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SERVICES FOR SCIENCE AND EDUCATION

Challenges and Market Opportunities for Solar Energy in Saudi Arabia

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ABSTRACT

At present, the renewable energy sector, especially solar energy, is the world's future destination for a clean future in terms of resource consumption. The world's solar obsession, and the quest for the best use of sunlight, are of particular interest to countries in the world and Saudi Arabia. Although sunlight is highly suitable in Saudi Arabia compared to other countries, it still pays large sums for traditional energy sources. Saudi Arabia experienced significant population and economic growth in recent years, a direct result of an increase in consumption of traditional energy sources, which poses a major threat to the country's economy, as well as the negative environmental impacts of the use of non-renewable energy sources. The following points are the outputs of the study: Reviewing previous projects on solar energy in Saudi Arabia, comparing the performance of photovoltaic solar power systems from concentrated solar power systems in Saudi Arabia, and studying the structure of the solar energy sector in Saudi Arabia, as well as the challenges and opportunities in the solar energy sector to reach recommendations that would support the transition towards renewable energy in Saudi Arabia. For this purpose, a questionnaire was developed to strengthen the solar energy sector and formulate recommendations. The SWOT analysis was used to understand the strengths and weaknesses of the solar sector in the Kingdom, as well as the opportunities and threats facing the sector. Results of SWOT analysis revealed that Saudi Arabia citizens are aware about climate change and want to shift to renewable energy, but the cost of renewable energy transformation for end users is not cheap, among other results. One of the most significant opportunities in Saudi Arabia is the Vision 2030 that focuses on Renewable Energy transformation, while the economic feasibility of renewable energy projects is considered a major challenge. Renewable Energy projects in Saudi Arabia can contribute to 2.1% reduction in local CO2 emissions.

Keywords: Solar Energy Market Saudi Arabia, Vision 2030, Market Challenges and Opportunuties

INTRODUCTION

Saudi Arabia is located between latitudes of 31°N and 17.5° N and longitudes of 50° E and 36.6°E with complex terrain where land elevation varies between 0 at sea level such Jeddahcity and 2600 m above sea level in Abha city case. The east and west coasts of the kingdom are located on the Arabian Gulf and Red Sea, respectively. The kingdom is known for its hotweather, long hours of sunshine duration and high intensities of solar radiation.

Saudi Arabia has more than 2 MWh/m2 average yearly GSR on horizontal surfaces. According to a study, the yearly average minimum and maximum GSR values vary from 1.63 MWh/m2 to 2.56 MWh/m2 in Tabuk and Bisha, respectively ([1]). The higher values of GSR in the kingdom can be found in the areas of Nejran, Bisha, Al-Sulayyil, etc., located in the Southern part of the kingdom, while relatively lower values can be found in the Northern region in the areas of Hail, Sakaka, and Tabarjal. comparing such relatively lower values withvalues from western and European countries areas shows that the values are much higher incomparison which offers an opportunity of harnessing solar power to generate electricity and heat in Saudi Arabia. For the seasonal variations of GSR in the kingdom, lower solar radiation can be observed in winter seasons compared to much higher values in summer months. Daily minimum and maximum values of 3.82 kWh/m2 and 7.09 kWh/m2 were observed in the months of December and June, respectively according to [1].

The Kingdom of Saudi Arabia is divided into 13 administrative regions where each region is divided into several cities whose number differs from one region to another while the regions have been divided into the north, south, west, east, and central of the Kingdom of Saudi Arabia. 13 different cities will be studied where each city is from a different region.

The main objective of this study is to investigate the solar energy market challenges and opportunities in Saudi Arabia, as well as issuing recommendations for the authorities in charge, that could support the renewable energy transformation in Saudi Arabia.

In addition to above objectives, below points can be considered as an outcome of the study:

1. Review the historical studies and projects related to solar energy in SaudiArabia.
2. SWOT analysis to further understand the market
3. Evaluate the possibility of renewable energy projects to reduce CO2 emissionsin Saudi Arabia.
4. Compare and analyze PV technology with CSP in the kingdom

Through the Vision 2030 plans and priorities, Saudi Arabia has concentrated on investing in solar energy as a promising means of meeting increasing energy needs, keeping in mind the availability of solar and wind resources.

