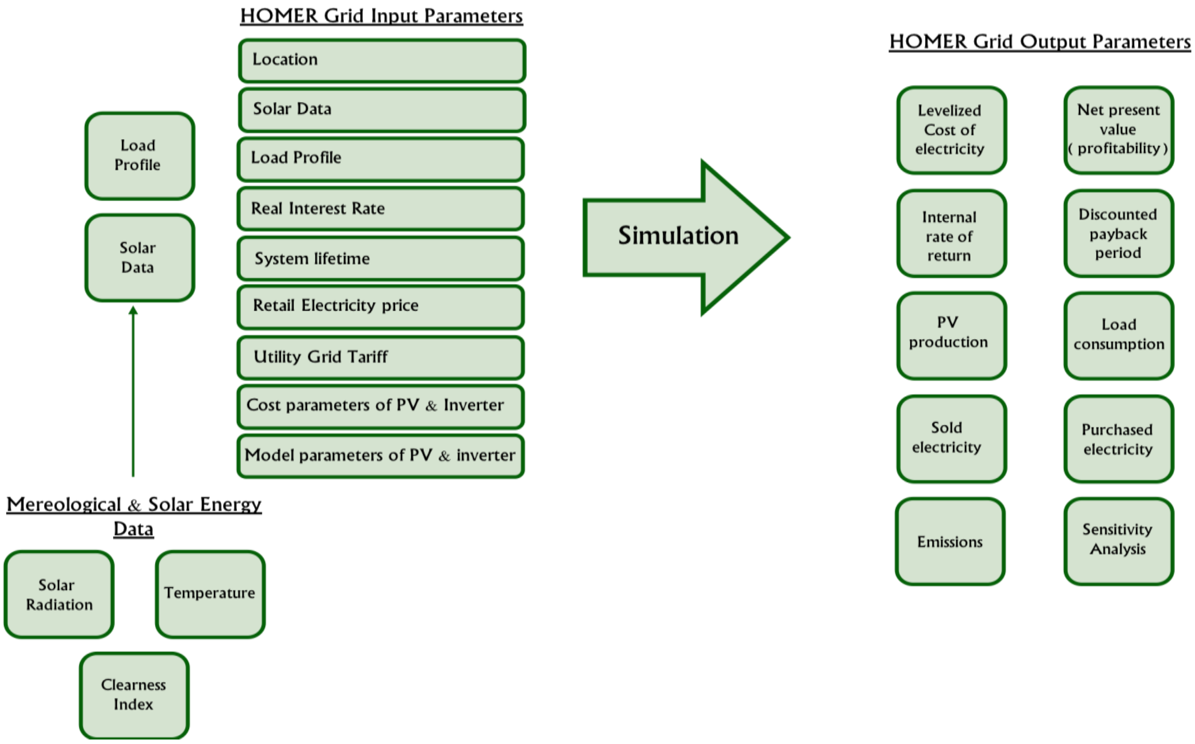


Figure 2. HOMER Grid Schematic Diagram.

The HOMER Grid software generates a report that assesses the feasibility of renewable energy policies using a variety of criteria, such as environmental impact, technical feasibility, and economic viability. Among the key factors considered in ranking different energy system configurations are the net present cost (NPC) and the levelized cost of energy (LCOE), which are widely recognized as important economic determinants. By analyzing these and other relevant indicators, the software provides valuable insights into the potential benefits and drawbacks of different renewable energy policy mechanisms.

Net present cost (NPC) of energy—The net present cost (NPC) is calculated by adding up the present costs of installing and operating a renewable energy system over its projected lifetime and subtracting the present value of the expected revenues. The HOMER software determines the best system configuration by evaluating the total NPC for each option, which can be calculated using the following formula:

$$NPC = \frac{C_{ann,tot}}{CRF(i, N)} \tag{8}$$

where $C_{ann,tot}$ is the total annual cost, i is the annual interest rate, N is the project lifetime, and CRF is the capacity recovery factory given by the below equation:

$$CRF(i, N) = \frac{i\,(1+i)^N}{(1+i)^N - 1} \tag{9}$$

Levelized cost of energy ($LCOE$)—In contrast, the $LCOE$ provides an estimate of the average cost of producing electricity over the lifetime of a renewable energy system. The $LCOE$ can be computed using the following equation:

$$LCOE\left(\frac{\$}{\text{kwh}}\right) = \frac{C_{ann,tot}}{R_{prim} + R_{tot,grid,sales}} \tag{10}$$

where R_{prim} is the primary load (kWh/year), and $R_{tot,grid,sales}$ is the total grid sales (kWh/year).

The $LCOE$ (levelized cost of electricity) serves the purpose of calculating the availability of renewable energy resources and assessing the cost-effectiveness of power generation systems. This metric considers all the necessary resources and assets required to produce one unit of electricity, including capital costs, operating expenses, and return on initial investment [32]. In addition to the $LCOE$ and NPC, other economic performance measures such as return on investment (ROI), discounted payback period ($DPBP$), internal rate of return (IRR), and profitability index (PI) are taken into consideration when making significant decisions.

Return on investment (ROI)—ROI measures the total return on investment for a given system. HOMER Grid software uses the following equation to calculate ROI:

$$ROI = \frac{\sum_{i=0}^{N} C_{i,ref} - C_i}{N\left(C_{cap} - C_{cap,ref}\right)} \tag{11}$$

where $C_{i,ref}$ is the reference system annual cash flow, C_i is the current system annual cash flow, C_{cap} is the current system capital cost, and $C_{cap,ref}$ is the reference system capital cost.

Discounted payback period ($DPBP$)—The $DPBP$ is a measure that indicates the number of years required to recover the initial cost of a project, while considering the time value of money. This is an essential factor for determining the feasibility of a system and assessing investment risk [33]. A longer $DPBP$ indicates a higher risk of not achieving the expected return on investment. However, the $DPBP$ does not consider any cash flows that occur after the payback period and, thus, does not provide information on the profitability of the project. The $DPBP$ can be calculated using the following equation:

$$\sum_{t=1}^{DPBP} \frac{C_t}{(1+i)^t} = C_o \tag{12}$$

where C_o is the initial investment cost, C_t is the net cash flow in period t, and i is the annual real interest rate (%). The annual interest rate is influenced by both the nominal interest rate and the inflation rate, which can be calculated using the following equation:

$$i = \frac{i_{n-f}}{1+f} \tag{13}$$

Internal rate of return (IRR)—The net present cost (NPC) of all cash flows is equal to zero when the internal rate of return (IRR) is at the interest rate. However, comparing projects with different economic scales using IRR may not be effective, but it can be useful when they have the same initial investment cost. It is important to note that the IRR should always yield a greater value than the initial discount rate to generate a profit. Therefore, the IRR can be calculated using the following equation:

$$\sum_{t=1}^{T} \frac{C_t}{(1+IRR)^t} - C_o = 0 \tag{14}$$

where C_o initial investment cost, C_t is the net cash flow in period t, T is the project lifetime, and IRR is the internal rate of return.

The last economic determinant is the profitability index (PI) or benefit–cost ratio, an index used to measure the ratio between the present value of future cash flow and the initial investment.

Profitability index (PI)—The PI is a useful tool for ranking projects, as a PI equal to one indicates that the project has reached the breakeven point. If the PI is greater than one, the project is generating value, while a PI value less than one means that the revenues do not cover the investment cost, and the project has no value. As the PI value increases, the profitability of the project increases, reducing its risk. The PI value can be calculated as follow:

$$PI = \frac{NPW}{C_o} + 1 \quad (15)$$

where NPW is the total net present worth of the project and C_o is the initial investment cost.

