HOW TO DIVERSIFY A FOSSIL-FUEL ECONOMY: OPTIMISING A POST-CARBON FUTURE FOR QATAR

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Overview

In April 2017, Qatar lifted its moratorium on expanding production from the North Field: the world's biggest gas field, which is shared between Qatar and Iran. Three months later, Qatar announced a 30% increase in liquefied natural gas production capacity. Being the biggest player in global LNG, these decisions will affect not only global gas markets, but also Qatar's own economy for the next decade or more. Apart from LNG, Qatar exports pipeline gas, crude oil, liquid fuels, fertilizer, plastics, steel, and aluminium, among other products, all of which are reliant on the country's hydrocarbon reserves, and make up around 90% of the country's export revenues [1]. Its domestic energy needs are met almost entirely by natural gas, whether for electricity generation and water desalination, or by liquid fuels for passenger and freight transport. Qatar has a growing population that is used to cheap, subsidised, energy and water, and recent geopolitical events have increased its desire to be self-sufficient in terms of its food, energy and water resources.

The aim of this research effort is to use the tools of data analysis and optimisation to inform the energy policy of Qatar. Our model uses historical data on energy and water consumption across the residential, commercial, industrial, agricultural and transportation sectors, in order to forecast future trends. This data is fed into a tailor-made energy systems optimisation model, which provides us with long-term infrastructure planning policies under various scenarios such as changes in global commodity markets and technological disruptions. Our results demonstrate that Qatar should diversify its energy exports by investing in hydrogen production (by steam reforming of natural gas). The country can also decarbonise its transport sector by electrification and its domestic power sector by large investments in solar energy. Policies such as rolling back subsidies for fossil fuels and domestic electricity are also recommended, but risk disturbing the social contract between the rulers and their subjects. While the Qatari economy can adapt well to decarbonisation at the customer-end, investments in carbon capture and sequestration will be required in order to bring down emissions at the source. Our model can provide policymakers with a blueprint for Qatar's energy transition.

Methods

We developed a database of historical trends across the industrial, transportation, residential, commercial and agricultural sectors in Qatar, with a focus on energy and water use. We correlated energy use with population in order to determine the future trends of energy consumption across these sectors. We also looked at data on Qatar's energy industry to map out the key products from each company, and how they fit into the domestic and international markets, in order to understand how Qatar's long-term sales commitments influence future investments in its energy infrastructure. This analysis laid the ground-work for our optimisation model.

We developed an energy systems model using the linear-programming framework of the Resource-Technology Network model developed within our research group [2]. Raw materials, finished products, water, electricity, end-use services such as air-conditioning, and even emissions, can be represented as resources that are produced, transformed or consumed by technologies such as power plants, cars, and chemical refineries. The costs of each technology and the prices of various resources are fed into the model, along with other parameters such as fossil-fuel subsidies, domestic demands, export commitments and a hypothetical carbon tax. Constraints such as production limits on oil and gas, retirement of old technologies, and balancing of supply and demand, for each resource, at each time step, are the core of the model. The objective function is the sum of revenues and expenses over the length of the modelling horizon, with a small discount rate on future cash flows. The model is evaluated at five-year time periods from 2020 to 2050, and has six seasonal/diurnal time steps. Due to its linear nature, the solution is obtained almost instantaneously. Our model was developed in AIMMS due to the software's graphical capabilities.

Results

We ran our model under various scenarios such as changing commodity prices, removing domestic subsidies and adding a hypothetical carbon tax. We found that in most scenarios, the optimal energy infrastructure included large solar photovoltaic capacity for domestic electricity consumption, decarbonisation of passenger and freight transportation (either electric or hydrogen) and the use of district cooling as an efficient form of residential and commercial air conditioning. The addition of an internationally-imposed carbon tax did not do much to change the energy infrastructure, mostly because of Qatar's reliance on hydrocarbon industry forcing it to pay up the emissions tax and continue business as usual. Finally, our model indicated a long-term shift towards large-scale hydrogen production from natural gas for export, which could bring home larger revenues than the LNG business given global trends in decarbonisation. In order to be truly post-carbon, however, the hydrogen production infrastructure will have to be combined with large-scale carbon sequestration capacity.

Conclusions

The aim of our work was to develop a quantitative model for the planning of energy infrastructure in Qatar over a thirty-year horizon. We have developed an extensive database on the energy production and consumption patterns in the country, which were used to forecast future trends. Our results demonstrate the large potential for solar power, electrification of transportation, centralisation of cooling and new ways of monetising the country's large gas reserves. Policymakers will find our tool useful in order to quickly simulate how the energy infrastructure must evolve under global and local scenarios, and use the results from our model to develop new policies and review existing ones.

References

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