The National Renewable Energy Program (NREP) is an essential activity under Vision 2030and the King Salman Renewable Energy Initiative. The program means to amplify the capability of sustainable power in Saudi Arabia.

The program sets out an explicit guide to expand local fuel sources and give maintainable financial steadiness to the Kingdom considering the objectives set for Vision 2030, which incorporate building up the environmentally friendly power industry and supporting the progression of this promising area while attempting to satisfy the Kingdom's responsibilitiesto lessening carbon dioxide emissions. The government, in Vision 2030, promised to review the legal and regulatory framework for private sector investment in renewable energies; localize the industry through the promotion of collaborations between the public and private sectors;

and ensure renewable energy competition through gradual fuel market liberalization. All these activities are expected to support renewable energy transformation.

During 2021-2026, the renewables market of Saudi Arabia is expected to grow over 24.2%. To lower oil consumption in power production Saudi Arabia is restructuring the energy sector and is thus driving the renewable energy market. This reduces Saudi Arabia's oil- export volume and export earnings annually. Saudi Arabia has also set a new renewable target in the next ten years, which in future is expected to increase the demand over the forecast period, to develop and install 58,7 GW of clean energy resources. Significant subsidies offered by the Government to its citizen are however removing the profit margin for renewable energy development and thus preventing the growth of the renewable energy market in Saudi Arabia from being generated mainly economically viable [2]. Despite having a high potential for solar power generation, Saudi Arabia lacks a domestic power generation business with competence in the renewable energy sector. The privatization of the electricity industry has allowed international businesses, particularly those from China and Europe, with extensive experience with solar energy to establish solar power facilities, offering several opportunities for market competitors.

Saudi Arabia's power generation is dominated by fossil fuels, with oil accounting for over 40% of total generation. The Government intends to diversify the fuels being used power generation to free up oil for export. With the addition of solar, wind, and nuclear power inthe power sector, as well as an increasing natural gas proportion in the energy mix, the power industry is undergoing a revolution. Renewable energy generation was negligible in2016 like in the past, but it is expected to play a key role in meeting rising demand and diversifying power generation in the future [2].

Without accounting for the consequences of COVID-19, the Middle East Solar Industry Association predicts that regional solar energy investment will exceed $1 trillion per year by 2023. The completion of Saudi Arabia's 300 megawatt Sakaka solar facility last year set a significant milestone for the growth of solar energy. Despite the economic crisis caused by the coronavirus, the 600MW Al-Faisaliah solar photovoltaic power plant, as well as other projects in the Kingdom, continue to move forward. Given the turmoil caused by the coronavirus, as well as the attendant interruptions to global trade and economies, there hasnever been a better time to enhance investment in solar energy capacity. In doing so, solar energy should be viewed as a complement to, rather than a direct competition to, oil and gas. More reliance on solar energy means more hydrocarbons for export. Similarly, to how Saudi Arabia currently controls global oil markets, while the world shifts away from oil, the Kingdom's expanding investment in solar technologies will help it significantly diversifying itseconomy. As a result, Vision 2030 serves as a steppingstone to a new economic model in which the Kingdom controls global solar energy production, technology, and innovation.

Saudi Arabia will set an example for the region and the world to follow by shifting to renewables, investing in technical advancements, combining solar with Big Data, and implementing cutting-edge storage technologies. The Kingdom must serve as a breedingground for 21st-century technologies capable of increasing efficiency, profitability, and energy capacity [3].

Nowadays, renewable energy sector and especially the solar energy, is the world's ultimate destination towards a future. The obsession with solar energy in the world, and the lack of the best use of sunlight has sparked controversy in the countries of the world and in Saudi Arabia. Although sunlight is very appropriate in Saudi Arabia compared to some countries in theworld, Saudi Arabia pays huge amounts for conventional energy sources.

Saudi Arabia is witnessing a large population growth in recent years, which is a direct resultof the consumption of traditional energy sources, which poses a great threat to the economy of the country, in addition to the negative environmental effects that are caused using non-renewable energy sources.

Despite the previously mentioned literature, there is a lack of reference for solar energy market analysis for Saudi Arabia since this sector is still emerging. However, up to our knowledge, none of these references considered the current regulatory framework in Saudi Arabia regarding solar energy, and there is no field survey targeting Saudi Arabia citizens, to measure their awareness about renewable energy transformation.

