A Study about Water and Electricity Consumption in Saudi Arabia using DEA and Regression Analysis: Future Prediction Considering Saudi Vision 2030

Nawaf Mohammad Alamri[1]* & Dr. Mohammed Balubaid[2]

[1]Teaching Assistant, Industrial Engineering, King Abdulaziz University, Jeddah, Saudi Arabia
*Corresponding Author E-mail: *nmhalamri@kau.edu.sa*

[2]Associate Professor, Industrial Engineering, King Abdulaziz University Jeddah, Saudi Arabia
E-mail: *mbalubaid@kau.edu.sa*

Abstract: Energy and water are intricately connected since electricity requires water in their production processes. Energy is required to make water resources available for human use and consumption through pumping, transportation, treatment, and desalination. However, there is there is a dynamic change in water and electricity policies in Saudi Arabia. The prices are adjusted because of the increase in consumption rate which affect the country economy negatively. The study will identify relative efficiency for the five main regions in Saudi Arabia (North, South, East, West and the Center) in water consumption considering region population and water consumption as inputs and number of subscribers per year in Ministry of Environment, Water and Agriculture as an output. In addition, future consumption and production of water and electricity will be predicted considering strategy in Saudi Vision 2030. General Authority of Statistics in Saudi Arabia will be the source to collect relevant data. These data will be analyzed using Data Envelopment Analysis (DEA) to identify the relative efficiency for thirteen regions in Saudi Arabia. In addition, water production from all plants and its consumption for the period from 2012 to 2016 will be analyzed using regression model to anticipate the future. Similarly, electricity consumption and production will be treated to forecast the future. Finally, Strategy related to water and electricity in Saudi Vision 2030 will be considered in order to predict the future considering the present time events and their potential interaction. It is found that center and south areas are efficient in water consumption. In the future, water consumption and production in Saudi Arabia will be increased considerable same as electricity. However, Saudi vision 2030 supports water and electricity sectors and contains number of strategic objectives and indicators to measure results. Programs related to water and electricity will be launched in accordance with the requirements required to achieve the vision of Saudi Arabia 2030.

Keywords: Water, Electricity, Saudi Vision 2030, General Authority of Statistics, Ministry of Environment, Water and Agriculture, Saudi Electricity Company

I. INTRODUCTION

Energy and water are intricately connected since electricity requires water in their production processes. Energy is required to make water resources available for human use and consumption through pumping, transportation, treatment, and desalination. The development of the electricity and water policies is important and not in isolation from each other. The importance of including water in its strategic plan is more essential than before considering high risks that the energy sector is now exposed to.

The study will identify relative efficiency for the five main regions in Saudi Arabia (North, South, East, West and the Center) in water consumption considering region population and water

consumption as inputs and number of subscribers per year in Ministry of Environment, Water and Agriculture as an output. In addition, future consumption and production of water and electricity will be predicted considering strategy in Saudi Vision 2030.

The following will be included: statement of the problem shows the importance and needs of the research, objectives shows what will be accomplished after the research, the literature reviews shows what has been done in other researches about this topic, methodology shows how the objectives will be achieved to reach to the results. Finally, results of the study will be shown along with its discussion.

Statement of the Problem

There is a dynamic change in water and electricity policies in Saudi Arabia. The prices are adjusted because of the increase in consumption rate which affect the country economy negatively.

Objectives

1. Identify the relative efficiency for the five main regions in Saudi Arabia in water consumption.
2. Predict the future consumption and production of the water considering strategy in Saudi Vision 2030.
3. Predict the future consumption and production of the electricity considering strategy in Saudi Vision 2030.

