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Growth Analysis for the Electric Energy Curves of Domestic Consumption in North Cairo Zone

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Abstract

This paper presents some factors for the correlation of readings of energy consumption in the capital city of Egypt based on the manual process of accounting and the recording cycle for the readings of consumption to control the exact monthly cost of energy. An official sample, for the domestic customers at north Cairo (the Capital of Egypt) over 26 years, has been included in the investigation and analysed while the mathematical formulation is applied. A sample for the total Energy curves in Cairo City is inserted and investigated where curves are classified statistically into two groups for the mathematical analysis. A statistical performance for the readings of studied energy curves is deduced and the results are discussed. The growth of energy consumption is proposed, and the statistical parameters of deduced load curves are estimated for the final equivalent load curve of Cairo. The rate of rise of energy consumption, for all readings in the model, is evaluated as a principle for economics related. The given investigation correlates the automatic random characteristics in the domestic loads of customers and the average load curve for Cairo is deduced according to the statistical results. Two types of correction for the original data have been treated as summation readings (multi-month reading) and the starting of utilization of energy (Zeros). The average (mean value) for energy consumption is calculated to cover the future consumption in distribution systems while the maximum value is computed for the demand power planning in generating stations. The mathematical analysis for either mean values of energy progress or statistical average loads, with the variation of domestic load curves performance, is presented. The principle rules for energy management are stated.

Keywords

Energy Consumption, Average, Monthly Reading Correlation, Domestic Load, Pricing Economics, Growth, Statistical Analysis

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1. Introduction

Recently, the energy consumption floats on the surface because the power generation becomes a complex problem on the Globe. The strategy of nations all is directed nowadays toward the renewable energy since the petroleum goes to the lack for covering the future requirements. Therefore, the rationalization comes in forward to minimize the energy consumption as well as to create a new energy source to be implemented. This title is a vital subject although the traditional fuel is still enough. The renewable energy has analysed in most recent researches, but the solutions are expensive sometimes. The improvement of energy consumptions comes from the modification of domestic appliances ratings although the rating as a power consumption is decreased with every day. Contrary, the number of domestic appliances is very increasing every day and exceeds the previously energy consumption. This leads to the importance of rationalization item in the process of

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energy utilization and consequentially, its consumption around the world. For illustration, the list of countries (Table A1 in the Appendix) by electric energy consumption is mostly based on the world factbook. Several non-sovereign entities are also included for informational purposes, with their parent state noted. The per capita data for many countries may be slightly inaccurate as population data may not be for the same year that the consumption data are. Population data were obtained from the list of countries by in 2016, except for years other than 2016, in which case they were obtained from the Wikipedia pages for the corresponding countries/territories. Average power per capita for some countries had been calculated and tabulated [1].

The published data for the economic measurements (average energy per capita) that considered to be for the year 2016 approximately because it depends on the population of each country at the same time. It should be mentioned that, the overall value for the world globally is 2,674 for 219 countries as indicated in Table A1 in the Appendix. The present paper studies the items in circle of required points to investigate, but others should be accounted too. Electricity consumption globally increases at a faster pace than other energy vectors due to electrification of energy uses. Most of the 2017 increase in global electricity consumption occurred in Asia. As in 2016, power demand grew in several countries and significantly in Iran and in Egypt, but it remained stable in the European Union [2]. This view means that, the study of energy economics in Egypt is important if the country development is the national target. The German industry consumes almost 50% of the total electricity produced in Germany [3], but contrary this research is pointing to domestic energy.

2. Energy Price

The energy costing is a major type of economics around the world due to the creative modification every day in the style of equipment not only for control or even in protection schemes, but also for the new types of power generation, especially the renewable energy. Thus, the characteristics of tariff may be defined well according to the progress in the economics of each country. On the other hand, the new types of stations and the performance of optimal power flow in electric networks would direct the costing problem of consumed energy to include the varied shape of load curves, i. e. the energy consumption. This transforms the importance of insertion of renewable energies in networks (either individual or common networks). Real-time pricing is a utility-offered dynamic pricing program to incentivize customers for making changes in their energy usage. A home energy management system automates the energy usage in a smart home in response to utility pricing signals [4]. The profit-maximizing demand response of a load, in the real-time electricity market, is significant for the pricing process. An energy load has the flexibility of shifting its usage in time, and therefore it is in perfect position to exploit the volatile real-time market price through demand response. The profit-maximizing demand response strategy can be obtained by several methods while the demand response strategy alleviated the supply-demand imbalance in a power grid to save the bills [5].

