Implementing a combinational framework to accumulate the most efficient regional renewable energy technique: Aid the power of decision making of the future energy planning in UAE

Mohamed Al-Ali
MSc Engineering Project and Systems Management
Kingston University - London
MHD.761@gmail.com

Abstract

By 2030 the United Arab Emirates (UAE) aims to increase the shares of renewable energy sources to 30%. However, the application of renewable energy is currently facing several challenges such as high competition with fossil fuel and energy efficiency. Meanwhile, the complexity of the implementation of renewable energy technologies has made the decision making more challenging. Accordingly, this research aims to highlight these problems and propose a decision making framework which combines different tools, methods and techniques to aid in decision making of renewable energy implementation in the UAE region. The decision making framework was designed based on decision making tools that being used in renewable energy sector, SWOT analysis which was conducted the renewable energy technologies individually, and PESTEL analysis which was conducted on renewable energy implementation in the UAE region. The framework was designed based on internal factors and external factors which were identified in the research methodology. The framework modelling was tested on one case study and a scenario case. The result described in this paper validates the framework.

Keywords: Framework, decision making, renewable energy, modelling, decision making factors, linear programing.

1. Background

Energy production is facing several challenges nowadays which is has affected the energy concerns of the UAE as well as the world in general. The annual energy demand in the UAE is expected to grow 9 percent every year (Al Nisr Publishing LLC, 2015). This is due to the civilization expansions as well as the increase in population, as shown in figure 1. The figure shows the UAE population growth in millions for the period 1975-2014. This increase in population has created the need to fill the gap between energy supply and demand. Meanwhile the fossil fuels which are considered as the primary source of CO_2 which has high environmental impact are taking the biggest portion of energy consumption in the country (Olivier et al., 2015). The renewable energy application has started to be growing in the UAE region through the governmental supports in order to reduce the dependence on fossil fuels.

2. Introduction

Renewable energy deployment has been targeted by the UAE government with its target to produce 24% of its energy requirements from renewable resources by 2021. Nevertheless, applying the principle in practice is not easy due to factors such as cost, location, and competition with the fossil fuel. To achieve high level of renewable energy share, further effort of integration should be engaged for longer strategic vision. Decision makers are obligated to create supportive techniques that provide effective methods of implementing renewable energy on real site. These include clear understanding of renewable resources availability and decent estimation of power generation for valid resources. The presence of different energy sources in a defined location, each type with its different area requirements, life time, and power generation has created the need for more efficient methods in making informed decisions on implementation. As a direct consequence, this project aims to implement a decision making framework to improve energy efficiency for the renewable energy system through optimal selection, operation management and strategic selection. The framework was designed to select the best renewable energy alternative thereby taking a step forward to support and motivate the expansion of renewable energy in the UAE.