4. Data Collection and Analysis

This section discusses the data collection and analysis part of the study, wherein the qualitative data aim to identify and validate the factors that influence the UAE's deployment of renewable energy, while the quantitative data aim to evaluate the efficacy of the RE policy mechanisms using technoeconomic analysis.

4.1. SemiStructured Interviews

The interviews with experts from the Dubai Electricity and Water Authority (DEWA) were conducted online via Microsoft Teams. Table 2 displays the profiles of eligible interviewees, each possessing between 15 and 31 years of relevant experience.

Table 2. Profile of Interviewees.

Interviewee	Position	Years of Experience
P1	Manager	25 years
P2	Senior Manager	31 years
P3	Manager	28 years
P4	Acting Manager	15 years
P5	Manager	21 years

In order to validate the findings from the literature and gain an in-depth understanding of experts' perceptions on the factors impacting the UAE's renewable energy deployment and identify the most prevailing renewable energy policy mechanism, the interviewees were asked about their perceptions of the identified factors impacting the UAE's renewable energy deployment and whether such factors can be overcome.

Based on the interview responses, nine factors significantly impact the UAE's renewable energy deployment based on their importance, as shown in Table 3.

Table 3. Validated Factors That Affect UAE's Renewable Energy.

Code	Factor
F1	Environmental protection
F2	Social acceptance and reduce fossil fuels
F3	Availability of RE resources
F4	Insufficient infrastructure
F5	Interrupted supply and grid reliability
F6	Policies, strategies, and grid connection standards
F7	Legal framework and discrepancy in regulation
F8	Lack of financial support
F9	Economic growth and increase in consumption

As such, in the experts' perception, the significant factors that impact the UAE's RE deployment include environmental protection, social acceptance, lowering the reliance on fossil fuels, the availability of renewable energy resources, insufficient infrastructure, interrupted supply and grid reliability, well-structured policies, strategies, and grid connection standards, a legal framework, discrepancy in regulation due to having different entities, and a lack of financial support. Other factors in Table 1 are excluded because they are deemed inapplicable to the UAE.

When asked about the factors affecting the adoption of renewable energy (RE) in the UAE, the interviewees collectively highlighted a few challenges that need to be addressed.

At the country level, environmental protection is a top priority, and the government is committed to promoting clean energy. However, at the local level, there are some barriers that need to be overcome. One of the main challenges is the lack of social acceptance, which is mainly due to high installation costs and extended return on investment. Nevertheless, efforts are being made to attract more investors to support RE projects financially. Additionally, some entities face challenges in terms of the availability of a legal framework, which hinders the funding of RE projects. At the implementation stage, some authorities lack a well-defined renewable energy policy, which affects the adoption of RE. Furthermore, some areas may face technical limitations such as insufficient infrastructure and grid stability, which can be resolved through further investment and development. Despite these challenges, the UAE is committed to promoting renewable energy, and with the right strategies and policies in place, the country can overcome these obstacles and achieve its clean energy goals.

The participants were asked about their perceptions of the renewable energy policy mechanisms and based on their expertise, which policy mechanism is the most viable to be promoted by the UAE's electricity authorities. As such, P1 argued that "looking at the set of implemented policy mechanisms, net metering is the most appropriate policy; it is already implemented by DEWA and doing a great job; the growth of the Shams Dubai initiative is huge and fulfilling the objective set". While P2 and P3 are in agreement, a balance is required to ensure successful implementation of the different RE policies to benefit all stakeholders, including project owners, investors, utility companies, and the country as a whole. Therefore, the net metering policy mechanism is the best fit for the UAE as it allows customers to profit from the grid-tied PV systems by reducing their electricity bills, and the excess is fed back to the DEWA grid. However, the RE is mature now because it has an attractive return on investment (ROI), provides energy security, and reduces dependence on fossil fuels. As such, the RE policies became feasible with the UAE's active participation in climate change and its commitment. P4 and P5 also agree that "the net metering policy mechanism is feasible from the customer and investor perspective as they would benefit at the market rate by reducing the electricity cost and feeding the excess back to the grid". While looking at the gross metering mechanism, it is more beneficial from the utility's perspective.

Feed-in tariffs—All interviewees agreed that the feed-in tariff (FIT) policy mechanism is typically used in countries where the demand for electricity is high and approaching its maximum capacity. In these cases, countries encourage people to adopt renewable energy (RE) by compensating them for each kilowatt of electricity they feed back to the grid. FIT is especially useful for countries that want to reduce consumption to avoid grid extensions or where the existing network is not strong enough to handle additional extensions. Additionally, in some countries, the installation cost of RE is high, and the return on investment is not attractive. In such cases, the government may pay customers to encourage the deployment of RE. However, in the UAE, the FIT policy is not recommended, as the network is already robust, and the cost of renewable energy has significantly decreased. Rooftop installations using net metering are a better fit for reducing consumption and lowering customers' bills.

Quota mechanism—The quota mechanism is not applicable in the UAE because, according to the interviewees, private companies are not allowed to sell electricity unless they are independent power producers (IPP) approved by the local utilities. However, these IPPs are not permitted to sell directly to customers. Instead, they would sell the electricity they produce to the local utility, which is the sole provider of electricity.

Tendering, auctioning, or biding policy mechanism—The process of tendering, auctioning, or bidding for energy production is a quantity-driven mechanism that aims to produce a specific amount of energy at a particular cost. According to two interviewees, P1 and P3, this approach is particularly suitable for large-scale projects and is already in use in the Emirates of Dubai and Abu Dhabi. Through tendering, investors can participate in the energy production process. However, interviewee P4 pointed out that obtaining a Regulatory and Supervision Bureau (RSB) license is necessary to bid.

Tax investment credit—All interviewees agreed that the tax investment credit policy is applicable to countries with a taxation system. However, the UAE has no taxation system and is implementing a value added tax (VAT) with a small percentage of about 5%. As a result, this policy mechanism is unsuitable for the UAE context.

In conclusion, it can be inferred that the most feasible policy mechanisms to be promoted by the UAE electricity authorities are net metering and gross metering. These mechanisms will be further assessed through quantitative analysis in this study.

4.2. Focus Group

The goal of the focus group was to identify the most important factors identified from literature and validated by the semistructured interviews. This was achieved by ranking these factors based on their significance using the Delphi method and analytical hierarchy process. The discussion took place online via Microsoft Teams and involved experts from the DEWA. Table 4 below provides an overview of the focus group's experience levels.

Table 4. Profile of Focus Group Participants.

Participant	Position	Years of Experience
P1	Specialist	35 years
P2	Manager	24 years
P3	Deputy Manager	16 years
P4	Senior Manager	29 years

As such, the experts were asked to pairwise rank the factors based on their impact on the UAE's RE deployment, while adopting a Delphi method to allow participants reach an agreement in the final round of assigning weights for the factors affecting UAE's renewable energy deployment using Saaty's pairwise comparison scale as shown in Table 5:

Table 5. Saaty's Scales for Pairwise Comparison.

Numerical Value	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Demonstrated importance
9	Absolute importance
2,4,6,8	Intermediate values

The experts used the Delphi method to agree on final weights, which were then used in an AHP analysis to identify the most significant factors.