II. LITERATURE REVIEW

P. Shine, T. Scully, J. Upton, L. Shalloo and M.D. Murphy presented a detailed analysis of electricity and direct water consumption of 58 pasture-based, Irish commercial dairy farms. Data was acquired through a remote monitoring system installed on each farm in 2014 alongside corresponding milk production, stock, infrastructural and managerial data. The results derived from the analysis of this data allow key drivers of both electricity and water consumption to be understood with the ultimate aim of generating data to develop footprint models, to achieve a reduction in electricity and water use and to improve the cost efficiency of Irish pasture-based dairy farms. Decreased correlation strengths for water consumption compared to electricity suggests consumption is less dependent on milk production and stock numbers and more dependent on managerial processes, environmental conditions and farm infrastructure. Results and methodologies from this analysis will facilitate the development of adaptive predictive and optimization methodologies for dairy farming electricity and water consumption [1].

Uisung Lee, Jeongwoo Han, Amgad Elgowainy and Michael Wang estimated the regional water consumption factors (WCFs) for thermal and hydroelectricity generation in the United States because the WCFs of these power plants vary by region and water supply and demand balance are of concern in many regions. For hydropower, total WCFs were calculated using a reservoir's surface area, state-level water evaporation, and background evapotranspiration. Then, for a multipurpose reservoir, a fraction of its WCF was allocated to hydropower generation based on the share of the economic valuation of hydroelectricity among benefits from all purposes of the reservoir. For thermal power plants, the variations in WCFs by type of cooling technology, prime mover technology, and by region were addressed. The results show that WCFs for electricity generation vary significantly by region. The generation-weighted average WCFs of thermoelectricity and hydropower are 1.25 (range of 0.18–2.0) and 16.8 (range of 0.67–1194) L/kWh, respectively, and the generation-weighted average WCF by the U.S. generation mix in 2015 is estimated at 2.18 L/kWh [2].

Behzad Elhami, Asadollah Akram and Majid Khanali applied optimization of energy consumption and environmental impacts of chickpea production was conducted using data envelopment analysis (DEA) and multi-objective genetic algorithm (MOGA) techniques. Data were collected from 110 chickpea

production enterprises using a face to face questionnaire in the cropping season of 2014–2015. The results of optimization revealed that, when applying MOGA, optimum energy requirement for chickpea production was significantly lower compared to application of DEA technique; so that, total energy requirement in optimum situation was found to be 31511.72 and 27570.61 MJ ha−1 by using DEA and MOGA techniques, respectively; showing a reduction by 5.11% and 17% relative to current situation of energy consumption [3].

III. METHODOLOGY

General Authority of Statistics in Saudi Arabia will be the source to collect relevant data. It includes the five main regions population in 2016, average water consumption by region for the period from 2012 to 2016 and average number of subscribers per year in Ministry of Environment, Water and Agriculture by region for the period from 2012 to 2015. These data will be analyzed using Data Envelopment Analysis (DEA) to identify the relative efficiency for the five main regions in Saudi Arabia.

In addition, water production from all plants and its consumption for the period from 2012 to 2016 will be analyzed using regression model in order to anticipate the future. Similarly, electricity consumption and production will be treated to forecast the future.

Finally, Strategy related to water and electricity in Saudi Vision 2030 will be considered in order to predict the future considering the present time events and their potential interaction.

IV. RESULTS

1. Relative efficiency for the five main regions in Saudi Arabia in water consumption

The study considers region population and water consumption as inputs and number of subscribers per year in Ministry of Environment, Water and Agriculture as an output. Historical data are shown in the following table:

Table 1: Input and Output Data

	Region Population	*Water Consumption (In Thousands of Cubic Meters)*	*Number of Subscribers per Year*
North	2,434,980	193,801	102,928
South	4,738,971	188,109	129,673
East	4,787,375	552,642	163,210
West	10,421,647	820,193	422,421
Center	9,438,613	989,979	576,396

After applying DEA, the results are shown in the following tables:

Table 2: Efficiency Score

	Efficiency Score	*Efficient or Not*
North	86.1%	Not Efficient
South	100%	Efficient
East	45.7%	Not Efficient
West	82.8%	Not Efficient
Center	100%	Efficient

