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Trends of Electricity Consumption in Jordan

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Trends of Electricity Consumption In Jordan

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***Abstract*— Electricity plays a crucial role in modern civilization. However, despite technological development in electricity generation, storage in large grids is still limited, which necessitates optimizing the electricity generation and distribution to meet demand and reduce waste which can help reduce costs and cut carbon emissions. Predicting the actual electricity consumption can be decisive in achieving these endeavors. This paper aims to investigate the trends of electricity consumption in Jordan based on a historical dataset covering one year. The analysis covers the temporal analysis of electricity consumption over hours, days, weeks, months, and seasons. It also examines the electricity consumption trends in different weather conditions and temperature levels. The dataset used in the analysis was processed using sophisticated data science steps, which involved (1) Data Wrangling, (2) Data Processing, (3) Features Engineering, (4)Trends Analysis, and (5) Result Evaluation. The trend analysis results achieved in this study were very promising, as it confirms the validity and potential of the data to carry out more predictive forecasting analysis using time series, regression, and machine learning algorithms.**

Keywords—Data Science, Trends Analysis, Smart Grid, Electricity Demand, Electricity Forecasting

I. INTRODUCTION

Electricity is vital for modern civilization, and its demand is ever-growing. However, generating electricity is an expensive process requiring sophisticated generators and complicated distribution grids [1].

Nevertheless, despite the growing advances in power generation technology, electricity storage on a large scale is still unattainable with the current technology [1, 2]. Furthermore, despite the growing use of renewable energy for households and industry in Jordan, electricity generation still consumes a huge amount of crud fuel which emits toxic gases that contribute to global warming and cause several harm to the environment [3-5].

The difficulties of enhancing the effectiveness and reliability of the electricity supply system operation are inextricably linked to the problems of calculating and forecasting electrical energy consumption [2, 6].

Forecasting electrical energy allows the generating companies to solve one of their most pressing problems: producing the required electricity. This task stands out because industrial-scale electricity storage is currently impossible [7]. Forecasting also enables production workers to create repair schedules and perform operational switching in electrical networks.

Thus, the efficient generation and distribution of electricity are vital to meet demand, reduce costs, and to carbon emissions [8, 9]. The accurate prediction of the actual consumption can significantly meet demand and optimize generation efficiency. Therefore, several studies were conducted to forecast electricity load and consumption in Jordan [10, 11] and other countries [10, 12, 13].

The second section of this paper describes the dataset used in this study and its attributes. The third section describes the applied methodology, which involves analyzing the temporal and weather-related electricity consumption trends. The fourth section summarizes the reported results and their discussion, while the fifth section draws a conclusion and comments on future work.

II. DATASET

The original dataset was acquired through a collaboration between Isra University and the National Electric Power Company (NEPCO) in Jordan. The dataset was originally recorded using spreadsheets in tabular form. The columns represent day hours, while the rows represent the date. The values in each cell represent the electricity consumption by the day hour. The dataset in its raw form was not suitable for performing any meaningful analysis. Thus, the dataset has undergone an intensive transformation, transposing, and preprocessing. As a result, two datasets were created and stored in two separate CSV files. Each consists of 4 features. The first dataset consists of 8,760 records representing the hourly electricity consumption, while the second consists of 365 records representing the daily electricity consumption for one calendar year. TABLE I. describes the features of the original dataset.

TABLE I. ORIGINAL DATASET DESCRIPTION

#	Feature	Description
1	Date	Calendar date in (dd/mm/yyyy) format
2	Time	Time in (24H:MIN: SS) format
3	Consumption	Hourly electricity consumption in Kilo Wats (KW)
4	Load	Hourly electricity load in Kilo Wats (KW)

III. METHODOLOGY

A. *Data Wrangling*

Data wrangling involves extracting, assembling, combining, transforming, and constructing data from various sources into a more manageable and useful format. The data can then be used to perform extensive data analysis or to build advanced machine learning and statistical models [14, 15].

The dataset was transformed from its original format into a more useful and manageable form. The dataset was originally collected in a tabular form where the columns represent the hours of the day, and the rows represent the date. The data was first transposed into a tabular format where each

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row represents an hour of the day, while each column represents a data feature.

The data was then combined with other temporal datasets representing weather conditions around the year, morning and evening temperatures, daylight savings, holidays, and other electrical load information.

B. Data Processing

Data processing involves performing several transformation procedures to clean the data and improve its structure, format, and quality [16]. This can be done by addressing missing values, outliers, and data with imbalanced classes [17]. The dataset used contained less than 0.1% missing data and no significant outliers.

C. Data Engineering

Data engineering involves performing several data transformations, extraction, and construction procedures, which may involve removing, deriving, or constructing new features to uncover more insights into the data, improving its quality, or facilitating a more sophisticated analysis [18, 19].

This study added 13 different data features to the original dataset. These cover a set of derived attributes such as the name of the day, day type, and other descriptive statistical analysis features such as average load, maximum morning and evening load, and load factor. More columns were added and combined to the dataset, such as weather conditions, daylight time saving, and temperature data, such as maximum and minimum morning and evening temperatures. TABLE II. describes the resulting data features.

