# Economic Analysis of the Electricity Mix of Iraq Using Portfolio Optimization Approach

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**Abstract**

Many challenges facing the current and the future governments of Iraq, and one of these challenges is the situation of the power sector in the country. This study is about finding economic optimization scenarios for Iraq power mix, as the country is in dire need to minimize its power generation costs and finding the ultimate power mix structure that can help in developing the country for the better. Mean Variance Approach (MVA) is used to optimize the national power mix. It considers various costs that are involved in the power generation and the associated risks of using a particular power generation technology. The three main generation power technologies that were taken into account are gas turbines, thermal and diesel power stations in addition to the electricity imported and the generated electricity by the independent power producers (IPPs). The study proposes an optimization scenario balancing between the involved costs and risks associated with the power mix. The optimal scenario is to use around 47% gas turbines, 14% thermal, 0.04% diesel, 2% hydro and 33% IPPs.

## 1. Introduction

Iraq's economy is going through a rough time. As the country's revenues and budget are mostly based on oil exports, the budget of Iraq is mainly from the oil industry. As of 2019, almost 90% of government revenue is coming from the oil and gas sector (Iraq Energy Institute, 2018). However, due to the fall in the oil price and the COVID-19 which has reduced the global oil demand, Iraq Gross Domestic Product fell and shrank by 5% in 2020 and revert to its low-base potential of 1.9 - 2.7% in 2021-2022 (World Bank, 2020). If there is no economic improvement and the oil price and demand increase, then the revenues of the country will shrink causing the investments which are needed to develop the economy, power sector, and moving towards a diversified economy, to be delayed further. Therefore, it is important when it comes to investments in the power sector to look for an optimized efficient plan that can help to minimize the required costs to develop the power sector with the lowest possible risks.

Iraq power sector faces many issues, as the population and consequently energy demand is growing annually, the increase in generation capacity is far from satisfying this growing demand, this has led to power shortages. As it can be seen in Figure 1, the peak demand is still higher than the grid supply even though the electricity supply has increased by one third (IEA, 2019). Iraq's current peak producing power capacity is around 19.2 GW in 2020, however, due to peak demand and the rise of consumption especially in summer the country often imports from the neighboring countries. Iraq electricity mix currently relies mostly on fossil fuel operated plants, however, there are plans to start investing in solar facilities. There are some hydropower plants but due to poor maintenance, and the decrease of water flow through the dams, this has led to the decline in their power generation. Iraq current electricity generation mix is shown in Figure 2.

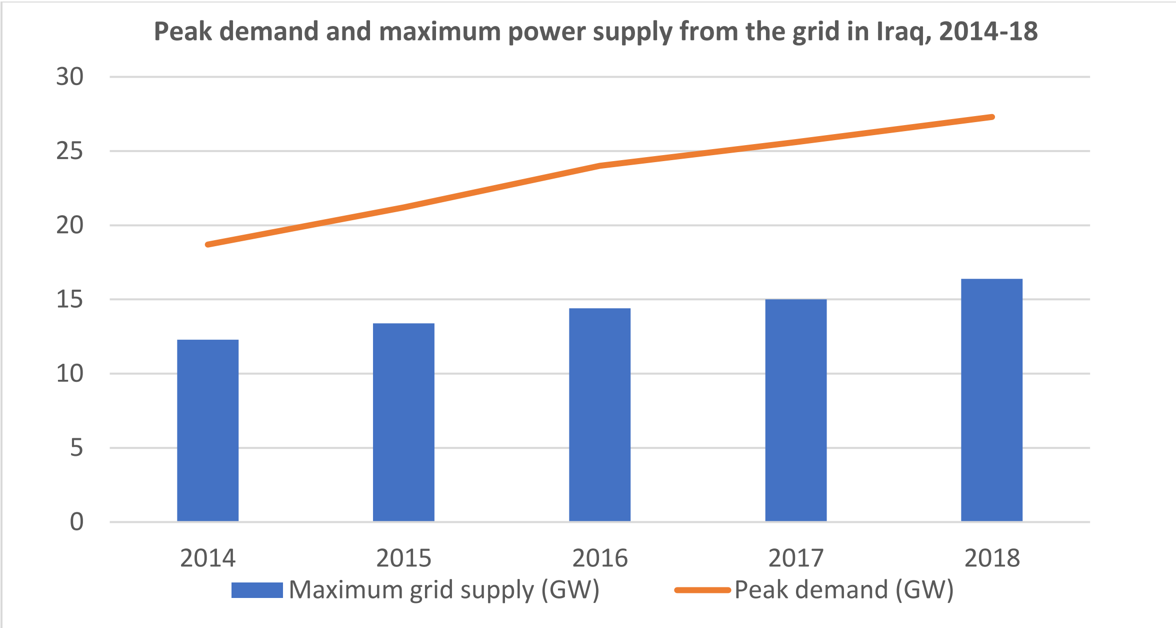


Figure 1:Peak demand and maximum power supply from the grid in Iraq, 2014-18 (Reference: IEA,2019).