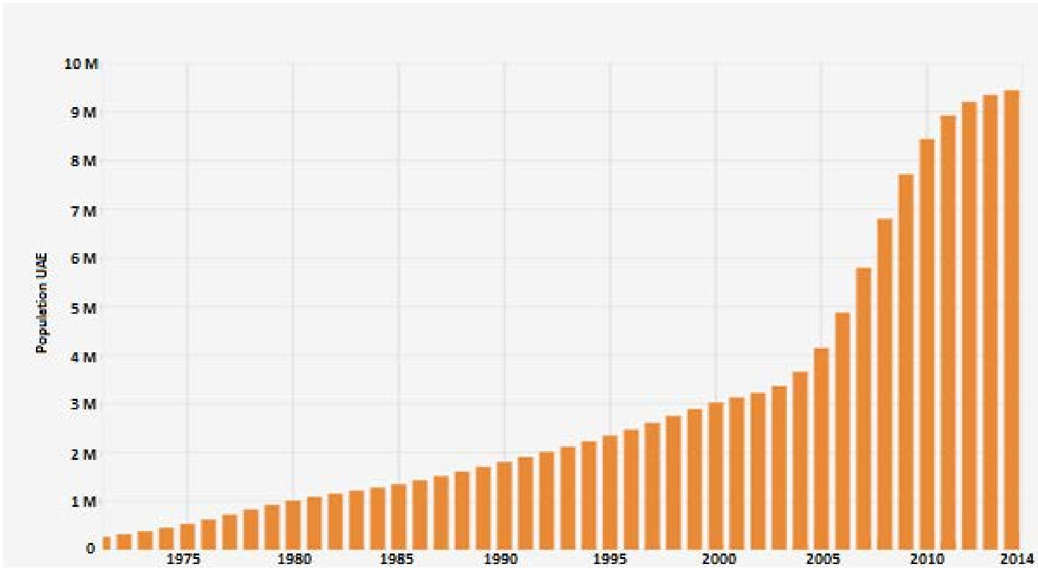

Figure 1. UAE population growth 1975-2014 (dubai-online.com, 2016)

3. Quantifying the Problem: Factors affecting the energy sector

Intensive research has been carried out to investigate problems and issues associated with energy generation. Understanding problems in the power plants sectors will help to eliminate issues that may arise in the future as a result of energy demand increase. The factors identified during the research process were: high cost of investment capital, fluctuation and uncertainty of fuel cost & energy prices, competition and investment risk, risk contributing to fuel transportation, high cost of operations & maintenance, energy efficiency and reliability, location and wide range of land required.

4. Literature review

Several decision making methods have been applied in the decision making process for renewable energy implementation, such as: mathematical modelling, simulation modelling, framework analysis and implementation, multi-criteria analysis and policies formulation.

Iniyan, Suganthi, and Samuel (2007) developed a mathematical model to optimise renewable energy utilization in developing countries. The renewable energies considered for the model were solar, wind and biomass. The objective of the model to minimise the ratio of cost/efficiency (with lower cost and higher efficiency) of renewable energy resources, while the model constraints were considered as social acceptance, energy demand, system reliability and potential of system availability. The result of conducting the mathematical model showed that renewable energy consumption for the year 2020-2021 would be $8.1 \times 10^{15} kJ$. This model was developed to support policy makers for the strategic implementation of renewable energy planning.

On the other hand, Gillenwater (2013) designed a simulation model for a wind power project. The model was formulated using Monte Carlo simulation in order to analyze decision making by investors. The data required for the model was gathered in probability distribution functions (PDFs) form. The data was collected by conducting interviews with investors and active professionals working in the United States wind power industry. Model simulation was used to study the effect of Renewable Energy Certificate (REC) on renewable energy generation in the United States market. As a result, the study showed that investment decisions of developing wind power project in the United States are unlikely to be transformed by the voluntary REC market.

Assessing the appropriate choice of renewable energy is a complex decision making process which generally involves: varied inconsistent attributes, and anonymous or incomplete attribute weight. Accordingly, Grandhi and Wibowo

(2015) formulated a fuzzy multi attribute decision making method, which assisted in meeting stakeholder's interests for selecting the most suitable renewable energy alternative. The multi attribute utility is a decision theory which is used to present preferences under uncertainty, whereas the fuzzy set theory is a mathematical framework which can be effectively used to address ambiguity of human decision. Grandhi and Wibowo's research revealed that the adoption of fuzzy multi attribute decision making method is proficient in sufficiently handling the present matter of renewable energy selection. In like manner, Wright, Dey, and Brammer (2013) proposed a method to assess feasibility of renewable energy technology. This method was developed based on Levelized Energy Costs measure with the implementation of fuzzy theory. Levelized Energy Costs is a type of calculation which is an essential aspect of energy market analysis as it depicts the net present value of electricity over the lifetime of generation in unit-cost (£/MWh or p/kWh). The proposed method was presented with the application of bioenergy project, whereas, the results showed that applying fuzzy theory to the Levelized Energy Costs approach can enhance information level presented to decision-makers.

Oikonomou et al. (2011) attempted to integrate multiple decision making aspects among policy implementation. This was achieved through the application of multi-criteria analysis and techno-economic modeling in a general analytical framework. The techno-economic method is a well-established process includes quantitative results like costs and certain policy targets, however, the approach does not reflect other essential factors for policy implementation like: macroeconomics, preferences of stakeholders and socio-political factors. While multi-criteria method is used to integrate different aspects, the analytical framework was proposed to bridge the gap between the techno-economic and the multi-criteria approaches.