TABLE II. DESCRIPTION OF THE DATASET FEATURES AFTER APPLYING FROM DATA ENGINEERING

#	Feature Name	Description
1	date	Calendar date in (dd/mm/yyyy) format
2	time	Time in (24H:MIN: SS) format
3	day	The name of the week of the day
4	day_type	[Week End/Week Day]
5	Holiday	Hourly electricity consumption in Kilo Wats (KW)
6	Daylight_Saving_Time	[Winter/Summer]
7	Consumption	Electricity consumption in Kilo Wats (KW)
8	Weather	Weather condition [Snow, rainy, sunny, etc.........]
9	Avg_load	Average daily load
10	Max_load	Maximum daily load
11	load factor	The ratio of load factor
12	min_load	Minimum daily load
13	min_temp	Minimum temperature
14	max_mor_load	Maximum morning load
15	max_mor_temp	Maximum morning temperature
16	max_ev_temp	Maximum evening temperature
17	max_ev_load	Maximum evening load

D. Trends Analysis

Trends analysis involves examining the distributions, associations, correlations, and relationships among data samples and features and prospecting its trends, patterns, and potential [20, 21]. The data exploration applied in this study will involve examining electricity consumption and temporal distribution over hours, days, months, and seasons. The exploration will also involve analyzing the electricity consumption relationship with the day type. It also investigates the correlations and associations between the dataset features and the relationships between electricity consumption and weather conditions, seasons, and temperature.

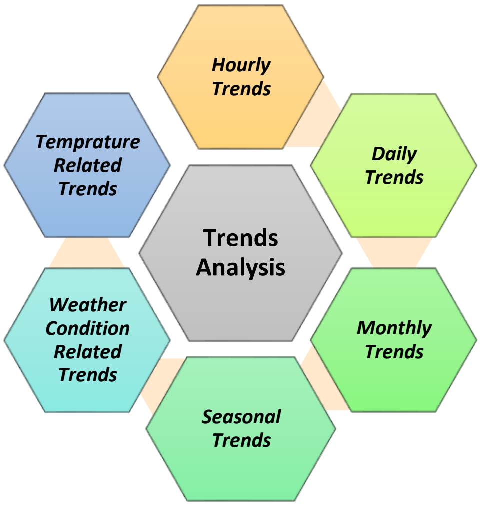

FIGURE 1. ILLUSTRATION OF THE RESEARCH METHODOLOGY DATA ANALYSIS PHASES.

E. Results Evaluation

The trends evaluation procedures involve assessing the trends analysis results and confirming their validity, usefulness, and potential. The evaluation involves performing a preliminary time-series analysis, which investigates the dataset's potential for further analysis using time series, regression models, and predictive machine learning algorithms.

IV. RESULTS & DISCUSSION

This section presents the results of the dataset trends analysis. The electricity consumption trends were analyzed for hours, days, weeks, months, and seasons. The analysis also covered the electricity consumption analysis based on weather conditions based on the recorded weather condition for each day of the year in addition to both morning and evening minimum and maximum temperatures.

The hourly electricity consumption trends were analyzed over 24 hours daily in the calendar year. The hourly consumption shown in Figure 1of shows that the consumption reaches its peak in the afternoon and evening. The consumption reaches its highest rate between 3:00 and 9:00 PM. During this period, the hourly consumption level ranges between 2,000 and 3,200 kWh.

In contrast, electricity consumption reaches its lowest during the off-peak during the early morning hours, particularly between 3:00 and 9:00 AM. The analysis shows that this consumption pattern applies to weekdays more than to weekends. During the off-peak period, the electricity consumption ranges between 1,300 and 2,300 kWh. The analysis of the weekly electricity consumption, illustrated in Figure 3, shows that consumption reaches its highest levels on Monday, Tuesday, and Wednesday and its lowest on Friday.