4.2.1. Analytical Hierarchy Process (AHP) Analysis

We used the pairwise comparison matrix generated through the Delphi method from the focus group to determine the weights of the most critical factors that impact the utilization of renewable energy in the UAE.

Using an average factor in a pairwise matrix is more convenient when different factors contribute to a product. This makes the geometric mean matrix a suitable approach for conducting an AHP analysis and obtaining the weight of critical factors that affect the deployment of renewable energy. Table 6 below shows the geometric mean matrix.

To ensure compatibility of the matrix, it is necessary to normalize the pairwise comparison matrix. Table 7 shows the normalized matrix using Equations (2) and (3).

Table 6. AHP Geometric Mean Pairwise Comparison Matrix.

Focus Group Matrix	F1	F2	F3	F4	F5	F6	F7	F8	F9
F1	1	0.52	0.2	0.69	0.58	4.16	4.16	1	1
F2	1.91	1	0.3	0.16	0.16	0.1	0.14	0.2	0.2
F3	0.2	0.2	1	0.2	0.2	0.2	0.2	0.2	1.79
F4	0.25	0.25	0.25	1	0.58	0.25	0.25	0.25	0.25
F5	0.49	0.49	1.06	1.58	1	1.65	2.62	2.62	2.62
F6	5.59	1.91	3.17	0.48	0.48	1	1	2	2
F7	1.71	0.58	2.08	1.71	1.71	1	1	7	0.16
F8	0.2	0.58	0.2	0.58	0.2	0.58	0.2	1	4.21
F9	0.48	0.1	1.44	0.16	2.88	0.55	0.55	0.14	1

Table 7. AHP Normalized Pairwise Comparison Matrix.

Normalized Matrix	F1	F2	F3	F4	F5	F6	F7	F8	F9
F1	0.08	0.09	0.02	0.105	0.07	0.43	0.41	0.07	0.07
F2	0.162	0.17	0.03	0.02	0.02	0.01	0.01	0.014	0.02
F3	0.01	0.03	0.102	0.03	0.03	0.02	0.01	0.014	0.12
F4	0.02	0.04	0.03	0.15	0.07	0.02	0.03	0.02	0.01
F5	0.04	0.08	0.11	0.24	0.12	0.17	0.25	0.18	0.19
F6	0.47	0.33	0.32	0.07	0.06	0.11	0.09	0.14	0.15
F7	0.14	0.103	0.21	0.25	0.22	0.11	0.09	0.49	0.01
F8	0.01	0.103	0.02	0.08	0.03	0.06	0.01	0.07	0.32
F9	0.04	0.01	0.15	0.025	0.37	0.05	0.05	0.01	0.08

After obtaining the normalized comparison matrix, the priority vector eigenvector was computed to obtain the different weights of the factors along with λ_{max} , the maximum eigenvector, as shown in Table 8.

Table 8. Weight of The Factors That Affect UAE's Renewable Energy Deployment.

Code	Factor	Weights
F1	Environmental Protection	15.24%
F2	Social Acceptance and Reduce Fossil Fuels	5.27%
F3	Availability of RE Resources	4.39%
F4	Insufficient Infrastructure	4.50%
F5	Interrupted Supply and Grid Reliability	15.78%
F6	Policies, Strategies and Grid Connection Standards	19.62%
F7	Legal Framework and Discrepancy in Regulation	18.24%
F8	Lack of Financial Support	8.07%
F9	Economic Growth and Increase in Consumption	8.90%

Based on the table above, we can conclude that the UAE's successful deployment of renewable energy (RE) is most significantly influenced by policies, strategies, and grid connection standards, as well as the legal framework and regulatory consistency. In contrast, factors such as insufficient infrastructure and the availability of RE resources were deemed less critical.

To determine the consistency index (CI), the average of the consistency vector will be computed, with a value of 9.672 for lambda (λ_{max}), given that there are nine criteria (n).

Therefore, the calculation for the consistency index is as follows:

$$CI = \frac{\lambda_{max} - n}{n - 1} = \frac{(9.672016898 - 9)}{(9 - 1)}$$

The last step is to calculate the consistency ratio (CR) to determine whether the pairwise comparison matrix, created during the focus group, is consistent. The random index value is 1.4 for nine criteria [28], and the CR can be computed as shown below:

$$CR = \frac{CI}{RI} = \frac{0.084002112}{1.4} = 0.057 < 0.1$$

Based on the computed CR value, it can be concluded that the pairwise comparison matrix created during the focus group is consistent. Therefore, it can be used in the subsequent HOMER Grid analysis.

4.2.2. Validating the AHP Analysis Weights

The most critical factors that act as a barrier to enabling renewable energy utilization in the UAE were identified, and their weights were determined. To validate the outcome of the AHP analysis, the results were presented to three experts from the focus group. Additionally, the interviewees were asked to weigh in on the factors identified through the AHP analysis, based on their perceptions. The analysis of the responses revealed that all interviewees emphasized the importance of having unified, well-structured policies, strategies, grid connection standards, and legal frameworks.

Analysis—the policies, strategies, and grid connections that are grouped under policy analysis represent the most significant contributing factor to the deployment of renewable energy in the UAE.

Technical analysis—One of the most critical factors for successful deployment of renewable energy, according to the interviewees, is having a reliable grid that can accommodate the integration of renewable energy sources without interruptions in energy supply. This factor, referred to as technical analysis, was ranked second due to its significant impact on the implementation of renewable energy. The interviewees emphasized the importance of ensuring uninterrupted energy supply through a reliable grid, and they highlighted the necessity of addressing this matter to pave the way for renewable energy development.

Environmental analysis—The interviewees highlighted the significance of protecting the environment and placed it third in the category of environmental analysis. This ranking reflects the critical role of mitigating emissions resulting from energy generation, which can be achieved by adopting renewable energy technologies.

Economic analysis—Moreover, the interviewees shared an intermediate perception as they stated that the UAE witnessed fast growth in energy demand in the past few years, whereas renewable energy adoption can reduce the burden of rising energy consumption. However, to encourage this renewable energy adoption, appropriate financial funding is recommended to reassure project developers in investing in clean energy, which makes the economic growth, increase in consumption, and the financial support factors interrelated and can be combined in the fourth rank under the economic analysis.

Therefore, the experts combined and ranked the factors based on their importance in Table 9.

After validating the AHP weights, the factors to be evaluated using the HOMER Grid software were combined and are ranked in Table 9 across four aspects: policy analysis, technical analysis, economic analysis, and environmental analysis. The HOMER Grid software was then utilized to investigate the impact of these factors and to identify feasible renewable energy policy mechanisms that can be implemented in the UAE, considering various economic determinants.

Table 9. Ranking of The Combined Renewable Energy Deployment Factors.

Participant	Position	Rank
Policy analysis	Policies, strategies, grid connection standards, legal framework, and discrepancy in regulation	1
Technical analysis	Interrupted supply and grid reliability	2
Environmental analysis	Environmental protection	3
Economic analysis	Economic growth, increase in consumption, and lack of financial support	4

4.3. HOMER Grid Technoeconomic Analysis and Sensitivity Analysis

4.3.1. HOMER Grid Software Inputs

The HOMER Grid software employed a range of inputs to perform a technoeconomic analysis, which included meteorological data for the selected location, load profiles, utility information, chosen renewable energy technologies, and component costs. These inputs were then used to simulate the system configuration in several steps:

Step 1: Location—We selected the emirate of Dubai as our study location, focusing on a building situated in Dubai Studio City with a total area of 5367 m^2. The building includes multiple floors that house various facilities, such as offices, apartments, a gym, and external services. This building is of particular interest as it has a large sloping rooftop, which allows for the installation of PV panels without obstructing the building's external view. Figure 3 presents the building study plan for the existing structure, obtained from Bayanati GIS powered by Esri.

