ASSESSMENT OF PRICE POLICIES IN THE POWER MATRIX OF SAUDI ARABIA UNDER THE SCOPE OF VISION 2030

Harif D. Fontecha, King Abdullah University of Science and Technology, 966 56 5457598, harif.fontechasanchez@kaust.edu.sa
Shashank Nagaraja, King Abdullah University of Science and Technology, 353 89 9544184, shashank.sakleshpurnagaraja@kaust.edu.sa
[Mani Sarathy, King Abdullah University of Science and Technology, 966 54 4700556, mani.sarathy@kaust.edu.sa]

Overview

Environmental and economic impacts are often seen as two disparate forces in the energy sector. For instance, more environmentally friendly alternatives tend to have an economic disadvantage and vice versa. Nevertheless, a selection of strategies has also demonstrated that environment and economics can coexist and in synergy. Such strategies are highly dependent on the policies and resources of each country. Hence, the goal of this work is to evaluate how different pricing policies affect the demand of electricity, as well as how they affect how much renewable energy should be used in an optimized grid mix by 2030.

By 2030, in a scenario free of reforms, liquid fuels would provide more than half of the fuel energy consumed for generation and would emit around 64% of the emissions. However, they would only represent 10% of the fuel costs at a domestic price.

In this work, the effect and pertinence of reforms to the electricity price and to the fuels consumed for generation are addressed. Tariffs for countries with similar size of economy are taken as a reference.

1. To elaborate a techno-economic evaluation of the status of the Saudi electricity grid mix and its associated greenhouse gas emissions.

2. To forecast the demand of electricity of Kingdom of Saudi Arabia by 2030, considering the effect of global warming and comparing the potential impact of changes in the price policies of electricity.

3. To calculate the optimized power mix needed by 2030 to supply for each demand scenario under the methodology of Capacity Expansion Planning.

The Capacity Expansion Planning (CEP) scenarios are as using the software PLEXOS and the optimization is done using CPLEX which works under.

Methods

We divide the Kingdom into 4 areas, adhering to the National Grid's boundaries through 2019. The demand scenarios were constructed using a variety of econometric models developed by KAPSARC, taking into account the impact of factors including weather, GDP per capita, power price, and population increase.

The weather variable was quantified using the concept of *Cooling Degree Days* and *Heating Degree Days*, which is an indicator of the amount of energy required for cooling and cooling, respectively, each year. Plotting historical data reveals a rising tendency. Despite the variability of the weather data, particularly in recent years, a linear model was used to project the future rate of climate change.

Three scenarios were defined based on the intentions of the Ministry of Energy to increase private participation in the national power market. For that, electricity prices were modified and the corresponding demand response is calculated. The scenarios are defined as follows:

1. Business As Usual Case (BAU): The current tariff of electricity remains untouched.

2. Transitional Case (TRN): The tariff of electricity for the residential, governmental and commercial sectors increases by 100% by 2030, with a 50% increase in 2023 and the other 50% increase in 2028. The tariff of electricity for the industrial and agricultural sector is increased by 44% in 2025 to reach international levels.

3. International Tariff Case (INT): The tariff of electricity for the residential, governmental and commercial sectors increases by 200% by 2030 to reach international equivalent values, with a 100% increase in 2023

and the other 100% increase in 2028. As well as in the Transitional Case, the tariff of electricity for the industrial and agricultural sector is increased by 44% in 2025 to reach international levels.

Afterwards, Capacity Expansion Planning (CEP) cases were optimized for each of the four regions, from 2022 to 2030. The optimization of the scenarios was done using Mixed Integer Linear Programming. Historical electricity demand and the distribution of generation per technology was taken from WERA public yearly reports and its official website. The technologies considered are gas turbines, steam turbines, combined cycle, cogeneration, diesel engines, PV, wind and nuclear energy. The historical distribution of fuel used for electricity (considering Crude Oil, HFO-380, HFO 180, Diesel and Gas) was taken from WERA public yearly reports and publications from KAPSARC.

Wind characteristic profiles were taken from the *Global Wind Atlas* web page and solar characteristic profiles were taken from the European Commission's PVGIS maps. The efficiencies of existing turbines were established according to datasheets of General Electric and the efficiencies of new turbines were assumed to be as those of the GE H-Frame turbine.

