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Research Article

ELECTRICITY GENERATION SCENARIOS FOR JORDAN (2018-2035)

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ABSTRACT

The planning for strong, productive and sustainable electricity generation is complex and challenging in Jordan. Therefore in this paper, a new approach for scenario planning has been conducted to give an effective tool for evaluating and examining the electricity generation technologies, for both conventional and renewable technologies, in Jordan. The aim of the scenarios is to prepare and implement innovative and robust plans for the electricity generation sector. Consequently, strengthen the readiness of the country to response to the growing demand and the emergency's circumstance. Accordingly, four scenarios, for the electricity generation from renewable and conventional power plants in Jordan for the years (2018 – 2035), have been developed by building economic, environmental and social models. These four scenarios have been developed based on the most two key uncertainties that make a crucial threat on the electricity generation sector in Jordan, which are; the economic and the geopolitical uncertainties. Finally, this paper identified the best power generation technologies form conventional and renewable systems, through conducting optimization process by using GAMS software for the three aforementioned models. The results of the optimization found that the best technologies in generating electricity are the GCC power plant, from conventional technologies and the PV utility and the wind turbine from the renewable technologies during the years (2018 – 2035). Accordingly, their average optimal shares in generating the electricity for the years (2018) and (2035) are for the GCC power plant (70%) and (10%), for the PV utility (19%) and (71%) and for the Wind turbine (11%) and (19%) respectively.

INTRODUCTION

The planning for strong, productive and sustainable electricity generation is complex and challenging in Jordan. Where Jordan, like many other developing countries in the Middle East and North Africa region (MENA), that has challenges in securing the required energy, electricity in particular, for meeting its growing demand. And this is due to several reasons mainly; lack of the local primary energy sources, high dependency on importing fossil fuel and continuous growing of population, especially, after the Syrian refuges influx crisis. Consequently, all these reasons caused to increase the pressure on the limited resources for generating electricity in the country.

In this context, we studied the status of the electricity generation in Jordan with respect to the electricity sector components (i.e. the primary energy, the consuming sectors of electricity, the economic situation, the electricity organization structure, and the regulated policies and legislations). This paper conducted a new approach for scenario planning to give an effective tool for evaluating and examining the electricity generation technologies, for both conventional and renewable technologies, in Jordan. Four scenarios for electricity generation from renewable and conventional power plants in Jordan for the years (2018 – 2035) have been developed by building economic, environmental and social models. These scenarios have been developed based on the most uncertainties that make a crucial threat on the electricity generation sector, which are; the economic and geopolitical uncertainties. So these scenarios would be an effective tool for the decision makers in Jordan to prepare and implement innovative and robust plans for electricity generation. Meaning that, strengthen the readiness of the country to response to the growing demand and the emergency's circumstance.

On the other hand, these scenarios assist in achieving the objectives of the existing strategies and polices, such as the main goal of the Renewable Energy and Energy Efficiency law no. 13 of 2012, which is "improve the electricity supply security in Jordan". And ensure the sustainability of the

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electricity generation sector in Jordan, through determining the most efficient technologies in the Energy system and increase the contribution of these technologies in the total energy mix. In addition, improve the energy market in Jordan through encouraging the investments in this sector.

Literature Review

In this paper we reviewed the related studies and researches at worldwide level and MENA region level.It was benefited from these studies in identifying the parameters, variables and constraints for the economic, environmental and social models for evaluating the electricity power generation in Jordan.

In (Eda Dal *et al* 2017) study, several scenarios between (2016) and (2035) were developed for Turkey using ANSWER – TIMES energy planning simulation program taking (2015) as the base year. Where in this study the least electricity generation based on various fuel mixtures with and without external costs was determined.

While (Di Bella *et al* 2017) focused on improving the efficiency and supporting the economic activities through strengthen the electricity sector. The study found that the inadequate management of the electricity sector usually brings fraud and nonpayment, or by weak enforcement.

Regarding the developing scenarios for electricity generation in Jordan, (Dababneh, 2018) studied in his paper the impact of penetration of the renewable energy on the electricity grid in terms of supply and demand management for energy in Jordan. Where he predicted the total energy mix for (2020) and developed five scenarios for the power generation technologies. Therefore, in this paper the evaluation pillars of the power generation in Jordan have been completed. Related to the development of scenarios for electricity generation, (Al-omary *et al* 2017) studied and assessed the electricity system in Jordan and then developed three scenarios for the years 2020, 2025 and 2030 taking 2015 as a reference year. Hisstudy shows that electricity from wind and solar can contribute indeed considerably to a more secure and climatic sound electricity supply system.

Regarding the input data of the (COE) and in particular the capital cost of the generation power plants, a detailed study with title" Ocean Energy: Cost of Energy and Cost reduction opportunities" was conducted by Intelligent Energy Europe in2013. Where in this study, the methodology of estimated the capital cost was studied.

Continuously speaking on the input data of the (COE) and in particular the capital cost of the generation power plants, (S.Rubin *et al* 2015) reviewed the learning rates for (11) power generation technologies(i.e. fossil fule, renewable energy and nuclear). Where the aim of this study was to understand how the costs of energy and energy supply change over time by reviewing the most prevalent model form.

Concerning the calculation of the (COE), Fraunhofer Institute for Solar Energy System ISE (Fraunhofer, ISE, 2018) has conducted a detailed study about the calculation of the cost of the electricity for the power generation technologies in Germany. It focused on calculating the cost of the electricity for photovoltaic, wind turbines and biogas plants in particular for the years 2018 till 2035.In this context and with focusing on the developing economic model by using COE calculation, (M. Rahman *et al* 2018) examined the costs of electricity generation by the power projects. It shows that the (COE) decreases with the scale and duration of the projects while the degree of economies of scale and time significantly varies across different technologies and locations.

Also in this topic, (Reddy, 2018) compared the major electricity generation technologies from conventional and renewable energy systems in India by using the (COE) approach. Where, the results show that the present trends and future forecasts of electricity-generating technologies change the electricity generation mix.

Regarding the environmental model, a comprehensive paper with title "Investigation of Green House Gas Emissions Scenarios based on fuel type's consumption in Jordan" has conducted by (Jaradat, 2018).It found that positive mitigation scenarios to reduce emission with reasonable cost. In this paper, the Carbon dioxide was only considered from the GHGs. Accordingly, the amount of the CO2 emissions has been calculated for the power generation technologies during the operation purposes.

Alsoregarding the environment topic, (Chakamera *et al* 2018) studied the effect of electricity related CO2 emissions on the growth contributions for both electricity consumption and ratio of electricity transmission and distribution losses (RETDL). It found that, CO2 emissions from electricity and heat production reduce the growth effect on the electricity consumption and electricity quality.

Continuing on the environmental model, in particular the CO2 emissions mitigation topic, (Rafiee *et al* 2018) conducted a detailed review on carbon capture, conversion and utilization routs and pathways.

Regarding the uncertainties that affect the electricity generation, (Wilson *et al* 2017) presents statistical methodology for quantifying uncertainty associated with the output of a computer model of the long-term of the future Great Britain (GB) electricity supply. It found that in real studies, there may be no historical data available to fit a model for structural discrepancy, or any available historical data may not be relevant to future projections.

On the other hand, (Faizan *et al* 2018) has made a detailed review on the optimization methods that used in the hybrid energy systems based on solar (PV) and wind resources.

Finally, (Ringkjøb *et al* 2018) prepared a thorough review of (75) modeling tools which are currently used for energy analysis and electricity systems. The objective of this research is to give an overview of currently available modeling tools.

Therefore, the GAMS, General Algebraic Modeling System, software was selected to be used in this paper for the optimization purpose.

Modeling and Optimization

METHODOLOGY

In this paper, we have followed the methodology was shown in figure (1).