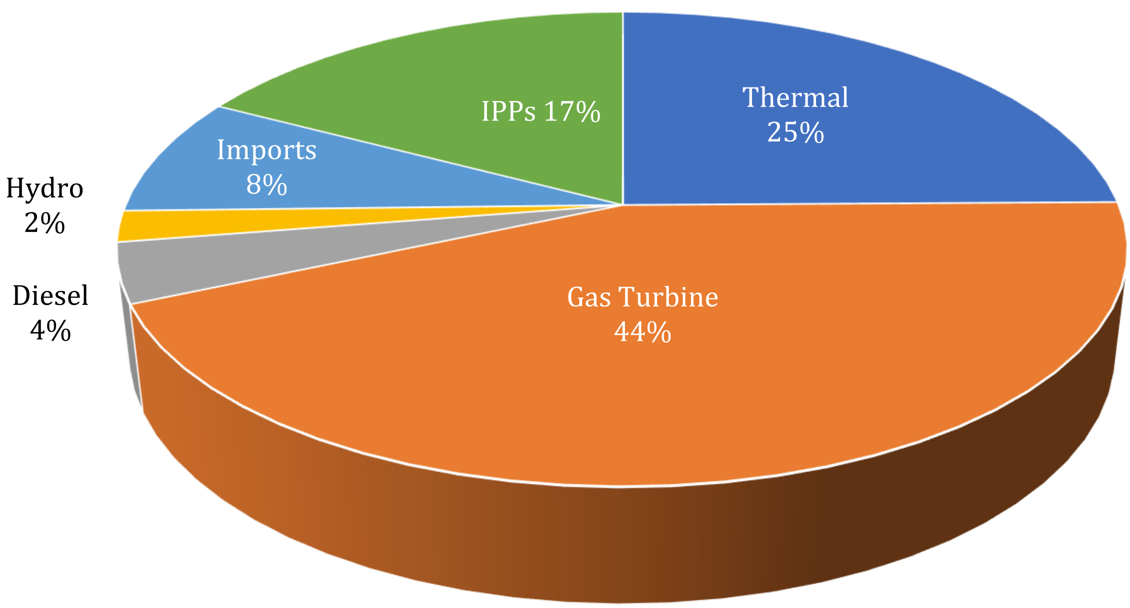


Figure 2: Generation mix in 2019 [Data Source: Ministry of Electricity]

The rest of the paper is organized in the following manner. Section 2 gives some background on the Mean-Variance Approach (MVA) and how it has been used in various cases to optimize the generating mixes in the electricity sector, and comparison between this methodology and other ones. Section 3 gives an insight into the applied model for optimization. Section 4 shows the results and economic analysis. Finally, sections 5 and 6 provide conclusion and policy recommendations.

## 2. Application of the Mean-Variance Approach in the electricity mix optimization

The method used to obtain the optimal portfolio is the Mean-Variance Approach, even though it is usually considered in the financial works to get the optimal financial asset portfolio design, however, the electricity sector also uses the method to obtain portfolios that maximize the return and minimizes the risk (Cunha and Ferreira, 2014). The traditional method to make electricity generation planning is to use the methodology which is concerned about the least cost (Zhu and Fan, 2010). The least-cost methodology is centered around using levelized-cost calculations of electricity generation, mostly conveyed in $/MWh. This is conducted for various technologies of production, followed by a comparison between those costs, and finally deciding based on the options with the lowest cost. Nevertheless, this method had come under criticism for when it is used for both private investment decision making and policy assessments.

When it comes to making energy policy decisions, various technologies can be used to generate electricity and operate in several contexts. Adding future uncertainty and complexity makes it challenging for electricity planners (Awerbuch, 2006). Also, another main factor that should be taken into consideration is the supply of fuel needed to generate electricity especially natural gas in case of Iraq, thus policymakers need to consider fuel shortages and take into account diversification of the electricity production technologies. Additionally, fossil fuel prices are volatile, and the policy maker needs to address this when deciding on what is the most suitable option for energy needs of the country.

Meanwhile, from the private investors' point of view, there are increased concerns regarding risk management due to fragile security, economic uncertainty, political instability, lack of proper legislations and widespread of corruption and nepotism. Also investing in electricity generation does not bring assured returns as many factors are playing a role in the determination of the heavily subsidized electricity price.

In this work, we are applying Markowitz's approach, which is based on mean-variance optimization and it results in an efficient frontier that gives a minimum risk for a given expected return (cost) or a maximum expected return for a given risk under preset constraints. The main assumption of this theory is that there are no transaction costs or taxes, and the investors when making the decisions are only considering the expected returns, standard deviations, co-variance of risky assets, and the return on assets have normal distributions (Gökgöz and Atmaca, 2016). The efficient frontier consists of efficient portfolios that are produced through numerical calculation of the risk (standard deviation), level of the return (cost), and correlation coefficients data. Figure 3 shows the efficient frontier, which the investor can use to choose the desired investment portfolio and see its associated level of risk. One of the applications of the mean-variance approach could be to choose the efficient portfolio in terms of power generation assets for a specific country or region (Farnoosh, 2016).