Figure 3. Building Study Plan.

Step 2: Meteorological data—The HOMER Grid software took inputs on the solar irradiance, ambient temperature, and clearness index of the photovoltaic array. The global horizontal irradiance (GHI) was obtained from the National Centre of Meteorology weather station located in Al Maktoum Airport. The solar irradiance ranged from 4.5 kWh/m^2/day to 14.57 kWh/m^2/day while the GHI exceeded the average from March to October, with a peak in May, as illustrated in Figure 4. To calculate the power output of the photovoltaic array, HOMER Grid took into account the cell temperature.

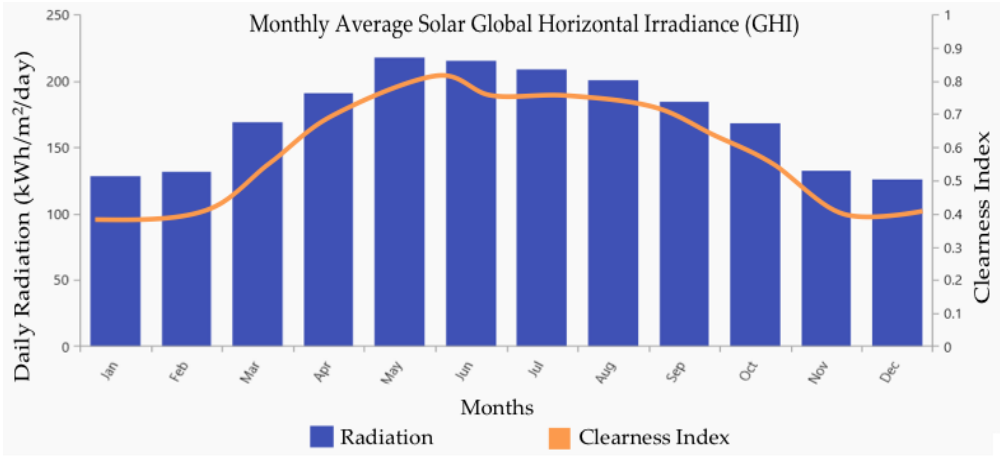


Figure 4. Monthly Average GHI and Clearness Index Dubai.

Meanwhile, we obtained the monthly average temperature data from 2003 to 2020, using a one-hour time step. The annual average temperature was 27.83 °C, with the highest temperatures recorded during the summer season, from May to September. The peak temperature of 36.2 °C was observed in July.

Step 3: Load profile—In this study, we obtained the building consumption load profile from DEWA's electricity bills for the selected building. The bills showed an annual demand of 189.75 kWh per year and a peak load of approximately 20.6 kW. Seasonal variations were also considered, with the highest consumption occurring in July. Additionally, consumption during each month was uniform between 8:00 and 15:00, as shown in Figure 5.

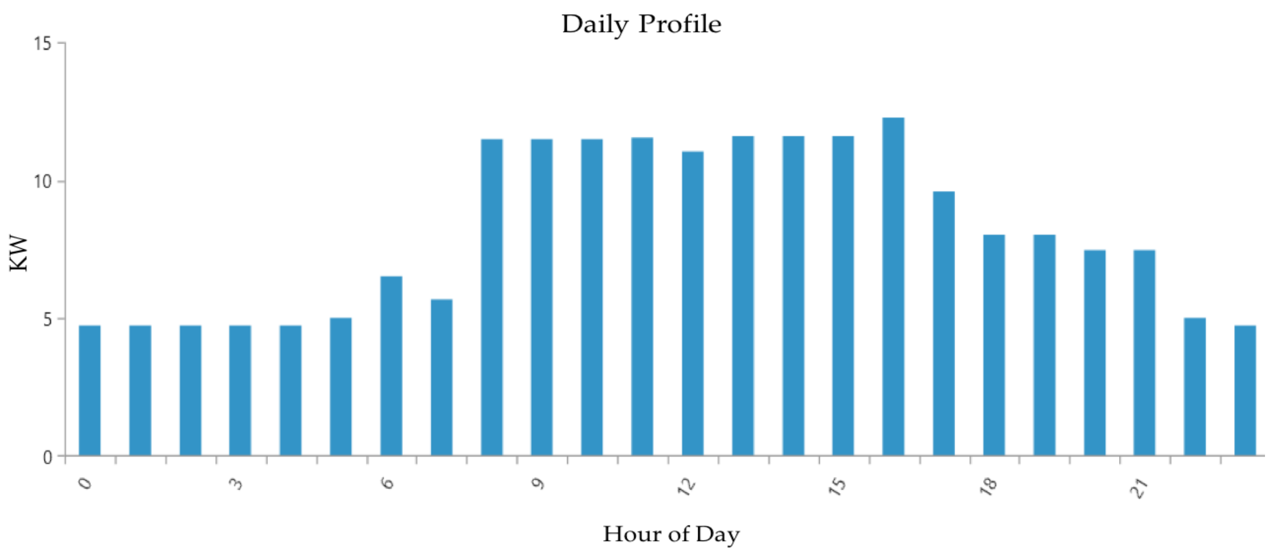


Figure 5. Daily load profile in Dubai.

Figure 6 displays the monthly average load profile, revealing a peak demand that starts in May, increases throughout the summer, and declines in the winter from October onwards. Therefore, based on the selected building load profile, the highest consumption occurred in July, reaching approximately 20.6 KW. The load profile also indicates that the relative frequency of consumption between 10.7 KW and 16.8 KW was the highest, accounting for 18.48% of total consumption. This suggests a high demand between May and September. The fluctuations in electricity demand can be attributed to various factors, such as weather variations and the need for additional cooling systems during extremely hot summers.

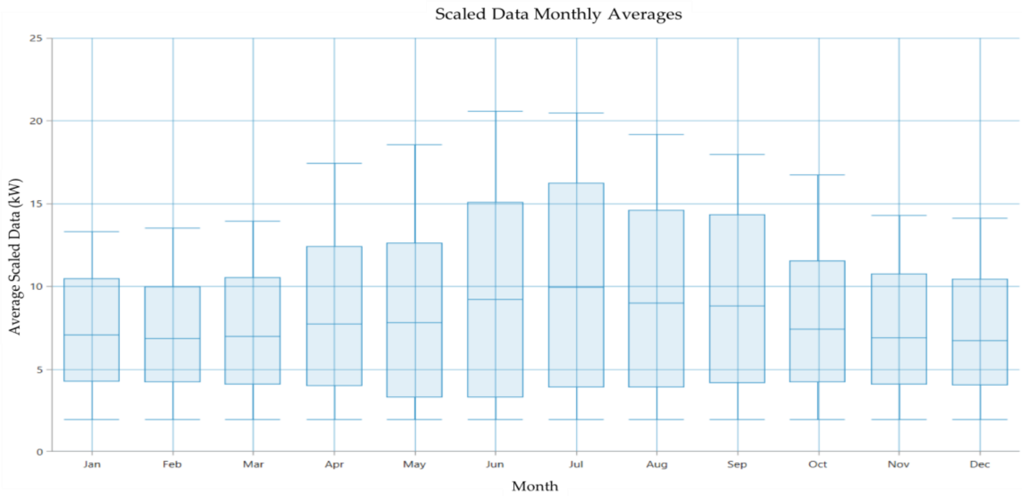


Figure 6. Monthly Load Profile in Dubai.