MATERIAL AND METHODS

The main objective of this study is to investigate the solar energy market challenges and opportunities inSaudi Arabia, as well as issuing recommendations for the authorities in charge, that could support the renewable energy transformation in Saudi Arabia.

The first step in this work was a review of the opportunities and challenges of Saudi Arabia's solar market to understand the subject matter further and to try to enhance the regulatory framework for thesolar market that would help support the sector forward. This was done by reviewing previous research papers on the subject as well as reviewing the instructions and laws issued by the relevant authorities in Saudi Arabia, such as The Electricity & Co-Generation Regulatory Authority (ECRA) and the Saudi Electricity Company (SEC).

The current legislative framework and the objectives that the Kingdom aspires to achieve, based on the plans announced by the official bodies, the opinions of experts and the questionnaire prepared for thesepurposes, were further elaborated on topics related to the Saudi Arabia solar energy market.

Based on the questionnaire prepared and distributed to a segment of the community and decisionmakers in the energy sector in Saudi Arabia, some recommendations have been made, which will contribute to supporting the development of this emerging sector, achieving the benefit of the consumer, and reaching the objectives announced by the relevant parties.

Analysis of the questionnaire in quantitative and qualitative terms has helped to measure awareness in Saudi Arabia regarding the solar energy market, as well as to help propose structural adjustment to this sector. Finally, the results were discussed as well as recommendations made.

Challenges and Market Opportunities with SWOT Analysis

Survey to Understand the Solar Market in Saudi Arabia:

To understand some aspects of Saudi Arabia's solar energy sector, a questionnaire has been prepared and distributed to a segment of Saudi Arabia's citizens and decision makers. The objectives of the questionnaire can be summarized as follows:

1. Measuring awareness in Saudi Arabia of a sector Solar power
2. Help develop a model that helps drive the energy sector Solar forward

The questionnaire consists of thirty-six questions distributed in two parts: Part I contains eight questions related to respondent's data, such as the work sector, age, educational level, and person's relationship with the renewable energy sector. The second part contains twenty-six questions that specialize in renewable energy in general, and solar energy, such as the impression for respondents in replacing renewable energy sources with conventional energy sources for electricity generation. And what does respondents have an idea of solar energy projects implemented by the Renewable Energy Development Office of the Ministry of Energy?

The questionnaire was completed by 449 participants, 46.5% of whom are employed in the government sector, 28.1% are employed in the private sector, and those who remain unemployed. The majority were males at 87.5% compared to 12.5% for females. The percentage of those holding a bachelor's degree reached 64.1%, those holding a postgraduate degree (master's or doctor's degree) to 14.5% and the rest of the diploma campaign. Those who studied scientific specializations reached 75.5% against 21.2% for literary specializations and 3.3% for other specializations. Regarding the relationship of participants with the renewable energy sector, the proportion of ordinary citizens who have no direct connection with this area reached 34.1% and those who are interested of this field reached 33.2%, 16.3% are consumers, and the experts in this field are 9.8% of the total population, and the remaining are either students (5.3%) or employees in this field (1.3%). In terms of age, 32.5% of participants are aged 25-30 years, 25.2% years over 40 years, 22.5% between 31-40 years, 11.8% from 19-24 years, and the remainder from 15-18 years.

Saudi nationality reached 92.9% and the rest are of other nationalities, with 94.4% resides in Saudi Arabia.

After the questionnaire has done, a quantitative and qualitative evaluation of the questionnaire led to better understanding of Saudi Arabia's awareness of the solar energy market and to the suggestion of structural changes for this sector.

Current Status of Solar Energy Market and Regulatory Framework in Saudi Arabia:

Saudi Arabia Regulation for Small-Scale Solar (ENERGY, 2020)

To resolve small-scale solar distribution systems connected to the grid, Saudi Arabia has launched a long-waited regulatory structure. The current structure is evolved from previously published (2017) White Paper, which will now pave the way for the growth of the commercial and industrial solar sector of the Kingdom. ([4]).

The official implementation of a net billing system comes with the regulations' announcement: a method for crediting energy to exported electricity at a fixed and predetermined rate (typically lowerthan imported electricity price). The White Paper of 2017 also introduced a net metering system to compensate exports of electricity by crediting the same rate of electricity imported. (ENERGY, 2020).

