

Time Series Cluster Analysis On Electricity Consumption Of North Hebei Province In China

Luhua Zhang¹, Miner Liu², Jingwen Xia², Kun Guo^{3,4,5}, Jun Wang¹

¹Jibe Electric Power Company Limited Metering Centre, Beijing 102208, China

²China University of Political Science and Law, Beijing, 100088, China

³School of economics and management, University of Chinese Academy of Sciences, Beijing, 100190, China

⁴Research Centre on Fictitious Economy & Data Science, UCAS, Beijing, 100190, China

⁵CAS Key Laboratory of Big Data Mining and Knowledge Management, Beijing, 100190, China

guokun@ucas.ac.cn

Abstract. In recent years, China has vigorously promoted the building of ecological civilization and regarded green low-carbon development as one of the important directions and tasks for industrial transformation and upgrading. It calls for accelerating industrial energy conservation and consumption reduction, accelerating the implementation of cleaner production, accelerating the use of renewable resources, promoting industrial savings and cleanliness, advancing changes in low-carbon and high-efficiency production, and promoting industrial restructuring and upgrading. A series of measures have had a negative impact on the scale of industrial production in the region, thereby affecting the electricity consumption here. Based on the electricity consumption data of 31 counties in northern Hebei, this paper uses the time series clustering method to cluster the electricity consumption of 31 counties in Hebei Province. The results show that the consumption of electricity in different counties is different. The macro-control policies have different impacts on different types of counties.

Keywords: Electricity consumption, Time series clustering, Wavelet analysis.

1 Introduction

In recent years, China has vigorously promoted the construction of ecological civilization. Efforts have been made to promote green development, cycle of development and low-carbon development. China seeks to create spatial patterns of resource conservation, industrial structure, mode of production and way of life, to achieve the purpose of environmental protection. The Fifth Plenary Session of the Eighth Central Committee announced that the task of reducing production capacity in the iron and steel and coal industries in 2016 has been completed. The output of raw coal fell 12.8% from the previous year, coke production decreased by 3.0%, and flat glass production decreased by 6.5%. Hebei made new achievement in energy saving. Hebei also has reached the goal of reducing industrial energy consumption. Hebei Province's

industrial energy consumption above designated size was 210 million tons of standard coal in 2017, which was a 0.4% increase over the previous year; energy consumption per unit of industrial added value was down 4.25% from the previous year. New and old kinetic energy is being transformed from traditional industries to high-tech industries. From the perspective of investment, the investment in high-tech industries accounted for 13.8% of the provincial capital, which was an increase of 0.8 percentage points from the first quarter. Six high-energy-consuming industries accounted for 16.3% of investment, decreasing by 0.4 percentage points. From the perspective of output value, in the first half of the year, the proportion of the six high-energy-consuming industries accounted for 39.5% of the industry scale, which was 0.9 percentage point lower than the same period of last year. High-tech industry accounted for 17.9%, which was an increase of 1.9 percentage points. Investment in high-tech industries will accumulate strength for the upgrading of industrial structure in the future and will play an important role in the economic development of Hebei Province. With the decline in industrial electricity consumption and the optimization of the industrial structure, electricity consumption in Hebei counties also declines.

In order to better understand the differential development of each district and county, and to formulate a more effective macro - control policy for a certain type of county, it is necessary to analyze the characteristics of the power consumption trend in different counties and find out its commonness and characteristics. In this way, the specific members of a county and every group can have some notable characteristics, such as a similar reaction to specific events. At the same time, these groups will also support the diversity of government regulation policies. Some of these counties have similar characteristics. In order to better choose the representative counties to carry out analysis, we use a new clustering method to group the counties, and then compare and analyze the group.

2 Literatures Review

MJ Gutiérrez-Pedrero et al., with the help of a static panel data model, found that technological advances will reduce the intensity of power consumption, material capital, and the cumulative increase in investment. However, the effect of price changes is limited. The conclusion shows that the policy on the demand side has some rigidity in changing energy intensity through price adjustments. It is necessary to supplement supply measures to improve low-carbon power generation capacity. [1]. Shahbaz et. al. used a nonlinear co integration approach to investigate the impact of electricity consumption, capital formation and financial development in Portugal on economic growth. These findings show that Portugal remains an energy-dependent economy; energy is one of the major inputs to economic growth and development; and energy-saving policies should not be implemented because energy is an important engine of growth [2]. Maria et.al. used panel data models and data sets from 22 European countries to analyze the impact of electricity regulation on economic growth and assess the impact of renewable energy promotion costs and network costs. The results show that these two regulatory tools have a negative impact on electricity consumption and