Step 4: Utility grid—For the purposes of this study, the main electricity supplier considered was the utility grid, with DEWA being the supplier in this case. DEWA provides basic tariffs of 0.38 AED/kWh for commercial projects. However, since solar photovoltaic panels generate electricity only during the daytime, any surplus energy that exceeds the primary demand load is fed back into the DEWA grid. As a result, a net metering and gross metering scheme was chosen for this project, with a selling price of 0.38 AED/kWh. This means that any surplus energy generated by the solar panels is sold back to the grid at the same rate.

Step 5: Components—The chosen system for this study is a grid-connected solar system, which is a photovoltaic (PV) array power system connected to a central grid to generate clean energy. The system design comprises PV modules, a bidirectional inverter, a grid system, and primary load. The PV modules are the primary power source for the system, ensuring a continuous DC supply. The size of the PV array depends on environmental conditions, such as the amount of solar radiation and temperature. The equipment consists of Trina, All Max TSM-PD05-05, a multicrystalline PV module that is included in DEWA's approved PV generation list. Additionally, for this project, we have selected the Schneider Conext XW + 5548 inverter, which has a 95% efficiency and a lifetime of 15 years. More detailed technical and economic information about the chosen PV module and inverter is available in Table 10.

Table 10. Technical and Economical Details of PV Module and Inverter [34].

PV Module		**Inverter**	
Type of PV panel	Multicrystalline	Model	XW + 5548
Nominal operational cell temperature	44 °C ± 2 °C	Capital cost	AED 1500
Temp. coefficient of power	−0.41%/°C	Replacement cost	AED 700
Efficiency at STC	15.5%	O&M cost	AED 800
Derating factor	0.8	Efficiency	95%
Capital cost	898.6 AED	Frequency	50/60 Hz
O&M cost	600 AED	Harmonic distortion	<5%
Lifetime (years)	25 years	Lifetime (years)	15

4.3.2. HOMER Grid Software Outputs

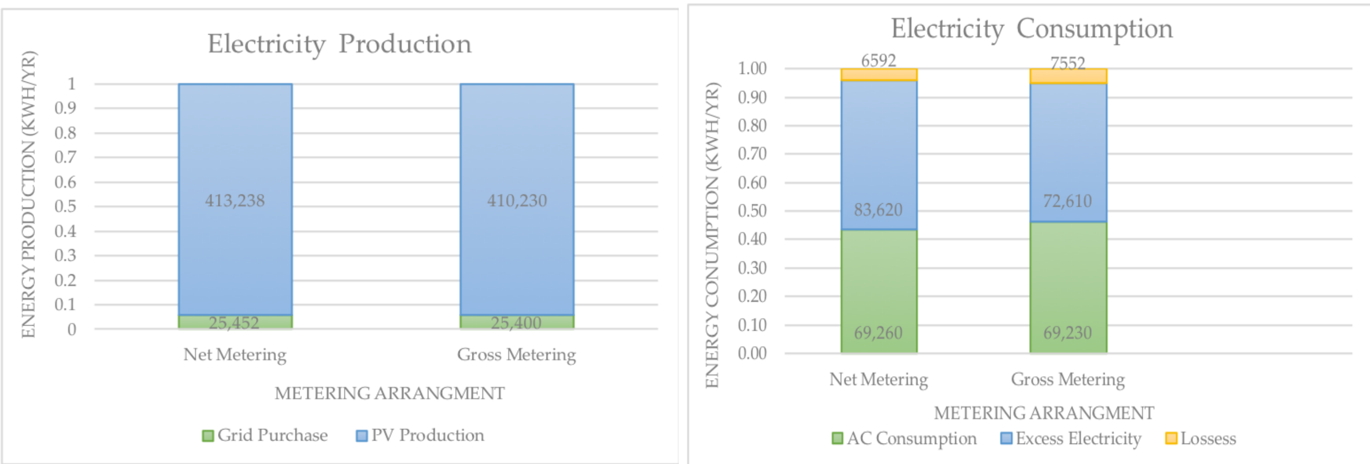
The HOMER Grid software was fed with inputs to evaluate the technoeconomic analysis of critical factors that impact the deployment of renewable energy in the UAE. These factors were identified from the literature, validated and tailored through semistructured interviews, and grouped into four categories: policy analysis, technical analysis, economic analysis, and environmental analysis, based on the AHP analysis. However, the feasibility analysis conducted using the built-in software equations focuses only on three categories: technical analysis, economic analysis, and environmental analysis.

Part 1: HOMER Technoeconomic Analysis

This research aims to identify the most feasible policy mechanism for promoting photovoltaic energy, reducing emissions, and protecting the environment. To achieve this, we conducted a technoeconomic analysis comparing the net metering and gross metering policy mechanisms. We evaluated these mechanisms in four categories: policy analysis, technical analysis, economic analysis, and environmental analysis. Our goal was to determine which policy mechanism yields a lower economic cost and higher photovoltaic energy output to meet demand.

Category 1: Technical analysis—To simulate the operation of the grid-tied system, we calculated the energy balance by determining the amount of energy generated by the photovoltaic system to meet the electrical demand. Using HOMER Grid, we simulated different configurations to meet the energy demand and investigated the feasibility of using net metering and gross metering policy mechanisms.

Therefore, it can be observed (Figure 7) that the net metering arrangement generated a greater amount of electricity using the photovoltaic system, producing 413,238 kWh/year compared to the 410,230 kWh/year generated by the gross metering arrangement. When examining the amount of excess energy fed back to the grid, it was found that net metering had a higher value of 83,620 kWh/year. However, the gross metering arrangement lost more energy, resulting in a higher energy loss of 7552 kWh/year, as shown in Table 11.



(**a**) (**b**)

Figure 7. (**a**) Electricity Production (kWh/yr); (**b**) Electricity Consumption (kWh/yr).

Table 11. Energy Production and Energy Consumption.

	Energy Production		Energy Consumption		
	PV Production (kWh/yr)	**Grid Purchase (kWh/yr)**	**AC Consumption (kWh/yr)**	**Excess Electricity (kWh/yr)**	**Losses (kWh/yr)**
Net metering	413,238	25,452	69,260	83,620	6592
Gross metering	410,230	25,400	69,230	72,610	7552

Overall, net metering tends to produce better results because it generates a higher amount of energy from the photovoltaic system while minimizing energy loss. As a result, the net metering policy mechanism is technically feasible because it generates sufficient energy to meet electricity demand. However, for such a system to work effectively, a reliable grid and uninterrupted power supply are necessary to ensure continuous energy generation.

Category 2: Economic analysis—The economic analysis primarily focuses on evaluating the cost-effectiveness of the photovoltaic system configuration, based on the net present cost (NPC) and levelized cost of energy ($LCOE$). After analyzing the results, HOMER identified the optimum scenario (as shown in Figure 8) and concluded that net metering is more economically viable than gross metering. The NPC for net metering is 528,327 AED, with an ($LCOE$) of 0.14 AED/kWh, which is a more cost-effective option. This finding implies that net metering can provide cheaper electricity and, thus, has good potential for grid-tied systems.