Energy policy is also a tool that being used to support and motivate the expansion of renewable energy. Wüstenhagen and Menichetti (2012) introduced a study intended to attract intellectual attention on matters of energy policy regarding the choices that influences strategic investment on renewable energy. The study showed that risk perception, the return of investment and policies path are dependencies affecting on decisions in energy investment. It was confirmed that energy policy was firmly related to the strategic choices of renewable energy investment. Besides, Boksh (2013) stated that the government of Newfoundland and Labrador formulated several policies concerning the development of renewable energy sector, focusing especially on hydroelectric power generation. This contributed to the successful launching of the third biggest hydroelectric power station in North America. The power station is located on the Churchill River while the power station was expected to produce power capacity of 5,428 MW. Boksh's paper presented an example of how renewable energy sector can be stimulated through policy formulation.

Painuly (2001) recommended a framework approach to be followed in order to identify penetration barriers of renewable energy technology. This approach involves literature survey, site visit and interaction with stakeholders. Omitaomu and Badiru (2012) proposed an evaluation framework to determine the economic implications for the installation of a renewable energy power plant. The framework was based on systematic approach, which considered the entire network from power generation to power consumption. The framework was presented in three phases (Select-Assess-Integrate) as a support for the process of data collection of project alternatives appraisal. In the first phase, selection of renewable energy type is identified. In Assess phase, evaluation of economic and financial indicators (i.e. salvage value, depreciation, interest rate) are identified and estimated. After that, the project of renewable energy plant is distinguished from other projects, i.e. benefit of air emission avoidance and cost impact. Furthermore, Masini and Menichetti (2012) proposed a conceptual framework that studies investors' comportment factors in renewable energy techniques with regards to decision making processes. Masini and Menichetti conducted the framework to examine how investors perform with regards to priori beliefs regarding investments, technological risk and performance over policy implementation. These beliefs are presented in the study as: background education, history of personal investment, and previous experience with investing in renewable energy. The study showed that in the investment process priori belief took more priority than market belief on technical effectiveness. This implied that providing technical reliability considered as an essential condition for investors. Whereas it was considered that investment risk could be reduced by establishing policies attempted to reduce market uncertainty. Additionally, Chou and Ongkowijoyo (2014) proposed an integrated framework that supports analytical process of group decision making regarding policy selection for renewable energy implementation. The framework was constructed through the implementation of Monte Carlo simulation with risk-based multi criteria decision making and graphical matrix modelling. While several barriers still exist within sustainability development, as well as, complexity of sustainability issues, Chou and Ongkowijoyo proposal provided decision makers with valuable approach to identify and measure sustainable development indicators.

5. Research methodology

This research was carried out in five stages. The first stage involves the investigation of the problems associated with the energy. The second stage was to determine the current stage of the renewable energy techniques. The required data for this stage were obtained through secondary data collection techniques (i.e. articles, reports, prior research …etc.). The third stage involves conducting the SWOT and PESTEL analysis based on the information obtained in the data collection stage, the evaluation of the factors affecting the decision making process for implementing renewable energy systems in the UAE region were analysed. The defined factors were used as parameters in the proposed framework methodology. In phase four, the combined framework methodology was proposed. Finally, a practical session of the proposed framework will be conducted.