economic growth, and estimate their growth effects from a quantitative point of view [3]. Matthew examines the balance between economic growth in the UK and the EU electricity market and the implications for policy and regulation. The UK electricity market is increasingly integrated with the European continent and is expected to be further integrated by mid-2020. This comprehensive economic benefit is estimated to be as high as about 100 pounds a year, reaching 1 billion pounds [4]. The study presented by Ivan examines resident households' consumption patterns and provides near real-time categorized electricity consumption data. The results show that households that shifted their load to off-peak periods were achieved by modifying the consumption patterns for the active load of a particular consumer category. Therefore, policies on protection and demand management should be specifically formulated to stimulate the expectations of resident customers [5]. Davis et al. completed an analysis of U.S. power generation data from 2001 to 2014 in order to understand the factors that may affect the development of the power sector. This analysis shows that several "building blocks" or decarbonization strategies encouraged by the CPP are already in place in the U.S. states Utilization during analysis led to a 12% drop in CO₂ emissions [6].

Through the studies of electricity consumption in various countries, it can be seen that there is a close relationship between electricity consumption and national economic growth, but there is still relatively little research literature on electricity consumption in China. This paper analyzes the electricity consumption of 32 counties in North Hebei Province to discuss the relationship between electricity consumption and economy, policies and geographical environment.

Cuy et al. used various clustering methods to study the structure of the position marginal price on the wholesale electricity market and introduced a new correlation based on the spiky time series of event synchronization as well as the string-relatedness based on the market-provided position names another kind [7]. Rhodes, who use the data to measure the electricity in Austin, Texas 103 families, in every season, with a similar pattern of hours of electricity for household use k-means clustering algorithm are clustered into groups, and the probability of regression to determine Room Whether the main survey response can be used as a predictor of clustering results [8]. Chévez determine the impact of geographic and other man-made major social demographic factors electricity demand and electricity consumption of these homogeneous areas, using K-means clustering method, per capita consumption from the 1010 Census form a large radius of La Plata obtained the results of the analysis [9]. Bah and Azam explored the causal link between power consumption, economic growth, financial development and carbon dioxide emissions in South Africa from 1971 to 2012. The results ARDL border inspection to verify the integrity of co-existence between the included variables; Granger causality test confirmed that there is no causal relationship between electricity consumption and economic growth [10].

Therefore, the effective cluster analysis of electricity consumption can not only guide the implementation of the policy better, but also make a good review of the economic development level and industrial structure of a certain area.

In this paper, we use a new time series clustering method to cluster the electricity consumption of 32 counties in North Hebei Province. The next section will introduce

our methodology briefly. The fourth part presents an empirical analysis and gives the clustering results. Finally, the conclusion constitutes section 5.

3 A New Integrated Method For Time Series Clustering

As there are many effective and relatively well-clustering algorithms, we focus on how the information will be introduced to the expertise in time series mining. And we tried to combine the normal clustering algorithm with the turning point detection method based on expert experience or event mining.

