Survey and analysis of the quantitative methods used in electricity research on GCC countries: 1983–2018

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ABSTRACT

This study provides a systematic analysis of research on the electricity sector in Gulf Cooperation Council (GCC) countries in the period 1983–2018. GCC countries have experienced tremendous economic growth in the past few decades. This was accompanied by a corresponding increase in electricity consumption. Therefore, a thorough review is needed to understand the research conducted on the electricity sector in GCC countries. This study reviewed articles published in five well-known energy journals: Applied Energy, Energy, Energy Economics, Energy Policy, and Renewable and Sustainable Energy Reviews. The articles were classified into seven categories based on the analysis tools implemented in the papers: 1. Simulation tools, 2. Scenarios tools, 3. Equilibrium tools, 4. Top-down tools, 5. Bottom-up tools, 6. Operations optimization tools, and 7. Investment optimization tools. This study also provides an overview of the research, including the increase in publications over time, an authorship analysis, a keywords analysis, and an analysis of the length of the publications.

1. Introduction

Gulf Cooperation Council (GCC) countries have experienced tremendous economic growth during the last four decades. This economic growth was accompanied by corresponding growth in electricity demand and supply. The average growth rate of electricity consumption per capita for GCC countries in the period 1971–2012 is 6.2% (Osman et al., 2016). Because of this marked increase in electricity demand and the expensive nature of investment in the electricity sector, several academic research papers have been published that address various aspects of demand and supply in GCC countries. This study aims to provide a synthesis of the research published in five well-known energy journals. These journals are Applied Energy, Energy, Energy Economics, Energy Policy, and Renewable and Sustainable Energy Reviews (RSER). To the best of the author's knowledge, this is the first study to provide a bibliographic analysis of current electricity supply and demand research in GCC countries. The author hopes that this literature review will provide researchers with a comprehensive understanding of electricity supply and demand issues in GCC countries. This review may also help these researchers to investigate important areas not yet explored. The author has attempted to include all publications pertaining to the supply and demand of electricity in GCC countries. However, there is no guarantee that all papers are included or identified. If any paper was published in the five aforementioned journals and not included in this research, please feel free to contact the author.

2. Main text

2.1. Methodology

Literature reviews on published research in a specific scientific domain is critical for gaining a deeper understanding of the relevant issues and problems of the research area. For example, Emrouznejad and Yang (2018) provided a comprehensive list of published articles that used Data Envelopment Analysis (DEA) as an analysis tool. In the energy domain, Pfenninger et al. (2014) reviewed energy systems modeling for twenty-first century energy challenges. They grouped the models into four categories: energy systems optimization models, energy systems

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2405-8440/© 2019 The Author. Published by Elsevier Ltd. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).
The detailed distribution of this number among the analytical tools used, yearly publication, number of authors, keywords representing 36%, followed by the UAE with 18%.

Articles were published about the electricity system in Saudi Arabia, followed by Applied Energy with a percentage of 25%. Moreover, 74 representing 37% of the total number of articles included in this review. This is due to the impact factor) journals. Table 1 provides the impact indicators of the journals used for the literature review.

| Journal Name       | Impact Indicators Quartile | 5-year Impact Factor | SJR |
|--------------------|----------------------------|----------------------|-----|
| Applied Energy     | Q1                         | 7.888                | 3.162|
| Energy             | Q1                         | 5.582                | 1.990|
| Energy Economics   | Q1                         | 4.963                | 1.916|
| Energy Policy      | Q1                         | 5.038                | 1.994|
| RSER               | Q1                         | 10.093               | 3.036|

This is followed by Applied Energy with a percentage of 25%. Moreover, 74 articles were published about the electricity system in Saudi Arabia, representing 36%, followed by the UAE with 18%.

The next section presents the descriptive statistics, including the analytical tools used, yearly publication, number of authors, keywords used, and page numbers of articles.