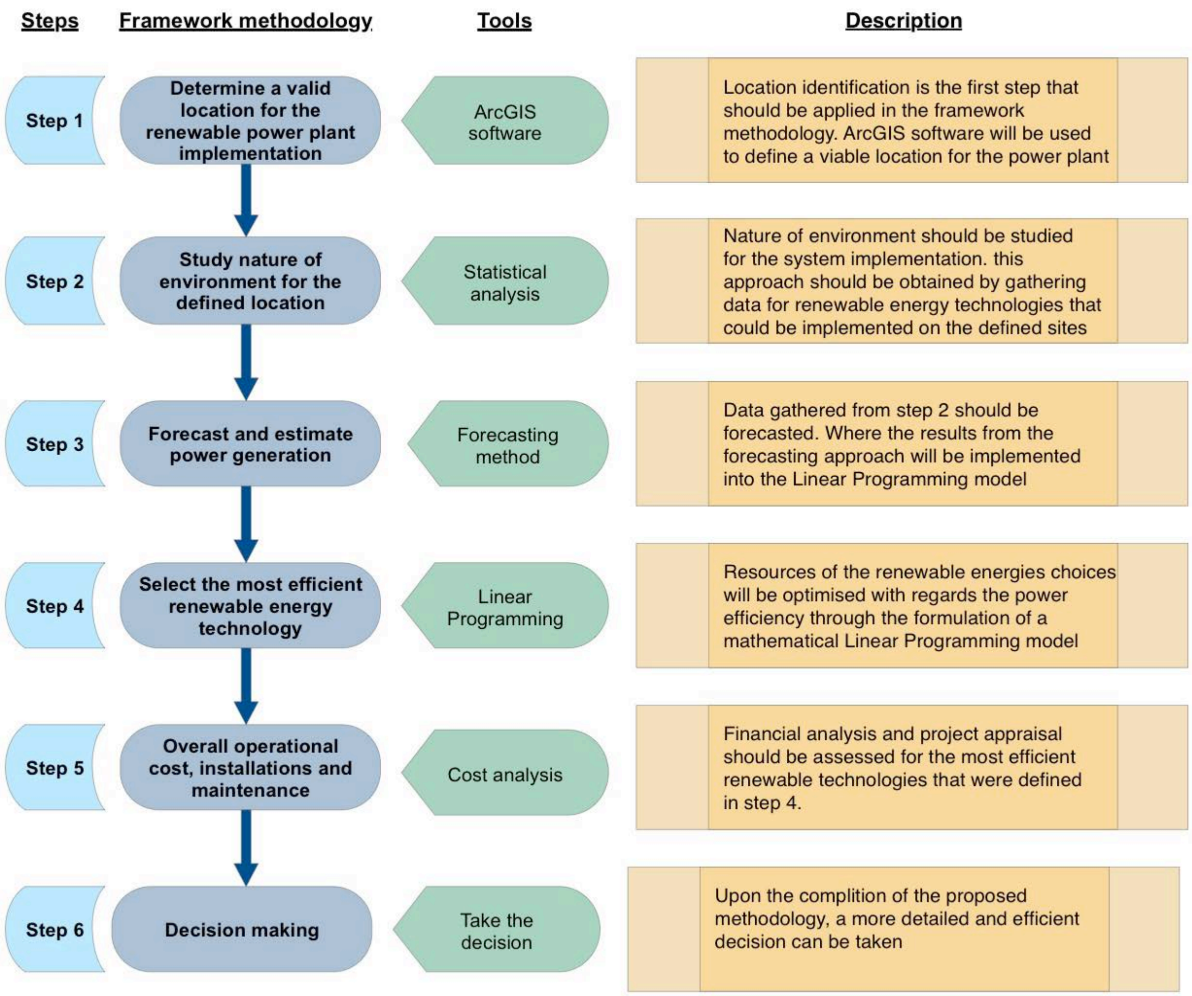

Figure 2. Scheme of combinational decision making framework for renewable energy implementation

5.1 Project challenges

- **Framework design:** the framework methodology was proposed to be used in a systematic way while limiting human errors in the decision making process for the UAE. Also in the framework design was the problem of selecting the optimal sequence of operations for the proposed methodology.

- **Linear programming design and unifying units:** A step in the proposed framework is the design of a Linear Programming to be specified for the selection of most efficient renewable technique. For the linear programing model, the unit should be unified. This was difficult due to the variety of the available renewable techniques. In this case, the unified units were selected to be required area in meter square (m^2) and power output in Kilowatt (kW).

6. The proposed framework

Based on a combination of factors which includes, available methodology obtained from extensive literature review, available renewable sources, SWOT and PESTEL analysis, a framework was developed. This framework as stated in the aim of this work describes a systematic approach for decision makers to implement more than one renewable energy power plant on any given site. This proposed framework methodology is represented in the flow chart shown in figure 3.