A limit per facilities of 1 kW to 2 MW per installation has also been added with a clearly specified national maximum cap that can today be measured as 1.8 GW on a national basis. A maximum capacityis available for each solar system. ([4]).

The existing structure has been published on 28 February 2020 in Um al-Qura, the official Kingdom of Saudi Arabia Gazette, by the Electricity & Cogeneration Regulatory Authority (ECRA).

The Structure sets out regulatory background, tasks and procedures for proper implementation andmanagement of the initiative by the appropriate distributed service provider (SAE). ECRA remains, among other obligations under the initiative, the designated dispute settlement, fees and price determination authority. ([4]). However, it is time to declare an implementation plan by SEC before officially introducing any solar systems applicable to the structure in the Kingdom. The regulation isreleased with immediate effect. ([4]).

Solar Energy Market Size and Opportunities in Saudi Arabia:

The Renewable Energy Project Development Office (REPDO) of Saudi Arabia's Ministry of Energy, Industry and Mineral Resources delivered the Request for Proposals (RFP) for its first utility-scale wind power project inside the National Renewable Energy Program (NREP). The RFP for 400MW of wind power in Dumat Al Jandal in Saudi Arabia's Al Jouf locale is presently accessible for qualified bidders on the NREP's devoted eProcurement entry, www.powersaudiarabia.com.sa. REPDO has qualified 25 organizations for the 400MW Dumat Al Jandal wind project. Remarking on the advancement of the NREP, His Excellency, Khalid Al-Falih, Minister of Energy, Industry and Mineral Resources, said, "We are pushing ahead to enhance the Kingdom's energy blend and to assemble a more supportable and cleanerenergy framework that benefits Saudi Arabia and its residents. Round two of the NREP will be dispatched before the finish of this current year, keeping us solidly on target to convey 9.5GW of environmentally friendly power by 2023." Khalid Al-Falih added, "The NREP will fabricate monetary strength and convey genuine financial advantages by making in excess of 7000 positions, expanding Saudi Arabia's non-oil Gross Domestic Product (GDP) and supporting a spotless tech startup industry; it is a program intended to help the homegrown inexhaustible worth chain and energize unfamiliar direct interest in the Kingdom, carrying flourishing to our residents as a feature of the objectives set up in Vision 2030."

Specialized models for round one NREP projects incorporate a 30% nearby substance necessity. This prerequisite will increment in future rounds to invigorate the development of a worldwide serious andreasonable environmentally friendly power production network in the Kingdom of Saudi Arabia. Roundone of the NREP likewise contains 300MW of Solar PV in Sakaka, Al Jouf district, for which the bid opening will happen on third October and winning

offers will be reported on November 27th. The Dumat Al Jandal and Sakaka projects are both 100% private IPP programs, which will be upheld by 20- and 25-year PPA individually. Organizations that certified as overseeing and specialized individuals for the 400MW wind project in Dumat Al Jandal, under the National Renewable Energy Program are:

The Renewable Energy Project Development Office (REPDO) at the Ministry of Energy, Industry and Mineral Resources (MEIM) in Saudi Arabia facilitated the bid opening service for the Sakaka 300 MW solar PV project, the primary task in the National Renewable Energy Program (NREP). The kickoff of offers uncovered the business potential for the primary seriously offered utility-scale sun powered task in the Kingdom. "The present bid opening addresses a critical achievement for the NREP, and a significant advance while in transit to differentiating Saudi Arabia's homegrown energy blend and building a forefront homegrown environmentally friendly power area, which will set out new openings and open doors. The business feasibility of utility-scale solar PV projects is a foundation of the program and the offers opened today will set the benchmark for this prospering new industry in the Kingdom and past" said His Excellency Khalid Al Falih, Minister of Energy, Industry and Mineral Resources. The Request for Proposal (RFP) for the 300MW PV project in Sakaka, situated in Saudi Arabia's northern Al Jouf area, was given on April seventeenth, 2017. Eight offers were presented by pre-qualified consortia drove by worldwide and local sustainable power designers. The bid opening outcomes reported and shown during the meeting do not address bidder positioning or a bidder's consistence with RFP necessities of the task, nor do they comprise an assurance by REPDO of the result of the offering round. REPDO will presently assess the offers got to check consistence with the necessities of the RFP Bidders will be shortlisted by November 28th, 2017 and the task will be granted to the triumphant consortium on January 27th, 2018, upheld by a 25-year PPA. The monetary shutting date will be February 28th, 2018and dispatching date is normal during 2019.