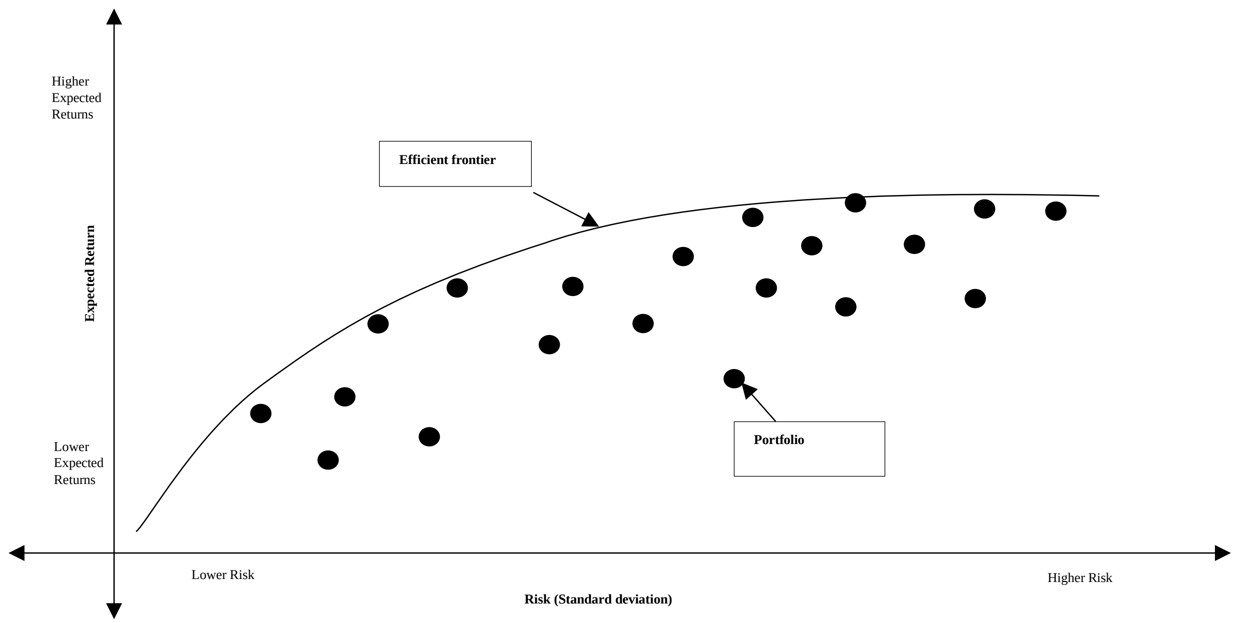


Figure 3: Schematic drawing of efficient frontier with portfolios

Rodoulis (2010) used the mean-variance portfolio to evaluate the energy mix in Cyprus. Whereby the generation mix was mostly dominated by oil which put the country under the risk of price fluctuation and high cost. While the driving force in Cyprus towards energy transition is to be less dependent on fossil fuels and move towards sustainable environmentally means of power generation (biomass, wind power, and solar) ensuring compliance with EU policies. According to Rodoulis's (2010) model, the considered power generation technologies were based on oil, natural gas, coal, and wind. The results of optimization showed that 60% of the oil is better to be replaced by natural gas, this will help in reducing the generation costs by 30% and the cost variability decreased by 15%. Also, involving wind power by 10% in the oil-gas portfolio can result in decreasing the total risk by 8%, without acquiring additional costs. However, diversifying into coal power generation is viewed as questionable because of the environmental effect and carbon dioxide ($CO_2$) price sensitivity.

Gökgöz and Atmaca (2012) employed the mean-variance approach to come up with portfolio optimization for the electricity market in Turkey. Their study considered spot market hourly prices as risky assets. The main objective was to find an optimal portfolio based on known electricity generation costs and bilateral contract prices. The study used the Turkish historical balanced market hourly system marginal and day-ahead hourly market prices between 2006 and 2011. It took into account the principle that the electricity market has generation companies and their ultimate goals are to maximize their profits and minimize their risks. So, the main risk evaluation which was considered was spot price risk.

Cunha and Ferreira (2014) used MVA to come up with optimal renewable electricity production portfolios for Portugal. In their study two mean-variance approaches were proposed, the first approach targeted portfolio output maximization and the second approach targeted portfolio cost optimization. The implemented models used data from the Portuguese electricity system collected for a period of four years. The energy mix consisted a set of renewable energy sources (RES) which were hydropower, wind power, and photovoltaic. The risk taken into account was the variability of the power output, as it depends on the intraday and seasonal variability of renewable energy sources. As in Portugal the RES comes from hydropower and wind power plants so its contributing share to the energy mix varies and vulnerable to rainfall as in 2003 and 2010 it was higher than the remaining years due to the rainy weather (37% and 52%, respectively). The study concluded that for the two models the option which is considered less risky is to have a mix of renewable energy sources making use of the diversification benefits. Also, the option which yield the highest return are the one associated with the higher risk however the structure of the portfolio relies on each technology's costs.