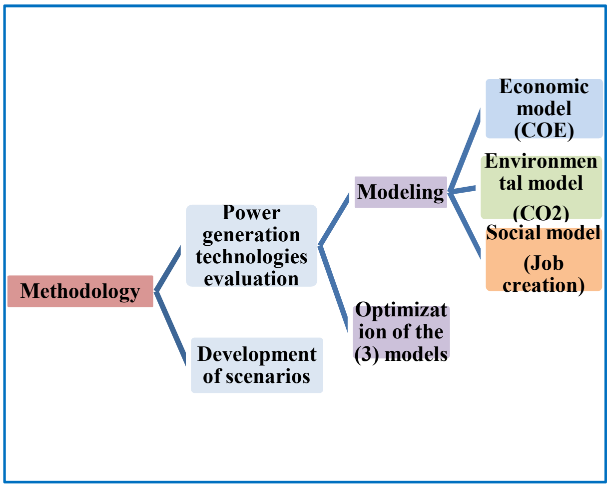

Figure (1) Paper methodology chart

As seen in the Above chart, the Methodology Consisted of two parts:

The first part: was evaluation of the power generation technologies through building three models for the conventional and renewable energy systems in Jordan.Where these models are:the Economic model which is represented by the Cost of Electricity (COE) calculation, the Environmental model which is represented by the (CO2emissions)calculation and the Social model which is represented by the determination of the number of job opportunities that created by the renewable energy technologies specifically for the solar and the wind technologies. These models were built using the Microsoft Excel. After that, optimization for these models by using GAMS software has been implemented.

The Second part: was developing of the four scenarios for the electricity generation technologies in Jordan for the years (2018-2035) based on the most two uncertainties that make a crucial threat on the electricity generation sector, which are: the economic and the geopolitical uncertainties.

Finally, In order to build the three aforementioned models, the first thing was identifying the technologies that would be considered in this paper which were: the steam turbines which used two types of fuel (Natural gas and heavy oil). The gas turbines which used also two types of fuel (Natural gas and heavy oil).The GCC power plants which used one type of fuel (natural gas). And the diesel turbines which used three types of fuel (natural gas, heavy oil and diesel) from the conventional (fossil fuel) energy technologies. While from the RE technologies, we selected the Solar (PV utility scale) and the wind energy (wind turbine). The contribution of these six power generation technologies in producing the electricity as seen in figure (2) was (96.4%) for (2017), which is the baseline year in this paper.

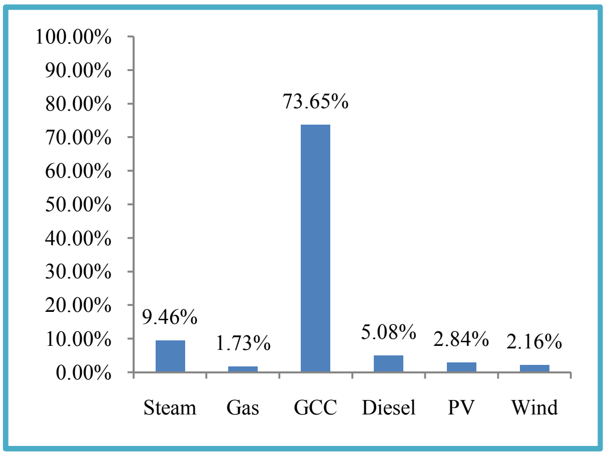

Figure (2) Share of the power generation technologies in (2017)

Modeling

Economic Model

The economic model is an important tool to evaluate the conventional and the renewable energy technologies. Since, it will give a feasible indication about the energy technologies used in the country.

Therefore, the Cost of Electricity (COE) has been selected to be the economic model in this paper. It is calculated as the ratio of the discounted cost of electricity production and the discounted sum of electricity output over the lifetime of a plant.The calculated COE is regarded as a minimum average price at which electricity must be sold to reach breakeven over the economic lifetime of a power plant (M. Rahman *et al* 2018).

Before addressing the procedure of building the COE model, the main factors that affect the COEcalculations have been considered according to (Fraunhofer, 2018) study and (EIA, 2017) reports, which hare:

1. The international Market prices for the generation technologies in particular the renewable energy technologies.
2. Fuel prices
3. Operation hours.
4. Location of the RE technologies.

Accordingly, we Conducted the Following (6) Stepsprocedure to Calculate the COE for each Technology

First: we have put Eight Assumptions

The Input data that includes the capital cost, fixed and varible O&M costsfor the power generation technologies (conventional & RE) ,except the PV utility, in Jordan are the same as the costs that published in the (EIA, Electricity Market Module, 2018). While for the PV utility capital and O&M costs, its costs same as the costs in the (Fraunhofer, 2018) study.

In order to have logical results, the capital costs have been estimated for the considered power generation technologies. Where for the RE power generation technologies, in particular the PV utility and wind turbine, we usedtwo approaches according to (S.Rubin *et al* 2015) study to estimate the capital costs:

The first approach was assuming a cost reduction in the capital cots.

The second approach was using the learning rate (LR)method. Consequently, the following one – factor model formula was adopted from (Ocean Energy: Cost of Energy and Cost reduction opportunities, 2013) to calculate the foreseen capital cots:

CF=CR*(PF/PR)ln(1-LR)/ln2 (1)

Where;
CF = Future capital cost of the power generation technology (JD / kW).
CR = Capital cost of the power generation technology in the reference year (2017) (JD / kW).
PF = Annual future installed capacity of the power generation technology (kW).
PR = Annual installed capacity of the power generation technology in the reference year (2017) (kW).
LR = Learning Rate (%).

While for the conventional power generation technologies, we used the first approach mentioned above to estimate the capital costs for the considered conventional power generation technologies. Regarding the fixed and variable O&M costs for both conventional and RE power generation technologies; we assumed that they would best able with no changes from the baseline year till 2035.

The new prices of the fuel (i.e. natural gas, heavy oil and diesel) have been assumed to be same as the prices that have been estimated by(EIA, AEO 2018) for the years (2018 – 2035).

The discount rate was assumed to be yearly interest rate. And it was assumed to be (4.25%) (CBJ, 2018) for all the years of this paper.

The yearly growth rate of the electricity generation was assumed to be as supposed by the Jordan National Energy Strategy (2015 – 2025), which is (5.3%) (MEMR, 2018).

The life cycle for the electricity power generation technologies is assumed to be (25) years like what was assumed by both (Reddy, 2018) and (Al- Omary) studies.

The shares of contribution of the considered technologies in this paper were assumed to bewhat assumed in the Jordan national energy strategy (2015 -2025).

The installed capacity for the conventional power generation technologies assumed to be the same as the capacity in the baseline year (2017).

Second: the input data (i.e. capital investments, O&M and fuel costs) was determined based on the aforementioned assumptions and they were shown in table (1) and table (2) respectively for the baseline year (2017). While the foreseen capital costs and the O&M costs for the years (2018 – 2035) have been shown in figure (5) in (JD /kW). As well as, the estimated fule prices for the years (2018 – 2035) were shown in figure (6), after we converted their unit price to (JD /kWh).

Third: the estimated annual generated energy (kWh) was calculated for each power generation technology based on the aforementioned shares.Where Et (kWh) for each year = Et0 + (Et0* Average annual growth rate * power generation share, which was calculated based on the Jordan National Strategy (2015-2025)). Et0 is the generated electricity (kWh) for the year 2017

Fourth: the estimated installed capacity (kW)for the RE technologies was calculated. However, for the RE technologies, we estimated the installed capacity (Pt) in (kW) from the capacity factor in 2017. Therefore, the Pt (kW) = {(Et (kWh) / 8760 (number of hours in a year)* capacity factor of the baseline year)}. It's worth mentioning that, when the share of the RE technologies decreased the installed capacity decreased too. However, since in this paperwe did not assume that there would be decommissioning for any of the power generation technology. The installed capacity in the case of decreasing the share of the PV utility or the wind turbine was assumed to be same as the previous year (before the reduction of producing the electricity).

Fifth: the net present value (NPV) (which is the value of the investments today considering the capital cost, O&M and fuel costs) was determined.

Sixth: the capacity factor (%) was determined for each technology from the actual generated electricity and the installed capacity for each power generation technology. Therefore, we calculatedthe capacity factor (%) by using this equation, Capacity factor = Et (kWh) / (Pt (kW) * 8760 hours).

Consequently, we adopted the following equation from (Fraunhofer, ISE, 2018) and (Reddy, 2018) to simplify the calculations of COE for both conventional and renewable energy technologies.

$$\mathbf{COE} = \frac{\mathbf{C_o} + \sum_{t=1}^{n} \frac{A_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+i)^t}} \qquad (2)$$

Where,

COE= Cost of Electricity (JD / kWh).
Co = Capital costs (JD).
At = Annual costs in year t (JD).
Et = Generated electricity in year t (kWh / kW).
i= Interest / discount rate (%).
n= Economic operational lifetime of the power plant (year).
t= Year of lifetime (1,2…, n).