### 2.2. An overview of GCC electricity literature

#### 2.2.1. Overview of analytical tools used

As mentioned earlier, Connolly et al. (2010) classified the computer tools used to analyze the integration of renewable energy into seven categories. These seven categories are:

1. Simulation tools: These tools simulate the operation of the energy system in question to supply a set of energy demands.
2. Scenario tools: These usually combine a series of years or period into a long-term scenario.
3. Equilibrium tools: These aim to explain the behavior of supply, demand, and prices in an economy or in part of an economy (general or partial) with several markets.
4. Top-down tools: These are macroeconomic tools using general macroeconomic data to determine growth in energy prices and demands.
5. Bottom-up tools: These tools identify and analyze specific energy technologies and thereby identify investment options and alternatives.
6. Operation optimization tools: These tools optimize the operation of the energy system being studied.
7. Investment optimization tools: Lastly, these tools aim to optimize investments in an energy system.

The 206 articles considered in this literature review were classified using this categorization. Table 3 shows the categorization of the articles according to the analysis tools.

#### 2.2.2. Temporal analysis of published research

Fig. 1 shows the increase in the number of articles on GCC electricity systems published from 1983 to 2018. There has clearly been an increase in the number of publications on the topic in recent years. There are three periods in the study period. The first period includes the years from 1983 to 2008. During this period, the minimum number of articles per year is zero and the maximum is four, with an average of approximately two articles per year. The second period goes from 2009 to 2015. The average number of articles is about 12, with a minimum of nine articles and a maximum of 15 articles per year. The third period is from 2016 to 2018. This period has a large number of publications, averaging 24 articles per year. The minimum is 11 articles, and the maximum is 31 articles published in 2017.

The increasing trend in the number of published articles concerning electricity in GCC countries matches the increasing trend of scientific publications in other fields. Bornmann and Mutz (2015) reviewed scientific publications from 1980 to 2012 using Web of Science (WoS) databases. They found that the global number of scientific publications experienced exponential growth, with an average annual increase of approximately 3%. Similarly, Sa’ed et al. (2015) analyzed the research output of 22 Arab countries published in 22 international Integrative and Complementary Medicine (ICM) journals indexed in the WoS databases. They identified 591 publications in 19 of these journals. Their analysis also showed an increase in the number of annual publications. In the period 1980–1989 (10 years), there were 29 publications. The number of publications increased to 256 in the period 2000–2009 (10 years) and 215 in 2010-2018.

The following sections present the descriptive statistics, including the analytical tools used, yearly publication, number of authors, keywords used, and page numbers of articles.

### Table 1

List of journals used for the literature review.

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| RSER               | Q1                         | 10.093               | 3.036|

### Table 2

Numbers of articles published by journals and the countries studied.

| Journals/Country | Bahrain | GCC | Kuwait | Oman | Qatar | Saudi Arabia | UAE | Total | % |
|------------------|---------|-----|--------|------|-------|--------------|-----|-------|---|
| Applied Energy   | 7       | 2   | 8      | 6    | 0     | 16           | 13  | 52    | 25%|
| Energy           | 3       | 2   | 8      | 6    | 1     | 13           | 4   | 37    | 18%|
| Energy Economics | 0       | 2   | 3      | 0    | 0     | 2            | 7   | 45    | 3% |
| Energy Policy    | 1       | 8   | 4      | 0    | 0     | 16           | 5   | 34    | 17%|
| RSER             | 2       | 12  | 5      | 13   | 2     | 27           | 15  | 76    | 37%|
| Total            | 13      | 26  | 28     | 25   | 3     | 74           | 37  | 206   | 100%|
| %                | 6%      | 13% | 14%    | 12%  | 1%    | 36%          | 18% | 100%  |
increased to 82 publications in the period 1990–1999. From the year 2000, the number of publications were presented on a yearly basis. In 2000, there were 25 publications. This number increased annually and reached 66 publications in 2013. In another study, Tadmouri and Tadmouri (2002) analyzed biomedical research in the Kingdom of Saudi Arabia during the period 1982–2000. They used the Science Citation Index (SCI) and PubMed databases and found 5,962 articles. The first article was published in 1982 and it was the only publication in that year. The number of publications increased annually, reaching 508 in the year 2000.