Typical Wind Turbine Output profiles were taken from NRELs System Advisor Model using the Vestas Turbine Model V150/4000-4200 as reference. This turbine reference has already been used in the Kingdom, more specifically in the Al Jubail project. Typical Solar Efficiencies were taken from the NRELs System Advisor Model.

Fixed and variable costs of each technology/fuel combination considered after filtration were defined based on the IAE Report: "Projected Costs of Generating Electricity" 2020 Edition.

Results

The characteristic regional differences in demand response were addressed. The demand per capita is the largest in the eastern region, followed by the central, west and south regions, in that order. Diverse authors have addressed this to the income level of each region, as well as the inherent existing infrastructure.

The eastern region has shown to be more sensitive to changes in the electricity price, which can elucidate the space for improvements in energy efficiency through awareness programs. In contrast, the demand of the western region is the most sensitive to income variations. As expected by its milder weather conditions, the southern region is the least sensitive to anomalous fluctuations of hot weather. Cold weather, in contrast affects only the demand of the southern and central regions, where temperatures in the winter can reach temperatures below 10°C.

When computing the three electricity pricing scenarios, it was found that the demand for the TRN case is 6.4% lower than the BAU case. Additionally, the demand of the INT case is in total 9% lower than in the BAU case.

We found that raising the electricity price to international tariffs could reduce the demand projections for 2030 by up to 9%. Being the industrial sector more sensitive to price changes than the residential sector.

The distortion between fuel price and consumption could be adjusted by increasing the domestic fuel prices to 30% of the international reference, which affects mainly liquid fuels. In this scenario, photovoltaic panels (PV) become a competitive substitute for gas turbines (GT). However, renewables would not exceed 43% of the total capacity and 28% of the energy generated without the early retirement of firm capacity. The resulting cost of emissions avoided by reforming fuel prices is of $43/ton CO2eq.

Simultaneously reforming electricity prices and fuel prices would favor the penetration of renewables without additional costs of investment. Besides, the marginal cost of electricity would remain close to $45/MWh.

Finally, reforming the price of fuel and exporting the saved fuel would derive in additional revenue of up to $6.6 billion by 2030, and would reduce the annual emissions by 2030 by up to 66 million tons of carbon dioxide. The economic gain from exporting the fuel saved by 2030 would be enough to relieve the additional cost in the electricity bill to the residents which represent 73% of the total consumption, through social programs.

Conclusions

Reducing the demand through electricity price reforms has been effective so far. However, further increments in the price will be considerably less impactfull in the demand. Increasing the electricity tariffs towards international prices (INT case) reduces the demand 9% contrasted with the BAU case. Around 70% of the same impact can be effected by a, less aggressive, intermediate pricing policy change (TRC case), with a demand that is 6.4% lower than the BAU case. Social awareness campaigns and the installation of smart meters are examples of additional strategies that do no affect economically the users and can be more effective.

Combined cycle gas turbines (CCGT) remains as the most efficient and cheapest technology available if no price reforms are levied (REF). In this scenario, the limited access to gas in the southern region forces the installation of new gas turbines (GT). The potential for wind turbine (WT) projects is limited in the Kingdom. Only 5 GW of WT in the windiest part of the western region (NEOM) is economically competitive.

In a scenario free of reforms (REF), liquid fuels would provide more than half of the fuel energy consumed for generation, and would emit around 64% of the emissions by 2030. However, they would only represent 10% of the fuel costs at a domestic price. This distortion could be adjusted with an adjustment to the domestic fuel prices to 30% of the international reference, which affects mainly liquid fuels. Under this scenario, photovoltaic panels (PV) become a competitive substitute for gas turbines (GT).

Even with a drastic reform, renewables would not exceed 43% of the total capacity and 28% of the energy generated. Additional shares of renewables would only be possible with the early retirement of existing firm capacity. The additional investment costs of the S30 reform would be 19% larger than the reference case (REF). Nevertheless, the reduction in demand caused by simultaneously levying an electricity price reform (S30-MID) would take the additional costs of investment to zero.

Reforming the price of fuels would reduce the annual emissions by 2030 by up to 66 million tons of carbon dioxide, or 12% of the annual emissions of the reform-free scenario (REF). Finally, the economic gain from exporting the fuel saved by 2030 would be enough to relieve the additional cost in the electricity bill to the residents which represent 73% of the total consumption through social programs.