Finally; we calculated the COE for each power generation technology for the years (2018 – 2035)by using the above equation (2).Where the results have been shown in section four of this paper. It's worth mentioning that, in order to find the COE in (JD/ kWh) the total costs in (JD / kW) have been divided into a specific amount in (kWh / kW). Where this specific amount is = Et (the estimated generated electricity (kWh)) / Pt (the estimated installed capacity (kW)).

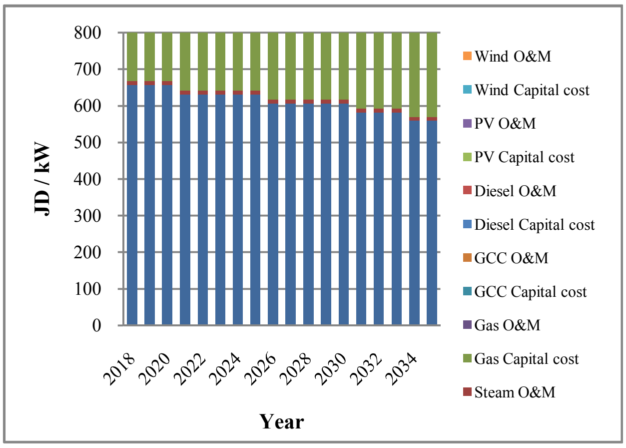

Figure (3) Estimated annual average capital costs and O&M for the power generation technologies (2018 – 2035) in (JD /kW)

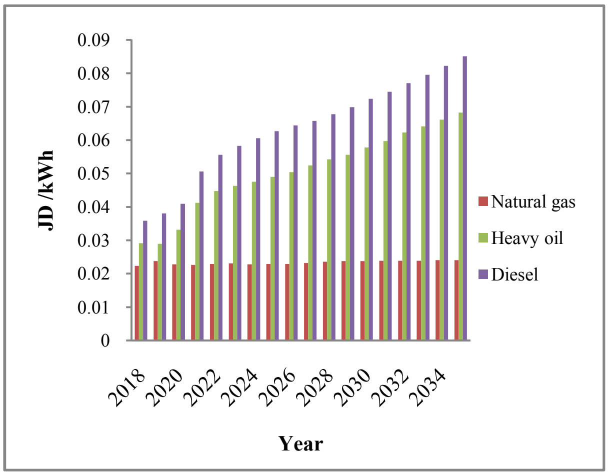

Figure (4) Estimated fuel prices for the years (2018 – 2035) in (JD /kWh). Source (AEO, EIA 2018)

Environmental Model

The conventional technologies basically generating the electricity from burning the fuel, and this burning process will generate huge amount of GHG emissions in particular the carbon dioxide (9 -26 %) (Rafiee *et al* 2018), which is the main factor of the climate change (Jarad at, 2018). In this regard, Jordan has witnessed strongly the climate change recently in two main disasters in Jordan in this year (2018).Where these disasters resulted from strong rains caused water flows that destroyed infrastructure in the effected regions in Jordan and, unfortunately, led to loss many lives of people.

In reference to the National Climate Change Policy for the Hashemite Kingdom of Jordan (2013 – 2025), the energy sector (including transportation and industrial energy activities) produced the highest amount of GHGs emissions with about (74). It also mentioned that, Jordan contributions in GHGs are equivalent to less than (20) million tons of CO2.

Therefore, we built the environmental model because it becomes very important to be as a tool for helping the decision makers through giving the specific amount of CO2 produced from each power generation technologies in Jordan. Consequently they can identify the technologies that have the highest and lowest amount of producing the CO2. As well as putting the needed actions to mitigate the carbon dioxide emissions from these technologies as recommended in (Kahului *et al* 2018) study.

Accordingly, We Followed The Simple (4) Stepsprocedure, Which Was Adopted From The Electric Power Annual Report (Eia, 2018), To Calculate The Co2amount In (Kg / Kwh) For Each Power Generation Technology That Produced In The Operational Process (Producing Electricity) Only and Did Not Include the Manufacturing Process of the Power Technology

First; identify the input data (i.e. the type of fuel used by each power generation technology, the average tested heat rate (Btu / kWh) for each generator and the CO2 emission factor for the fuel) as shown in table (3).

Second; use the same assumptions in the Economic model, regarding the calculation of the expected annual generated electricity and the Installed capacities for the power generation technologies for the years (2018 – 2035).

Third; assume the heat rate for each power generation technology as well as the CO2 emission factor for each type of fuel will be the same for all the years from 2018 till 2035.

Fourth; the total amount of the CO2 in metric ton (Mt) has been calculated for each power generation technology in Jordan.

Table 1 Environmental model Input data. Source: Electric power annual report (EIA, 2017) and (NEPCO, 2017)

Power Generation Technology	Fuel type	Average tested Heat rate for the generator (Btu / kWh)	CO_2 emission factor (kg / million Btu)
Steam turbine	Natural gas	10,353	53.07
	Heavy oil	10,199	73.16
Gas turbine	Natural gas	11,176	53.07
	Diesel	13,491	73.16
GCC power plant	Natural gas	7,649	53.07
	Diesel	10,301	73.16
Diesel turbine	Natural gas	9,120	53.07
	Heavy oil	10,301	73.16

Accordingly, the amount of CO2 in (kg / kWh) has been calculated for each power generation technologies for the years from 2018 till 2035, by using the following equation:

CO2amount (kg/kWh)=(H*F)/(1x106) (3)

Where;

H: is the generator heat rate in (Btu / kWh).

F: CO2 emission factor for the fuel in (kilograms of CO2 / million Btu).

The results of the environmental model are shown in section four of this paper.

Social Model

To this end, the social impact of the renewable energy technologies does not discussed in these two models.

Therefore the aim of this new model "Social model" is to highlight the social impact of the renewable energy technologies in Jordan in order to facilitate the shift to the green energies in producing the electricity.It's worth mentioning that, there are many social impacts topics of the RE technologies (e.g. job creation, land use, awareness … etc.), but in this paper, we selected the job creation topicbecause of its importance at different levelsthat summarized in the following points:

1. At local level, it will improve the economic situation of people through finding jobs for them, consequently improving their living conditions.
2. At national level, it will support the government of Jordan in securing jobs for the citizens. Consequently decrease the unemployment percentage that reached (18.7%)in 2018, (DOS, 2018).
3. At environmental level, it will reduce significantly the GHGs emissions, especially the carbon dioxide.
4. Accordingly, by the Job creation model we have studied the sustainability components (i.e. economic, environmental and social) for the power generation technologies in Jordan.

We conducted the following (4) steps procedure to build the Job creation model:

First: determine the value chain for each RE technology considered in this paper; through:

Conduct SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis for the local manufacturing for PV utility and Wind turbine.

Determine the value chain for PV utility and Wind turbine, It's worth mentioning that the general components of the value chain for a technology as shown in the below chart:

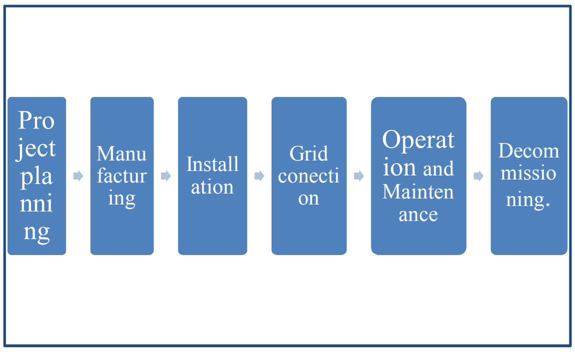

Fig 5 The general components of the RE technologies value chain. Source: IRENA, 2018

Second: use the same assumptions in the Economic model, regarding the calculation of the expected annual generated electricity and the Installed capacities for the power generation technologies for the years (2018 – 2035)

Third: determine the jobs for each component selected in the value chain of PV utility and Wind turbine.Where we assumed to use the employment factor for the PV utility for manufacturing, installation, grid connection and decommissioning (MIGD) (7.1 jobs /MW) and for O&M was (0.1 jobs /MW). And for Wind energy we used theemployment factor for manufacturing, installation, transport, grid connection and decommissioning (MITGD) (2.6 jobs /MW) and for O&M (0.1 jobs /MW) respectively. Then we formulated the following equation to calculate the number of jobs that created by the PV utility and the wind turbine for the years (2018 – 2035):

$$J = Fm * P \quad (4)$$

Where;

J= is the number of the jobs created by the component activities in the value chain.
Fm = is the employment factor (number of job / MW).
P = is the annual installed capacity (MW).
The results of the Job creation model were presented in section four of this paper.

