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Electricity sector reforms in Saudi Arabia and their impact on demand growth and development of renewable energy

Samir El-NAKLA[1,a*], Chedly Belhadj YAHYA[2,b], Jamal NAYFEH[1,c]

[1]Department of Electrical Engineering, Prince Mohammad Bin Fahd University, AlKhobar, Saudi Arabia

[2]Electrical and Computer Engineering Technology, Chattahoochee Technical College, Marietta, GA, USA

[a]snakla@pmu.edu.sa, [b]chedly.yahya@chattahoocheetech.edu, [c]jnayfeh@pmu.edu.sa

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Abstract. The Kingdom of Saudi Arabia (KSA) has experienced widespread development over the last four decades. This has resulted in tremendous increase in electricity demand. This paper reviews the status of the KSA's electricity consumption and demand to date; discusses the current and future challenges facing the Saudi electricity sector; and the Saudi government's initiatives taken to address these challenges. The study shows that KSA government started to apply the long term strategy, Vison 2030 to reduce energy consumption and high energy demand in the country. The paper evaluates the outcomes of applying the tariff reform programs that introduced in 2016 and 2018 respectively and its impact on different consuming sectors especially the residential and also the renewable energy program.

Introduction

The Kingdom of Saudi Arabia (KSA) is located in the Middle East and spread over about 2.15 million km^2, which constitutes around 80 percent of the Arabian Peninsula [1]. The country has a very harsh environment where the temperature varies from as high as 50°C in the shade in mid-summer to 0°C or even lower in winter. The high variation in temperature produces strong variance in electricity demand over the year resulting mainly from high demand of electricity for air conditioning during the hot weather season.

In the last four decades, KSA has witnessed massive economic development coupled with high population growth and urbanization; driven by crude oil revenues [2,3]. The population of the kingdom has grown at an annual average rate of 3% over the last 40 years. Overall, the total population has dramatically increased from 7 million in 1975 to about 34 million in mid of 2019. Furthermore, urbanization in KSA increased from 48% in the early 1970s to around 80% in the year 2000 and projected to reach 88% in 2025 [4]. High economic development as well as population and urban growth have resulted in exponential growth of the country's electricity demand [5].

In 2015, the electricity peak demand reached as high as 62.3 Gigawatt (GW). The current demand is typically met through conventional crude, heavy oil, and gas powered plants spread across the country [6]. In addition to ever-increasing electricity demand, the electricity sector in KSA is struggling with many other issues that may jeopardize the sector sustainability including: aging power plants, suboptimal electricity tariff, inefficient legal and institutional framework, and low public awareness of electricity conservation.

Moving towards a more sustainable model, the KSA government established King Abdullah City of Atomic and Renewable Energy (KACARE) with the aim to utilize the indigenous renewable energy resources through science, research and industry [6]. The ambition of KACARE program is to generate 72 GW energy from renewable energy sources such as solar, wind, nuclear and

waste-to-energy (WTE) by 2032 [7]. The performance of KACARE and the Saudi Government plan for electricity sector development have never been scientifically studied and evaluated. Additionally, there are very limited studies that document the status of electricity system in the Kingdom and little have been done to evaluate the system performance.

The Kingdom of Saudi Arabia's government has applied a new strategy for the future called Vision 2030, which was announced on April 2016, that emphasizes the challenges to meeting the future's growing requirements. The Council of Saudi Economic and Development Affairs introduced historic vision 2030 which aimed toward a number of targets and reform strategies for the Kingdom's future. Electricity demand is dramatically increasing in Saudi Arabia, with increasing peak load over the past two decades [8].

The Kingdom's energy plan is to eliminate oil overuse, to reduce subsidies by increasing the energy tariff in several stages over next ten years, and to conduct a large-scale energy reform to re-evaluate all the energy resources. The Kingdom government began its plan to reform energy prices in 2016 and 2018 which led to reduce the energy consumption [9]. The new Electricity Tariffs rate was the real challenge for the residential sector, especially for the consumer who used more than 6,000 (kWh/month) [10]. The residential sector is the main electricity consumer, constituting at least 50 percent of total consumption. Increased electricity tariffs did not affect the government and industry sectors as affected residential sector.