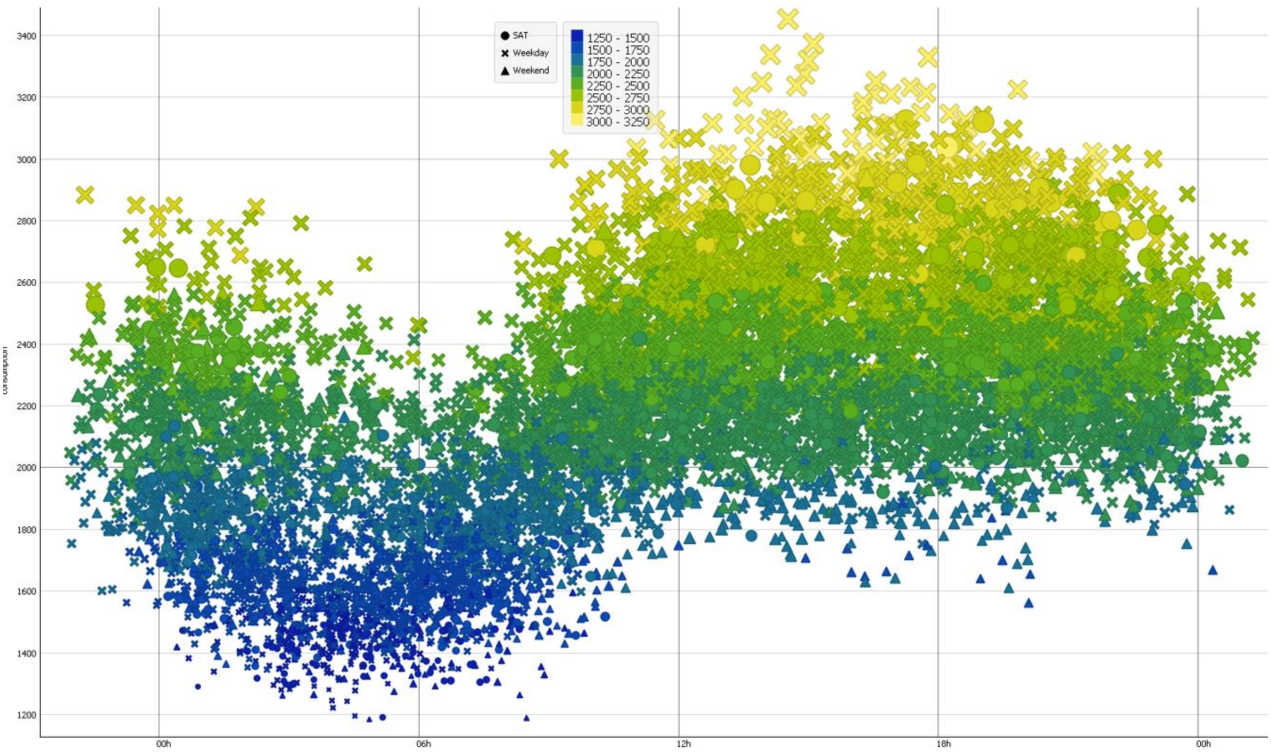

FIGURE 2. ELECTRICITY CONSUMPTION TREND DURING THE DAY HOURS

The electricity consumption on Saturday, Sunday, and Thursday was found to be around the average. At the same time, electricity consumption ranges between 1300 and 2800 kWh on Friday. The consumption level ranges between 1,450 and 3,300 kWh at its highest level on Monday, Tuesday and Wednesday, while it ranges between 1,400 and 3,100 on Thursday, Saturday, and Sunday. Figure 3. Distribution of electricity consumption over the weekdays day of the week. Each day is represented using a distinct color on the X-axis, while the Y-axis represents the electricity consumption in kWh.

On the other hand, Figure 4. Electricity consumption according to the day type (weekday, weekend, or Saturday). The figure shows that electricity consumption increases during the weekdays, while it tends to decline during weekends. This can be explained by the energy consumed by industry and other businesses which function during the weekdays only.