Modeling Optimization

Economic Model Optimization

The objective of this partwas to minimize the total cost of the generated electricity in Jordan Dinar (JD), through find the optimal value of the powergeneration in (MW)from each technology (conventional and renewable) considered in this paper. Consequently we found the optimal share (%) ofeach power generation technology in producing the electricity in Jordanto cover the demand growth for the years (2018– 2035) with total respect to the Jordan National Energy Strategy (2015– 2025) proposal and recommendations regarding the contribution in the total energy mix.

Considering the optimization methodology, there are many known optimization techniques that used in the minimization and maximization purposes (such as: mathematic algorithm, particle swarm optimization, genetic algorithms, liner program methods … etc.). Where, each technique has specific characteristics as explained in details in (Faizan *et al* 2018) research. So the selection of the suitable technique depends on the purpose of the optimization of the problem and also the available software for making the optimization process as well as the relationship between the variables of the problem for instance if it is linear or non – linear.

Accordingly, in this study the main challenge was in selecting the suitable optimization approach for the COE model. Since there was no specific optimization technique used for minimizing the total cost of the already existmixed generation technologies. Where most of the related studies, mentioned in chapter two of this study, either used exist models that already prepared on software (such as: Bass model used in (Reddy et at 2018) study and TIMES model that used by (Eda Dal *et al* 2017) study). Or using known optimization methods (such as: particle swarm optimization) for only designing purposes of hybrid energy systems that used to increase the share of RE technologies. Moreover, another challenge was in formulating the appropriate constraints in order to get the logical and useful results.

Therefore, we selected and used the GAMS softwareto conduct the optimization of the three models, by using the non – linear programming approach (NLP). Where this software as explained in (Ringkjøb *et al* 2018) study, is one of the known software used for scenario planning, which is the purpose of this paper.

Consequently, we conducted the following procedure for the optimization usingGAMS software:

First; identify the optimization problem; as mentioned above the purpose of the optimization is to minimize the total cost of electricity generation from all technologies. The below chart defines in general the optimization problem that consists of three main components:

1. Decision variables that describes the choices that under controls.
2. Objective function that describes the criterion would be minimized or maximized.
3. Constraints that describe the limitations restrict the choices of the decision variables.

Accordingly the following mathematical function of technology (tech) and time (t) has been formulated:

TOTAL_COST (tech, t) = Σ {COE (tech, t) * P (tech, t)};(5)

Where;

TOTAL_COST (tech, t): is total cost of the generated electricity in (JD) depends on technology (tech) and time (t) and it is the objective function that would be minimized.

COE (tech, t): is the Cost of Electricity in (JD / MWh) depends on technology (tech) and time (t).

P (tech, t): is the value of the generation capacity in (MW), which is unknown value in this function. It's optimal value would minimizeTOTAL_COST
(tech ,t).

Second; identify the GAMS entities / components, which are four basic entities that define the data structure, initial values, data modification and symbolic relationships (equations) of the model.

Third; the above model optimization steps have been applied according to a certain criteria which was of selecting three cases of daily hourly load profiles at the baseline year andfive years, in order to see the feasibility of the economic model for these years as well as to see what is / are the technology (ies) that minimize the total cost of the generated electricity for these years. Therefore,the three hourly load profile cases in the baseline year considered for this study (2017) were:

i. The highest daily hourly load profile in 2017 which was on Thursday, July 27th, 2017 with total load (67903 MW).
ii. The lowest daily hourly load profile in 2017 which was on Friday (weekend), April 21st, 2017 with total load (42492.4 MW).
iii. The average hourly load profile in 2017which was (53049.76 MW).
iv. Where, as supposed by the Jordan national energy strategy (2015-2025) and assumed in this paper the annual rate of increasing of the peak load is (5.5%), therefore this rate has been considered and added when calculating the three hourly load profiles for the years (2018, 2020, 2023, 2025 and 2035).

Fourth; run the model and display the results.In this step, the model has been run and the results have been displayed and shown in the section four.

Environmental Model Optimization

Ourobjective of the optimization herewas to minimize the total amount of CO_2 emission (million Mt), through find the optimal value of the power generation in MW from each technology (conventional and renewable) considered in this paper.Consequently we found the optimal share (%) of each power generation technology in producing the electricity in Jordan to cover the demand growth for the years (2018 – 2035). Therefore, the same optimization procedure, which we used for the COE model as well as the same assumptions that explained in details above, has been conducted for the CO_2 model.

Accordingly the following Mathematical function of Technology (tech) and time (t) has Been Formulated

TOTAL_CO2 (tech, t) = Σ {C (tech, t) * P (tech, t)}; (6)

Where;

TOTAL_CO2 (tech, t): is the total amount of the CO_2 emissions in (million Mt) depends on technology (tech) and time (t) and it is the objective function that would be minimized.

C (tech, t): is the amount of CO_2 emission in (million Mt / MW) depends on technology (tech) and time (t).
The results were shown in the section four.

Social Model optimization

Our objective of the optimization herewas to maximize the total number of jobs created by RE technologies (PV utility and Wind turbine) in Jordan, through find the optimal value of the power generation in MW from each technology (conventional and renewable) considered in this paper, to cover the demand growth for the years (2018 – 2035).

Thus, the same optimization procedure, which used followed for the COEmodel and the CO_2 model as well as the same assumption that explained in details above, has been conducted for the Job creation model.

Accordingly the following mathematical function of technology (tech) and time (t) has been formulated:

TOTAL_J (tech, t) = Σ {F (tech, t) * P (tech, t)}; (7)

Where;

TOTAL_J (tech, t): is total number of Jobs created by RE technologies (PV utility and Wind turbine) depends on technology (tech) and time (t) and it is the objective function that would be maximized.

F (tech, t): is the employment factor (Job / MWh) depends on technology (tech) and time (t).
The results were shown in the section four below.

RESULTS

Economic Model Results

Hereafter the results of the economic model weredivided into two parts; the first part is the results of COEmodel for the electricity power generation technologies for conventional and RE systems in Jordan. And the second partis the results of the economic model optimization.
First part:COE model results

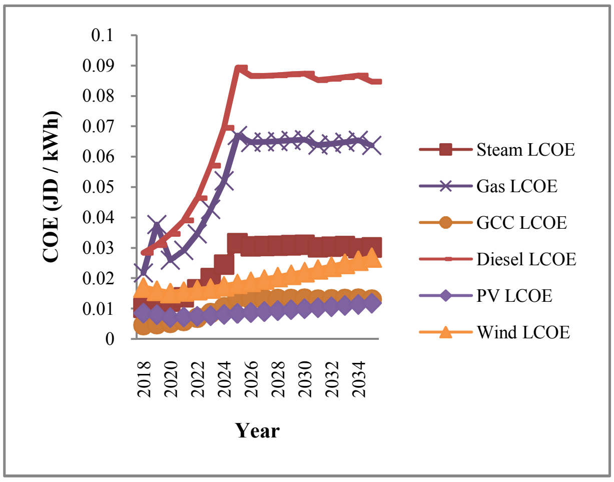

Fig (6 -A) COE for the power generation technologies in Jordan for the years (2018-2035)

Where as shown in the above figure, it's noticed that there are key parameters affected the value of the COE, namely; the economic parameters (i.e. the capital costs, O&M costs and fuel prices) and the technical parameters (i.e. the annual generated electricity and the installed capacity) for each power generation technology.