6.1 The framework tools and parameters selection

Through the analysis, factors were found that could affect the decision making process. These factors are broadly classified into two groups. These groups are defined as internal and external factors. Internal factors affecting the decision making process are those factors which have direct effects on the power plant implementation while external factors indirectly affect the implementation of the power plant. In the design of the framework, the factors as seen in table 1. Taken into account for the framework design are all the defined internal factors and two external factors which are energy demand and location and space limit. These external factors were implemented into the framework because they also critically affect the renewable energy selection process.

Table 1. Internal and external affecting the decision making process

Factors affecting on decision making of renewable energy implementation	**Type**
Social concerns	External
Political impact	External
Economic impact	External
Environmental impact	External
Stakeholders concerns	External
Risks	External
Energy Demand	External
Location and Space limit	External
Investment cost	Internal
Operations and maintenance cost	Internal
Structure of renewable energy process	Internal
Technology	Internal
efficiency	Internal
Renewable energy source	Internal

6.2 The framework methodology description

Step 1: Location identification

This step involves the identification of a valid location where the renewable energy power plant can be installed. This is an extremely important step for two reasons; the renewable power plant is a land intensive project therefore adequate resources should be invested to make the right decision. The second reason is that all other steps in the framework are dependent on this step. The location can either be pre-determined or might be require being identified. The tool required to select a viable location for the renewable power plant is the ArcGIS software. The ArcGIS is geographic information system software. The software is used worldwide for analytical processes related to location identification. Although power plant allocation can be defined through: study policies and regulations and technical requirements of renewable energy technologies, the use of ArcGIS as a tool for the process of location identification will greatly influence the accuracy of the decision making process.

The UAE has a potential to install several types of renewable energies among the region, whereas allocating power plants in remote sites will contribute the issue of energy loses from transmitters and distributors. It is recommended to select the optimal site based on the identified social factors.

Step 2: Study the nature of environment

The nature of environment for the location as defined in step 1 should be studied for the renewable energy system implementation. This step identifies the renewable energy source available in the defined location. This information can be obtained either through the meteorology institute that takes records of the climate in the region in which the location identified in step 1 is located or onsite measurement. The onsite measurement is preferred because it is more accurate since the behavior of the renewable energy source varies from time to time. The onsite measurement is also considered as more diverse than the method of data collection from meteorology institutes because it can be applied to all possible renewable sources.

Step 3: Forecast and estimate power generation

Data gathered from studying the nature of the environment should be forecasted in order to predict the behavior of the available renewable energy source. Forecasting can also be used to predict the power generation of the identified renewable energy sources. The results obtained from the forecasting approach will be implemented into the Linear Programming model where the resources will be optimized according to required power demand, renewable energy technologies and valid space. Forecasting methods that can be applied in this step include moving average method, exponential smoothing etc.

Results obtained through the application of forecasting techniques for renewable energy sources include:
- Wind speed and density for wind power
- Solar radiations for solar power
- Analysis of wave and tidal behavior
- Wastage statistics for biomass resources
- Study nature of earth layers (porosity, permeability, heat reservoir) for geothermal energy

Step 4: Select the most efficient renewable technology

This step should be obtained via the application of a mathematical linear programming model, where renewable energy resources will be optimized. The linear programing model was designed based on the following parameters:

- Power output of each of renewable energies alternatives
- Required power demand
- Area of selected site
- Space requirement for each renewable energy technology

The objective function of the linear programming model is to minimize the total area available for the implementation of renewable energy resources. This is due to the fact that the implementation of a renewable energy plant requires large area therefore it is necessary to select renewable energy systems that can cover the available demand while minimizing space. The objective function defined above is subject to the constraints of space limits and the forecasted output. Below is the liner programming model with its objective function and constraints.

Objective function:

Minimise $Z = \sum_{i=1}^{rs} A_i X_i$

Subject to constraints:

Space limit: $\sum_{i=1}^{rs} A_i X_i \leq Valid\ space\ area$

Forecasted power output: $\sum_{i=1}^{rs} P_i X_i \geq Required\ power\ demand$

Avoid minus sign: $\sum_{i=1}^{rs} X_i \geq 0$

Integer: $\sum_{i=1}^{rs} X_i$

Where;

Z = Objective function
A_{i} = Required area for the renewable energy technology i
X_i = Renewable energy technology i
P_{i} = Power output of renewable energy technology i
rs = total number of renewable energy technologies

A_{i} is a constant variable given by the supplier or via design specification and technological requirement, while, X_i is variable number which will be determined in the linear Programming solution is defined as the optimal number of renewable energy techniques. The power output P_{i} is also considered as a constant input for the linear programming model, where it can be calculated based on the performance of renewable energy technology.