Costa et al. (2017) carried out a study using MVA in Brazil. They had three objectives to focus on. Firstly, was to find out an energy portfolio with the minimum worst-case volatility and a fixed maximum expected energy cost. Secondly, finding an energy portfolio of minimum worst-case expected cost with fixed maximum volatility of the energy cost. Thirdly, looking for a combination of the expected and variance of the cost, weighted by a risk aversion parameter. They used a matrix to avoid the imprecision of data when using Monte Carlo. They used robust optimization, as the mean-variance portfolio model is sensitive to changes in input. In their case, it is the covariance matrix of asset returns and expected returns of assets. So the robust optimization model works by assigning nominal values for the parameters which would represent the original model, and the uncertain parameters are assumed to belong to a set and the end model is known as the robust counterpart of the original model. Investment costs, operational and maintenance costs, and fuel costs in the LOCE (Levelized cost of energy). However, because they vary for the constructed plants and the new plants which are planned and those which are in the completion process it was to assign the cost risk according to two categories the old energy (constructed power plants) and new energy (planned power plants). They also considered three methods for LCOE which are based on CO2 emission costs ( none, intermediate, and high emission costs). As for the risk factor they took into consideration the uncertainty in terms of representing the 8 energy technologies that were used in the model classified as "new" and "old" energies, following the box, ellipsoidal, and polytopic uncertainty sets. The results obtained from the box uncertainty model found that the effect of considering a higher CO2 price will result in replacing the fossil fuels by renewables sources, which even extends to the point of reducing natural gas presence in the energy mix to 5.9%. As for the ellipsoidal uncertainty model, it shows that the CO2 emission for the portfolio obtained is higher when compared with other uncertainty models. For the polytopic uncertainty model, it is noticed that there is high participation of wind energy in both the optimal and robust cases if compared with the original reference mix. In addition, the robust portfolios include a high gas participation.

Cucchiella, Gastaldi, and Trosini (2017) used MVA to conduct a study in Italy to see the feasibility of investing in RES and what is optimum for the energy mix. This comes as it is necessary to move the hydrocarbon dominated generation mix in Italy towards using cleaner energy sources. As per the European Union target of 2020 to achieve a 20% reduction in emissions as compared to that of 1990, achieving energy use efficiency of 20% and having a renewable share of 20% in the power generating mix. The technologies involved in their study were biomass, hydro, photovoltaic, and wind. They used in their study the Sharpe Index to evaluate the portfolios where it measures the profit from each portfolio and its associated risk. Each technology used in the portfolio can vary in terms of class of power ( 10 kW- 10 MW) and its cost (Low, Medium, and High). Three optimal scenarios were found where the technologies are grouped according to the cost. The results showed that generating mixes which include technologies with large power capacities are not good options. Because even if they yield proper returns but they have a large risk margin that doesn't permit decent values on the Sharpe Index. However, the results showed that investing in small capacity power is more sustainable especially for technologies like hydro and wind. However, Cucchiella, Gastaldi, and Trosini (2017) have only looked at future investment scenarios where the energy mix only consisted of renewable resources. They did not look at the RES compatibility, efficiency, and the percentage of participation when other fossil fuels were used in the power generating mix in Italy such as coal, and natural gas.

Malala and Adachi (2020) carried out research using MVA in Kenya. The objective was to find the efficient frontier for the electricity sector to find an optimized, diversified, and lower cost portfolio that includes technologies that have low investment costs, are environment-friendly, and provide secure supply of electricity. Currently, the geothermal power and hydropower (25% and 31% respectively) make up more than half of the generating energy mix as for wind 13% and thermal power 31%. The country even has a surplus in its generating capacity, however not all areas are connected to the grid as only 56% were connected in 2016. Even though there is a surplus in electricity produced, but it is estimated that there will be a gap between supply and demand that will appear from the year 2027 as a result of population growth and industrialization. The results of Malala and Adachi's (2020) study showed the portfolio with the lowest risk is the one with the highest RES, as the fuel price volatility increases the risk. To shift to an ideal optimized portfolio, the Kenyan government will have to invest in geothermal, wind, solar, and natural gas power plants. Also financing investments is another issue, as Kenya was depending on loans to finance a big portion of the existing geothermal power plants. Thus, it is better to promote future plans by showing the return and profit that can be gained from such investments to attract investors instead of taking loans that will burden the country in the future.

In this paper we mainly focus on the mid and short term optimization of the current Iraq's energy system. Therefore, for the Iraq's model, fossil fuel power generation based on oil, natural gas, and diesel technologies were considered. As for renewables, the model takes into account the operating electricity plants and their possible mid and short-term optimization thus incorporating hydropower. But technologies needing very longer-term investment strategies, particularly in the case of Iraqi energy system, such as solar facilities can be considered in future studies. The risk of securing the liquid fuel especially crude oil and HFO needed for power generation is considered to be much lower in Iraq, as almost half of the energy mix relies on crude oil used for thermal power stations which is available locally, besides a big portion of the gas needed to power the gas turbine is used from local production. Moreover, the electricity market is mostly dominated by the Ministry of Electricity (MoE).

In Iraq, as MoE is the main supplier there is no significant profit gained from providing electricity as it falls under government obligation, and money collected is unable to cover operating expenses. Due to the dependence of the Iraqi budget on the revenues from oil production and sale, the budget is highly vulnerable to variations. Thus, this study is focused on energy obtained from technologies that are currently operating and their future development. While future non-probable investments were not considered. Another concern is the attraction of investors and getting financial aid to develop the electrical sector, which could be challenging due to the unstable security and related uncertainties.