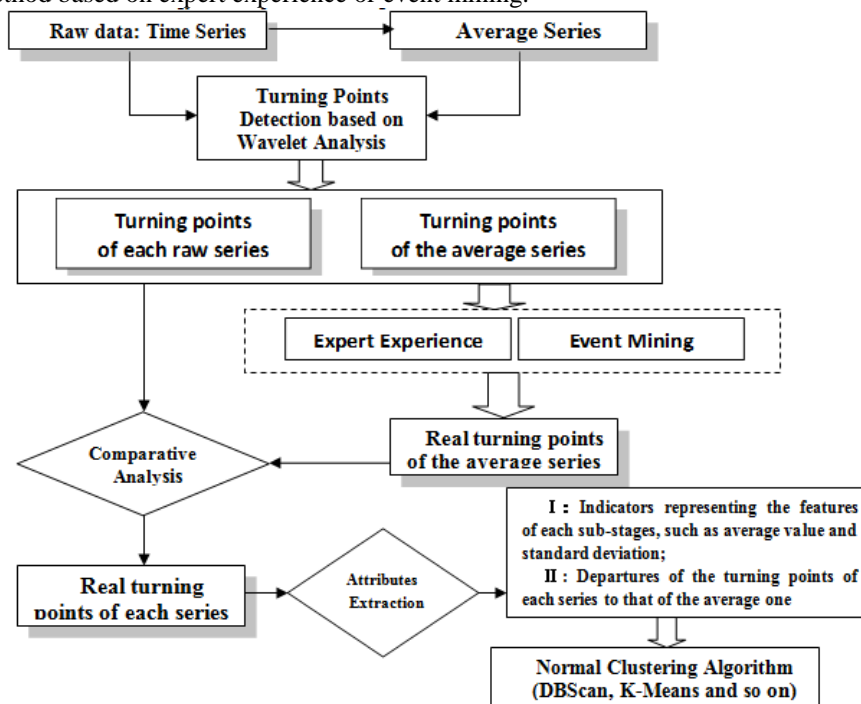


Fig.1. Technology roadmap of the integrated time series clustering methodology

There are five steps of our integrated time series clustering methodology as shown in Fig.1.

- Step 1: Detect all the turning points t_{ij} for each time series and the average series using wavelet analysis. t_{ij} is the j th turning point for series i ; and for the average series $i=a$.

- Step 2: Based on the results of Step 1 for the average series, find several real turning points T_1, T_2, \dots, T_k that can correspond to some big events using expert experiences, so that there are $k+1$ stages;

- Step 3: Scan the turning points from Step 1 of each series, discard the points that far from T_1, T_2, \dots, T_k and keep only k points T_{ij} like the average series.

•Step 4: In each stage, calculate the average growth rate and standard deviation. And for each series, figure out the departures from turning points T_{ij} to the corresponding T_j . So that, there will be $2(k+1)+k=3k+2$ attributes of the time series.

•Step 5: Use the attributes calculated in Step 4 for clustering.

4 Empirical Analysis on Town Electricity Consumption

4.1 Data description

In order to study the power consumption of the counties in northern Anhui, we collected electricity consumption data from January 2013 to May 2016 in 32 counties in northern Hebei Province. Due to the lack of data in Xuanhua, we only use the electricity consumption of the remaining 31 counties as samples, including: Bazhou, Changli, Wen'an, Kuancheng, Pingquan, Luanping, Ayutthaya, Fengning, Zhangbei, Qinglong, Sanhe, Gu'an, Zhulu, Shangyi, Funing, Yuxian, Huai'an, Wanquan, Chengde, Xianghe, Huailai, Yard, Chicheng, Xinglong, Kangbao, Chongli, Yangyuan, Longhua, Dachang, Yongqing and Lulong. The average power consumption of the sample and the selected three typical countries power consumption changes are shown in Fig. 2.

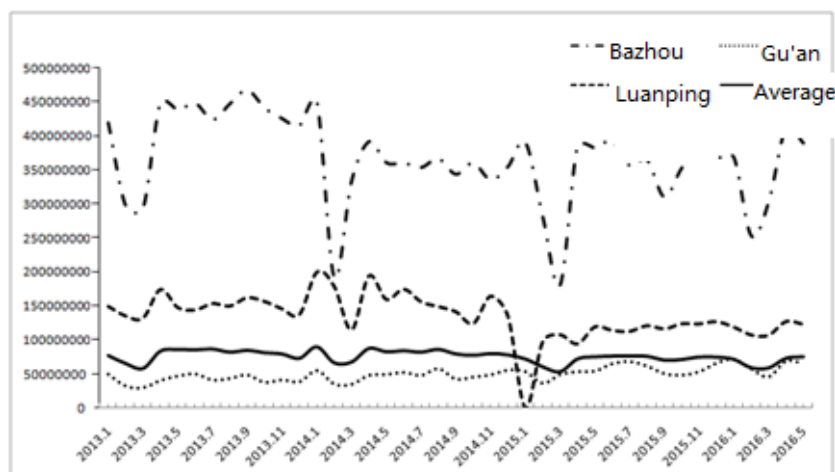


Fig.2. Some samples of the power consumption changes.

4.2 Development stages of Hebei electricity consumption

First we use wavelet decomposition and singularity detection to obtain the original turning point for each county's electricity consumption. Using the decomposition level $J = 5$, we find that the singularity is the most efficient at the first level. The horizontal axis k in each input signal indicates the position of this point. In our study, the horizontal axis position corresponds to the time of the event.