However, the price of energy must be updated, sequentially, according to the modification in the economic system so that the tariff of electric energy in Egypt (as an example) is considered for the technology of economic evaluation. The principle of tariff for energy consumption has been widely investigated for a long time, consequently, this tariff in Egypt is based on the striped style according to the social dependency with the official support as listed in Table A2 and Table A3 corresponding to the social content of the society [6]. Table A2 related to the domestic loads while Table A3 gives the tariff for the commercial sector including industrial loads. Also, the domestic sector will be considered where the updating of the updated tariff can be accounted as given in Table A4 for the last modification in the domestic tariff according to the new tendency for the social supporting. A minimum cost network flow model for the aggregated control of deferrable load profiles has been described where the load aggregator responds to indicative energy price information succumbing a flexibility bid to a high-resolution real-time balancing market. This bid represents the possibility of the cluster of deferrable loads to deviate from the scheduled consumption because it considers the discretized power profiles of individual loads.

The minimum cost network flow problem belongs to a restricted class of discrete optimization problems for which efficient and scalable algorithms exist. This can be useful in the control of many smart appliances in future real-time balancing markets since it is efficient enough to be employed by an aggregation module with limited computational resources. Alternatively, when indicative price information is not made available by the system operator, this strategy can be combined with an external forecast to minimize possible imbalance costs [7]. The energy pricing depends on two basic sections of cost as given by Sara Nada & M. Hamed, 2015 [6]:

$$\text{Total Cost} = \text{Fixed Cost} + \text{Running Cost} \quad (1)$$

This equation means that, the costing of energy must depend on, firstly, the capital cost of stations (Power Stations and Substations) and the connection between them (Transmission Systems) with the ends of utilization containing transformers, Boards and Cables (Distribution System). This Capital Cost is expensive because it includes the price of lands for the electric networks (Stations and Lines). Secondly, the total cost depends also on its second term of the running cost, including both generated and consumed powers where the presented research is concentrated to investigate the part of consumption energy with respect to both sides (customers and Electricity Company). Therefore, the fixed cost will be neglected out of the present study to concentrate the analysis on the energy consumption only. Since the process of determination of the tariff contains diverse factors in different countries, the average nominal price of the energy in Egypt is listed as given in Table A2 for the old tariff of domestic consumption and in Table A4 for the last updated tariff in Appendix. The average monthly price P_{av} in the units of L. E. for the total energy (E_t) may be formulated as a function of the total energy used in the units (kWh) by:

$$P \quad v = (1/\mathrm{E} \quad) + \sum_{i=1}^{nc} (P_i \quad kWh \ _i) \tag{2}$$

This average price should be equivalent to that deduced according to the stripes of the customers where they have (m) classes for each sector and the price in each can be remarked as P_m for the m^{th} stripe [8]. Then, the average price will obey the same given expression in equation (2). This reflects the interaction between the energy consumption and the operating cost (Running Cost) so that the energy investigation may be a major factor for the determination of the energy price. Then, the evaluation of the price could be energy utilization dependent where the consumers may be classified into strips. Therefore, the corresponding tariff strips can be estimated to cover the actual cost of the required energy generation including the fixed cost as illustrated through equation 1 above.

The present paper studies the domestic consumption only without the cost of both commercial and industrial loads or others. Otherwise, this item may be investigated later in the same sequence and tendency although the collection of all together will be difficult to analyse. On the other side, the main sector of consumption is the domestic because a social vision should be included especially for developing counties. It is remarked that, the rate of rise of price RRP for base conditions is highly increased with respect to initial cases of Table A2 & Table A3. However, the dynamic values were vibrated between 1 to 5.68 (instead of 1 to 1.37) for industrial loads and 1 to 2.81 (instead of 1 to 1.52) for the domestic. This means that, the system of accounting is directed to protect small customers as a social integration for the society where the rate of increase in cost is usually changed not only between stripes but also inside each stripe itself. This phenomenon is repeated for the recent tariff in Egypt since the community goes towards the base of non-support dependency.