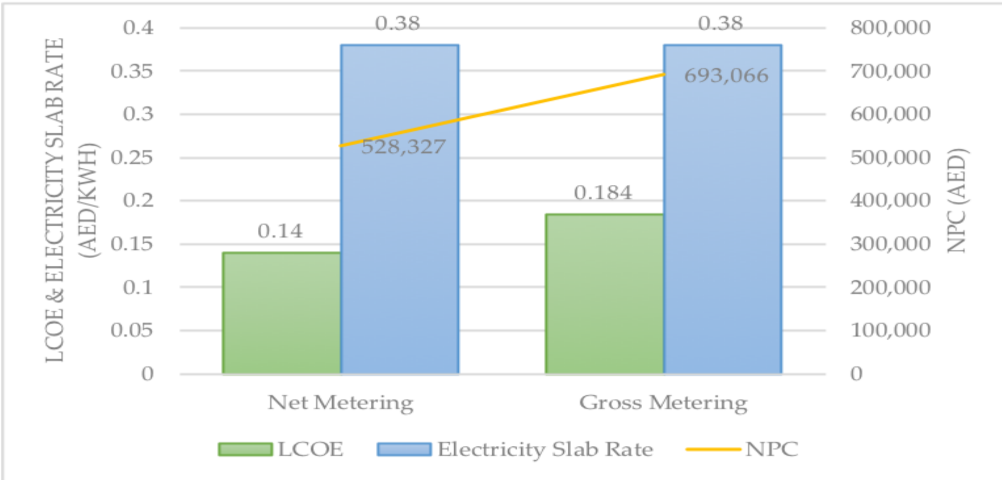


Figure 8. Cost Characteristics of Grid-Connected PV System.

Furthermore, the feasibility of grid-connected PV systems was evaluated based on other economic indicators, as presented in Table 12 below:

Table 12. Economic Determinants' Results.

	DPBP (Year)	IRR (%)	PI	ROI (%)
Net metering	2.93	39.2	4	34.3
Gross metering	3.41	34.2	3	29.4

It was noted that net metering requires 2.93 years to recover its initial cost, indicating low investment risk due to the $DPBP$. The IRR and PI are both high, indicating a lower investment risk and higher profitability. The IRR shows that investors can earn more profit by choosing net metering. The PI denotes higher profitability and lower investment risk. Additionally, net metering provides a higher ROI, which is the yearly cost savings from the initial investment cost. This makes it a more attractive option for investors and project developers. In summary, net metering is a profitable and low-risk investment that can yield high returns.

Furthermore, the HOMER Grid software determines an optimized energy system by calculating the energy output of a photovoltaic (PV) system. This provides project developers with the opportunity to consider renewable energy (RE) options and compare the costs and savings of different systems to reduce their electricity bills. For the purposes of this study, simulations were conducted for both net metering and gross metering schemes to determine the optimal PV generation system, which is summarized in Table 13.

Table 13. Costs and Savings Results.

Costs and Savings	Net Metering	Gross Metering
Capital expenditure CAPEX (AED)	AED −310,234	AED −310,234
Operating expenditure OPEX (AED)	AED −92,732	AED −77,505
Annual utility bill savings (AED)	118,596 AED/year	103,370 AED/year
Project lifetime savings 25 years (AED)	AED 2,964,900	AED 2,584,250

After analyzing the cost and savings data, the net metering system was identified as the optimal choice. This system provides an annual electricity bill savings of AED 118,596, with total savings over the project's 25-year lifetime amounting to AED 2,964,900.

Category 3: Environmental analysis—Sustainable deployment is a strategy used to mitigate environmental problems such as pollution caused by emissions of carbon dioxide (CO_2), sulfur dioxide (SO_2), and nitrogen oxides (NO_x). The impact of these emissions can be measured by comparing the amount of emissions produced by a photovoltaic (PV) net metering grid-tied system versus a system without PV. Table 14 presents the comparison of these emissions.

Table 14. Pollutants' Environmental Impact.

Pollutants	Utility Grid (Tons/Year)	PV-Grid Tied (Tons/Year)
Carbon dioxide (CO_2)	43,772 tons/year	16,084 tons/year
Sulfur dioxide (SO_2)	190 tons/year	69.7 tons/year
Nitrogen oxides (NOx)	92.8 tons/year	34.1 tons/year

It is evident that CO_2 produces the highest emissions compared to other pollutants. However, the environmental impact can be mitigated by reducing fossil fuel consumption and transitioning to grid-tied solar energy generation.

Part 2: HOMER Sensitivity Analysis

The aim of conducting a sensitivity analysis using the HOMER Grid software is to demonstrate the impact of specific variables on the optimal system output in terms of NPC, COE, and CO_2 emissions. By examining the effect of various variables on the output, the sensitivity analysis can provide a more precise policy implementation for the PV market. For this study, the selected variables were solar energy and demand load. The reason for selecting these variables is that the variation in solar irradiance has the greatest influence on the amount of energy produced by the PV system, while the variation in demand has a significant impact on the optimal system decision.

As shown in Figure 9a, both the *NPC* and *LCOE* values increased with an increase in demand load from 189.75 kWh/day to 253.4 kWh/day, indicating that grid-tied solar energy is dependent on the load profile. Additionally, Figure 9b shows the sensitivity analysis of PV production and grid purchase in response to solar energy variations. As solar energy increased, PV production increased while grid purchase decreased. Furthermore, Figure 10 illustrates the impact of PV energy on CO_2 emissions, demonstrating that increased PV energy generation leads to lower CO_2 emissions, thus benefiting the environment.

By utilizing the net metering scheme with higher PV production, energy purchased from the DEWA grid can be reduced, leading to a decrease in both *NPC* and *LCOE*. Furthermore, generating more solar energy results in lower emissions, making net metering a promising option for both end-users and electricity providers.

(**a**) (**b**)

Figure 9. (**a**) Impact of Demand Load (kWh/day). (**b**) Impact of Solar Energy (kW).

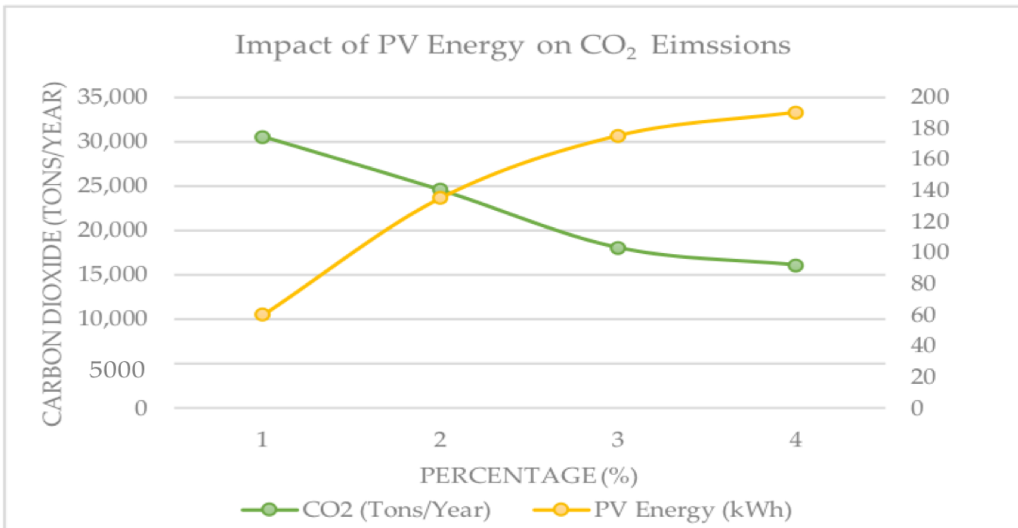


Figure 10. Impact of PV Energy Penetration on CO_2.