When location $t=1$ means January 2013, $t=41$ means May 2016. The obvious singularities at $t=5, 12, 17, 24, 29, 36$ correspond to May 2013, December 2013, May 2014, December 2014, May 2015 and December 2015. The equidistant distribution of these singular points exactly matches the characteristics of the seasonal transformation of electricity consumption. Therefore, we have obtained seven stages throughout the period. See Figure 2 shows that the average electricity consumption in the sample county in the different stages of the trend is broadly divided into two. In the second, fourth and sixth phases, the trend is stable and the ups and downs are small. There are obvious fluctuations in the first, third, fifth and seventh phases, and the electricity consumption in the medium term significantly reduced. However, the electricity consumption in different counties and cities also has different reactions to the changes in the phases. Taking Bazhou, Gu'an and Luanping as an example, as shown in Figure 3, Bazhou experienced a mid-term decline in the first, third, fifth and seventh phases. However, in the second, the six stages also showed obvious ups and downs. In the first five phases, Gu'an was in line with the average level. However, the average level in the sixth phase was stable, but there was a big fluctuation in Gu'an. Luanping and the average level of roughly have the same trend.

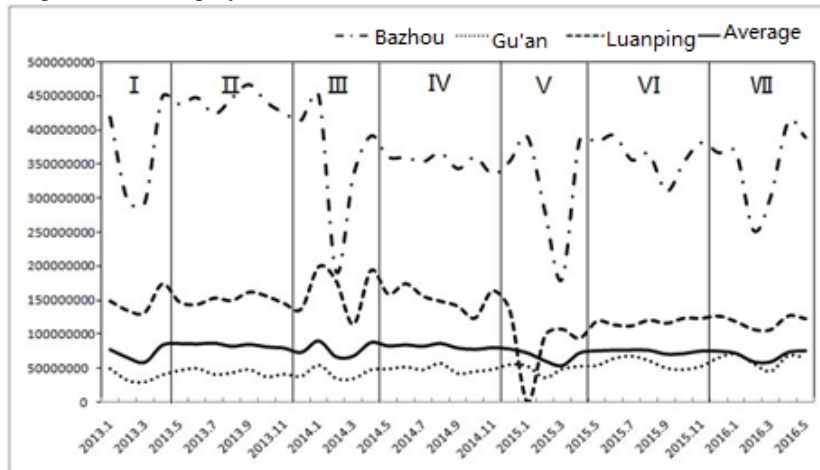


Fig.3.Seven sub-stages of electricity consumption.

4.3 Clustering

In order to better describe the various characteristics of different stages, the indicators that represent the trend of each stage are clustered as attributes. Therefore, calculate the average growth rate, variance, and the deviations from the average of each series of turning points for each stage as attributes of the cluster analysis. Based on a total of 21 attributes in each stage, Ward's method was used to cluster 31 counties. The clustering results are shown in Table 1, 31 counties are divided into three categories.

Table 1. Results of clustering

Group No.	Number of Instances	Clustered Cities
1	2	Wen'an, Bazhou.
2	4	Kuancheng, Pingquan, Luanping, Dacheng.
3	25	Changli, Sanhe, Funing, Chengde, Chicheng, Chongli, Dachang, Fengning, Gu'an, Huai'an, Huailai, Kangbao, Longhua, Lulong, Qinglong, Shangyi, Wanquan, Weichang, Weixian, Xianghe, Xinglong, Yangyuan, Yongqing, Zhangbei,

According to the results of cluster analysis, the proportions and growth rates of electricity consumption by industry in the three categories are shown in Table 2 and Table 3. Figures 4, 5 and 6 show the average electricity consumption trends of primary, secondary and tertiary industries in three counties from January 2013 to May 2016.

Table 2. The proportion of electricity consumption

Group No.	Industry	2013	2014	2015	2016	Average
1	Primary Industry	0.0221	0.0195	0.0214	0.0215	0.0212
	Secondary Industry	0.9219	0.9171	0.9071	0.8993	0.9116
	Tertiary Industry	0.0559	0.0634	0.0716	0.0792	0.0672
2	Primary Industry	0.0132	0.0130	0.0193	0.0183	0.0157
	Secondary Industry	0.9382	0.9411	0.9328	0.9033	0.9300
	Tertiary Industry	0.0486	0.0460	0.0657	0.0783	0.0584
3	Primary Industry	0.0532	0.0689	0.0833	0.0763	0.0698
	Secondary Industry	0.8186	0.7884	0.7290	0.6907	0.7602
	Tertiary Industry	0.1390	0.1521	0.1913	0.2331	0.1763
Average	Primary Industry	0.0226	0.0222	0.0269	0.0258	0.0243
	Secondary Industry	0.9164	0.9125	0.8970	0.8807	0.9024
	Tertiary Industry	0.0621	0.0662	0.0817	0.0935	0.0752