## 3. The optimization model's framework and structure

Portfolio theory gives the advantage for the investors to choose the best portfolio that makes them avoid the extra risk associated with the investment. If the Iraqi government is considering investing in assets to generate power, then an appropriate measurement would be the total cost of power generation per unit of energy ($/kWh) which is equivalent to the inverse of a return (kWh/$) (Farnoosh, 2016).

In this study, the expected portfolio cost is the weighted average of the expected generating costs. Each portfolio includes costs of electricity generated by gas turbine, thermal, diesel, hydro, imported electricity and electricity generated by the independent power producers, as shown in the following equation:

$$E(Cp) = X_1 \times E(C_1) + X_2 \times E(C_2) + X_3 \times E(C_3) + X_4 \times E(C_4) \qquad (1)$$

In which $X_1$ , $X_2$ and $X_3$ represent the fractional shares of three technologies involved in the generating mix and $E(C_1)$, $E(C_2)$ , $E(C_3)$ and $E(C_4)$refer to the expected levelized costs per kWh. $X_4$ represents the electricity produced by hydro power stations, electricity produced by IPPs, and imported electricity. For the imported electricity, the cost taken into account is 0.0925 $/kWh (Iraq paid $ 432.62 million in 2018 for generating 4,678,144 MWh) and MoE purchased electricity from the independent power producers at an average price of US¢ 9 per kWh (data from MoE annual report 2018 and IEI Iraq Residential Tariff Reform Analysis, 2018). The average costs for the IPPs and Imported electricity were used to represent the 27% contribution share, however the hydro contribution which is about 2% was included in the average due to lack of data in terms of operational cost for hydro power stations.

The expected portfolio risk E $(\sigma p)$ refers to the difference in the year to year of generation cost. It is the weighted average of the single technology cost variances, as influenced by their covariance:

$$E(\sigma p) = (X_1^2\sigma_1^2 + X_2^2\sigma_2^2 + X_3^2\sigma_3^2 + X_4^2\sigma_4^2 + 2X_1X_2\rho_{1,2}\sigma_1\sigma_2 + 2X_1X_3\rho_{1,3}\sigma_1\sigma_3 + 2X_2X_3\rho_{2,3}\sigma_2\sigma_3)^{0.5} \quad (2)$$

Whereby $\sigma_1$, $\sigma_2$ and $\sigma_3$ represent the standard deviations of the holding period returns of the annual cost technologies and $\rho_{1,2}$, $\rho_{1,3}$ and $\rho_{2,3}$ are their correlation coefficient between two technologies costs. As for the standard deviation for the imported electricity and the electricity generated by the independent power producers it was taken as zero as the cost values are fixed.

The holding period returns measures the change rate in the cost of stream from one year to another, and it is estimated by the following equation (Awerbuch and Berger,2003):

$$Holding\ Period\ Returns = \frac{Cost\ in\ year\ (\ t{+}1) - Cost\ in\ year\ (t)}{Cost\ in\ year\ (t)} \quad (3)$$

As previously explained (section 2°), in the Iraqi case, there are three technologies involved in the generation mix which are gas turbines, thermal and diesel power stations. So, the total expected portfolio cost of the Iraqi mix is:

$$E(C_{Iraq}p) = X_{gas} \times E(C_{gas}) + X_{thermal} \times E(C_{thermal}) + X_{diesel} \times E(C_{diesel}) + X_{IPPs+imports} \times E(C_{IPPs+imports+hydro}) \quad (4)$$

As for the total expected risk (standard deviation) of the portfolio:

$$E(\sigma_{Iraq}p) = (X_{gas}^2\sigma_{gas}^2 + X_{thermal}^2\sigma_{thermal}^2 + X_{diesel}^2\sigma_{diesel}^2 + 2X_{gas}X_{thermal}\rho_{gas,thermal}\sigma_{gas}\sigma_{thermal} + 2X_{gas}X_{diesel}\,\rho_{gas,diesel,}\sigma_{gas}\sigma_{thermal} + 2X_{thermal}X_{diesel}\rho_{thermal,diesel}\sigma_{thermal}\sigma_{diesel})^{0.5} \quad (5)$$

Where the shares and costs of the Iraqi power generation technologies are $X_i$ and $C_i$ respectively. The standard deviation for each technology is $\sigma_i$ and the correlation coefficient between the different fuels used in the technologies is $\rho_i$, measured in power units. For the correlation between the fuel prices used for different technologies, thermal power stations are operated by crude oil, for diesel power stations they are operated by diesel, and for gas turbine power stations they are operated by gas, the price of the gas imported from Iran was the one taken into consideration as reference price 1. Figure 4 represents the correlation between these fuels.