3. Domestic Model

Electrical power consumption data and load profiles of major household appliances are crucial elements for demand response studies. This paper analyses and discusses load profiles of selected major household appliances in the capital of Egypt, based on the official readings (Data) of Electric Distribution Company for North Cairo. Their electrical power consumption data measured exactly as input original data for the present investigation while the demand response opportunities provided by these appliances are also discussed [9]. Since the price stripe inside total consumption depends on an actual period for the measurement, the recording date of consumed energy individually must be the same each month, i. e. a constant cycle of time (T). This process is very difficult due to the manual system for recording so that a deflection may be occurred in the determined consumed energy. This can be treated according to the automation system for recording the energy consumption for each individual consumer to ensure the time of 30 days. Otherwise, the economic style based on the statistical mean value could be implemented to correlate the variation in the time cycle of recorded reading.

Since the large initial data must be treated, the statistical mean value could be implanted in the computational analysis of the present work. It means generally that; all values of a subject cannot represent a problem for study so that only one value may summaries all of them. Consequently, the input data for the energy curves are summarized as a population mean which may be taken as a mean value (average) X [10] in the form:

$$X = \frac{\Sigma X}{N} \ (a = 1, \ldots, N) \tag{3}$$

The average value of either a load curve or an energy curve [11] is the same as the mean for statistical studies, but here this average is tailored in separate ways such as the *Instantaneous Mean* for the two different groups inside the same overall readings of the energy curves in Cairo [12]. Otherwise, the Weight Loads Mean is required for the analysis of energy curves as given in the initial data or the treated data. The effect of peak on the Energy curve appears to be the most important item for economists and so, a statistical study for either peak or light loads may be applied [10] as:

$$X \quad = \frac{\Sigma X \quad W}{\Sigma W} \tag{4}$$

It is well known that, the load curve for a specified place cannot be the same everyday due to the performance of its variation, and so, the speech about all populations of loads may be impracticable. Hence, the concept of simulation (sampling) may be the way to investigate the overall characteristics of loads, however, it will be a step in the way to cost the energy consumption in the network. The sample must reflect the overall view of consumers in the studied field since it may be for only one sector of customers. Two directions for the variation in a random way are needed [10]. The first is the change in the number of customers connected at the ends of the distribution network while the second will be the continuous addition for due to consumers or all together [11-13]. There are two axes for possible mistake in the process of accounting where total cost of a consumed energy in a certain reading must be modified. The average (mean value) concept can simply solve such problems.

A sample of official readings is registered for a time range of (1992-2017) years as given in Figure A1 for the energy consumption with an oscillated character. The annual average energy can be expressed as the sum of monthly readings within the year divided by the number of months despite the number of readings may be different. This case represents the first axis of mistake that needs not only a correlation as proved by the extracted points of mistake, but also to estimate the actual mean value based on the statistical principle. Whatever, the load varied not only by time but also with place or person because the end users are continuously increased day by day, and consequently, the load may be changed. The statistical study leads to a new correlation due to the unused energy in the network despite the company reserve it for them. So, the allowable energy to be generated will be included through the energy too inside the term of running cost of equation (1) while its installed value is computed with the capital cost. This can balance the process of costing for the energy consumption.

The present model represents the north part of Cairo (capital of Egypt) because the original data are real. The reason for reality is based on the Electric Distribution Company of North Cairo since the company gave the data officially for 15 consumers, representing the consumers of the company, as a model for all the area. The data had the variety in loading (energy consumption) where all data are monthly readings continuously without any break or stop (Figure A1 in the Appendix). These data of Electric Distribution North Cairo Co. for an ideal 15 Samples (Jan 1992–Jan 2018) are transformed from the Table style into a Figure.

4. Treatment of Original Data

There are two types of distortions in the original readings of the present research since the target is the overall characteristics of the energy consumption in Mega Capitals around the world such as Cairo. The first distortion is the single reading for the multi-month consumption while the second appears as the starting moment (energy utilization stop) for the consumption of energy either at the beginning of utilization or the stopping for a long time inside the model period (Jan 1992-Jan 2017). The studied data of 15 ideal consumers have been classified in two groups where the first and the second groups contain 8 and 7 consumers, respectively.