Table 3: Potential Improvement

	Region Population	*Water Consumption*	*Number of Subscribers per Year*
North	0%	-13%	0%
South	0%	0%	0%
East	0%	-54%	0%
West	0%	-17%	0%
Center	0%	0%	0%

2. Foresting of the future consumption and production of the water

Historical data for the years from 2012 to 2016 are shown in the following table:

Table 4: Water Consumption and Production (In Thousands of Cubic Meters)

Year	*Water Production*	*Water Consumption*
2012	997,233	1,977,870
2013	1,055,159	2,717,536
2014	1,139,964	2,873,908
2015	1,292,162	3,025,238
2016	1,185,524	3,129,067

Trend analysis was conducted using Minitab software to generate 3 periods forecast for the years 2017, 2018 and 2019 as shown in the following figures:

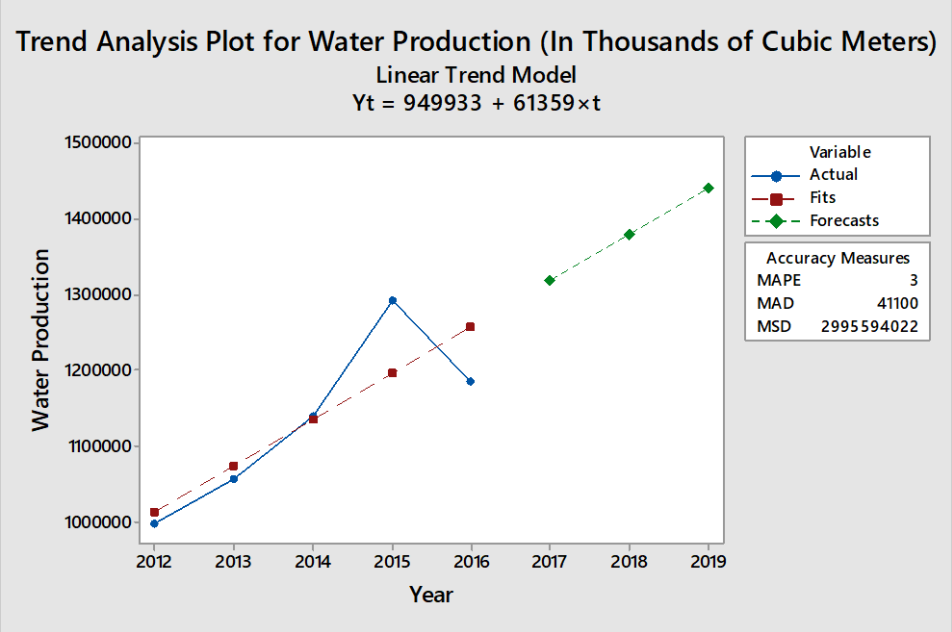

Figure 1: Trend Analysis Plot for Water Production (In Thousands of Cubic Meters)

The figure shows that data are trended, and the forecasts are:

Table 5: Forecasted Water Production (In Thousands of Cubic Meters)