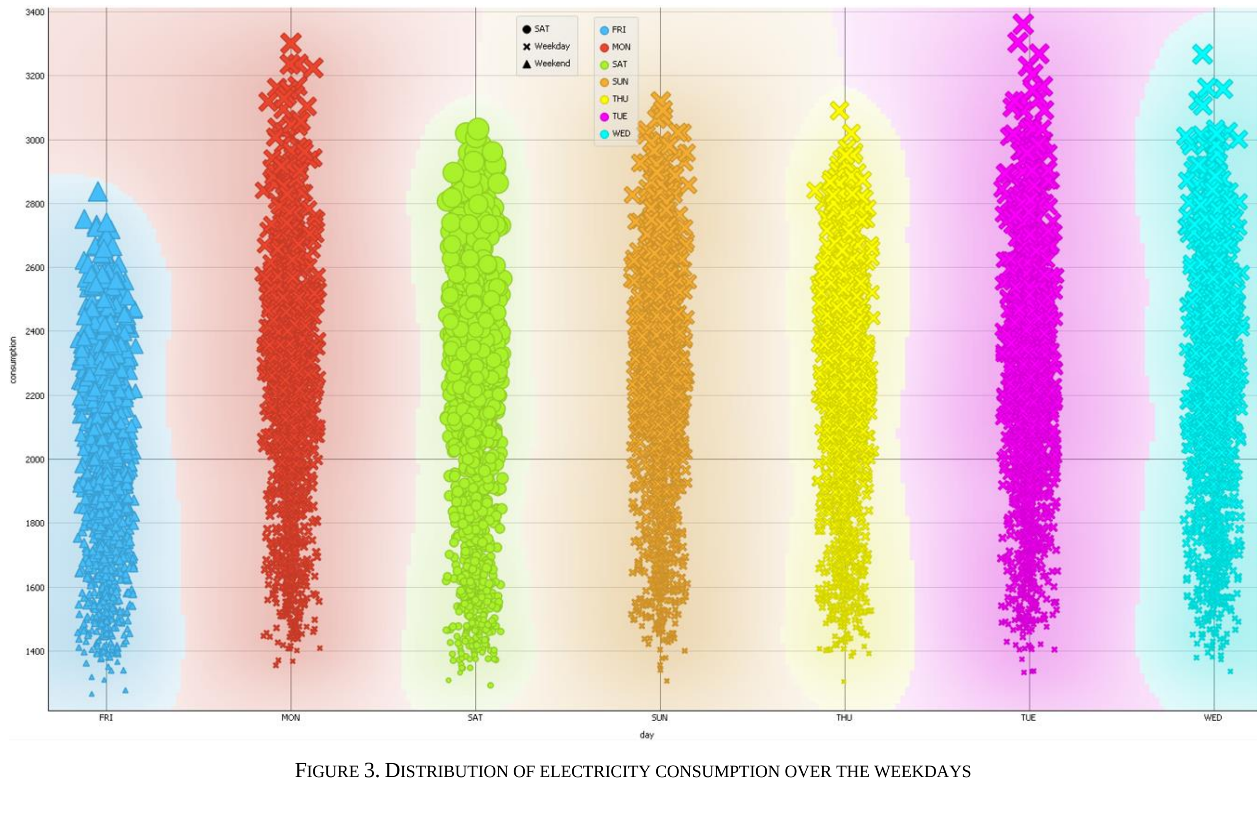

FIGURE 3. DISTRIBUTION OF ELECTRICITY CONSUMPTION OVER THE WEEKDAYS

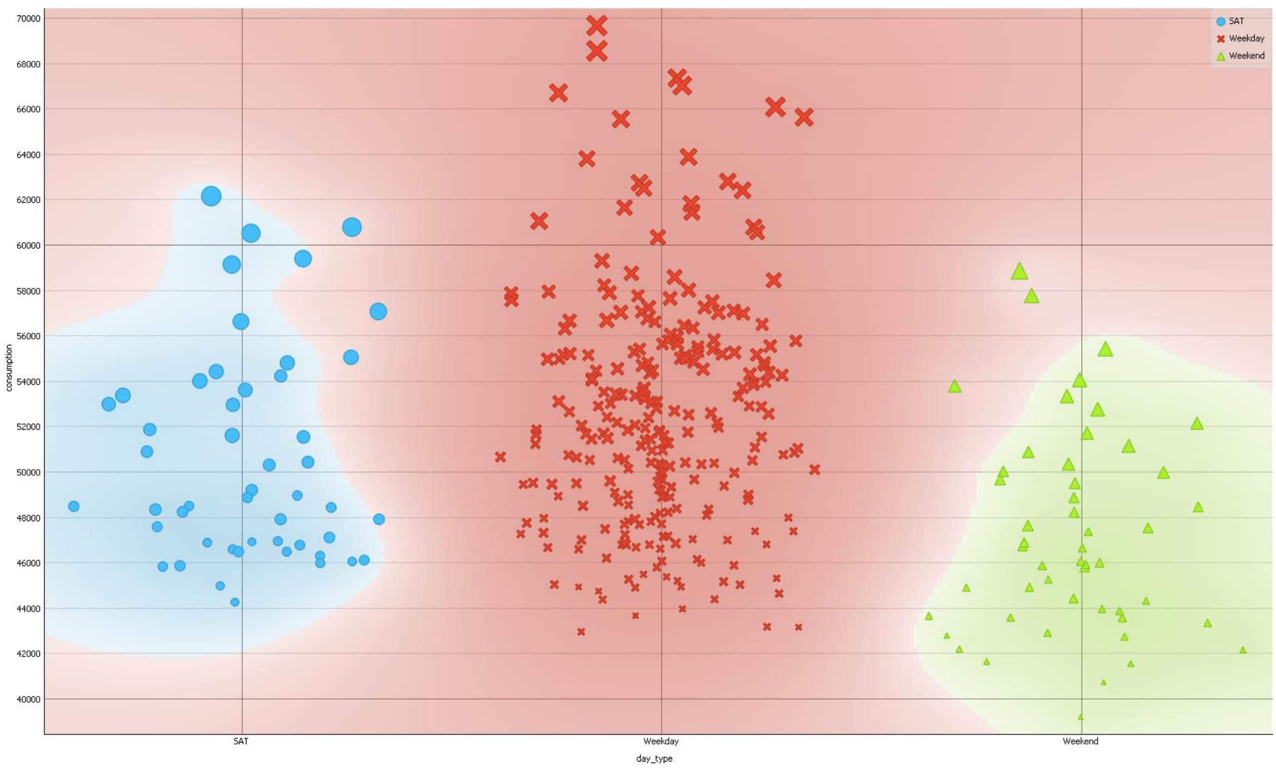

FIGURE 4. ELECTRICITY CONSUMPTION ACCORDING TO THE DAY TYPE (WEEKDAY, WEEKEND, OR SATURDAY)

The electricity consumption trends over the years and months are also analyzed in this study. Figure 5. Shows the trends of consumption along the year months. The data is also annotated with the type of weekday. The monthly trends show that the maximum consumption happens between mid-July and mid-October, followed by the period between mid-December and mid-February. The lowest consumption occurs between mid-March, June, July, mid-October, and mid-November. However, the dataset shows some exceptions for these patterns in April, with some peaks, which are very scarce to reflect any trend or pattern. This monthly distribution unveils a seasonal dimension of the electricity, which is also illustrated in Figure 6. Change in Electricity Consumption During Summer and Winter. The figure shows a significant association between changing summer and winter time and electricity consumption. This might be explained by the difference in the length of the day and the change in weather conditions between summer and winter days, which is analyzed in depth by the trends shown in the next figures.