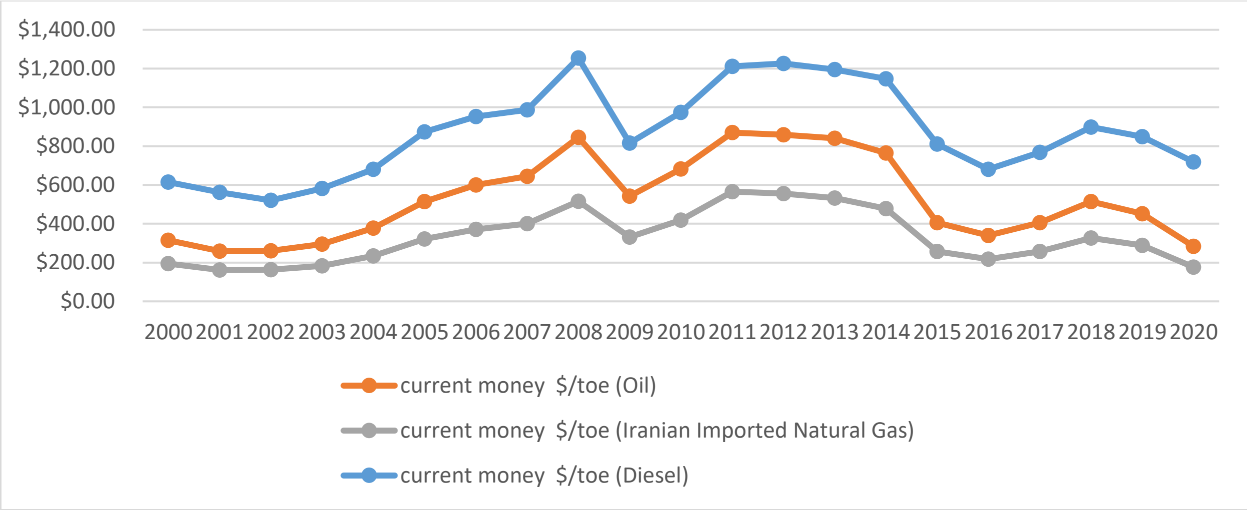


Figure 4: Correlation between different fuels used in generating mix

Table 1: The correlation coefficients between the fuels used in different technologies

| | Crude Oil | Imported Iranian Natural Gas | Diesel |
|---|---|---|---|
| Crude Oil | **1** | | |
| Imported Iranian Natural Gas | **0.99839663** | **1** | |
| Diesel | **0.98001395** | **0.980195703** | **1** |

In the model Monte Carlo simulation technique is used. Where calculations are performed by the simulation to create different outcomes using normal distribution based on the contribution share of each technology given for each generating mix combination.

The cost of each power generation unit is given to the simulation model. Table 2 shows the initial input values for the normal distribution. The values of the diesel are assumed to be similar to that of thermal due to the similarity of the two technologies and lack of precise data. Different portfolios have been considered in the simulation process and each portfolio represents a different share structure of various technologies producing in the generating mix. These different scenarios were considering that the Iraqi government intends to reduce its dependency on thermal power stations and reducing the imported electricity, while increasing the share of gas turbines. The data in Table 3 represents each technology and its contributing share to the current state of the generation mix.

Table 2: Technology Risk Estimates /Standard Deviation (Iraq Energy Institute,2020)

| | Fuel Cost $/kWh | Operation Cost $/kWh |
|---|---|---|
| Gas Turbines | 0.0667 | 0.0408 |
| Thermal | 0.016 | 0.009 |
| Diesel | 0.016 | 0.009 |

Table 3: The current power generation mix in Iraq and the standard deviation of the total cost for each technology

| Current situation | | |
|---|---|---|
| | Contributing share to generation mix (x) | Standard deviation |
| Gas | 0.44 | 0.06373 |
| Thermal | 0.25 | 0.018813 |
| Diesel | 0.04 | 0.016112 |
| IPPs + Imported Electricity+ Hydro | 0.27 | 0 |

For each variable a set of thousand trials was performed to obtain the final required result. The total cost of the portfolio is the total of all the levelized costs distribution, so the Monte Carlo simulation generates the total cost of the portfolio. The calculated current cost and current risk according to the MVA (eq.1 and eq.2) are 0.08533$/kWh and 0.03337 standard deviation respectively. While the current costs with subsidized fuel and without subsidized fuel according to 2018 MoE's data are shown in Table 4:

Table 4: Electricity generation costs

| | | |
|---|---|---|
| Total generated electricity (MWh) (MoE, annual report 2018) | 106,174,608 | |
| Net sold electricity (MWh) (MoE, annual report 2018) | 39,593,993 | |
| | With Subsidized Fuel | Without Subsidized Fuel |
| Total cost of electricity production (billion IQD) [billion US$] (MoE and IEI Analysis ,2018) | 7,218 [6.04] | 12,032 [10.07] |
| Cost (IQD[USD]/kWh) = (Total cost of electricity production / Net sold electricity) | 182.3 [0.1525] | 303.9 [0.2543] |
| Cost (IQD[USD]/kWh) = (Total cost of electricity production / Total generated electricity) | 67.97 [0.0569] | 113.26 [0.0948] |

There are some differences between the current cost calculated using MVA (0.08533$/kWh) with that calculated from MoE's data when it's compared with the cost based on the net electricity sold (0.1525 $/kWh with subsidized fuel, and 0.2543 $/kWh without subsidized fuel). However, if the cost estimated by MVA (0.08533$/kWh) is compared with the cost for the total electricity generated (0.05689 $/kWh with subsidized fuel, and 0.0948 $/kWh without subsidized fuel) is the value is very close.