The general increase of scientific publications can be attributed to three reasons. The first reason is the global increase in the number of scientists. The second is the increasing number of scientific discoveries worth communicating to peers and the public. The third is the
administrative pressure of academic institutions on their members to publish (Pautasso, 2012). These three reasons can also be applied to the increase in studies in GCC countries, which have experienced marked economic and academic growth in the last four decades. One more plausible reason for the increase in scientific publication on electricity in GCC countries could be the improvement in means of communication, such as the use of the Internet to share scientific publications with peers all over the world.

2.2.3. Author statistics

Fig. 2 shows the frequency and percentage of authors of the articles considered in this study. A total of 33 articles (16.02%) were published by a single author, while two articles (0.97%) were published by nine authors, the maximum number of authors identified in this study. The average number of authors per article is 2.73. The highest number of articles (73) were published by two authors, which is the mode.

2.2.4. Keywords statistics

Most of the articles surveyed included keywords. Table 4 shows the top 50 keywords used in these articles. “Renewable energy” is the most-used keyword in the articles. This reflects the importance of considering renewable energy to supply electricity in GCC countries. The second most-used keyword is “Saudi Arabia,” which appeared in 22 articles, and the third is “United Arab Emirates,” followed by “GCC” and “Energy consumption.”

2.2.5. Statistics based on length of publications

Altogether, more than 2,300 pages have been published on GCC electricity issues in the five selected scientific journals. The number of pages per article ranges from five to 46 pages, with an average length of
approximately 11.6 pages per article. Approximately 36% of the articles are between nine and 11 pages in length and about 79% of the articles are between 7 and 15 pages. Fig. 3 shows the distribution of the GCC electricity articles according to the number of pages.

2.3. Current and future research

To evaluate researchers’ current topics of interest concerning electricity in GCC countries, the keywords for the articles in the last three years (2016–2018) were analyzed. Table 5 shows the top five most used keywords in the surveyed articles. “Renewable energy” is the keyword that appears most often in the articles. This indicates that renewable energy is an emerging technology that GCC countries are seriously thinking of utilizing to provide electricity to their people. Moreover, “energy consumption” also appeared frequently, suggesting that high energy consumption puts pressure on GCC countries to meet the energy needs of the people.

3. Conclusion

This study conducted a systematic analysis of current published research on electricity supply and demand in GCC countries during the period 1983–2018. The scope of the review was limited to the following five well-known energy journals: Applied Energy, Energy, Energy Economics, Energy Policy, and Renewable and Sustainable Energy Reviews. First, the study showed that the number of publications were very small at the beginning of the period. However, the number increased from 2009 and in the last three years (2016–2018), there was an average number of publications of approximately 24 per year. Second, more that 63% of the articles were published by two or three researchers, indicating a trend toward collaborated research. Third, “renewable energy” and “energy consumption” were among the highest number of most-used keywords in these studies, indicating the importance of renewable energy resources and controlling energy consumption in GCC countries.

This paper contributes to electricity literature in two distinctive ways. First, it shows how different electricity demand and supply issues in GCC countries are analyzed using the seven quantitative analytical tools classified by Connolly et al. (2010). The study found that the two most-used analytical tools are the bottom-up and simulation tools. The use of quantitative tools to analyze demand and supply is crucial because of the expensive nature of the electricity infrastructure and the need to analyze different scenarios by changing parameters. The second scientific contribution of this study is that it provides a comprehensive list of articles that addressed several issues in the electricity sector in GCC countries. This list can assist scientists and researchers in conducting further research. For example, a researcher may investigate the link between electricity consumption and economic growth in a specific country or in the GCC countries as a group. According to the literature, there are four hypotheses that can be tested concerning the nexus between electricity and economic growth: conservation, growth, feedback, and neutrality (Payne, 2010). Another possible area of research is the provision of demand forecasts for electricity consumption in GCC countries by considering the latest actions of energy conservation policies. Additionally, GCC countries are seriously thinking of using renewable resources such as solar electricity to provide energy to meet its growing demand. This study provides a list of the articles that researchers need to conduct their research in the above-mentioned areas as well as other possible research areas.