In order to control electricity consumption and energy management, the Kingdom government reconstructed and rehabilitated several organizations such as the Water & Electricity Regulatory Authority (WERA) which is the regulator body for electricity and water in the country and Saudi Energy Efficiency Center (SEEC) which an organization dealing with customer's awareness and educating the public.

The Saudi Energy Efficiency Center (SEEC) conducted a broad awareness campaign to educate the public about consumption reduction methods by issuing leaflets, preparing workshops that explain how to select the appropriate electrical equipment, and insisting that sales outlets adhere to the required specifications for consumption reduction [8].

In addition to the previous effective reforms implemented by energy programs, the Kingdom government launched the National Renewable Energy Program (NREP) as an essential long-term program in Future Vision 2030 which aims to substantially increase renewable energy's share in the total energy mix with carbon emission reduction [11].

The NREP during the National Transformation Program (NTP) towards which Vision 2030 will increase renewables' share in the energy mix from zero to four percent [11]. In addition, the Saudi government issued permission to households to install solar power systems. Although there are still several obstacles facing energy consumption reduction, the Kingdom's ambitious reform programs are progressing in the right direction.

The paper summarizing and presenting the data of power consumption, peak load, per capita and also looked at the consumption per different sectors within the last ten years. As tariff reforms introduced in the years 2016 and 2018, the paper looked at those increases in tariff on different consuming sector especially the residential and evaluated the impact on the government plan and vision and initiatives of renewable energy.

Challenges and Reforms

The high growth in electricity demand coupled with falling oil prices in 2014 made it very hard for the government to meet the demand without increasing help from private independent power producers (IPPs). These conditions pushed for serious reforms to tackle the demand and allowing for increased share for private sector towards a more stable and sustainable supply. Figures 1 and 2 show the growth of total electricity sold and the peak demand, the data is obtained from WERA (Water and Electricity Regulatory Authority) [5]. Both Figs. show a high growth mode up to 2015,

then from 2016 to 2021 a reduced growth mode as a result of the undertaken government reforms especially the increased tariffs as will be detailed later.

In 2010 the National Energy Efficiency Program (NEEP) was converted to the Saudi Energy Efficiency Center (SEEC) tasked with improving efficiency in buildings, transport and appliances. In coordination with MEWA and SASO (Saudi for building insulation and air conditioning Efficiency) [8]. The SASO 2662/2012 air conditioning Energy Efficiency Ratio (EER) have been Standards Organization), new standards were introduced implemented in stages beginning 2013 and by 2015 all appliances not meeting the EER requirement were taken Out from the market. Both standards on building insulation and air conditioning will have a huge impact on cutting electricity consumption since buildings (residential, commercial and government) account for up to 70% of the total electricity consumed. In addition, efficiency was targeted at the generation level by upgrading old plant and increasing the share of more efficient combined cycle (CC) turbines. The number of CC unit went from 74 in 2014 to 122 in 2017 and the share of CC increased from 8.3% in 2010 to 30.8% in 2018. The improved efficiency was directly translated into more fuel saving, so oil consumption went from 2.01 barrels per MW in 2009 to 1.71 barrels in 2017 [9].

On the restructuring side, the transmission business was separated from the Saudi Electricity Company (SEC) and named National Grid SA beginning 2012. The single buyer company was created as Saudi Company for Energy Procurement on 31/5/2017. Both companies are still 100% owned by the government. So with WERA acting as an independent regulator and the new single buyer, the electricity market became more open for competition. This resulted in IPPs share in generation increasing to about 30%. For example, Table 1 shows the list of power projects planned for 2018-20, totaling 17 GW, SEC share is only 7.5GW (44%) while the remaining 9.5GW (56%) by other companies [10]. IPPs relieve budget pressure by providing upfront capital. In addition, they are more cost competitive due to bidding process and can deliver projects faster.