The Renewable Energy Project Development Office (REPDO) of Saudi Arabia's Ministry of Energy, Industry and Mineral Resources (MEIM) has given the RFPs for Round Two of the Kingdom's NationalRenewable Energy Program (NREP).

The six Round Two projects will see a complete sun powered PV limit of 1.47 gigawatts (GW) offered to qualified organizations. In June 2019, REPDO qualified 60 organizations, including 28 from Saudi Arabia. Qualified organizations will presently continue to the RFP stage as either overseeing part, specialized part, or under a recently made class of 'nearby overseeing part'. This new classification will support more noteworthy nearby and worldwide associations during the framing of offering consortiums. RoundTwo projects have been separated into two classes: 'Classification A' for more modest ventures and 'Classification B' for bigger tasks. 'Classification A' projects require consortium individuals to collaborate with one local party. Ventures inside Round Two will convey a base prerequisite of 17% local content as determined by the systems characterized by the Local Content and Government Procurement Authority (LCGPA), which intends to build the worth added commitment of items and administrations in the publiceconomy. The six ventures being offered inside Round Two address the principal half of REPDO's 2019 task advancement pipeline. A further six tasks will be offered by the last quarter of the year and will comprise Round Three of the NREP.

Proposition for Round Two 'Class B' projects should be put together by 18 November 2019, and the cutoff time for 'Classification A' projects is 3 December 2019. Consequences, everything being equal, will be live gushed on REPDO's eProcurement entry: www.powersaudiarabia.com.sa. All tasks offered by REPDO are 100% IPPs that will be supported by 20 to 25-year PPA.

The Ministry of Energy has given the Request for Proposals (RFP) for Round Three 'Class B' Solar PV freeforce maker (IPP) of the Kingdom's National Renewable Energy Program (NREP). The RFP for Round Three 'Class A' tasks will be delivered to the market in the not-so-distant future. Round Three is contained four Solar PV projects with a consolidated age limit of 1,200 megawatts (MW). The ventures,which are situated on four locales in the focal district of the Kingdom, will be as per the following: - 'Classification A' projects: Wadi Ad Dawasir 120 MW Solar PV IPP and the Layla 80 MW Solar PV IPP. - 'Classification B' projects: Ar Rass 700 MW Solar PV IPP, the Saad 300 MW Solar PV IPP.

The offering procedure for Round Three will proceed with the methodology set up by the Ministry of Energy in Round Two of the NREP, whereby more modest projects, to be specific the Wadi Ad Dawasir120 MW Solar PV IPP and the Layla 80 MW Solar PV IPP, marked as 'Class A', will have loosened up capability models taking into consideration local designers to partake in the NREP as lead individuals. The two bigger projects, specifically the Ar Rass 700 MW Solar PV IPP and the Saad 300 MW Solar PV IPP, marked 'Class B', are focused towards pulling in global designers to additionally put resources intothe Kingdom.

The Ministry of Energy gave the Request for Qualifications (RFQ) for Round Three of the NREP on the ninth of January 2020 and has gotten on the sixth of February 2020 an aggregate of 83 uses of which, asum of 49 organizations have been pre-qualified for lead jobs, including 28 local Saudi organizations.

Pre-qualified organizations will presently continue to the RFP stage as either a Managing Member or potentially Technical Member and additionally Local Managing Member (the later just applying to Round Three 'Class A' projects). Considering business and travel limitations during this period, the Ministry of Energy has broadened the RFP period on this round of ventures from four to a half year. Also, the Ministry will have virtual gatherings to encourage bidders' meetings. Recommendations from forthcoming bidders will be submitted online through the Ministry's NREP obtainment gateway. These actions have been carried out to this round of activities in acknowledgment of the Kingdom's obligationto advancing its sustainable power improvement objectives.