Declarations

Author contribution statement

Mohammed A. AlKhars: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Table 5
The five most-used keywords in GCC electricity articles in the period 2016–2018.

| No | Keywords                                      | Number of Articles |
|----|-----------------------------------------------|--------------------|
| 1  | Renewable energy                              | 13                 |
| 2  | Saudi Arabia, Kingdom of Saudi Arabia         | 10                 |
| 3  | GCC countries, Gulf Cooperation Council, Gulf | 10                 |
| 4  | United Arab Emirates (UAE), United Arab Emirates, UAE | 9                      |
| 5  | Energy consumption                           | 9                  |

Fig. 3. Distribution of electricity-related articles by number of pages (1983–2018).
No additional information is available for this paper.

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References

Abdel-Aal, R.E., Al-Garni, A.Z., Al-Nasar, Y.N., 1997. Modelling and forecasting monthly electric energy consumption in eastern Saudi Arabia using autoregressive models. Energy 22 (9), 911–921.

Abdel-Aal, R.E., Al-Garni, A.Z., 1997. Forecasting monthly electric energy consumption in eastern Saudi Arabia using univariate time-series analysis. Energy 22 (11), 1059–1069.

Abdelrahman, M.A., Said, S.A.M., Ahmad, A., 1993. A comparison of energy consumption and cost effectiveness of four masonry materials in Saudi Arabia. Energy 18 (11), 1181–1186.

Abdoumouleh, Z., Alammary, R.A., Gastli, A., 2015. Recommendations on renewable energy policies for the GCC countries. Renew. Sustain. Energy Rev. 50, 1181–1191.

Abdel-Majeed, M.A., Al-Hadhrami, L.M., Al-Soufi, K.Y., Ahmad, R., Rehman, S., 2013. Captive power generation in Saudi Arabia—overview and recommendations on policies. Energy Policy 37, 379–385.

Abd-ur-Rehman, H.M., Al-Sulaiman, F.A., 2016. Optimum selection of solar water heating (SWH) systems based on their comparative technical-economic feasibility study for the domestic sector of Saudi Arabia. Renew. Sustain. Energy Rev. 62, 336–349.

Ahmad, A., Ramana, M.V., 2014. Too costly to matter: economics of nuclear power for Eastern Saudi Arabia. Appl. Energy 140, 1225–1236.

Al-Badi, A.H., Malik, A., Gastli, A., 2009b. Assessment of renewable energy resources which have improved the manuscript. Renew. Sustain. Energy Rev. 5 (1), 59–66.

Al-Mulali, U., Ozturk, I., 2014. Are energy conservation policies effective without fixed thermostat-setting scheme in air-conditioning systems? Renew. Sustain. Energy Rev. 38, 639–650.

Al-Mulali, U., Tung, C.F., 2013. Investigating the validity of pollution haven hypothesis in the gulf cooperation council (GCC) countries. Energy Policy 60, 813–819.

Al-Sanea, S.A., Zedan, M.F., 2008. Optimized monthly-sizing of hybrid PV–SWH systems based on their comparative techno-economic feasibility study for the domestic sector of Saudi Arabia. Renew. Sustain. Energy Rev. 5 (1), 23–29.

Al-Sanea, S.A., Zedan, M.F., Al-Husaini, S.N., 2012. Effect of thermal mass on performance of insulated building walls and the concept of energy savings potential. Appl. Energy 105, 131–140.

Al-Ali, A., Islam, M.D., Kudo, I., Hwang, Y., Radermacher, R., 2012b. Modeling of a solar powered absorption cycle for Abu Dhabi. Appl. Energy 93, 160–167.

Al-Amir, J., Abu-Hijleh, B., 2013. Strategies and policies from promoting the use of renewable energy resources in the GCC countries. Renew. Sustain. Energy Rev. 50, 1181–1191.

Al-Farsi, A.R.E., 2002. The demand for electricity in the GCC countries. Energy Policy 30 (2), 117–124.