Accordingly, the Effect of These parameters was as Following

Economic parameters: the main effective parameters were the capital costs and the fuel prices, since as mentioned previously in chapter (three) that the fixed and variable O&M costs have been assumed to be the same for the years (2018 – 2035) for the all power generation technologies. Where the effect of the capital costs on the COE value was proportional; when the capital cost has been decreased, as seen in the figure (5) in section (three), for a technology the COE also has been decreased. Thus, it can be explained that the COE for the PV utility decreased when the capital cost decreased to, which was seen clearly in the year (2020), where the COE decreased from (2018) to (2020) with about (17%). On the other hand, the effect of the fuel prices on the COE value was also proportional; when the fuel prices have been increased, as seen in the figure (6-A) in section (three), for a technology the COE also has been increased. That is why as seen in the figure (9) there where a significant increase of the COE for the gas turbine, which uses two types of fuel; the natural gas and the diesel, from (2018) to (2019) with about (42%); since the fuel price in particular the diesel price has increased significantly.

Furthermore, it can be observed that the COE for all conventional power generation technologies have been significantly increased in the year (2025) because of the fuel prices have increased dramatically. Consequently, the conventional power generation technology that uses the fuel with higher price has higher COE. In this study was the diesel turbine that has the highest fuel prices thus it has the highest COE among other power generation technologies during the years from (2018) till (2035). And vice versa, the conventional power generation technology that has the lowest fuel price, which was the GCC power plant, has the lowest COE for the years (2018 – 2035).

The technical parameters; the main effective parameters were the share of producing the annual generated electricity in each year as well as the capacity for each power generation technology. Accordingly, the effect of these technical parameters on the COE value was in vers; when these parameters increased the COE decreased. That is why; the COE for the power generation technologies has been increased when their contribution in generating the annual electricity has been decreased significantly in the years 2020, 2023 and 2025.

In order to see the COE for the power generation technologies for the years that have specific share of contribution in the total energy mix, according to the national energy strategy (2015 – 2025). The following figure has been produced for the years (2018 – 2025):

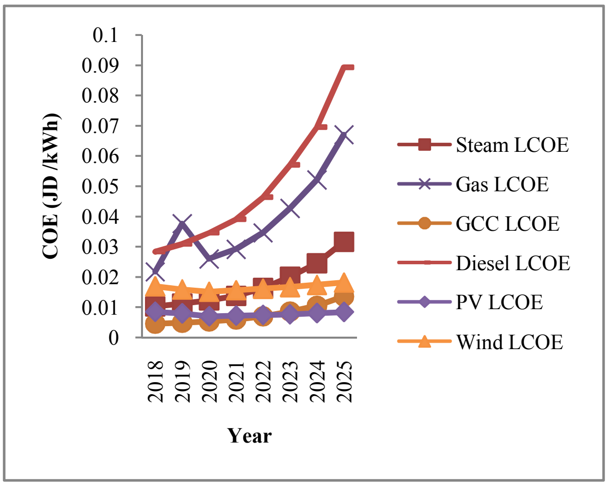

Fig (6-B) COE for the power generation technologies in Jordan for the years (2018-2025)

In the figure (6-B), it can be observed that, in general the COE for the conventional technologies increased with time. While the COE for the RE technologies decreased with time. Comparing with the figure (11), the same results can be observed till the year (2025) for both the conventional and the RE power generation technologies. However, after the year (2025), as assumed in section three, the contribution in producing the electricity till the year (2035) for both the conventional and the RE power generation technologies was same as in the year (2025). That is why for the years (2026 – 2035) the COE for the conventional technologies decreased with time. While the COE for the RE technologies increased with time. Since the annual generated electricity from the conventional increased while it decreased form the RE technologies.

It can be concluded that, the most competitive power generation technology during the years from 2018 till 2035 among other technologies from the conventional and the RE systems was the PV utility. Its value in 2035 was (0.0107 JD / kWh). And the second technology was the GCC power plant with (0.013 JD /kWh). The third technology was the Wind turbine with (0.0278 JD / kWh), the fourth technology was the Steam turbine with (0.0301JD / kWh), the fifth was the Gas turbine with (0.0637 JD / kWh) and the least technology with the highest value of COE was the Diesel turbine with (0.0846 JD / kWh).

On the other hand, the COE model in this study considered the technical aspect of the generation technologies. Since the technical aspect is a crucial pillar in the electricity generation process as well as in the values of the COE; where as shown above the technology that has the higher share of producing electricity as well as the installed capacity has the lower value of the COE and vice versa. Therefore, the performance indicator that represents the technical aspect in the COE model was the Capacity factor. Where, the capacity factor depends strongly on the installed capacity. Therefore and because it was assumed that the installed capacity of the conventional power generation technologies would be the same as the baseline year, the capacity factor has been reduced from the year 2018 to 2035. Since the only affected parameter is the annual generated electricity that has been changed based on the national energy strategy assumptions. However, for the RE power generation technologies, the PV utility and the wind turbine, their capacity factor in the baseline year (2017) has been used in calculating the foreseen capacity in the years (2018 – 2035).Thus their capacity factor was stableduring the years from (2018) till (2035).

Accordingly, as seen in the figure (7), the technologies that has the highest capacity factors from the conventional was the GCC power plant with (48%), and from the RE was the Wind turbine (29%), then the PV utility with (26%).

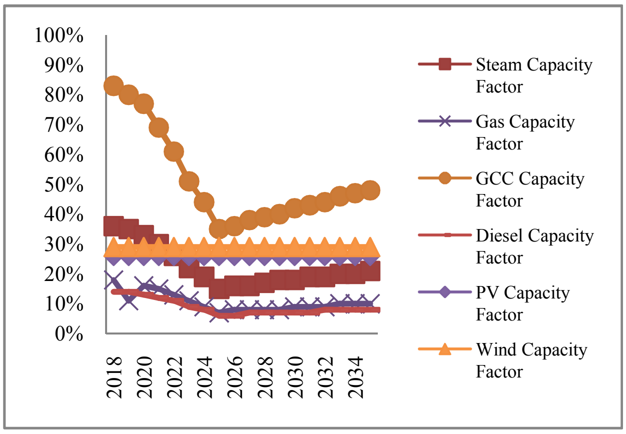

Fig 7 Capacity factor for the power generation technologies in Jordan for the year (2018 – 2035)

Where the value of the capacity factor for the PV utility and the wind turbine is within the range of the grid – feed in Capacity factor in Jordan according to (Dababneh, 2018) study. Moreover, the results of the capacity factor for the PV utility it is within the range of the global capacity factors (17 – 28%) and for the wind turbine also it is within the global capacity factors (20 – 45%) (Renewable power generation costs, IRENA).

Finally, it is worth mentioning that the calculated COE, for each power generation technology in this study, represents a new installation. Since the COE for the power generation technology would be constant during its operational lifetime (Fraunhofer, 2018).Furthermore, the COE is very sensitive value; since within the technology itself the system costs were distinguished based on power plant size and power plant configuration (Fraunhofer, 2018).Thus the economic and technical characteristics for each power generation technology are very essential in calculating the COE.As well as, the assumptions that put to calculate the COE, which they are different between studies.

Sensitivity Analysis for Economic Model

The sensitivity analysis for the economic model is very useful, because of the variances of the COE model results that influenced with numerous technological, economic and political variables (Fraunhofer, 2018).

Therefore, in the sensitivity analysis, we examined the assumptions regarding the capital costs and fuel prices for the two technologies that have the lowest COE from both conventional and RE systems, which were theGCC power plant technology and the PV utilityrespectively. Where a simple sensitivity analysis has been conducted as explained in the following points:

- The first case has been conducted through assumed that the capital costs and fuel prices would be stable from (2018) till (2035) for the GCC and the PV utility.
- The second case has been conducted according to the assumptions explained in details in section three of this paper that assumed that the capital costs and the fuel prices would be changed from (2018) till (2035) for the GCC and the PV utility.
- The following figures shown the results of the sensitivity analysis for the COE for the GCC power plant and the PV utility respectively based on the above mentioned cases.