4.1. Multi-Month Readings

The above-mentioned data are original, but these data contain a multi-month reading, sometimes. This represents a distortion for the real consumption so that a mathematical treatment may be required. So, it must be correlated to be distributed equally (occupied houses) on the present reading month P_i and all past zero readings n_0 because the apartment unit is usually closed (as a normal behaviour in society), and a non-digital counter is installed inside, normally. This theoretical process would be related to the nominal regular of all readings next since the actual status is absent in original readings. Statistically, the average month reading P_m can be expressed mathematically as a function of the registered reading P_a and the number of past zero reading months (P_s) in the form:

$$P = \frac{P}{P} \quad (5)$$

Applying this formula to all assumed months, where the pre-registered value has been missed, the new treated values for energy consumption can be seen next. It should be noted that, these consumers have such readings at different points because they use traditional counters. On the other hand, the counters in Egypt have various performance with diverse types as there is traditional counter, prefunded (prepaid) electronic cart, inside installed counter, outside installed one, blind electronic type and may be others. The first group is presented in Figure A2 and Figure A3 for all consumers in periods 1992-2011 and 2012-2017, respectively. Then, the second group may be shown in Figure A4 and Figure A5 although a repeating characteristic may be remarked. These Figures indicate the normal behaviour of consumers since a vibrated (oscillated) vision takes continuous repeating values. The oscillation in energy consumption is acceptable because human activity has a great variety in a day away from each other or even during. These shown results must be treated for the second distortion in readings since the starting point may be different for a consumer relative to others.

4.2. Zero-Start Readings

If the second correlation for treated readings is considered again for all points, the computational effort would be great and consequentially, drawing curves. This attitude goes towards the mean value of computation principle so that the illustration may be clear. However, the second distortion will be appeared in some consumers either at start time or even during the period. Both cases are found in the model (1st & 2nd groups) and treated curves would be explained although mostly there is no distortion. Then, estimation can be applied for sequence of years.

5. Average Energy

Residential energy management modelling is a widely studied topic in current research community; different models are available in the literature to achieve various objectives as the minimization of consumers electricity bills, shaving of peak hours demand, peak to average power ratio reduction, minimizing the distribution losses, maximization of consumers satisfaction, improvement of load factor, voltage level, and economic efficiency of electricity consumption. To simplify the scheduling algorithms and to reduce the implementation and operational complexity, various tools and procedures are available in the literature [14].

5.1. First Group

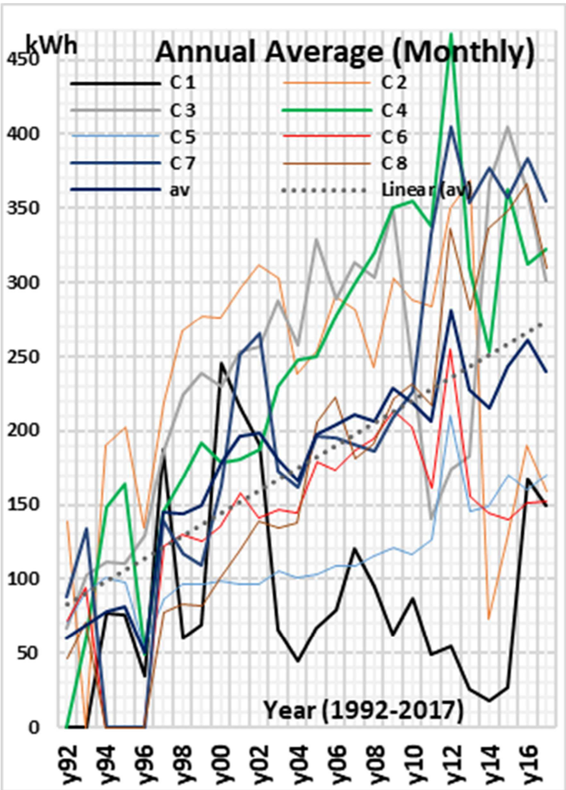

Figure 1. The mean value of annual consumption (1st group).

Since the model is sorted into two groups, the first group, containing 8 consumers, is subjected for study. Then, the details of estimated energy consumption besides the mean value of annual consumption for the first group are drawn in Figure 1 along the period of study while the tendency of future energy consumption pointed to a great increase.