Table 3. Electricity consumption growth rate

Group No.	Industry	2014	2015	2016
1	Primary Industry	-0.1185	0.0945	0.0083
	Secondary Industry	-0.0053	-0.0109	-0.0086
	Tertiary Industry	0.1336	0.1292	0.1060
2	Primary Industry	-0.0187	0.4869	-0.0494
	Secondary Industry	0.0031	-0.0088	-0.0316
	Tertiary Industry	-0.0548	0.4294	0.1925
3	Primary Industry	0.2938	0.2100	-0.0845
	Secondary Industry	-0.0368	-0.0754	-0.0526
	Tertiary Industry	0.0944	0.2573	0.2185

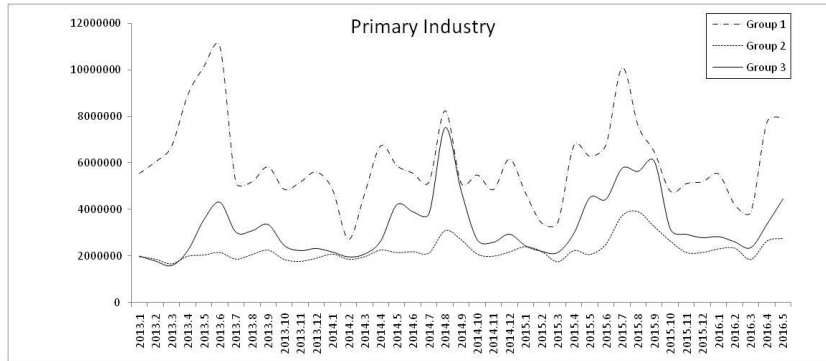


Fig.4. Primary industry electricity consumption of three groups.

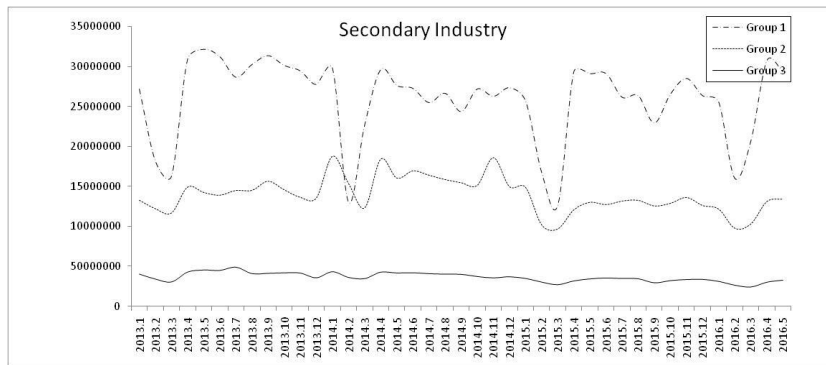


Fig.5. Secondary industry electricity consumption of three groups

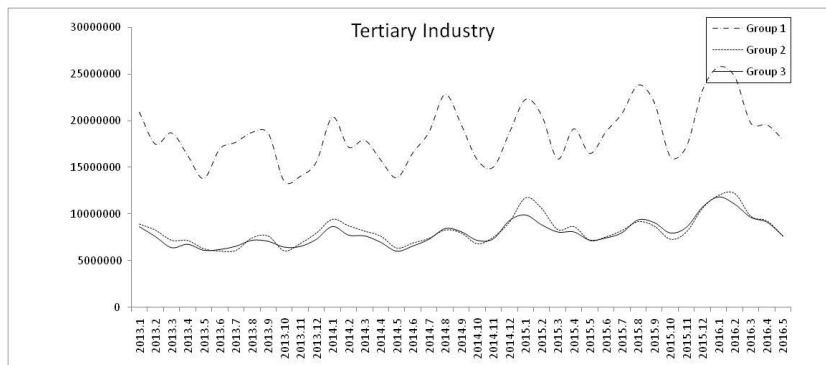


Fig.6. Tertiary industry electricity consumption of three groups

The electricity consumption of the secondary industry in Group 1 accounted for an absolutely large proportion, and the ratio of electricity consumption in three industries to the average in four years was 3: 90: 7. However, the share of electricity consumption in the secondary industry dropped continuously in four years, corresponding to

the ever-increasing share of electricity consumption in the tertiary industry. The proportion of primary electricity consumption has been stable at a small value.