5. Summary and Conclusions

This research aimed to contribute to mitigating climate change and reducing CO_2 emissions in the UAE by promoting the use of renewable energy sources and diversifying the country's energy mix. Renewable energy sources can help sustain the UAE's electricity needs for the future. After exploring the energy sector in the UAE, it was concluded that solar energy is an effective solution for meeting the country's increasing electricity demand. As the UAE lies within the sun belt, it has the potential to take advantage of abundant solar energy. The study identified a number of policies that promote RE energy deployment, including feed-in tariffs, net metering, renewable energy auctions (tendering), quotas, and tax credits. Adopting such policies would align with the UAE's 2030 vision of creating an environmentally sustainable society and reducing dependence on fossil fuels for energy generation.

The UAE is making significant strides towards integrating renewable energy sources into its energy mix. This research aims to assess whether grid-tied solar energy policy mechanisms can be an essential component of the UAE's energy strategy. To do so, the study examined the current state of renewable energy deployment in the country and identified some critical factors that may act as barriers, such as the lack of unified policies, strategies, and grid connection standards. However, by drawing on these insights, the study concludes that implementing a unified renewable energy policy mechanism could significantly enhance the adoption of grid-tied solar energy generation across all of UAE's electricity authorities. This would represent a positive step towards a more sustainable future for the country.

According to the comparison conducted by HOMER Grid software, the net metering policy mechanism emerges as the most viable policy to be adopted by the UAE electricity authorities. This policy is highly effective for both customers and electricity providers. The impact of photovoltaic energy on CO_2 emissions is remarkable. As we generate cleaner energy, we can lower emissions, which is a great step towards protecting our environment. By using the net metering scheme with a higher photovoltaic production, we can reduce the energy purchased from the DEWA grid. This will not only reduce the net present cost and leveled cost of energy but also create a more sustainable future. The generation of more solar energy will result in fewer emissions, making the photovoltaic grid-tied systems using the net metering policy mechanism the best renewable energy policy with tremendous potential.

Based on the conclusions drawn from the present study, here are some potential gaps and future research avenues:

- The technical feasibility of grid-tied solar energy: The emphasis of this study was on the regulatory mechanisms that may facilitate grid-connected solar energy deployment in the UAE. Nonetheless, it would be beneficial to investigate the technological viability of integrating solar energy into the current grid system. This might involve investigating grid stability, voltage regulation, and load balance concerns.
- A comparative analysis of renewable energy policies: While the study identified a variety of renewable energy policies that could promote solar energy deployment in the UAE, it would be interesting to compare these policies with those implemented in other countries facing comparable energy challenges. This might aid in identifying best practices and highlighting possible improvement areas.
- The analysis of energy storage options: The study did not address the potential function of energy storage technologies in boosting renewable energy adoption in the UAE. It would be beneficial to investigate the viability of the current energy storage alternatives in the context of the UAE. This may involve investigating the feasibility of large-scale battery storage systems.
- The social and economic impacts of renewable energy policies: The study emphasized the environmental advantages of adopting renewable energy regulations in the UAE. Yet, it would be beneficial to investigate the social and economic consequences of these measures. For example, what would be the impact of renewable energy deployment on local employment, energy affordability, and energy security?
- Innovative financing mechanisms: It would be interesting to investigate alternative finance mechanisms that might promote the adoption of renewable energy in the UAE. It would be beneficial to evaluate the viability of alternative financing mechanisms, such as green bonds, crowdsourcing, and energy performance contracts, in the context of the UAE.
- Data sources: Although the selected case study enabled the utilization of multiple sources for data collection to explore the critical factors affecting the UAE's renewable and the most feasible renewable energy policy mechanism, the data collected were limited to the Dubai Electricity and Water Authority, rather than the UAE electricity authorities, due to the prolonged process of obtaining approvals. It is hoped that future research will include more comprehensive data.

Author Contributions: Conceptualization, M.A. and V.A.; methodology, M.A., V.A., Z.B. and S.S.; software, M.A.; formal analysis, M.A. and V.A.; investigation, M.A.; resources, M.A.; data curation, M.A. and V.A.; writing—original draft preparation, M.A.; writing—review and editing, M.A., V.A., Z.B. and S.S.; visualization, M.A.; supervision, V.A.; project administration, M.A. and V.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of The American University of Sharjah (protocol code 20-071 and date 25 April 2021) for studies involving humans.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

Abbreviation	**Meaning**
AED	Emirati Dirham
AHP	Analytical hierarchy process
CAPEX	Capital expenditure
CO_2	Carbon dioxide
COP21	21st Conference Of the Parties
CR	Consistency ratio
DC	Direct current
DEWA	Dubai Electricity and Water Authority
DPBP	Discounted payback period
FIT	Feed-in tariff
GCC	Gulf Cooperation Council
GDP	Growth domestic product
GHG	Greenhouse gasses
GHI	Global horizontal irradiance
GIS	Geographic information system
HOMER	Hybrid optimization of multiple energy resources
IPP	Independent power producers
IRR	Internal rate of return
KW	Kilowatt
kWh	Kilowatt hours
LCOE	Levelized cost of energy
MW	Megawatt
NO_x	Nitrogen oxides
NPC	Net present cost
NREL	National Renewable Energy Laboratory
O&M	Operating and maintenance
OPEX	Operating expenditure
PI	Profitability index
PURPA	Public Utility Regulatory Policies Act
PV	Photovoltaic
RE	Renewable energy
RI	Random index
ROI	Return on investment
RPS	Renewable portfolio standards
RSB	Regulatory and Supervision Bureau
SO_2	Sulfur dioxide
UAE	United Arab Emirates
USA	United States of America
VAT	Value added tax

Appendix A. Interview Questions

Which type of RE is more applicable to be implemented in UAE and why?

Note that the factors affecting RE deployment are deduced from literature, thus based on your expertise do you believe these factors are valid within UAE context?

Do you think there are other contributing RE deployment factors to be added?

In your opinion is there a way to overcome such barriers?

In which stage within the UAE electricity authorities would these barriers occur?

Are you aware of the existing RE deployment policies?

Refer to the set of RE policies implemented worldwide in your opinion which RE policy is feasible to be implemented in UAE and why?

Appendix B. Focus Group Questions

Do you believe UAE faces challenges while implementing renewable energy sources?

From your expertise do you suppose the factors affecting renewable energy deployment as shown in the table below that are deduced from literature and cross referenced with the interviews are valid for UAE context? Please explain each factor.

Based on the factors from literature are there any missing critical renewable energy deployment factors that should be taken into consideration?

What are some recommendations to overcome such challenges in UAE?