The computed average of both cases (before and after estimating first zero readings) for the overall sum of first group is shown in Figure 2 where a difference between treated data and start zero readings curves is occurred only for years 1992-1996. The difference is disappeared as the maximum value reaches 187.3 for the case of starting correction and 129 for the treated values (the homogeneous distribution for loads on months). It is concluded directly from Figure 2 that; the tendency of energy consumption is higher for the case of treatment while the deduced actual curve says less increase. This means that, the first zeros in energy curves lead to higher relative values. Also, results in Figure 2 prove that, the actual average value for energy consumption (without start zeros) is only higher than the treated while the same shape of oscillation is appeared in curves both.

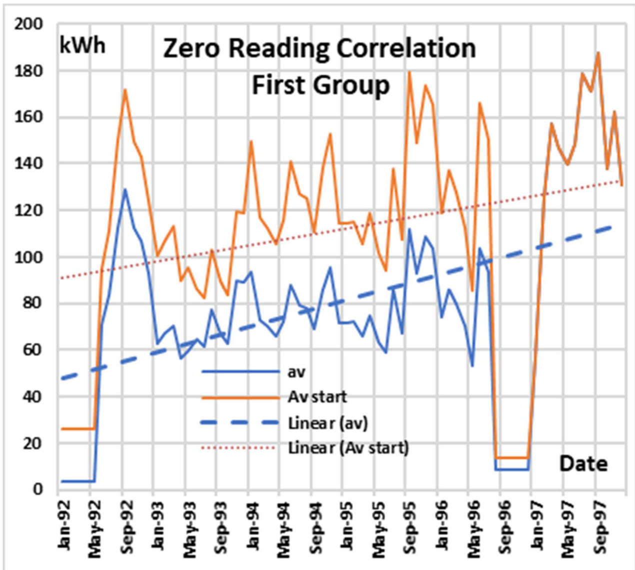

Figure 2. The effect of actual energy utilization (1st group).

The average values of the consumers in first group are going to be the same for both cases (before and after) after 1996 since it is approved according to the evaluation of this average in both cases as shown in Figure 2 at the ends of the year 1996 (as the two values go to overlap at the beginning of 1997). Then, the two values of mean value became the same exactly if zero readings are disappeared. However, average value for maximum readings per each month may differ since it will be explored next. It is important to illustrate the behaviour of consumers in first group within the studied period (1992-Jan 2018) where Figure 3 presents the characteristics of this group in the form of monthly average calculations. Then, the monthly average is transformed into the yearly reading to be drawn in a simple form as shown in

Figure 3. It is based on the mean value of energy consumption as shown in Figure 3 while both curves of treated correction and the correlation of starting zeros are drawn. The effect of actual readings is clear and the overlap of both is appeared after 1996.

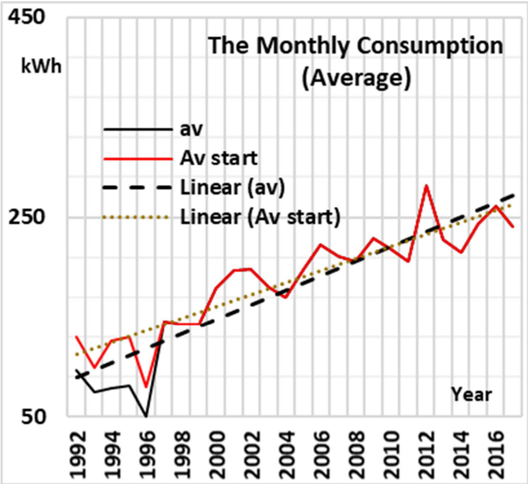

Figure 3. The mean value for the average energy consumption (1st group).

5.2. Second Group

However, the second group cab be studied through the readings since the average of annual energies for each consumer is estimated and then developed as shown in Figure 4 for the period of investigation (1992-Jan 2018). The average of all consumers is given too in Figure 4 where the tendency of variation indicates totally that the energy consumption is going up with time. This means that the already energy consumption (without the addition of new consumers) is growing always so that a new source of energy generation should be installed. Similarly, the second group would be inserted in the mathematical process if there are zero continuous readings. The total mean value for the consumers of second group can be deduced for all the group as above.