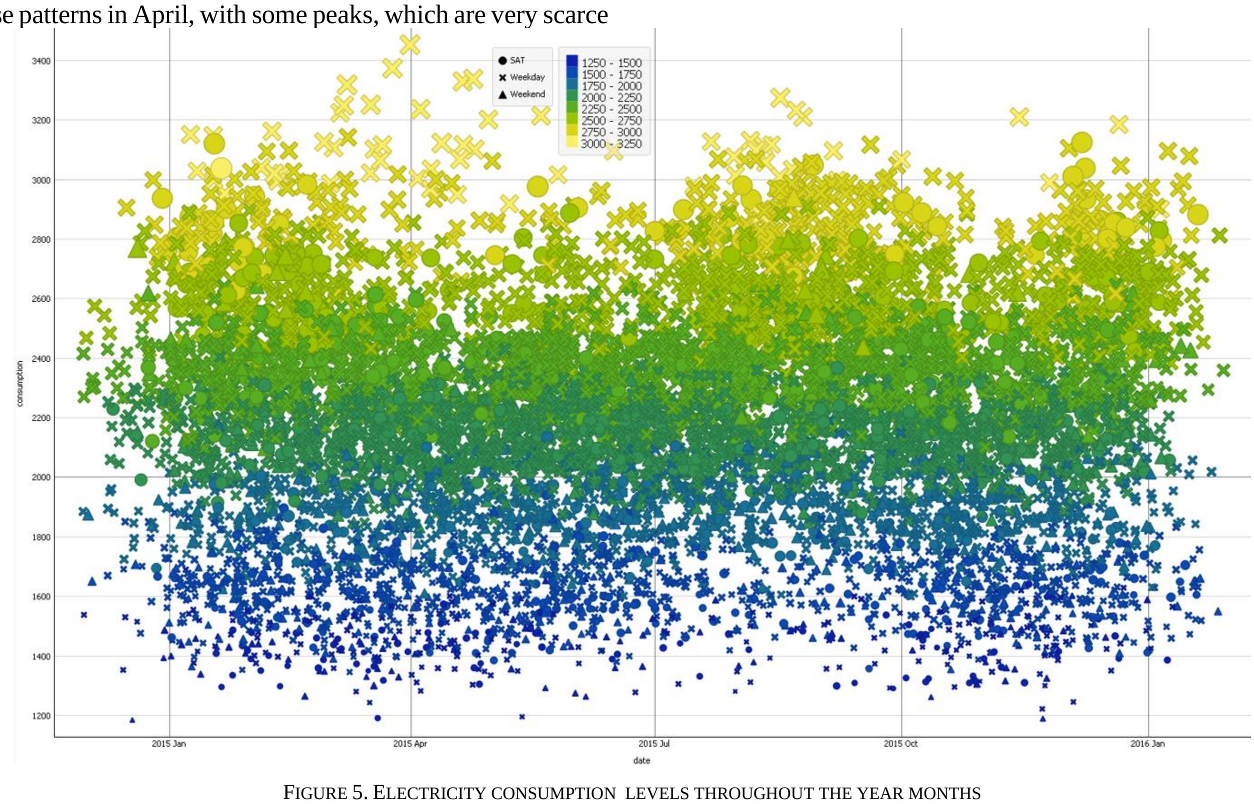

FIGURE 5. ELECTRICITY CONSUMPTION LEVELS THROUGHOUT THE YEAR MONTHS

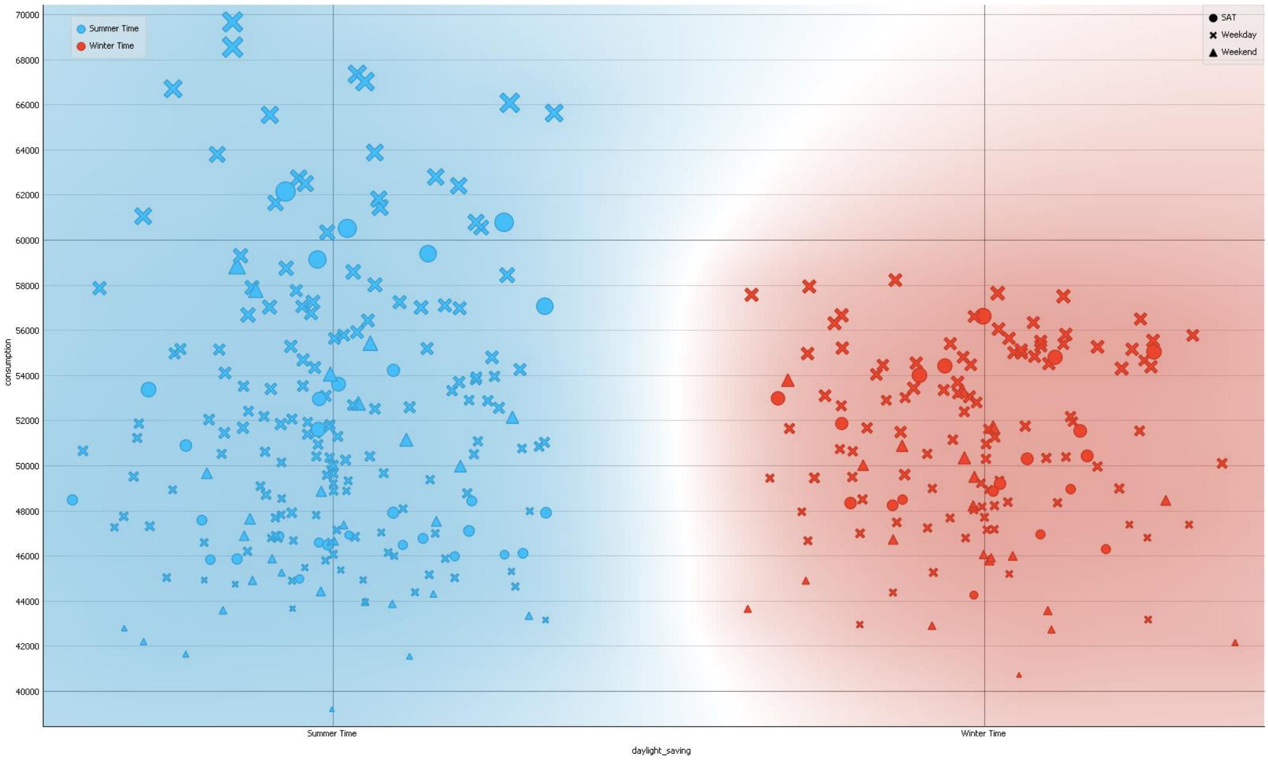

FIGURE 6. CHANGE IN ELECTRICITY CONSUMPTION DURING SUMMER AND WINTER

The consumption trends according to the weather conditions were also analyzed and studied based on daily weather conditions. This is illustrated in Figure 7. The figure shows that electricity consumption increases during warm summer days and peaks when the days get very hot. The analysis of these trends leads to uncovering of a significant relationship between electricity consumption and high daily temperature, particularly during the evening, which is illustrated by the trends shown in Figure 8. In contrast, the figures show a low consumption trend during moderate and chilly days, represented by a high density of data points in the figure. It is also noticeable that electricity consumption increases slightly during heavy rain and snowy days. Still, the data points for these days are quite a few due to the limited number of these days during the calendar year in Jordan.