References

1. Jayaraman, R.; Colapinto, C.; La Torre, D.; Malik, T. Multi-criteria model for sustainable development using goal programming applied to the United Arab Emirates. *Energy Policy* **2015**, *87*, 447–454. [CrossRef]
2. Matsuo, Y.; Yanagisawa, A.; Yamashita, Y. A global energy outlook to 2035 with strategic considerations for Asia and Middle East energy supply and demand interdependencies. *Energy Strat. Rev.* **2013**, *2*, 79–91. [CrossRef]
3. IRENA. Renewable Energy and Climate Pledges: Five Years after the Paris Agreement, International Renewable Energy Agency. Available online: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Dec/IRENA_NDC_update_2020.pdf (accessed on 20 December 2020).
4. Lahn, G.; Preston, F. Targets to promote energy savings in the Gulf Cooperation Council states. *Energy Strat. Rev.* **2013**, *2*, 19–30. [CrossRef]
5. Al-Badi, A.; AlMubarak, I. Growing energy demand in the GCC countries. *Arab. J. Basic Appl. Sci.* **2019**, *26*, 488–496. [CrossRef]
6. Said, Z.; Alshehhi, A.A.; Mehmood, A. Predictions of UAE's renewable energy mix in 2030. *Renew. Energy* **2018**, *118*, 779–789. [CrossRef]
7. Kahia, M.; Ben Aïssa, M.S.; Lanouar, C. Renewable and non-renewable energy use-economic growth nexus: The case of MENA Net Oil Importing Countries. *Renew. Sustain. Energy Rev.* **2017**, *71*, 127–140. [CrossRef]
8. Juaidi, A.; Montoya, F.G.; Gázquez, J.A.; Manzano-Agugliaro, F. An overview of energy balance compared to sustainable energy in United Arab Emirates. *Renew. Sustain. Energy Rev.* **2016**, *55*, 1195–1209. [CrossRef]
9. Rissman, J.; Bataille, C.; Masanet, E.; Aden, N.; Morrow, W.R.; Zhou, N.; Elliott, N.; Dell, R.; Heeren, N.; Huckestein, B.; et al. Technologies and policies to decarbonize global industry: Review and assessment of mitigation drivers through 2070. *Appl. Energy* **2020**, *266*, 114848. [CrossRef]
10. Carrington, G.; Stephenson, J. The politics of energy scenarios: Are International Energy Agency and other conservative projections hampering the renewable energy transition? *Energy Res. Soc. Sci.* **2018**, *46*, 103–113. [CrossRef]
11. Coria, G.; Penizzotto, F.; Pringles, R. Economic analysis of photovoltaic projects: The Argentinian renewable generation policy for residential sectors. *Renew. Energy* **2018**, *133*, 1167–1177. [CrossRef]
12. Watts, D.; Valdés, M.F.; Jara, D.; Watson, A. Potential residential PV development in Chile: The effect of Net Metering and Net Billing schemes for grid-connected PV systems. *Renew. Sustain. Energy Rev.* **2014**, *41*, 1037–1051. [CrossRef]
13. Jacobs, D.; Sovacool, B.K.; Sayigh, A. 1.06-feed-in tariffs and other support mechanisms for solar PV promotion. *Compr. Renew. Energy* **2012**, *1*, 73–109.
14. Mastropietro, P.; Rodilla, P.; Rangel, L.E.; Batlle, C. Reforming the colombian electricity market for an efficient integration of renewables: A proposal. *Energy Policy* **2020**, *139*, 111346. [CrossRef]
15. Takao, Y. Low-carbon leadership: Harnessing policy studies to analyse local mayors and renewable energy transitions in three Japanese cities. *Energy Res. Soc. Sci.* **2020**, *69*, 101708. [CrossRef]
16. Atalay, Y.; Kalfagianni, A.; Pattberg, P. Renewable energy support mechanisms in the Gulf Cooperation Council states: Analyzing the feasibility of feed-in tariffs and auction mechanisms. *Renew. Sustain. Energy Rev.* **2017**, *72*, 723–733. [CrossRef]
17. OCED. Overcoming Barriers to International Investment in Clean Energy. Available online: https://www.oecd.org/fr/publications/overcoming-barriers-to-international-investment-in-clean-energy-9789264227064-en.htm (accessed on 10 April 2020).

18. Darghouth, N.R.; Barbose, G.; Wiser, R. The impact of rate design and net metering on the bill savings from distributed PV for residential customers in California. *Energy Policy* **2011**, *39*, 5243–5253. [CrossRef]
19. Mezher, T.; Dawelbait, G.; Abbas, Z. Renewable energy policy options for Abu Dhabi: Drivers and barriers. *Energy Policy* **2011**, *42*, 315–328. [CrossRef]
20. Malik, K.; Rahman, S.M.; Khondaker, A.N.; Abubakar, I.R.; Aina, Y.A.; Hasan, M.A. Renewable energy utilization to promote sustainability in GCC countries: Policies, drivers, and barriers. *Environ. Sci. Pollut. Res.* **2019**, *26*, 20798–20814. [CrossRef]
21. Kumetat, D. *Managing the Transition: Renewable Energy and Innovation Policies in the UAE and Algeria*, 1st ed.; Routledge: Oxfordshire, UK, 2014.
22. Mezher, T.; Goldsmith, D.; Choucri, N. Renewable Energy in Abu Dhabi: Opportunities and Challenges. *J. Energy Eng.* **2011**, *137*, 169–176. [CrossRef]
23. Zhao, Z.-Y.; Chen, Y.-L. Critical factors affecting the development of renewable energy power generation: Evidence from China. *J. Clean. Prod.* **2018**, *184*, 466–480. [CrossRef]
24. Shah, S.A.A.; Solangi, Y.A.; Ikram, M. Analysis of barriers to the adoption of cleaner energy technologies in Pakistan using Modified Delphi and Fuzzy Analytical Hierarchy Process. *J. Clean. Prod.* **2019**, *235*, 1037–1050. [CrossRef]
25. Griffiths, S. Strategic considerations for deployment of solar photovoltaics in the Middle East and North Africa. *Energy Strat. Rev.* **2013**, *2*, 125–131. [CrossRef]
26. Sindhu, S.P.; Nehra, V.; Luthra, S. Recognition and prioritization of challenges in growth of solar energy using analytical hierarchy process: Indian outlook. *Energy* **2016**, *100*, 332–348.
27. Luthra, S.; Kumar, S.; Garg, D.; Haleem, A. Barriers to renewable/sustainable energy technologies adoption: Indian perspective. *Renew. Sustain. Energy Rev.* **2015**, *41*, 762–776. [CrossRef]
28. Franek, J.; Kresta, A. Judgment Scales and Consistency Measure in AHP. *Procedia Econ. Financ.* **2014**, *12*, 164–173. [CrossRef]
29. Lo, F.-Y.; Rey-Martí, A.; Botella-Carrubi, D. Research methods in business: Quantitative and qualitative comparative analysis. *J. Bus. Res.* **2020**, *115*, 221–224. [CrossRef]
30. Al Garni, H.Z.; Awasthi, A.; Ramli, M.A. Optimal design and analysis of grid-connected photovoltaic under different tracking systems using HOMER. *Energy Convers. Manag.* **2017**, *155*, 42–57. [CrossRef]
31. Zou, H.; Du, H.; Brown, M.A.; Mao, G. Large-scale PV power generation in China: A grid parity and techno-economic analysis. *Energy* **2017**, *134*, 256–268. [CrossRef]
32. Raikar, S.; Adamson, S. Renewable energy finance in the international context. In *Renewable Energy Finance*; Elsevier: Amsterdam, The Netherlands, 2020; pp. 185–220.
33. Tomar, V.; Tiwari, G. Techno-economic evaluation of grid connected PV system for households with feed in tariff and time of day tariff regulation in New Delhi—A sustainable approach. *Renew. Sustain. Energy Rev.* **2017**, *70*, 822–835. [CrossRef]
34. DEWA. List of Eligible Equipment. Available online: https://www.dewa.gov.ae/en/consumer/solar-community/shams-dubai/contractors-and-consultants/list-of-eligible-equipment (accessed on 15 November 2021).