Table 1. Major Projects 2018-20 [10]

Project	Capacity MW	Fuel	Startup date
PP13 (SEC)	1800	Gas	2018
Shuqaiq (SEC)	2650	Oil	2018
Waad Alshamal	1390	Gas/Solar	2018
Jizan IGCC (Aramco)	4000	-	2018
Duba 1 (SEC IPP)	550	Gas/Solar	2019
Fadhili IPP (SEC/ Aramco)	1500	Gas	2019
Sakaka 1 (REPDO IPP)	300	Solar PV	2019
PP14 (SEC)	1640	Gas	2020
Yanbu 3 (SWCC)	3100	Oil	2020
Total	**16,930**		

Tariff Reforms

The electricity tariff was heavily subsidized for a long period which encouraged overconsumption and inefficiency. According to WERA 2014 report, SEC collected an average of 0.138SR/ kWh, while its subsidized average cost was 0.154 SR/kWh and real unsubsidized cost was 0.80SR/kWh. This means that customers pay only 17% of the real cost on average. Table 2 shows the details of the two tariff increases beginning 2016 and 2018 for the residential sector only. The first increase (2016) only affected customers with consumption higher than 4000kWh. This increase did not bring significant income to the power companies as shown by a detailed analysis by WERA [11],

77.2 % of the residential consumption is less than 6000 kWh. For commercial sector 65.1% consume more than 6000 kWh, for government and industrial sectors 90.7% and 99.82% consume more than 8000 kWh. This explains why for the second tariff reform in 2018 the focus was on the majority consuming less than 6000 kWh to increase the income for the power companies. According to SEC 2018 report [9], the income from residential and commercial increased from about SR4.83 Billion for 2017 to SR11.8 Billion for 2018.

Table 2. Electricity Tariff Reform (Residential)

Consumption Categories (kWh)	Pre- January 2016	Jan 2016- Dec 2017	January 2018
1- 2000	5	5	18
2001- 4000	10	10	
4001- 6000	12	20	
6001-7000	15	30	30
7001-8000	20		
8001-9000	22		
9001-10000	24		
More than 10000	26		
** Tariff is in Saudi halala, 1SR=100 halala=$0.267			

Impact of Reforms on Electricity Demand

Since the electricity sector reforms are not complete yet and the tariff major reform is less than two years old, it will be very hard to make good conclusions. Therefore, only the initial facts will be mentioned until more information becomes available.

For the impact of reforms on electricity demand, Figs. 1 and 2 clearly show that the growth started slowing after 2016 and went below 1% for the last two years. Figure 3 shows the change kWh per customer between 2009 and 2021 which supports the same trend from Figs. 1 and 2, that there is a decrease in demand growth. If we compare the change by sector, Figure 4 and 5 show the residential and commercial sectors. Again a clear reduction in growth, in particular from 2017 to 2019, the residential consumption decreased by 9.1% and commercial by 3.1%. This indicates that the tariff reform beginning 2018 had a clearer impact on residential consumers. Does this decrease in demand come from consumer reaction to tariff increase or from improved efficiency? most probably both until further information becomes available.

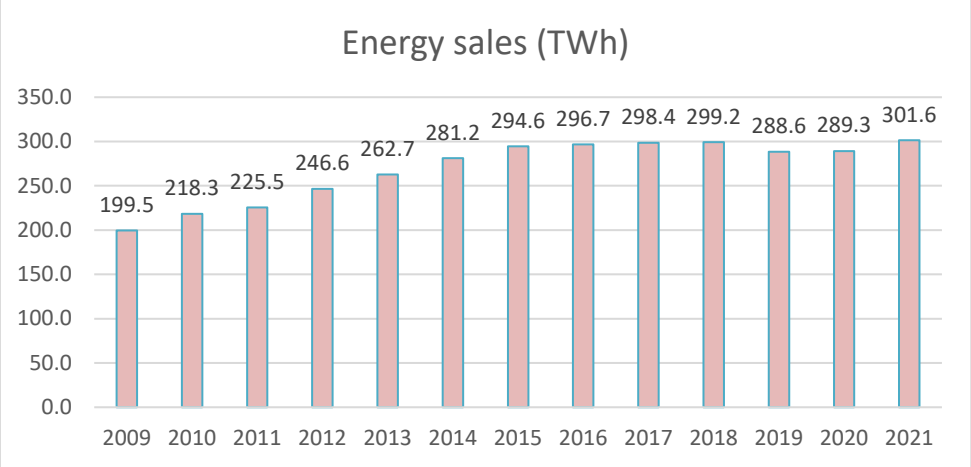

Figure 1. Total Energy Sold in TWh from 2009 to 2018 [12].