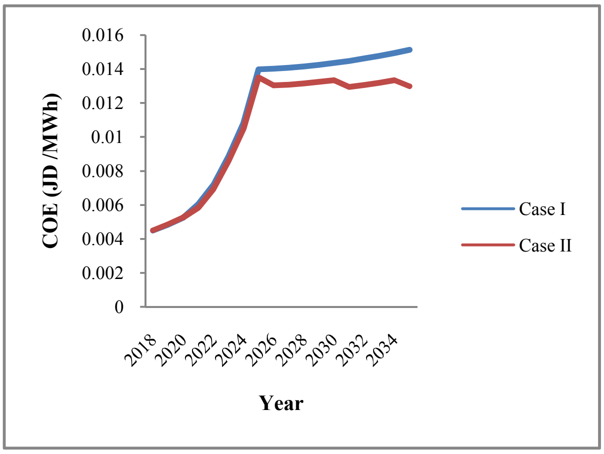

Figure 8 Sensitivity analysis results for the GCC power plant

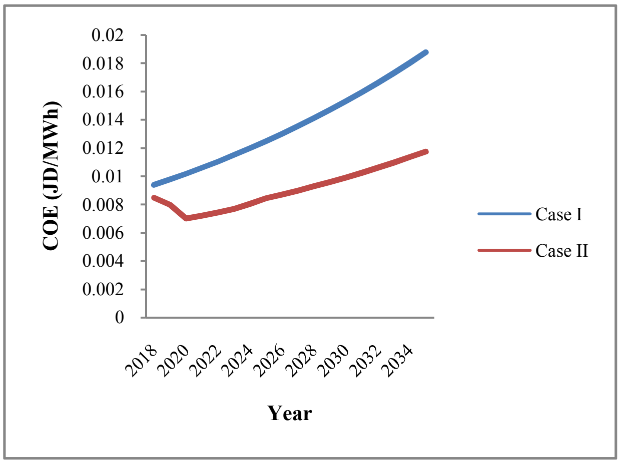

Figure 9 Sensitivity analysis results for the PV utility

Second part: Economic Model Optimization results Hereafter are the results of the economic model optimization. Where based on the defined economic model entities written on GAMS, which were explained in details in section three above, and according to the criteria were explained also in section three.

After the optimization for the power generation technologies in the year (2018) in order to minimize the total cost of the electricity generation, the optimal share for covering thehourly load profile for case (I)would from theGCCpower plant with (68.5%), steam turbine with (13.6%) and from the PV utility with (17.9%).

Where in the year (2035), the optimal share of the power generation technologies would be form both the PV utility and the GCC power plant with shares (54.5%) and (45.5%) respectively.

Therefore, the total reduction in the COE for the power generation technologies in Case (I) for the year (2018)would be from (0.09 JD / kWh) to (0.006 JD / kWh).
While in the year (2035) the total reduction of the COE would be from (0.23 JD / kWh) to (0.0123 JD / kWh).

For case (II), only the GCC power plant had the optimal share to cover the demand with (100%) for the three years (2018, 2020 and 2023).

However, in the year (2035), the PV utility with share (87%) and the wind turbine with share (13%) would cover the demand.Consequently, the total COE would reduce from (0.254 JD / kWh) to (0.0045 JD / kWh) in (2018) it would be reduced from (0.23 JD / kWh) to (0.0119 JD / kWh) in (2035).

However, for the last case (III), the best technologies were the GCC power plant with (87.7%) and the PV utility with (12.3%) for the year (2018). And it would be from the PV utility with (70%) and the GCC with (30%) in the year (2035).

Thus, the total reduction in the COE would be from (0.09 JD / kWh) to (0.005 JD / kWh) in the year (2018). In the year (2035), the total reduction would be from (0.23 JD / kWh) to (0.0121 JD / kWh).

Therefore and based on the above optimization results, it's concluded that the GCC power plant technology from conventional and PV utility from RE have the highest optimal share in the electricity generation. Meaning that, they are the best technologies among other technologies in covering the required demand in a feasible way.

Moreover, the Optimization results Streng then the Jordan National Energy Strategy (2015 – 2025) in two aspects Regarding the Electricity sector as Explained below:

1. The first aspect; reducing the share of the conventional power generation technologies and increasing the share of the renewable will decrease the total cost of producing the electricity.
2. The second aspect; strengthen the recommendations concerning the importance of conducting continuous review for the economic impacts of the potential options for electricity generation in order to maximize the benefit and minimize the losses to satisfy the stability in the electricity system.

Environment Model Results

The results of the environmental model were divided into two main parts; the first part is the results of the CO2model. And the second part is the optimization of the CO2model.

First part: CO2model calculation results

The below table and figure shown the amount of CO2 in (kg / kWh) and (million Mt) respectively, for each power generation technology in Jordan from 2018 till 2035.

Table 2 CO2 amount (kg / kWh) for each power generation technologies in Jordan

Technology	CO2 amount (kg / kWh)
Steam turbine	1.296
Gas turbine	1.58
GCC power plant	0.406
Diesel turbine	1.99
PV utility	0
Wind turbine	0

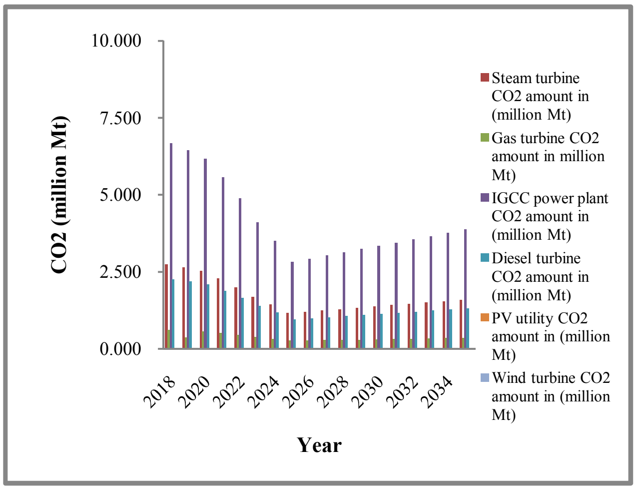

Fig 10 The amount of CO2 in million Mt for each power generation technology in Jordan for the years (2018 – 2035)

It's Noticed from the table and Figure Above the Following Points

The relation between the electricity generation and the amount of CO2 produced by the power generation technology is proportional. Since as seen, in the figure when the share of the conventional power generation technologies is decreased, as the Jordan national strategy (2015 – 2025) proposal, into (70%) in 2020 the total amount of CO2 is reduced to(8%), and when the share is decreased to (41%) in 2023 the total amount of CO2 is reduced to (50.1%)and when the share is decreased to (26%) in 2025 the total amount of CO2 is reduced to (46%). While the total reduction in the amount of CO2 from 2018 till 2035 is about (73%).However, when the share of the conventional power generation technologies has been assumed in this paper to be the same, which is (26%), from 2025 till 2035 and the annual electricity generation demand will be increased by (5.3%) each year. Thus, the total amount of CO2is increased from 2025 to 2035 with (27%).

The power generation that produced the highest amount of CO2 from the year 2018 till 2035, is the power generation that produced the highest amount of the electricity (has highest share in producing the electricity) which is the GCC power plant. That is why even though, the GCC power plant has the lowest CO2 amount in (kg /kWh) among other conventional power generation as seen in the table no. (6) with an amount (0.406 kg / kWh), but it has the highest total amount of the CO2 emissions in million Mt because of its highest share in producing the electricity from 2018 till 2035.Where the total amount of CO2 emissions produced by the GCC power plant in 2018 and 2035 are (6.672 million Mt of CO2) and (6.865 million of Mt of CO2) respectively. On the other hand, the technology that has the highest amount of CO2 emissions (kg / kWh) is the Diesel turbine technology with an amount (1.99 kg / kWh). Therefore, the best technology of the conventional power generation technologies is the GCC power plant since it has the lowest amount of CO2 emission in (kg / kWh), for that if for instance the diesel would have the highest share of producing the electricity instead of the GCC power plant, the total amount of CO2in (million Mt) would be (18.92 million Mt of CO2) in 2035 instead of (3.865 million Mt of CO2) which is about five times the amount that would be produced from the GCC power plant that would lead to a very bad impact on the environment.

Finally, the best technologies among the conventional and RE power systems are the PV utility and Wind turbine since they have Zero amount of CO2 emissions in the generation process.

Second part: CO2 model optimization results

Hereafter are the results of the environmental model optimization. After the optimization of the environmental model for the power generation technologies in the year (2018) in order to minimize the total amount of the CO2 emissions, the optimal share for covering the hourly demand in case (I) would be from four technologies which are: the GCC power plant with (68.5%) and steam turbine with (2.1%) from the conventional power generation technologies, the PV utility with (17.9%) and the wind turbine with (11.5%)from the RE technologies.