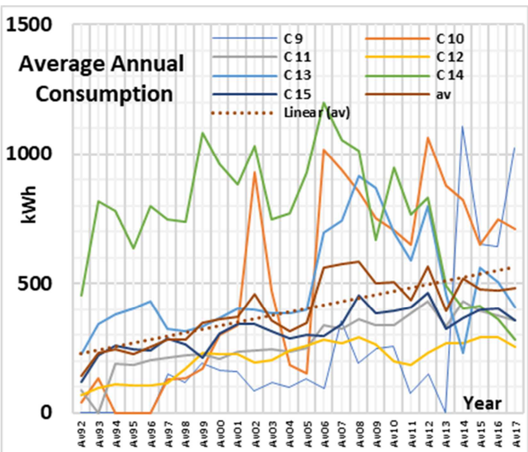

Figure 4. The average annual energy consumption (2nd group).

The results of estimation are drawn in Figure 5 since 1992, too, till Jan 2018 while the customers here are titled as 9-15. Figure 5 shows the average values for the seven consumers as annual energy consumption so that all the investigation period is drawn. The consumers have diverse character as the oscillation is appeared in all but with various maximum and minimum each. The consumer 14 has the biggest energy consumption as shown in Figure 5, but the consumer 12 has the less consumption. Whatever, consumer 12 has less oscillatory performance but consumer 9 brings the highest vibration in sequential readings (oscillation).

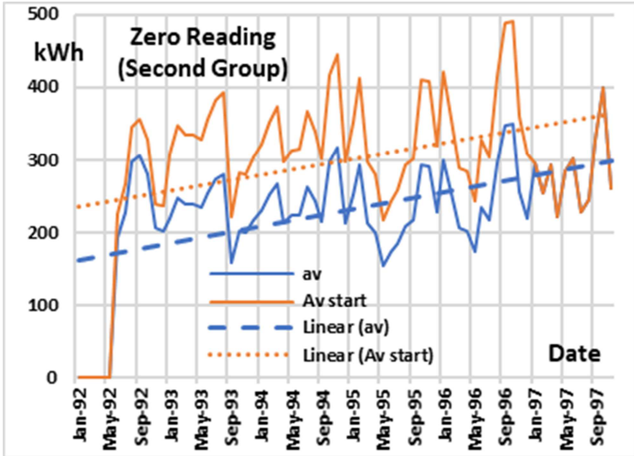

Figure 5. The average month energy consumption (2nd group).

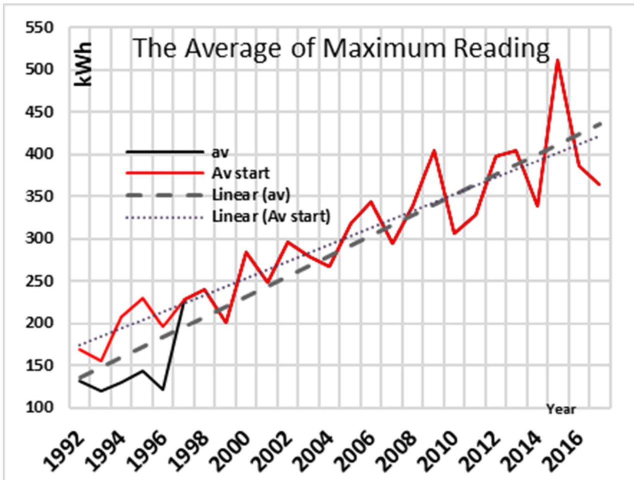

Figure 6. The monthly mean value for the Maximum of energy consumption.

The average value for all consumers of the second group is drawn on Figure 5 in brown where the variation is less in general. Also, the total average of the second group is going up always so that the energy consumption is increasing every month, approximately. Thus, the electrical energy consumption in domestic sector is grown for present consumers although there are many others are joining daily to the network. Secondly, if the correction due to start zeros of readings as shown in Figure 5 in the beginning years is applied, the results may be presented in Figure 6 for mean value of each corresponding to the years 1992-1997. Figure 5 says the same as first group given above while the correlation is done for readings of the years 1992-1996. Coming readings after are the same as Figure 6 proves this condition. Contrary, the slop of tendency lines for the average curves in both cases appears as the same (parallel lines) so that the elimination of start zeros will not affect the energy growth.