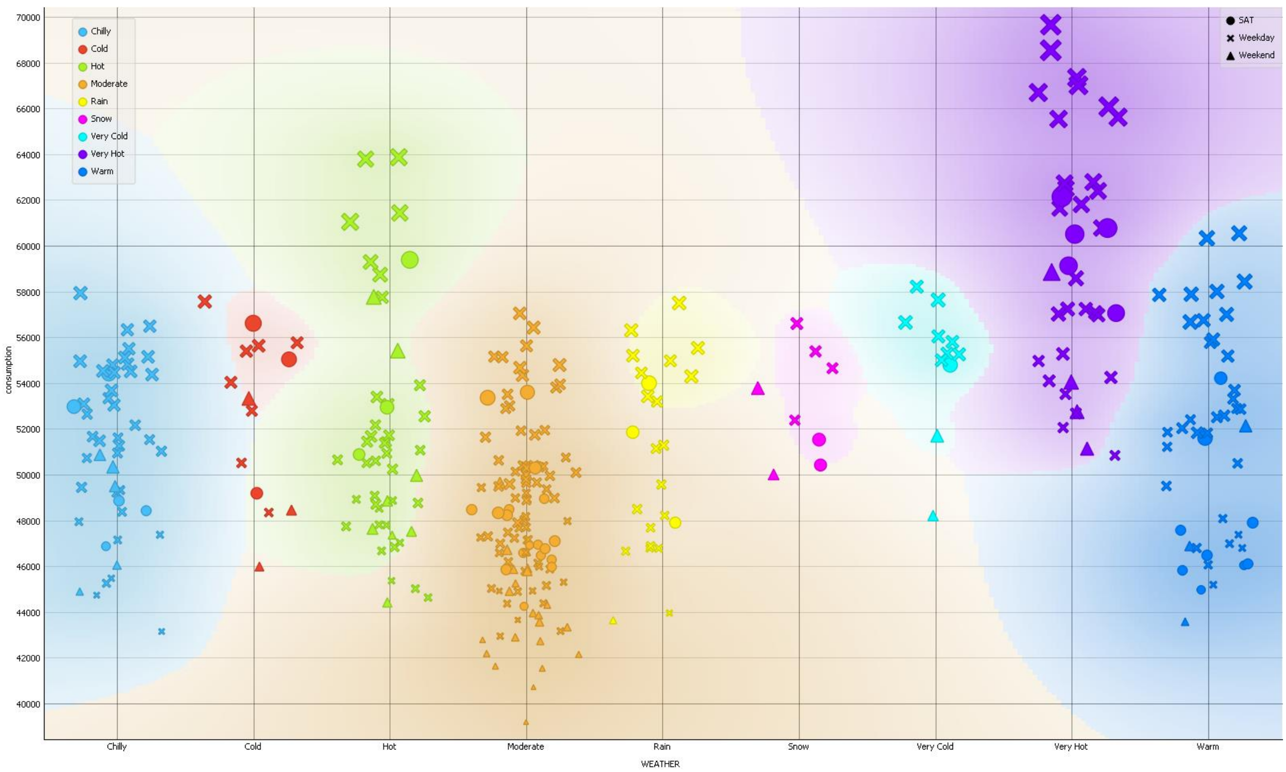

FIGURE 7. DISTRIBUTION OF THE LEVELS OF DAILY ELECTRICITY CONSUMPTION OVER VARIOUS WEATHER CONDITIONS

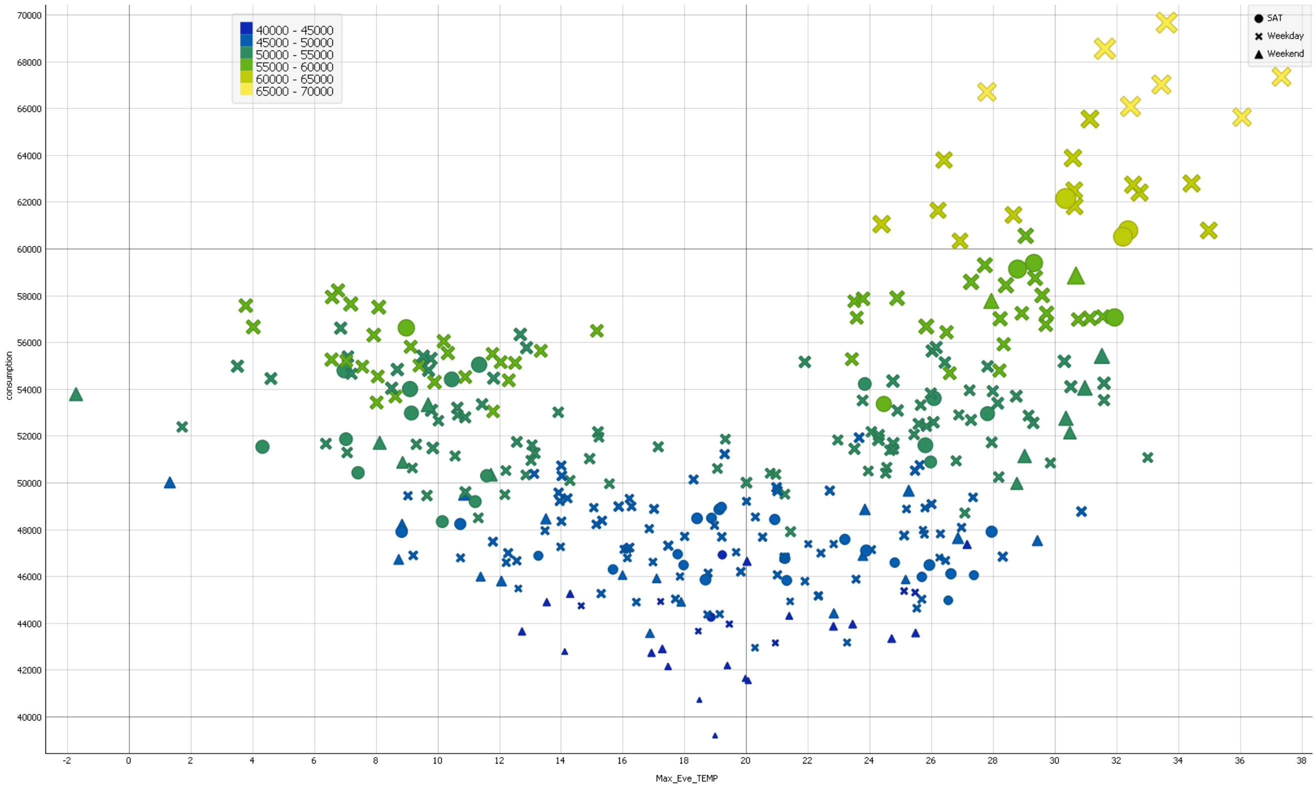

FIGURE 8. TRENDS OF ELECTRICITY CONSUMPTION AGAINST MAXIMUM EVENING TEMPERATURE

A more thorough analysis was also conducted to investigate the relationship and association between electricity consumption and temperature. This is illustrated as a time series curve in the chart shown in Figure 9. The chart compares the daily consumption trend on the one hand and the daily minimum, maximum morning, and maximum evening temperatures on the other. The comparison shows a significant association between the consumption and the maximum evening temperature, which can be used in addition to time, days, and weather conditions as a significant predictor of electricity consumption and high electricity loads during the hot days of summer.