Round Three ventures will convey a base necessity of 18% local material as determined by the mechanisms characterized by the Local Content and Government Procurement Authority (LCGPA), which expects to expand the worth added commitment of items and administrations in the public economy. All ventures offered by The Ministry of Energy are 100% IPPs supported by 25-year Power Purchase Agreements (PPA) with the Saudi Power Procurement Company (SPPC) as offtaker. Since itsinitiation, The Ministry of Energy, through the NREP, has pre-

created and tendered, 2170 MW of environmentally friendly power limit in the Kingdom, of which 700 MW was granted in 2019 and a further 1,470 MW will be granted in 2020.

In conclusion, below are the most promising opportunities in Saudi Arabia:

- The interest of Vision 2030 in expanding renewable energy market is attractive for localand foreign investments, and this is clear in the NREP.
- High average peak sun hours in most cities in Saudi Arabia (2200 – 2400 kWh/m2/y)
- Large areas of non-occupied desert, such as Dahnaa, Nofoud deserts.
- Abundancy of sand is a key driver for nationalization of solar cells manufacturing
- Saudi Arabia is committed to Paris Agreement, which would support renewable energytransformation
- Saudi Arabia citizens have high interest to renewable energy Duty-free renewable energy products

Solar Energy Sector Challenges in Saudi Arabia:

Although the possibilities of a solar fueled KSA would be magnificent, specific issues exist in its point.

Institutional and Administrative Constraints:

Two government offices by the name of – King Abdullah City for Atomic and Renewable Energy (KA- CARE) and the Electricity and Cogeneration Regulatory Authority (ECRA) are administering elective energy creation. In any case, the unambiguous job description of the two specialists can bring aboutauthoritative issues.

Infrastructure:

The most basic advance of any Solar power plant is the infrastructure network, which would guarantee the dispersion of the power produced. Most foundation issues show up when interfacing with the transmission network. In Saudi Arabia, solar power suppliers just have ensured admittance rather than need access. Thus, in circumstances when the grid cannot change all the approaching power, they will not have any need over petroleum power plants.

Lack of Subsidies:

The electricity tariff is subsidized in Saudi Arabia, which means the kWh generation cost is higher than the selling price. However, there is no any subsidy for consumers to install renewable energy projects,and this will not support the economic feasibility of the project.

According to The General Authority of Statistics, 34% of Saudis live in rented housing, which will not be motivated to install solar power systems on their homes, not to mention the high cost of switching to renewable energy, a particularly large recovery period with low-tariff segments and a lower sale price ofsurplus electricity production by renewable energy sources compared to the purchase price. In addition, there is lack of renewable energy companies on the market. All the above poses challenges to the solar market in Saudi Arabia. One of the most important technical challenges to Saudi solar power systems is the extremely high temperatures in many regions of Saudi Arabia, which negatively affect the efficiency of the PV system. In addition to the density of dust and its continuous presence in most of the kingdom's

regions, which negatively affects the PV System, and which entails additional maintenance costs. The absence of any form of financial incentive to install solar power systems is another challenge for this sector, as there are no loans for homeowners and enterprises to set up a solar system or sharing part of the cost of the system form government, for example. In academic terms, training institutes are not spread as required, and the same applies to renewable energy awareness associations. In universities, bachelor's or graduate programs for renewable energy engineering are still not highly prevalent.

SWOT Analysis

S.W.O.T. is a Strengths, Weaknesses, Opportunities and Threats abbreviation. As you can see, the S.W.O.T. has four factors that clearly each have their own identity and purpose.

External and internal factors are generally classified in the S.W.O.T. It comprises chances and threats forexternal factors, while internal factors are strengths and weaknesses. S.W.O.T. and S.W.O.T. In several applications or situations, the analysis which can sometimes be called can be carried out. It could be used as an analysis of the situation as feedback into a corporation level strategic planning. It may also apply in terms of its ability to assess the situation. As an analytical technique, we use S.W.O.T. The following figure visually illustrates the S.W.O.T analysis.

In our work, the S.W.O.T analysis will be used to identify the four aspects of this technique and classifythem into internal and external factors, from a decision maker point of view. The S.W.O.T analysis will be done based on the current situation of the Saudi Arabia's renewable energy market and theconducted survey results.