The difference in costs can be attributed to the different expenses that may have been taken into account, as for the model the calculation is based on the operational cost and the fuel cost.

**4. Results and economic analysis**

Figure 5 shows the obtained efficient frontier from the MVA model. It is observed that the most significant effects in the model are attributed to gas turbine and imports. Increasing the use of gas turbines decreases the cost, while the imports' increase is going to drive up the cost. In the model the risk may decrease when the imports are going to increase, however it will still have a high-risk effect in real life as the country will be depending on foreign imports outside of its control.

The cost in the current situation can be lowered than the average actual cost and the estimated cost by the model, with the same risk, if the Iraqi government can achieve a situation where the contributing technologies shares match the efficient frontier curve. Table 5 shows the optimized cost and risk and the reduction percentage for the costs. The contributing shares in the generation mix of the optimized portfolio consists of around 47% gas turbines, 14% thermal, 4% diesel, 2% hydro and 33% independent power providers. Hydro power was assumed to have a fixed contribution due to the saturation of Hydro technology in Iraq and the fact that there is no more new investment opportunities except for improving the existing sites . Although IPPs and imported electricity were merged under the same contributing share as the imported electricity have almost the same cost of the IPPs, but IPPs are more economically viable as they provide employment opportunities and contribute to the country growth. Reducing the cost further down horizontally will cause the risk to increase, also it will result in the reduction of IPPs and growth of gas technology operated by the MoE. However, it does not come with the long-term plans of the government to decentralize the electricity market towards more privatization and reducing the operating expenses.

The optimized portfolio suggested by this study aligns with the future plans of the Iraqi government as it intends to reduce the dependency on imported electricity and thermal power stations and to utilize the gas turbine power stations.

Table 5: The current cost and risk for the current situation portfolio

| | **Current situation** | **Optimized portfolio** | **Cost Reduction Percentage** |
|---|---|---|---|
| **Cost ($/kWh)** | 0.0569<br>(based on actual average cost) | 0.0394 | -30.79 %<br>(based on actual average cost) |
| | 0.0853<br>(based on MVA estimation) | | -53.86 %<br>(based on MVA estimation) |
| **Risk (standard deviation)** | 0.0334 | 0.0335 | - |