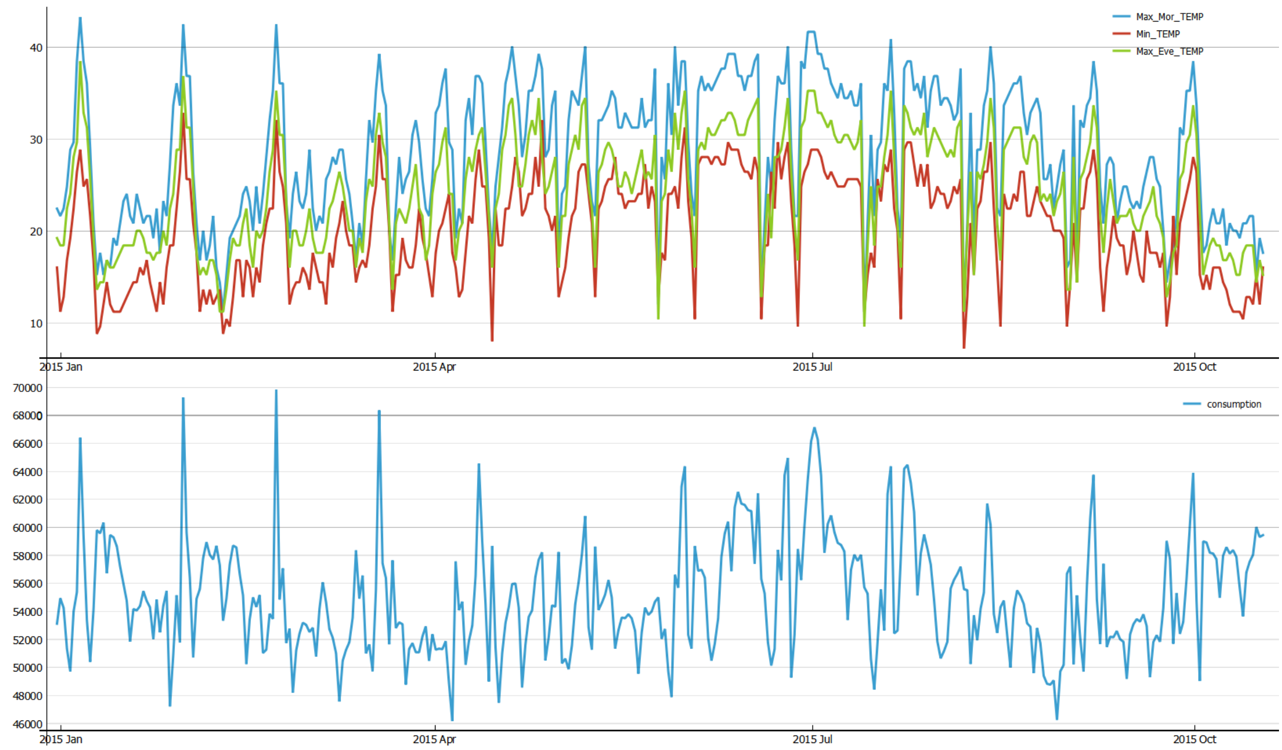

FIGURE 9. A TIME-SERIES SHOWS THE TREND OF ELECTRICITY CONSUMPTION COMPARED TO DAILY MAXIMUM AND MINIMUM TEMPERATURE.

V. CONCLUSION

The analysis of the electricity consumption trends in Jordan uncovered a significant association between the consumption trends and the hours of the day, days of the week, months, and seasons. The analysis also unveils a significant association between the daily weather conditions and temperature on the one hand and the electricity consumption trends on the other. A further illustration of these trends is presented in Figure 10. and Figure 11.

These findings can be used as a basis for building a time-series predicting model that provides accurate forecasting and prediction for electricity consumption throughout the year, which can help electricity companies to generate just the right amount of electricity required without any waste or interruption of service.

The authors of this work are currently working on a project which involves further analysis of the electricity consumption and load trends using regression, clustering, classification, and other machine learning prediction algorithms. These techniques are expected to provide even more accurate forecasting and prediction results.

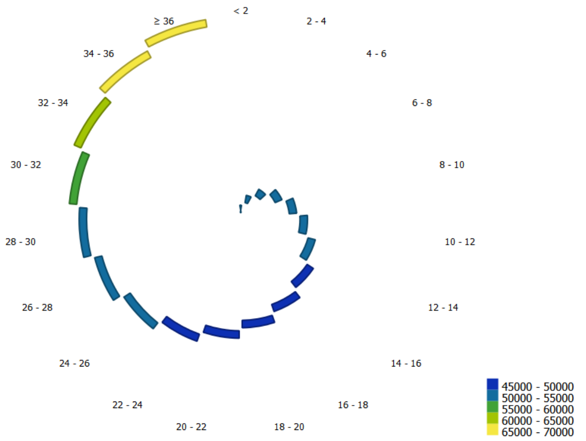

FIGURE 10. A SPIRAL DIAGRAM SHOWS THE INCREASE IN ELECTRICITY CONSUMPTION WITH THE INCREASE IN WEATHER TEMPERATURE

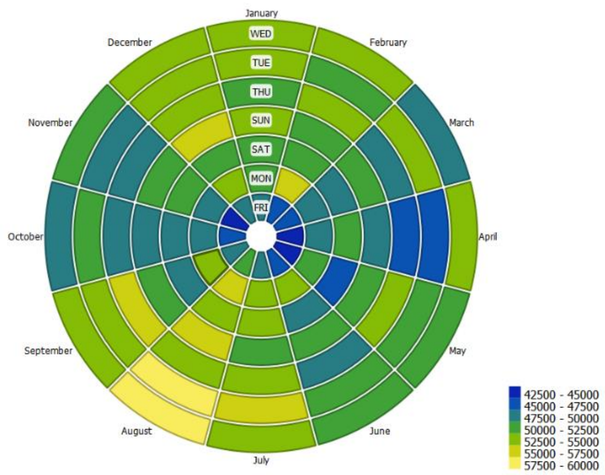

FIGURE 11. LEVELS OF ELECTRICITY CONSUMPTION AROUND THE YEAR AND THE WEEKDAYS. CIRCLE SLICES SHOW MONTHS, WHILE THE CIRCLE ZONES SHOW WEEKS

ACKNOWLEDGMENT

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