While for the year (2035), the optimal share would be the PV utility with (54.5%) and the wind turbine with (45.5%).Therefore, the total CO2 emissionswould be reduced from (5.272kg / kWh) to (0.3053kg / kWh) in (2018).And in (2035), the total CO2 emissions would be reduced from (5.272 kg / kWh) to (0 kg / kWh).

For case (II), the optimal share of the power generation would be from three technologies (GCC, PV and Wind) with the share for each (53%), (28.7%) and (18.3%) respectively in (2018).

However, in (2035), only the PV utility with optimal share (87%) and the wind turbine with share (13%) would cover the needed demand. Consequently, the total CO2 emissions would be reduced as in the case (I).

Finally, for the case (III), andagain as in case (II) three technologies (GCC, PV and wind) would cover the demand with shares (30.4%), (39%) and (30.6%) respectively in (2018). And only the PV utility with optimal share (70%) and the wind turbine with share (30%) would cover the needed demand. Consequently, the total CO2 emissions would be reduced as in case (I) and case (II) above.

From the above optimization results, it's interesting to notice that the PV utility and wind turbine from the RE technologies have the highest share of the electricity generation in the three load profile cases for the five selected years. Since the aim of the optimization is to minimize the total amount of the CO2 emissions.Since as discussed in the first part of the Environmental model above, this model strongly encourages the RE technologies because it aims to reduce the CO2 emissions. However, as seen also from the figures, the conventional power generation technologies still have share in the electricity generation especially to cover the demand in the year (2018)which iscomefrom only the GCC power plant, because it has the lowest amount of CO2 emissions as shown in the first part of the environmental model results above.

Finally, it can be concluded that the best technologies based on the environmental model are the PV utility and the Wind turbine from RE technologies andthe GCC power plant technology from the conventional technologies in covering the required demand with minimum amount of CO2 emissions.

Social Model results

As in the previous models results, this part also was dividedinto two main parts; the first part is for the Job creation model calculation and the second part is for the Social model optimization results.

First part: Job creation model results

The figure below shown the total number of the direct Jobs created by the PV utility and the Wind turbine for the years (2018 – 2035). Where as seen in the figure, the total number of the jobs created by the PV utility was in 2018 (3821) jobs and increased to (8976) jobs in 2035, which is higher than the total number of the jobs created by the Wind turbine that was (914) jobs in 2018 and increased to (3449) jobs in 2035. That for the following reasons:

The installed capacity for the PV utility is higher than the Wind turbine for the years 2018 till 2035.

The employment factor for manufacturing, installation, grid connection and decommissions for the PV utility is higher than the Wind turbine due to several reasons related to the local manufacturing and market of the country.

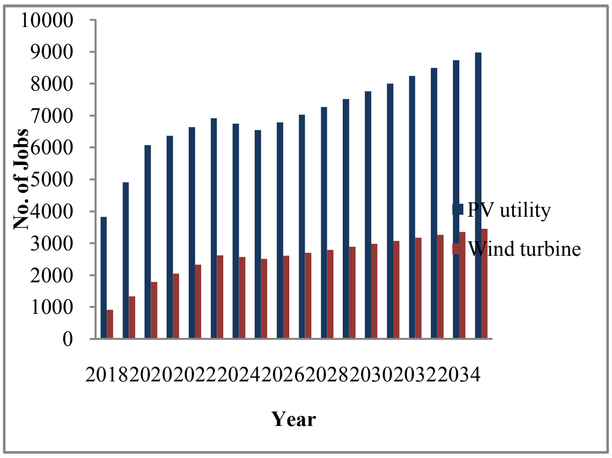

Fig 11 The total number of Jobs created by PV utility and Wind turbinefor the years (2018 – 2035)

Second Part: Social model optimization results

Hereafter are the results of the social model optimization. After the optimization of the social model for the power generation technologies in the year (2018) in order to maximize the total number of jobs created by the RE technologies; in particular the PV utility and the Wind turbine. The optimal share for covering the hourly demand in case (I) would be from the GCC power plant with (69%), the PV utility with (19%) and the wind turbine with (12%).

For the year (2035), the optimal share would be from the PV utility with share (54%) and the wind turbine with share (45%) to cover the required demand. Therefore, the total number of jobs created by the PV utility and the wind turbine (Job / MW) would be increased from (0.663 Job / MW) to (1.692 Job / MW) in (2018). And it would be increased from (4.3 Job / MW) to (5.2 Job / MW) in (2035).

For case (II), the optimal share of the power generation would be from also the three above technologies (GCC, PV and Wind) with the share for each (53%), (28.7%) and (18.3%) respectively in (2018).

And for the year (2035), the optimal share would be from the PV utility with share (87%) and the wind turbine with share (13%) to cover the required demand. Thus, the total number of the jobs would be increased from (0.663 Job / MW) to (2.56Job / MW) in (2018). And it would be increased from (4.3 Job / MW) to (6.6 Job / MW) in (2035).

In the last case (III), the results of the optimization found that the optimal share would be from the three technologies that covered the previous cases, which are the GCC with (62.3%), the PV utility with (23%) and the wind turbine with (14.7%) in (2018). And the PV utility with share (70%) and the wind turbine with share (30%) would cover the demand in the year (2035). Consequently, the above optimal shares would increasethe total number of the jobs from (0.663 Job / MW) to (2.053 Job / MW) in (2018). And it would be increased from (4.3 Job / MW) to (5.9 Job / MW) in (2035).

Therefore, it can be concluded that the best technologies based on the social, the environmental and the economic models are PV utility and Wind turbine from RE technologies and GCC power plant technology from the conventional technologies in covering the required demand with providing maximum number of Jobs created by PV utility and Wind turbine and minimum amount of CO_2 emissions produced by GCC power plant.As well as, they will minimize the total cost of generating electricity.

Scenario Planning For Electricity Generation In Jordan (2018 – 2035)

In this section the four scenarios planning for the electricity generation in Jordan have been developed for the years (2018 – 2035), after the three main models namely; the Economic (COE) model, the Environmental (CO_2 emissions) model and the Social (Job creation) model have been built.

It's worth mentioning that, these scenarios have been developed by using new approach, which was adopted from the Mafraq Scenario planning that was developed by the collaboration between the VNGI (International Agency for the Netherlands' Municipal Union) and GoJ represented by MOPIC and MOMA as well as the concerned entities (i.e. Royal Geographic Center, DOS … etc.) in Jordan and it was launched formally on September 2018. Where this approach was innovated by the city of Amsterdam and applied in different cities in Netherland such as Rotterdam and Eindhoven. This new approach defines the scenario as exploration possible conditions of the future and is not prediction of the future through identifying the priorities and strategic options based on the most uncertainties, which defined after specifying all the external and internal barriers and drivers.

Accordingly, we Conducted the Following Procedure to Develop the four Scenarios

First; identify the most uncertainties in the electricity generation sector in Jordan. In this step the main external and internal barriers and drivers forces of the electricity generation sector were identified then the two key uncertainties have been specified as following:

Identifying the main barriers and drivers for electricity generation sector in Jordan.

Identifying the Uncertainties of the Scenarios

Geopolitical; since Jordan located in geographical area witnesses many political conflicts that affect Jordan. And this factor could be characterized by stable and instable.

Economic; the development of local economy that could be characterized to either economic growth or stagnation relates to the growth rate in the region (high or low).

Building the four scenarios; the four scenarios have been developed.

The Description of the Features of each four Scenarios

The first scenario: Geopolitical stability and Economic growth; the scenario characterized as international field because of the following reasons:

- Open borders crossing with neighboring countries (Iraq and Saudi Arabia).
- Safe and comfortable investment environment for implementing more energy projects, in particular RE technologies.
- Increasing of PV local manufacturer productions.
- More international cooperation for supporting the electricity sector in terms of technical and financial aspects.
- Increasing the PPP investments in RE projects.
- Larger demand for skilled and unskilled labor in RE projects.
- Focusing on expanding the grid connections projects (such as Green corridor project).

The Second Scenario: Geopolitical stability and Economic stagnation; the scenario characterized as regional field because of the following reasons:

- Still the border crossing with neighboring countries (Iraq and Saudi Arabia) Open.
- Rapid growth of population.
- Infrastructure and public services deteriorating.
- Rise of unemployment and poverty rate cause people move out of the region.
- Rapid development of RE technologies worldwide especially of PV manufacturing led to decrease the local production of PV.
- Decrease the natural gas prices dramatically led to continue in importing the natural gas.