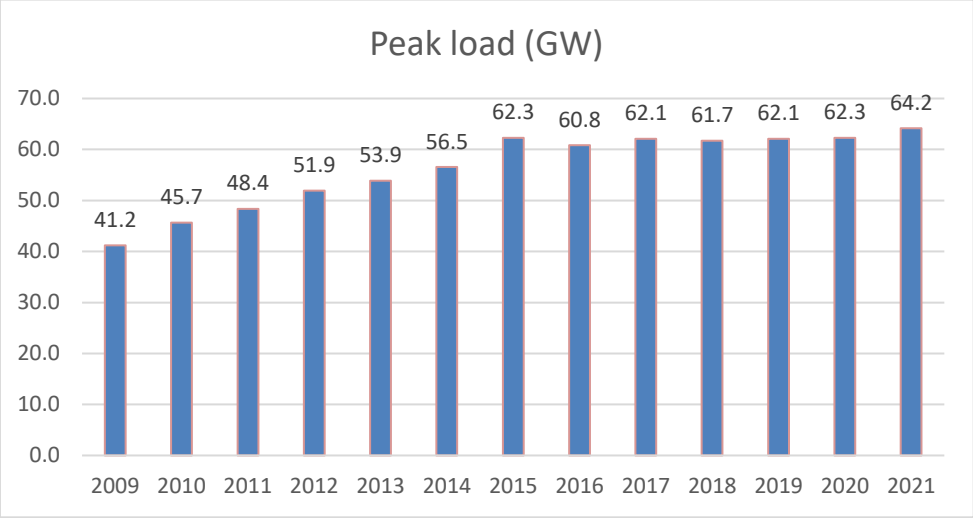

Figure 2. Peak Load in GW between 2009 and 2018 [12].

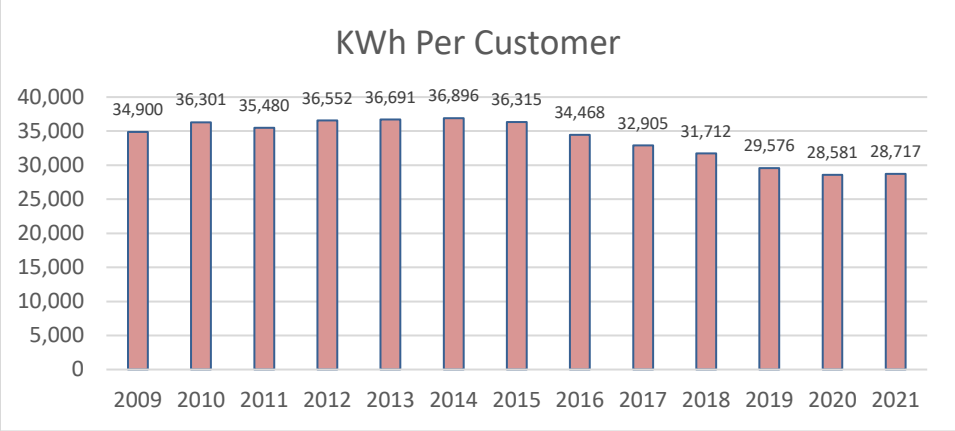

Figure 3. Consumption kWh per customer from 2009 to 2018 [12].