AlFarra, H.J., Abu-Hijleh, B., 2012. The potential role of nuclear energy in mitigating CO2 emissions in the United Arab Emirates. Energy Policy 42, 272–285.

Al-Garni, H.Z., Awatramani, A., 2017. Solar PV power plant site selection using a GIS-AHP based approach with application in Saudi Arabia. Appl. Energy 206, 1225–1240.
Sagha, M., Gadalla, M., 2017. Thermo-economic optimization of hybrid solar Maisotsenko bottoming cycles using heliostat field collector: comparative analysis. Appl. Energy 190, 686–702.

Salahuddin, M., Alam, K., Ozturk, I., Sohag, K., 2018. The effects of electricity consumption, economic growth, financial development and foreign direct investment on CO2 emissions in Kuwait. Renew. Sustain. Energy Rev. 81, 2002–2010.

Salahuddin, M., Gow, J., 2014. Economic growth, energy consumption and CO2 emissions in Gulf Cooperation Council countries. Energy 73, 44–58.

Salahuddin, M., Gow, J., Ozturk, I., 2015. Is the long-run relationship between economic growth, electricity consumption, carbon dioxide emissions and financial development in Gulf Cooperation Council Countries robust? Renew. Sustain. Energy Rev. 51, 317–326.

Shaahid, S.M., Al-Hadhrami, L.M., Rahman, M.K., 2013. Economic feasibility of development of wind power plants in coastal locations of Saudi Arabia—A review. Renew. Sustain. Energy Rev. 19, 589–597.

Shaahid, S.M., Al-Hadhrami, L.M., Rahman, M.K., 2014. Review of economic assessment of hybrid photovoltaic-diesel-battery power systems for residential loads for different provinces of Saudi Arabia. Renew. Sustain. Energy Rev. 31, 174–181.

Shaahid, S.M., El-Amin, I., 2009. Techno-economic evaluation of off-grid hybrid photovoltaic–diesel–battery power systems for rural electrification in Saudi Arabia—a way forward for sustainable development. Renew. Sustain. Energy Rev. 13 (3), 625–633.

Sgouridis, S., Abdullah, A., Griffiths, S., Saygin, D., Wagner, N., Gielen, D., et al., 2016. RE-mapping the UAE’s energy transition: an economy-wide assessment of renewable energy options and their policy implications. Renew. Sustain. Energy Rev. 55, 1166–1180.

Sharif, M.B., Haji, S., Salman, A., Abdali, H., Alnaffar, A., 2016. Time series analysis of Bahrain’s first hybrid renewable energy system. Energy 103, 1–15.

Siddiqi, A., Anadon, L.D., 2011. The water–energy nexus in Middle East and North Africa. Energy Policy 39 (6), 4529–4540.

Squadri, J., 2007. Electricity consumption and economic growth: bounds and causality analyses of OPEC members. Energy Econ. 29 (6), 1192–1205.

Sultan, A.Y., Charabi, Y., Gastli, A., Al-Alawi, S., 2010. Assessment of wind energy potential locations in Oman using data from existing weather stations. Renew. Sustain. Energy Rev. 14 (5), 1428–1436.

Sweidan, O.D., Alwaked, A.A., 2016. Economic development and the energy intensity of human well-being: evidence from the GCC countries. Renew. Sustain. Energy Rev. 55, 1363–1369.

Tadmouri, G.O., Tadmouri, N.B., 2002. Biomedical research in the Kingdom of Saudi Arabia (1982–2000). Saudi Med. J. 23 (1), 20–24.

Taleb, H.M., Sharples, S., 2011. Developing sustainable residential buildings in Saudi Arabia: a case study. Appl. Energy 88 (1), 383–391.

Treyer, K., Bauer, C., 2016. The environmental footprint of UAE’s electricity sector: combining life cycle assessment and scenario modeling. Renew. Sustain. Energy Rev. 55, 1234–1247.

Wood, M., Alsayegh, O.A., 2014. Impact of oil prices, economic diversification policies and energy conservation programs on the electricity and water demands in Kuwait. Energy Policy 66, 144–156.