Year	*Water Production*
2017	1,318,084
2018	1,379,442
2019	1,440,801

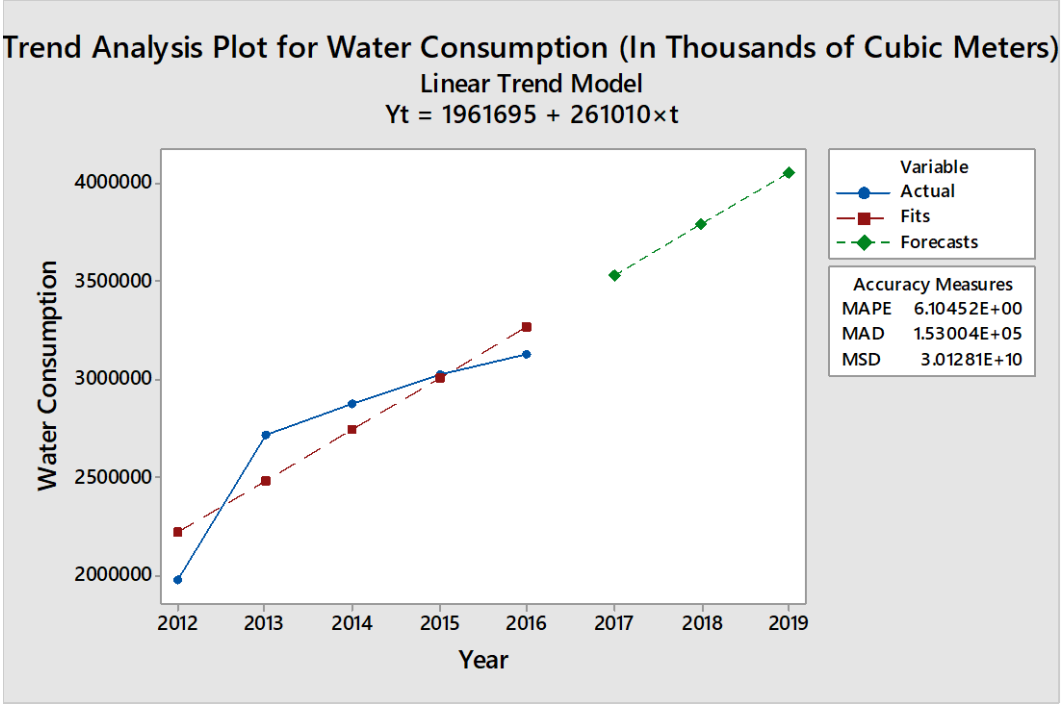

Figure 2: Trend Analysis Plot for Water Consumption (In Thousands of Cubic Meters)

Also, the figure shows that data are trended, and the forecasts are:

Table 6: Forecasted Water Consumption (In Thousands of Cubic Meters)

Year	*Water Consumption*
2017	3,527,753
2018	3,788,762
2019	4,049,772

3. Foresting of the future consumption and production of the electricity

Historical data for the years from 2012 to 2016 are shown in the following table:

Table 7: Electricity Consumption and Production (MWH)

Year	*Electricity Production*	*Electricity Consumption*
2012	211,603,747	240,288,070
2013	203,371,685	256,687,605
2014	219,132,833	274,502,216
2015	215,669,889	286,102,855
2016	209,687,361	287,442,172

Trend analysis was conducted using Minitab software to generate 3 periods forecast for the years 2017, 2018 and 2019 as shown in the following figures:

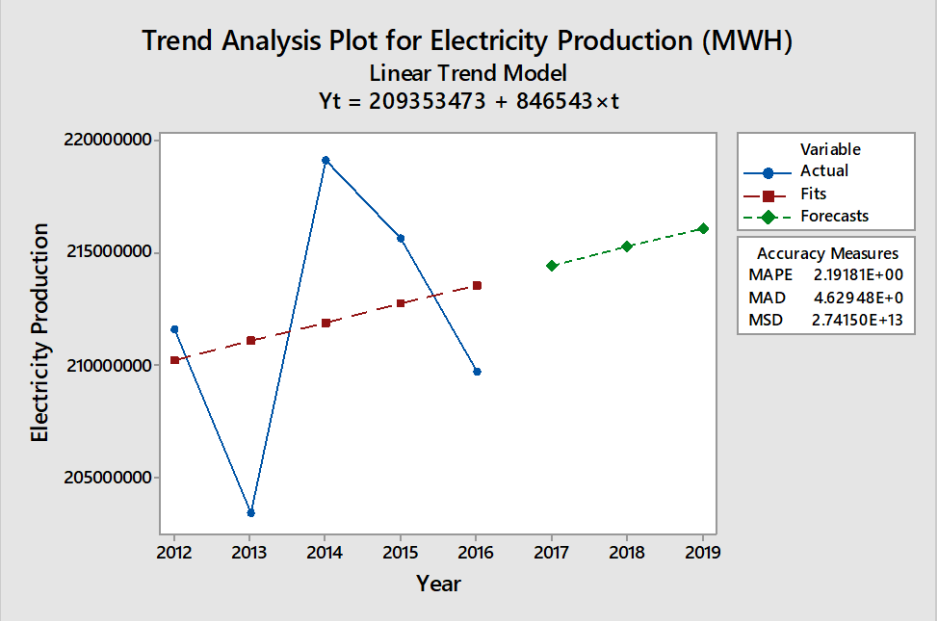

Figure 3: Trend Analysis Plot for Electricity Production (MWH)

The figure shows that data are trended, and the forecasts are:

Table 8: Forecasted Electricity Production (MWH)

Year	*Electricity Production*
2017	214,432,733
2018	215,279,276
2019	216,125,819

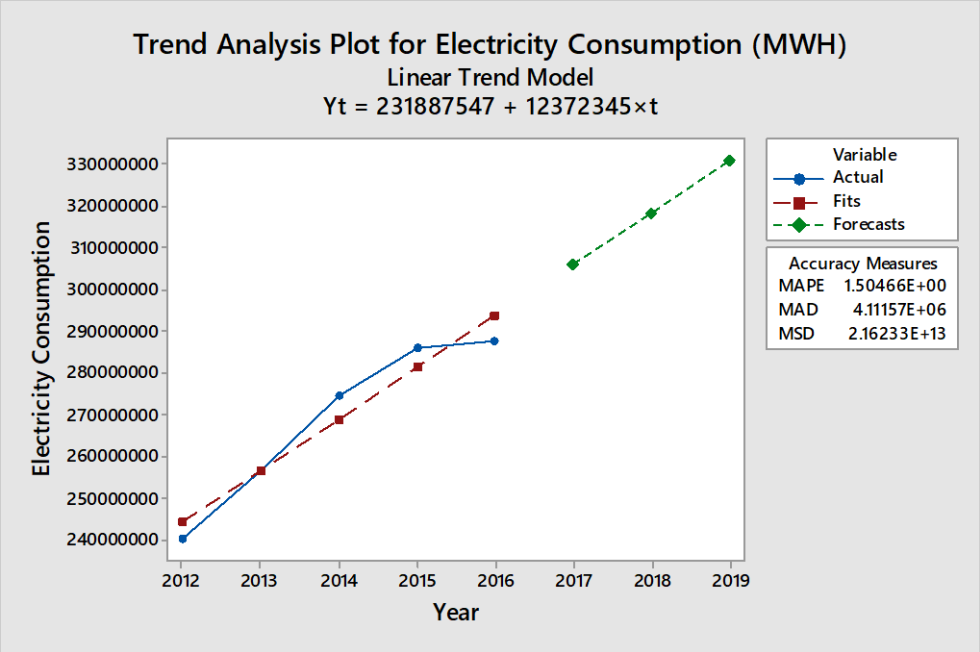

Figure 4: Trend Analysis Plot for Electricity Consumption (MWH)

Also, the figure shows that data are trended, and the forecasts are:

Table 9: Forecasted Electricity Consumption (MWH)

Year	*Electricity Consumption*
2017	306,121,620
2018	318,493,965
2019	330,866,311

4. Prediction using Saudi Vision 2030

Saudi vision 2030 contains number of strategic objectives and indicators to measure results. The Council for Economic Affairs and Development has endorsed an effective and integrated governance framework with the aim of translating this vision into multiple operational programs, each of which fulfills part of the strategic objectives and general directions of the vision. These programs are based on new work mechanisms that are commensurate with the requirements of each program and its time-bound targets. These programs will be launched in accordance with the requirements required to achieve the vision of Saudi Arabia 2030. One of these programs is Water National Transformation Program which includes four challenges each of with its objectives and initiatives to achieve them as shown in the following table:

Table 10: Water National Transformation Program [4]

Challenges	*Objectives*	*Initiatives*
Sector dependence on government funding	• Institutional Development and Privatization • Improving financial and operational efficiency	• Expansion of targeted cities for the National Water Company and private sector participation • Creating a Water Regulatory Authority • Privatization of Saline Water Conversion Corporation • Increase efficiency an performance
Excessive water consumption	• Raising the efficiency of municipal and agricultural consumption	• Program for reducing water consumption per person • Measure the consumption of wells water in the agricultural, industrial and commercial sectors • Reduce water consumption for agricultural purposes
Improve the water healthy in the kingdom	• Reduce the time required to deliver the service • Improve service quality	• Reduce water losses • Increase digital content to improve customer services
Ensure sustainable supply of water to cope with growing demand	• Enhancement supply sources and security • Increase coverage of services • Increase local content	• Increase capacity for strategic water storage • Enhancement of surface water sources from dams and harvesting of rainwater • Enhancement groundwater sources from wells • Enhancement sources of desalinated water • Delivery of drinking water to consumers • Irrigation of Badia and social security • Providing of Sewerage services • Reuse of treated water • Building local content capabilities

On the other hand, Saudi Electricity Company has Strategic Transformation Program which contains strategic objectives as shown in the following: [5]

World-class operations:

Efficient:

- Thermal efficiency of fossil-fired plants improved.
- Non-fossil generation.
- Efficient co-generation projects with customers.

Reliable:

- Grid upgrade and improvement investments.
- Outage times reduced by > 60%.
- Flexible DSM capacities to react to regional demand peaks.

Services and solution provider:

Customer-Centric:

- Customer partner in energy services (ESCO).
- Enabler of energy efficiency, distributed generation, district cooling.
- Best-in-class remote customer service processes.

Smart:

- Fully digital customer experience.
- 100% smart meter penetration rolled out by 2025.
- Smart and self-healing grid infrastructure.

Financially sustainable:

Diversified:

- Expansion into non-commodity service business.
- Commercialize idle fiber optic and real estate assets.
- Explore strategic opportunities in new segments and geographies.

International:

- Power trade capacity with neighboring countries.
- Long-term ambition to connect to Europe.
- Strategic international investments.

Strategic objectives will be achieved through the following enablers:

- Developing the Kingdom's brightest talents.
- Priority for Safety, security & Environment.
- World-class IT services meeting highest security standards.
- Activation of research and development programs.

- Financial stability and rigorous steering.

V. DISCUSSION

The results show that center and south areas are efficient in water consumption and other areas are nor efficient with score of 86.1% for north, 45.7% for east and 82.8% for west area. The potential improvement is reducing the percent of water consumption by 13% for north, 54% for east and 17% for west area. This can be done by increasing the awareness for people living in these areas. In addition, center and south area have the highest number of water plants as shown in the following table:

Table 11: Number of Water Plants [4]

Directions	*Number of Water Plants*
North	9
South	35
East	14
West	12
Center	22

In the future, water consumption and production in Saudi Arabia will be increased considerable same as electricity. The normal water consumption per person is 83 liter while it is 256 liter in Saudi Arabia. Therefore, currently, Saudi Arabia is the third country in water consumption in the world after United States of America and Canada. On the other hand, it is one of the highest five countries in the world in energy consumption in the houses. So, increasing the consumption in the future may make Saudi Arabia the top country in the world and will lead to increase the production causing higher operational cost. Recently, the price is correlated with the consumption so that it may lead to control the consumption and achieve the economic development based on Saudi vision 2030.