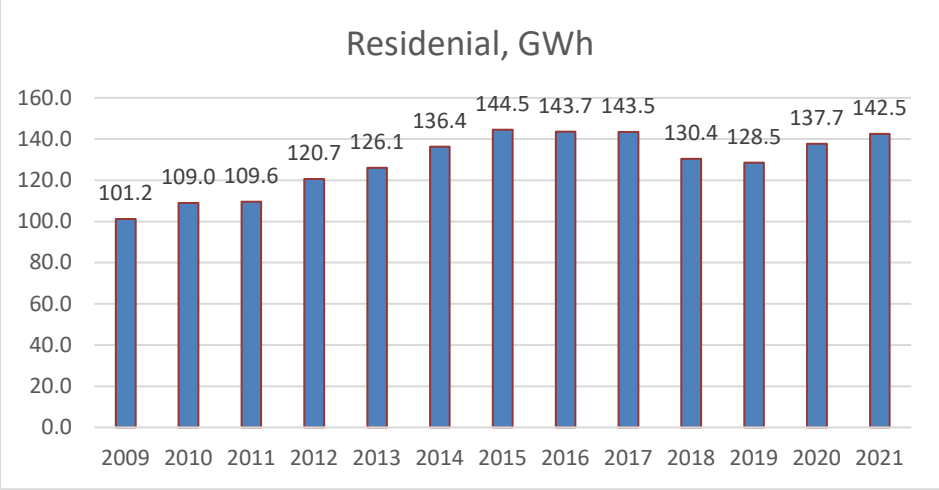

Figure 4. Residential consumption from 2009 to 2018 [12].

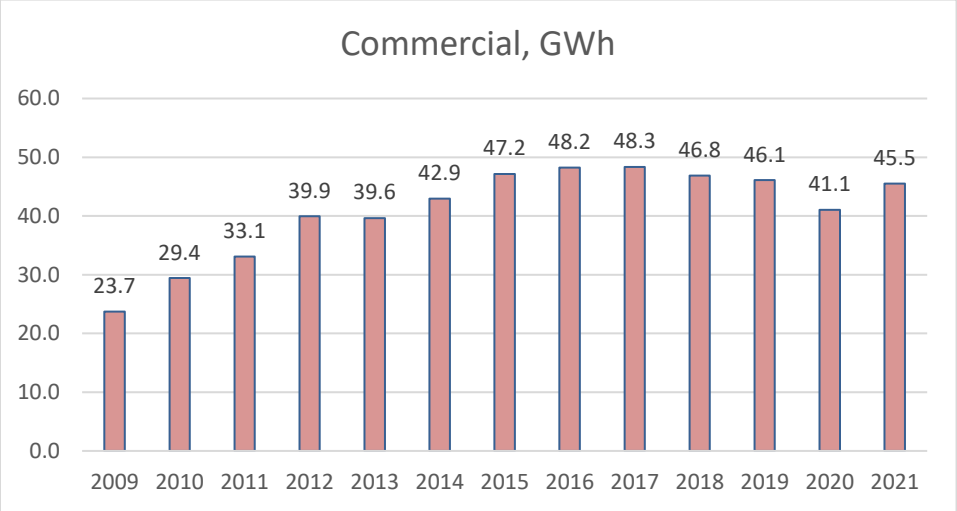

Figure 5. Commercial consumption from 2009 to 2018 [12].

Impact of reforms on Renewable Energy Program

Saudi Arabia enjoys perennial clear skies with approximately 3,000 hours of sunshine per year and annual insolation levels reaching 2450 kWh/m^2. In addition, KSA has empty stretches of desert that can host solar arrays and vast deposits of sand that can be used in the manufacture of silicon photovoltaic cells. As a comparison, Germany has insolation levels that barely reach 1700 kWh/m2 in Freiburg and is one of the top five global leaders. As mentioned earlier, since the initial KACARE plan was announced in 2010, it experienced repeated delays and revisions. Several companies were setup in preparation for getting a share of the expected large number of solar energy projects. Some of these companies invested in factories to make photovoltaic (PV) solar cells and panels while other companies focused on solar energy project installation. Table 3 lists the main players in PV modules fabrication and project implementation.

