Qatar energy storage for demand response

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The reliance of Gulf States on fossil fuels has led to domestic challenges as well. Unsustainable energy and water use in the region, driven in part by energy subsidies, has contributed to environmental degradation: from increasing groundwater salinity [3] to urban air pollution [4]. Moreover, anthropogenic climate change will lead to severe environmental and social consequences in the Middle East [5]. It is in the interest of all countries in the region to mitigate the effects of these changes through long-term planning by deploying technologies and policies that can lead to sustainable resource use.

Optimization tools were first applied to economic planning and later extended to energy systems modeling [6]. Until now, there has been limited use of such tools in the Gulf States. Almansoori and Betancourt-Torcat modeled the electricity system in the UAE, using a stochastic approach to determine the effects of uncertain natural gas prices [7]. Established energy system models have also been used to study energy policies for Kuwait (using TIMES-VEDA) [8] and the UAE (using MARKAL) [9]. The Saudi case was modeled using a mixed-complementarity model that integrated the energy system into the wider economy [10].

Qatar''s energy economy is unique in that it is tailored towards the export of processed hydrocarbons. The country''s domestic resource consumption uses only a small fraction of the energy infrastructure. Our work is the first optimization approach applied to the Qatari energy system as a whole: across the largest sectors of the economy, and covering major energy products, from natural gas and hydrocarbon fuels to electricity and desalinated water. Our aims are two-fold: first, to develop an open-source tool that can be used for national-level planning and policymaking, and second to use this tool to generate key technology and policy insights that can aid the transition of Qatari energy infrastructure in the long term.

Qatar has a unique energy system. The country''s infrastructure is geared towards producing and exporting large volumes of natural gas, either directly (in a gaseous or liquefied state), or conversion to liquid fuels (gas-to-liquids) and petrochemicals. Domestic demand for electricity, water (mostly produced by thermal desalination), and liquid fuels, plays only a small part in the national energy economy, and these resources are subsidized by the state. Large investments in infrastructure, across all sectors, are funded wholly or partially by the government. All large-scale industries are either state-owned or closely regulated by the government. Hence, we assumed that there is only one actor, the state, whose economic objective is to be maximized.

We developed a tailor-made optimization model, called the Qatar Energy System Modelling and Analysis Tool (QESMAT), to accurately capture the peculiarities of the Qatari energy system. The Arabic word "kismet", also used in English, means "fate" or "destiny". Our optimization model can be used to plan for Qatar''s kismet. The following sub-sections describe various parts of our research methodology.

Historical population data and forecast

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We developed an energy service demand forecast to 2050, which generated demands for residential and commercial energy consumption (for cooling, water, and electricity), along with service demands for passenger and freight transportation.

For sectors that were based on demographics, such as residential and commercial infrastructure, per-capita service demands were used to project energy needs based on currently available technologies and changing population. We used two values of per-capita service demands (a higher and lower value) to determine "high" and "low" domestic demand scenarios for the uncertainty analysis. In the residential sector, we divided the population into small and large households (aligned with the census data), and determined the energy service needs of populations living in each type.

Residential electricity and water consumption is linked to the populations that reside in "households"--the state utility considers the demand from labor accommodation within the "commercial" sector, and we use the same approach to maintain consistency.

Electricity requirements for household populations were calculated using per-capita cooling, lighting, and appliance needs, adjusted by annual factors for efficiency improvements, increased energy needs, and increased cooling need due to climate change. These parameters, for high- and low-demand scenarios, are listed in Table 2. All of these parameters are estimated by us, so that the resulting forecast, when extrapolated to the past, provides upper and lower bounds for the historical data (from IEA, Kahramaa, and ministry reports) (see Fig. 2 for an example of this approach).

Historical water demand (residential use) and forecast

The annual residential electricity demand is then calculated using Eq. (1)

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