In summary, the first constrain of the linear programming model which is space limit was set as $\sum_{i=1}^{rs} \mathrm{A}_i\, X_i \leq Valid\ space\ area$. This to obtain the optimal number of renewable energy technologies that can be implemented within the valid space. Since different technologies of renewable energy will require different space. The second constrain however was $\sum_{i=1}^{rs} P_{\mathrm{i}} X_i \geq Required\ demand$. This is to insure that the optimal solution or renewable energy technologies presented will cover the required power demand. The integer incorporated into the linear programming model for practicability. For example, it is impossible to obtain 10.578 wind turbines or solar panels. As a final point, the $\sum_{i=1}^{rs} X_i \geq 0$ was also assigned to avoid minus sign from the linear Programming solution.

Step 5: Overall operational cost, installations and maintenance

After the most efficient renewable technology has been selected, financial analysis can be conducted. This is done to provide information on the financial implications of selecting the renewable energy technology obtained using the linear programming model. Obtained in this step are payback period, installation cost, operation and maintenance cost. This stage is an advisory stage which will be presented to the investor to aid in the decision making process. This is due to the fact that cost concerns highly depend on negotiations and shareholders' interests. This step would be meaningful for the decision makers however it will not affect the selection of the most efficient renewable technology.

Step 6: Decision making

Based on step 1 to 5, a well-informed decision can be made regarding if it is viable and profitable to implement a renewable energy plant in the defined location. The successful implementation of this framework for the purpose of decision greatly reduces the risks of uncertainty while creating an avenue for a more informed decision making process.

7. Case study

Solar power in the UAE has the potential to provide substantial electricity demand. Accordingly, Mohammed bin Rashid Al Maktoum Solar Park has been implemented in Dubai city. In October 2013, phase I of the solar park was completed with operational capacity of 13,000 kilowatts powered by 152,880 FS-385 Black modules and covering an area of 238,764m^2.

The following steps will present the framework implementation through the case study. As described in the framework methodology section the first step should be defining the valid location for the power plant implementation. For this case study the location has been determined by the government, where the power plant will be situated as previously stated. The second step is presented by studying the environment of the defined location as well as determined valid renewable energy resources that can be operated on the defined location which has also been determined to be solar while the solar module selected was the FS-385 solar panel. The framework was tested using the FS-385 solar panel only. Next, the power generation of the chosen solar panel was simulated based on the weather forecast. The average weather in the UAE has a typical 80-90 percent clear skies with an average solar radiation that exceeds 6 kWh/m^2.

Given this condition, the power capacity of the FS-385 solar panel can be 0.085 kW per solar panel. This information of the solar panel power was obtained from the supplier which is First Solar manufacturing company.

With the information given above, the optimal number of solar panels were determined using the linear programming model. The inputs variables are described as the following:

- Valid space area: 238,764 m^2
- Required demand: 13,000 kilowatt
- Renewable energy technology: Solar (PV)
- Required area for the renewable energy technology: 0.72 m^2

The required area that was used in the linear programming model was 1.512m^2(2.1*0.72). This is because a gap tolerance is required between the solar panels, where a value of 2.1 was chosen to be the tolerance of the solar panel. The results of the linear programing model obtained using MATLAB showed that the optimal number of the FS-385 solar panel should be 152940, which is very close to the number of solar panels that were used in the case study (152,880 FS-385 Black modules). The required area was calculated by the software as 231,248 m^2. The difference between the obtained area (231,248m^2) and the area used in the case study (238,764m^2) was assumed as an unoccupied area was left in the power plant place.