However, Saudi vision 2030 supports water and electricity sectors and contains number of strategic objectives and indicators to measure results. Programs related to water will be launched in accordance with the requirements required to achieve the vision of Saudi Arabia 2030. This can be done through initiatives of national transformation for Ministry of Environment, Water and Agriculture which are:

- Structuring of the water sector: The existence of an entity concerned with the regulation and control of water resources.
- Programs to reduce the daily water consumption of the individual: Raise awareness of the community to implement a package of activities and enact laws to implement standard specifications for all water consumables.
- Irrigation Badia and social security: Drilling wells to meet the needs of drinking and water for Badia and border areas and remote areas and support social security beneficiaries in water bills.
- Reduce water consumption for agricultural purposes: Studying the possibility of setting tariffs to reduce excessive exhaustion and encouraging the use of modern irrigation techniques.
- Measure the consumption of well water in the agricultural and industrial sectors: The installation of measuring meters on wells and the use of modern technologies in measuring water consumption in the distance in the agricultural, industrial and commercial sectors.
- Reuse of wastewater: Increasing the utilization of treated wastewater as an alternative source of water, rehabilitating existing plants and improving the quality of productive water.
- Provision of sanitation services: Expand sanitation services and increase coverage to cope with urban growth.

- Increased capacity for strategic water storage: Establishing tanks in cities that do not have underground water and do not have storage to meet the shortage of supplies for emergency situations.
- Reduce water losses: Detection and treatment of leaks to reduce the percentage of losses in water networks.
- Enhancement of surface water sources from dams and harvesting of rainwater: Increasing the sources of surface water by harvesting rainwater and floods to contribute to the provision of water and feed the underground layers and to prevent the dangers of floods.
- Strengthening groundwater sources from wells: Increasing the sources of groundwater by drilling wells, extending pipelines, pumping stations and constructing purification plants.
- Expansion of targeted cities and private sector participation: Establish partnerships with the private sector in production, distribution, treatment and expansion of target cities.
- Delivery of drinking water to consumers: Expanding water services and increasing coverage to meet drinking needs.
- Provision of sanitation services**:** Expand sanitation services and increase coverage.
- Increase digital content to improve customer service: Upgrading services to customers in the water and sanitation sectors.

Perspective for Future Research

Researchers could go deeper and discuss in detail the dams and wells in water aspect in addition to gas and oil in energy aspect. Their research may focus on its effect on water and energy sector. Moreover, they can make the study on the thirteen regions in Saudi Arabia instead of the five main area. They may include Gulf Cooperation Council countries in the study.

VI. CONCLUSION

The consumption and production of the water and electricity was assessed and knowledge about it was enhanced by reading old researches. I learned how Ministry of Environment, Water and Agriculture manage water sector and how to make strategic plans that challenges, objectives and initiatives to achieve them. Similarly, for Saudi Electricity Company that has Strategic Transformation Program which contains strategic objectives.

General Authority of Statistics in Saudi Arabia was the source to collect relevant data. These data will be analyzed using Data Envelopment Analysis (DEA) to identify the relative efficiency for the five main regions in Saudi Arabia. In addition, water production from all plants and its consumption will be analyzed using regression model to anticipate the future. Similarly, electricity consumption and production will be treated to forecast the future.

Finally, Strategy related to water and electricity in Saudi Vision 2030 will be considered to predict the future considering the present time events and their potential interaction.

It is found that center and south areas are efficient in water consumption. In the future, water consumption and production in Saudi Arabia will be increased considerable same as electricity. However, Saudi vision 2030 supports water and electricity sectors and contains number of strategic objectives and indicators to measure results. Programs related to water and electricity will be launched in accordance with the requirements required to achieve the vision of Saudi Arabia 2030.

Conflict of interest: The authors declare that they have no conflict of interest.

Ethical statement: The authors declare that they have followed ethical responsibilities.

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This volume is dedicated to Late Sh. Ram Singh Phanden, father of Dr. Rakesh Kumar Phanden.