In Group 2, the proportion of second-generation electricity consumption in the same county reaches an average of 93% within four years. The tertiary industry accounts for more electricity consumption than the first industry. Similar to the first category of counties, the share of electricity consumption in the secondary industry shows a downward trend while that of the tertiary industry shows a rising trend. The proportion of electricity consumption in the primary industry also increases.

The electricity consumption of the third type of secondary industry is slightly smaller, about 80%, and the decline is most obvious in four years. The proportion of tertiary industry electricity consumption also has increased by 10 percentage points in four years. In the past two years, the proportion of primary industry electricity consumption also increased obviously. It can be seen that the third type of county has a better industrial structure and more remarkable achievements in the transformation of the industrial structure.

In Group 3, the growth rate of electricity consumption by secondary industry in three years was almost all negative while that of the tertiary industry was all positive. It can be seen that the overall policy of industrial restructuring in Hebei Province has achieved initial success. Finally, classification has little to do with geographic information.

5 Conclusions

In this paper, we develop a new method of time series clustering. Based on the wavelet analysis, we found seven phases of electricity consumption in Hebei province from January 2013 to May 2016, and then clustered the different stages and locations of turning points as the characteristic indicators. This better reflects the classification results in different stages of change and the sensitivity of large events. The results show that 31 sample counties can be divided into three categories. Judging from the average trend of electricity consumption in each group, the progress of industrial structure optimization in each county has some differences. Group 1's primary industry is relatively stable, while Group 2 is all in an upward trend except for the secondary industry. Group 3 has the highest sensitivity to policies and the secondary industry has the most obvious drop in electricity consumption. From this we can make an effective suggestion: the policy of optimizing the industrial structure can be more targeted at certain counties, so that all counties can further implement energy conservation and emission reduction. At the same time, the first group and the second groups of counties to third types of counties can be studied to improve the policy sensitivity, optimize the industrial structure as far as possible, and reduce the energy consumption of the industry.

References

1. Gutiérrez-Pedrero, M. J., Tarancón, M. Á., Ró, P. D., & Alcántara, V. (2018). Analysing the drivers of the intensity of electricity consumption of non-residential sectors in europe. *Applied Energy*, 211, 743-754.
2. Shahbaz, M., Benkraiem, R., Miloudi, A., Lahiani, A., Shahbaz, M., & Benkraiem, R., et al. (2017). Production function with electricity consumption and policy implications in portugal. *Mpra Paper*, 110, 588-599.
3. Costacampi, M., Garciaquevedo, J., & Trujillobaute, E. (2018). Electricity regulation and economic growth. *Social Science Electronic Publishing*.
4. Lockwood, M., Froggatt, A., Wright, G., & Dutton, J. (2017). The implications of brexit for the electricity sector in great britain: trade-offs between market integration and policy influence. *Energy Policy*, 110, 137-143.
5. Kantor, I., Rowlands, I. H., & Parker, P. (2016). Aggregated and disaggregated correlations of household electricity consumption with time-of-use shifting and conservation. *Energy & Buildings*, 139.
6. Davis, C., Bollinger, L. A., Dijkema, G. P. J., & Kazmerski, L. (2016). The state of the states. *Renewable & Sustainable Energy Reviews*, 60(3), 631-652.
7. Cuy, T., Caravelli, F., & Ududec, C. (2017). Correlations and clustering in wholesale electricity markets. *Papers*.
8. Rhodes, J. D., Cole, W. J., Upshaw, C. R., Edgar, T. F., & Webber, M. E. (2014). Clustering analysis of residential electricity demand profiles. *Applied Energy*, 135, 461-471.
9. Chévez, P., Barbero, D., Martini, I., & Discoli, C. (2017). Application of the k-means clustering method for the detection and analysis of areas of homogeneous residential electricity consumption at the great la plata region, buenos aires, argentina. *Sustainable Cities & Society*, 32, 115-129.
10. Bah, M. M., & Azam, M. (2017). Investigating the relationship between electricity consumption and economic growth: evidence from south africa. *Renewable & Sustainable Energy Reviews*, 80(80), 531-537.