7.1 Scenario case

A scenario case for the chosen case study will be examined though the proposed framework. This is to show how the framework can operates in the case where alternative of renewable energy technologies is selected. In this case, Solar PV manufactured by First Solar company and wind turbine manufactured by Siemens Company were selected. These companies were selected because the UAE government currently have some of renewable energy projects under construction with them. The alternatives of wind turbines and solar panels are described in the tables 2 and 3.
The local wind speed of the solar park region is estimated to be 5 m/s (Wind and weather statistic Al Maktoum airport, 2016). For the given wind speed, the power output was provided by the supplier as it shown in table 2. The distances between wind turbines were determined as $D^2 X$ 5. This is due to the fact of that the distances between wind turbines should be D X 5 where D is the wind rotor diameter. The approximate power output for the wind turbines in table 2 were obtained from the supplier.

Table 2 Different wind turbine designs proposed by Siemens manufacturing company (Siemens AG, 2016)

Wind rotor diameter (m)	Product name	Approximate power output in kw with average of 5 m/s wind speed	Required area/space (m^2)
101	SWT-2.3-101	215	51005
108	SWT-2.3-108	324	58320
120	SWT-2.3-120	400	72000

Table 3 Different solar panel designs proposed by First Solar manufacturing company (First Solar, 2014)

Maximum Power (kW)	Panel area (m^2)	Manufacturer	Model No.
0.085	1.512	First Solar	FS-385
0.09	1.512	First Solar	FS-390
0.0925	1.512	First Solar	FS-392
0.095	1.512	First Solar	FS-395

The results of the linear programing model showed that the optimal number of the FS-395 solar panel should be 136,840 and the required area for the system installation is 206,906 m^2. The result shows that using the proposed framework with the linear programming model could help make more informed decisions. The cost analysis was exempted during the implementation of the framework due to the time constraint and the unavailability of the required data. Nevertheless, this will not affect the results obtained from the previous steps.

8. Discussion

This paper proposed a combinational framework that aids in decision making based on multiple choices in the selection of best alternative for the implementation of renewable energy technologies. The design of the framework was conducted based on the problems affecting the energy sector, renewable energy technologies and the status of renewable energy application in the UAE. This framework was implemented for a case study and a scenario case. The results obtained from the case study were 238,764 m^2 and 152,880 for the plant area and FS-385 solar panel modules respectively. This results obtained goes on to ascertain the effectiveness and accuracy of the framework as the implemented solar power plant have values of 152,940 and 231,248m^2 for the FS-385 solar panels and the plant area respectively.

The scenario case had multi renewable energy sources which were solar and wind. Through the described methodology, as in the case study, the optimum plant area and number of modules were obtained. The modules in this case were solar panels and wind turbines. The results obtained based on the input for the wind turbines and solar panels provided by Siemens manufacturing company and First Solar were required for the space and power output of each renewable energy plant. The results obtained showed that the optimal renewable energy source is solar which would require 136,840 FS-395 solar panels and installation area of 206,906 m^2.

9. Conclusion

Decision making in renewable energy implementation can be enhanced by building the decision progress based on the given facts while reducing the bias of human errors. This is adequately shown in this work in which a detailed framework was developed to solve the decision making challenges in implementation of renewable energy technology. Although the Framework implementation has some limits while considering external factors affecting the decision making, the proposed framework can still be used as a powerful tool to make accurate, detailed and well informed decisions for use in the renewable energy industry.

9.1 Recommendations

Based on the research carried out for this work, the following recommendations are made:

- More case studies will have to be identified in order to conduct further analysis. This will also aid in the identification of more sites for renewable power plant implementation in the UAE and other parts of the Middle East region.
- Implement the defined external factors in the framework in order to make the scope of the framework wider.
- The cost implication of the framework implementation will have to be critically analysed in other to present the stakeholders with the financial requirements of the optimal renewable energy plant obtained from the implemented framework.

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Biography

Mohamed Al-Ali obtained his Bachelor's degree in Industrial and Management System Engineering in Kuwait University. He also studied project management in accordance with the Project Management Institute (PMI) and obtained a trainer certification on project appraisal with the application of COMFAR software, which is accepted by the United Nations Industrial Development Organization. He attended several courses working with ArcGIS (Geographic Information System software). In addition, he obtained his Master Degree from Kingston University – London in Engineering Project and Systems Management. His research interests include Decision making processes, financial assistance and economics analysis, and risk association.