Table3. List of KSA Renewable Energy Companies

No.	Company	Date
1	KACST: R&D Labs	2010
2	Taqnia : Eng Solar, Wind	2014
3	AlAfandi Group: Solar (Jeddah)	2015
4	Desert Technologies (Jeddah): Solar PV Modules	2016
5	ACWA Power: Eng Projects (Riyadh)	2008

Another important strength is the establishment of research centers such as the KACST Water Energy Research Institute (WERI) and the KACST R&D Labs. The KACST WERI cooperated with the US National Renewable Energy Laboratory (NREL) to establish a network of 12 solar radiation stations spread over all KSA regions [11]. The radiation stations have been used by KACARE to produce the Renewable Resource Atlas of Saudi Arabia in support of achievement of a sustainable energy mix. The KACST R&D Labs provide another important resource that specializes in PV module testing and certification based on International Electrotechnical Commission (IEC) and newly developed desert certification procedures by KACST [13].

KSA had an early start on Solar energy (1983) compared to Gulf and MENA, but fell behind until the recent pickup in pace. After the recent tariff, regulation reforms and the decline in renewable cost, ACWA was able to complete the first large scale PV project at Sakaka (300MW) at record LCOE of 2.32 c/kWh which was completed mid November 2019 [14]. The project is a good example of IPP with a 25 years contract of power purchase. Another renewable energy

400MW wind project was awarded in July 2018 for a record LCOE of 2.13c/kWh at Dumat AlJandal (near Sakaka PV project), different renewables completed projects shown in Table 4. Figure 6 shows the revised renewable energy program for the next 5 years and 12 years [15].

Table 4. List of KSA Completed Renewable Energy Projects

No.	Project	Power	Com Date
1	KACST (Uyaynah)	350kW	1983
2	KAUST Solar Park	2 MW	2010
3	Pilot project	500 kW	2011
4	Saudi Aramco Solar Car Park	10.5 MW	2012
5	Princess Noura University (Thermal)	25 MWth	2012
6	King Abdullah Financial District	200 KW	2012
7	King Abdulaziz Int. Airport Dev Proj.	5.4 MW	2013
8	Al-Khafji PV plant (RO Desalination)	15 MW	2017
9	PV Plant at Al-Aflaj (Taqnia)	10 MW	2019
10	PV Plant at Sakaka (ACWA)	300 MW	2019
11	Dumat Al Jandal Wind Farm	400 MW	2020
12	Al Rajaf Wind Farm	400 MW	2021
13	Waad Al Shamal Solar Park	600 MW	2022
14	Sudair Solar Power Plant	1,500 MW	2022
15	Red Sea Project Solar Plant	100 MW	2022
16	Domat Al Jandal North Wind Farm	600 MW	2023
17	Al Kharsaah Solar Power Plant	1,200 MW	2023

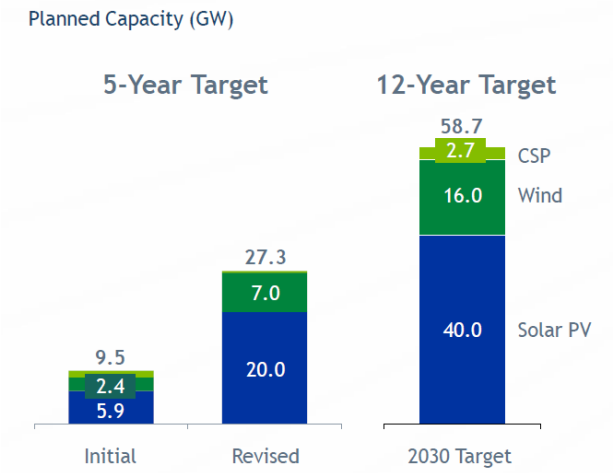

Figure 6. National Renewable Energy Program [11].

Conclusion

The research presented a review of the KSA electricity sector challenges and the government initiatives and reforms undertaken to address these challenges. Even though the reforms are in their early stages, the data shows that the reforms had a positive impact on the electricity demand growth and acceleration of renewable energy program implementation. However, more time and data are needed to have a clearer idea about the reforms impact.

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