The Third Scenario: Geopolitical instability and Economic growth; this scenario is characterized as national field because of the following reasons:

- Jordan remains a stable factor in a region dominated by instability.
- Continued unrest and conflicts in Syria that led to influx of refugees to Jordan.
- Pressure on electricity supply.
- Work on completing the Green corridor project to expand the grid connections.
- Increase national energy projects by focusing on extraction oil shale and increase it share in electricity generation production.
- Good relationships with International donors that provide fund for implementing RE projects.

The Fourth Scenario: Geopolitical instability and Economic stagnation; this scenario is characterized as local field because of the following reasons:

- Continued unrest and conflicts in Syria that led to influx of refugees to Jordan.
- Pressure on electricity supply.
- Close the crossing border with Iraq again due to conflict.
- Increase the production of local PV manufacturer.
- There is a lot of skilled and unskilled labor available but the opportunities are limited in electricity sector.
- There is limited international cooperation with donors in supporting the implementation of RE projects.
- International roads suffer from deteriorations and need maintenance.

Determining the generation technologies based on the optimization results.

Examining these generation technologies in terms of the possibility of implementing this type of technology in each scenario.

The below table shows the priorities / options for the four scenarios summarized in the below table:

Table 3 Final identified priorities for the electricity generation technologies in Jordan

Technology / option	Scenario 1	Scenario 2	Scenario 3	Scenario 4
GCC power plant	+	++	+	+
PV utility	++	+-	++	++
Wind turbine	++	-	+	+-

Therefore, it's interesting to notice that from the examination practice on the probability of implanting each technology in each scenario that the GCC power plant has the highest probability, the next is PV utility and the third is Wind turbine.

Finally, identify the current situation of the electricity generation in Jordan for the year 2018. Then propose the situation for the electricity generation in 2035.We have selected scenario (2) {Geopolitical stability and Economic stagnation for the year (2018), however the four scenarios have been developed for the year (2018), since according to the uncertainties factors , always there is possibility to move from scenario to another. Therefore the priorities / options have been defined for each scenario as shown in the below figure.

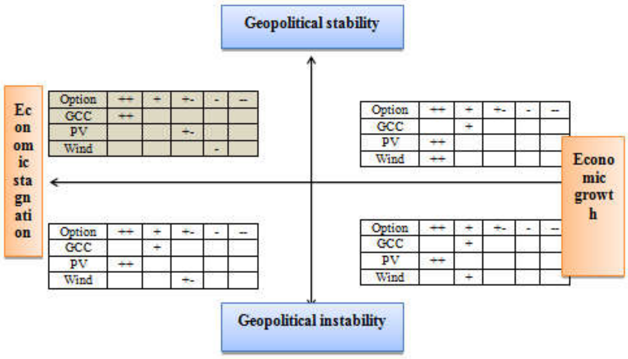

Fig 12 Electricity generation scenarios for (2018)

Scenario planning for electricity generation technologies for 2035, we identified the vision for 2035 to be in scenario (1) {Geopolitical stability and Economic growth, however the four scenarios have been developed since, as mentioned previously, according to the uncertainties factors , always there is possibility to move from scenario to another. Therefore the priorities / options have been defined for each scenario as shown in the below figure.

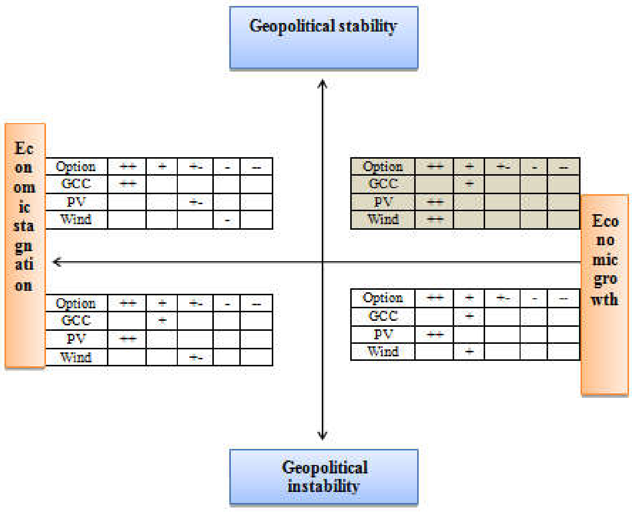

Fig 13 Electricity generation scenarios for (2035)

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

In this study three models have been built and optimized in order to develop practical scenarios for electricity generation technologies in Jordan for the years (2018 – 2035). These scenarios are a tool for the decision makers in selecting robust and effective generation technologies from conventional and RE technologies that would strengthen their strategies and action plans in improving the electricity generation sector in Jordan. Moreover, these scenarios would increase the readiness of this sector to respond to any emergency circumstances.

Therefore, the CO Emodel strengthens the Jordan National Energy Strategy (2015 – 2025) recommendations regarding the electricity sector. Because the results of the COE model found that the best cost- effective power generation technologies from the conventional was the GCC power plant. And from RE technologies, were thePV utility and the Wind turbine.Where their CO Evalues were (0.013 JD/kWh), (0.0117 JD/kWh) and (0.0268 JD/kWh) respectively in 2035.

Furthermore,the optimization of COE model results found that the GCC power plant technology from conventional and PV utility from RE have the highest optimal share in the electricity generation. Meaning that, they are the best technologies among other technologies in covering the required demand in a feasible way.

On the other hand, the Environmental (CO2) model evaluate the electricity sector in Jordan in terms of the amount of CO2 emissions that produced by the power generation technologies for the years (2018 – 2035).. Consequently the best technology among other conventional technologies is the GCC power plant with (0.406 kg / kWh) and the total amount of CO2 is (6.672 million Mt CO2) in 2018 and (3.865 million Mt CO2) in 2035 respectively.

In reference to the optimization results of the CO2model, shown that the best technologies are PV utility and Wind turbine from RE technologies and GCC power plant from the conventional technologies in covering the required demand with minimum amount of CO2 emissions.

In the last model which is the social model (Job creation), the number of Job opportunities has been determined based on the value chain and the employment factor (Job / MWh) for the PV utility and Wind turbinefor the years (2018 – 2035). Where, the number of the jobs that would be created from PV utility in 2018 is (3821.5) and that would be reached to (8976) in 2035. Where the number of jobs that would be created from Wind turbine in 2018 (913.8) and that would be reached to (3449) in 2035. It's interesting that the optimization results regarding the best share of the power generation technologies are the same of the optimization results of the environmental model.

Finally, the four scenarios have been developed for the years (2018 – 2035) as seen in section five. In these scenarios the priorities of the robust and efficient technologies have been identified for the years 2018 and 2035. Where, the current scenario that has been identified for the year 2018 is the second scenario (Geopolitical stability and economic stagnation) and the robust option would be the GCC power plant. On the other hand, in 2035 the vision was expected to be in the first scenario (Geopolitical stability and economic growth) and the options would be the PV utility, the wind turbine and the GCC power plant technologies.

Recommendations

We Recommended the Following Actions

1. Conduct cost analysis to study the variation in the costs of the power generation technologies in Jordan based on scientific approaches and modules such as the learning curve approach.
2. Provide sufficient integrated storage soptions in order to avoid the intermission of supplying electricity from the PV utility and Wind turbine.
3. According to the social model results, we recommended to increase the local experience in manufacturing for both PV utility and Wind turbine. As well as, to conduct scientific analysis to determine the exact number of the employment factors for PV utility and Wind turbine in Jordan.

Finally, the following points are recommendations have been put for the GoJ to take into account in order to achieve the Jordan National Energy Strategy (2015 – 2025) goals:

1. Adopt the four scenarios for the electricity generation technologies in Jordan (2018 -2035) by the GoJ, in order to limit its priorities and focus on the most efficient technologies in terms of economic, environmental and social aspects.
2. Expand the developed four scenarios to include all the energy sector components (i.e. heating, transportation … etc.) in Jordan.
3. Establish a specific and separate market for electricity in Jordan and reduce the subsidies. In order to increase the competitiveness in generating the electricity, especially through the RE technologies.

Acknowledgment

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