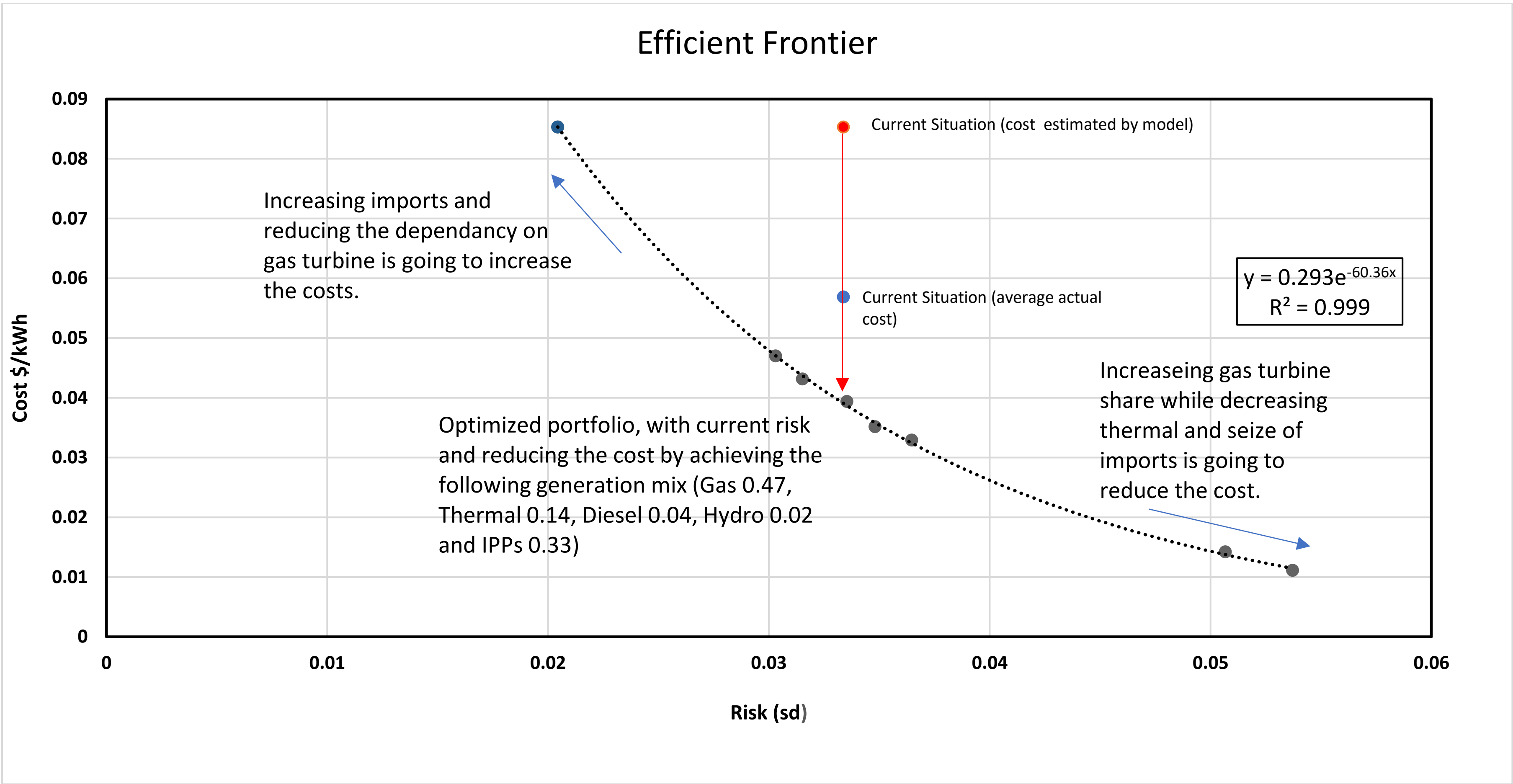


Figure 5: Efficient frontier and the optimization's results.

## 5. Conclusion

Iraqi power sector currently is in a dire state as the production of electricity is below the average demand. The country depends very much on fossil fueled power stations for electricity generation and this is harmful for the environment because of both local and global pollutions generated by those plants. Moreover, the crude oil used as fuel for thermal power stations can be exported if thermal power stations are replaced with associated gas to operate the turbine power stations. As reported by (Saadi, June 2020) the deputy oil minister said that Iraq is planning to move ahead with plans to develop associated and free gas projects in the coming two to three years. If the Iraqi government accelerates the development of the natural gas sector then there will help in providing the needed gas for the gas turbines, this will fasten the possibility of replacing thermal power stations with gas turbines. When it comes to the current socio-political situation of Iraq, the electricity sector is one of the main priorities for governments because dissatisfied people may protest which can lead to unrest as it happened in the past. Thus, focusing on optimized planning is necessary to ensure rational and successful investment for the future.

Lastly, this study is limited to the current situation based on the short and midterm strategies in which there is no intention for any investment in new technologies and the main and absolute priority of the Iraqi authorities is to become able to satisfy the current demand and eradicate the energy poverty of households and industries. However, it is highly recommended for the long-term strategy that other alternative renewable technologies than Hydro (e.g. solar and wind) to be considered in future studies to give more investment options and solutions.

## 5. Policy Recommendations

In order to achieve the desired energy mix, there are some policies that need to be implemented to pave the way for that transition.

Iraq needs to work on its fuel switching and to achieve this by replacing the inefficient fuels used to generate power such as crude oil with cleaner and economical alternatives such as heavy fuel oil, gasoil and diesel. This can be done by augmenting the existing fuel processing projects and building new ones.

Supplying gas to power streams should become another priority by investing in infrastructure that is able to transport the gas needed and make sure to link it to the power stations as this will reduce the dependency on imported gas. At the same time, this strategy will provide Iraq with alternatives, such as replacing imported gas with gas produced in Kurdistan region (Saadi, November 2020). Additionally, the government should start looking at reducing the costs for oil production. By upgrading the current facilities, the government can increase the efficiency and reduce the operation and maintenance costs. The country could also invest in gas capturing, not only to reduce flaring (as a large part of the associated gas is flared) but also to provide the necessary fuel to gas plants instead of importing the gas.

Implementing tariff reform would be also essential for Iraq's energy system sustainability. A large part of the losses in tariff collection happens in the housing sector, as it makes up of 48.3 percent of the total number of consumers (Istepanian, 2020). One of the main issues facing the electricity sector is the tariff collection, theft, and power piracy as there are many who do not pay for electricity and this results in the government paying on their behalf (Dourian, 2020). A gradual subsidies removal (or at least a significant decrease) should be applied by setting a percentage of reduction annually. Even then, the differences in society in terms of wages and income should be taken into account.

A new detailed bill is needed that show the breakdown of the price of consumed electricity and help in monitoring the consumption. In terms of measuring and controlling the electricity use, the government should invest in having a new metering system that allow for precise and well-timed billing that give the consumers control over their electricity usage (IEI,2020). Also, the government should look into improving customer service in electricity departments, and providing different payment methods such as online payment.

Increasing the IPP share in generation mix and power purchase agreement (PPA) model implementation in Iraq will also help moving the electricity sector towards competition. Using IPP system takes off the burden from the MoE in terms of operational cost as private sector is more flexible in terms of only employing the necessary manpower.

In parallel with making investment in increasing the generation capacity, the government should consider investing in the transmission and distribution infrastructure to limit the aggregated technical and commercial (AT&C) losses. As the AT&C losses that occur to the generated electricity when it is transported reached over 58% in 2017 (IEI,2020).

Last but not the least, in the long-term investing in renewable technologies is a viable option for Iraq. Solar power can be utilized on a large scale in the western and southern part of Iraq, where the solar radiation duration is between 2,800 to 3,000 hours per year with over 6.5 - 7 kWh/m$^2$ horizontal irradiation per day (IEA,2019). However, providing incentives for more investments in those assets and their sustainable development would not be possible without first reforming the current techno-economic situation of the Iraq’s energy system.

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