RESULTS AND DISCUSSION

	Helpful for the organization	Harmful for the organization
Internal factors	**Strengths** 1. Ambitious vision 2030 that support transformation torenewable energy 2. The availability of renewableenergy resources, mainly Solar and Wind, 8 3. Saudi Arabia citizens are aware about climate change, 24,25,26,27	**Weaknesses** 1. Lack of specializedcompanies in the market and lack of clarity of regulations, 7 2. Lack of awareness about renewable energy, 7,9,15,19, 21, 22, 23
External factors	**Opportunities** 1. Saudi Arabia citizens want to learn about renewable energy and transform for it, 1,2,5,6,10,14,16,17 2. The high cost of electricitycould support the transformation, 20	**Threats** 1. The cost of renewable energy transformation for end users is not cheap, 4,12 2. The need to develop the infrastructure of the electrical system, 19

The SWOT analysis helps to simplify the problem and provides a better understanding of the questionnaire and extract results from it, as these results can be built upon later to make appropriate recommendations to stakeholders. SWOT's analysis showed that there were some

strengths and weaknesses that could all be acted upon to strengthen or avoid them, as well as some opportunities that could be used to move the transition towards renewable energy forward, while at the same time showing some threats that might stand in the way of the renewable energy sector and that neededattention from the relevant actors.

City	Annual energy [kWh]	Capacity factor	LCOE [¢/kWh]
Rabigh	1,999,556	22.80%	5.03
Najran	1,996,336	22.70%	5.03
Tabuk	1,969,317	22.4	5.1
Bisha	1,962,136	22.30%	5.12
Madina	1,904,910	21.70%	5.28
Jizan	1,872,984	21.30%	5.37
Hail	1,868,314	21.30%	5.38
Al-Qurayyat	1,851,388	21.10%	5.43
Turaif	1,846,362	21%	5.44
Al-Baha	1,846,302	21.00%	5.44
Jubail	1,827,441	20.80%	5.5
Riyadh	1,824,195	20.80%	5.51
Buraidah	1,823,116	20.80%	5.51
Najran	340.6	38.9	15.51
Bisha	325.9	37.2	16.19
Tabuk	325.8	37.2	16.2
Madina	317.4	36.3	16.62
Rabigh	314	35.9	16.8
Jizan	293.8	33.6	17.92
Hail	293	33.5	17.96
Al-Baha	288.5	33	18.24
Buraidah	284.8	32.5	18.47
Turaif	280.5	32.1	18.75
Jubail	280	32	18.78
Riyadh	278.3	31.8	18.9
Al-Qurayyat	277.3	31.7	18.96

For the LCOE, none of the mentioned projects would be considered feasible when compared to the lowprices of electricity in Saudi Arabia. In fact, when comparing PV simulation results to that of the CSP, it can be said that the LCOE of PV projects is almost the third of that in the CSP projects.

The high capital costs, immaturity of CSP technology in the market and the complexity of the power cycles associated with CSP technology are the main reasons that makes the PV technology has a muchhigher advantage and more feasible than that of the CSP.

Saudi Arabia is part of this world that seeks to reduce these emissions and from countries committed to the Paris Agreement, and this is one of the most important opportunities that could drive the renewableenergy sector forward.

Saudi Arabia has ambitious plans to invest in renewable energy, which will contribute to reducing reliance on traditional fuels for power generation. According to worldometer website, Saudi Arabia hasa total of fossil fuel emissions equal to 517,079,407 tons in 2016. This would account for 1.45% of the global share and for 15.94 tons per capita. The power generation sector contribution to these emissionsis about 42.5%, which translates to 219,758,748 tons of CO_2 [5].

Saudi Arabia initiated the National Renewable Energy Program for Energy (NREP). The program is designed to improve the local renewable energy dependency by 2023 and anticipates generating 9.5 GW of renewables, which is divided between Solar PV, Wind, and CSP power plants. The Solar PV contribution is expected to be 5.9 GW, and 2.4 GW for wind energy projects, and the remaining 1.2 GW for CSP projects [6]. If these targets are met by 2023, and keeping in mind the potential reduction of CO_2emissions by construction of renewable energy power plants, and if we consider the natural gas emissions as a benchmark, since it is the main fuel used for power generation in Saudi Arabia [7] and it produces 484 tons CO_2/GWh [8], the potential CO2 reductions by renewable energy sources would be asfollows:

Table 1: Potential CO2 reductions by renewable energy sources

Technology	CO2 emissions during fuel extraction Tons CO2/GWh	CO2 emissions during constructionTons CO2/GWh	CO2 emissions during operation Tons CO2/GWh	Total CO_2 emissions Tons CO2/GWh	Potential reduction inCO_2 emissions Tons CO2/GWh
Natural gas	-	-	484	484	0
Solar PV	-	5.4	-	5.4	478.6
Wind	-	7.4	-	7.4	476.6
CSP	-	3.6	-	3.6	480.4

If the table above is translated into absolute values, the average energy yield of 1892 kWh/kW for solarPV, 3000 kWh/KW for CSP, according to the calculations in section 6.3, and 3331 kWh/kW for wind energy projects according to (S. Rehman), the total CO2 reduction would be 10,882,087 tons of CO2, which accounts for 2.1% of the 2016 CO2 emissions. More details for these calculation in table 7.

Table 2: CO2 emission reduction by Ton

Technology	Potential reduction inCO_2 emissions Tons CO2/GWh	Energy yield kWh/kW	NREP targetGW	CO_2 emissions reductionTons
Solar PV	478.6	1892	5.9	5,342,516
Wind	476.6	3331	2.4	3,810,131
CSP	480.4	3000	1.2	1,729,440
Total			9.5	10,882,087

CONCLUSIONS

In terms of resource consumption, the renewable energy sector, especially solar energy, is currently theworld's future destination for a clean future. Countries around the world, as well as Saudi Arabia, are intrigued by the world's solar fascination and the search for the best use of

sunlight. Even though sunlight is more appropriate in Saudi Arabia than in other nations, the country still pays a high price for conventional energy sources. Saudi Arabia has seen rapid population and economic growth in recent years, owing to a rise in conventional energy use, which poses a major challenge to the country's economy, as well as the negative environmental effects of non-renewable energy use.

The following points can be considered the study's predicted outcomes: Reviewing previous solar energy studies and projects in Saudi Arabia, comparing the efficiency of photovoltaic solar power systems to concentrated solar power systems in Saudi Arabia, and investigating the structure of the Saudi solar energy market, as well as the obstacles and opportunities in the solar energy sector to develop proposals that would aid Saudi Arabia's transition to renewable energy. A questionnaire was created for this reason to improve the solar energy sector and formulate recommendations. The SWOT analysis was used to determine the solar sector's strengths and weaknesses, as well as the opportunities and threats it faces in the Kingdom.

Most important findings from SWOT analysis are listed below:

- Strengths: Vision 2030 and availability of solar resources in Saudi Arabia Weaknesses: lack of awareness about renewable energy and specialized companies
- Opportunities: Saudi Arabia citizens want to learn about renewable energy and transform for itThreats: The cost of transformation and the need to develop the required infrastructure

According to the work done in this research, we may suggest the following recommendation for decisionmaker that could support the renewable energy transformation in Saudi Arabia:

1. Increase the awareness about renewable energy using social media networks.
2. A financial incentive must be structured to support the economic feasibility of renewable energy projects in Saudi Arabia. The incentive could be introduced as long term interest- free loans, or tax incentives, or sharing part of the initial cost by the government.
3. The use of net billing systems with 0.07 SAR/kWh as a selling price would not promote solar PV projects, therefore a higher compensation is needed.
4. Electrical power system infrastructure enhancement should proceed in parallel with the targeted renewable energy transformation.
5. Specialized companies should be approved and announced on a regular basis by the stakeholders in charge.

In summary, it can be said that there are challenges that can be overcome from the work of society, such as education and awareness-raising in this area, since lack of awareness in this area is a major challenge. Some challenges can be overcome through the involvement of the competent authorities, such as the establishment of specialized training institutes and the introduction of programs within university programs in the field of renewable energy. Some challenges require further research and studies to overcome them, such as high temperature and dust density challenges.

There are many opportunities in the field of renewable energy in Saudi Arabia. Some of these opportunities have been created because of the Kingdom's location, which distinguishes it from manyother countries in the world, such as desert areas, suitable terrain, and the relatively high number of solar hours.

Some opportunities exist due to the Saudi Government's interest in this area, such as the establishmentof the National Renewable Energy Programme, the adoption of legislation and its clear and professionaldeclaration, and the customs and tax exemption for renewable energy products. Society has also playeda role in contributing to the creation of renewable energy opportunities in the Kingdom, as society has shown its desire for education and access to investment in this area.

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