5.3. The model Readings

Whenever, the analysis of energy consumption can be considered as a major item for each country since the energy consumption in mega city such as Cairo may be important. The average value (Mean Value) is computed for both first and second groups as shown in Figure 7 for the period (Jan 1992-Jan 2018). Figure 7 indicates that, the energy consumption in the two groups is approximately steady for the period (2001-2016) because the tariff is constant. The tariff began to be developed in 2015, but consumers detected this later. The high oscillations in readings of both groups after 2015 is appeared because consumers tried to go to a stable consumption (little oscillation). The same result is determined for the model totally since it is estimated for the average energy as illustrated in Figure 7, too. The overall tendency of model energy is increasing with time where this leads to generation excess required for future to cover consumption at user ends. This conclusion is the same for either the individual groups or model readings.

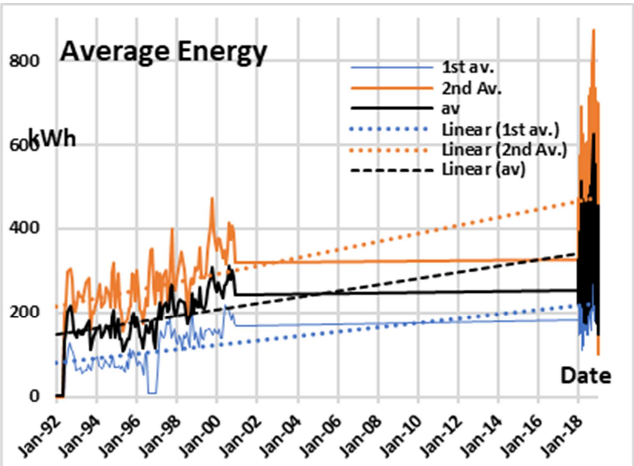

Figure 7. The profile of groups.

Expanding the x-axis in Figure 7 leads to clarifying of energy consumption for the last time (2016-2018) where resultant curves will be highly clear. This expanded oscillatory curves are given in Figure 8 for consumers while the group average consumption is added with.

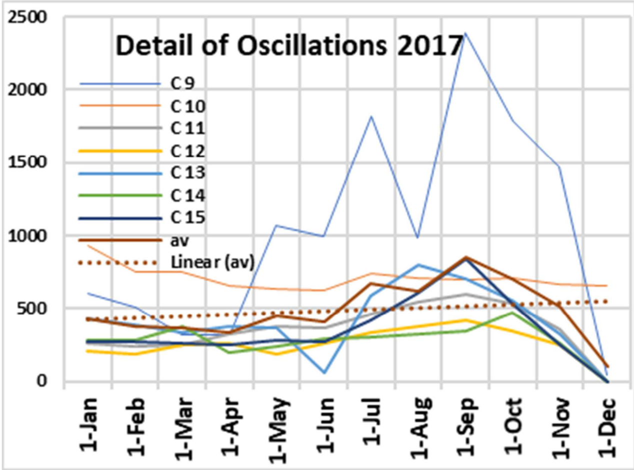

Figure 8. Modified energy consumption (2nd group 2017).

6. Maximum Value

With renewable energy systems, the desired frequency is maintained in Smart Microgrid when the generated power matches the grid load. Variability of wind power and fluctuations of the load are the main obstacles for improvement of frequency regulation. Active Power Control services provided by wind power generators is one of the main sources for performance improvement in frequency regulation since it is more suitable for domestic energy consumers [15]. Energy consumption can be measured by the mean value, but the generation of energy would be based on the demand value. This means that, the peak load is a goal for the generation side so that the maximum load (peak load) may be estimated. Consequentially, the maximum value as a statically base should be deduced since this process would be implemented to all input data to get the target value of maximum energy consumptions for all samples.

However, the evaluation of maximum loads is necessary because the above analysis pointed to a continuous increase in energy consumption. Then, a peak load should be determined to appoint the demand power required for network in future although energy consumption is increasing according to the continuous addition of consumers daily. Thus, the maximum energy can be transformed into a load as a peak value while the maximum determined energy is variable even for the same consumer every time. Otherwise, computations are applied for the model and maximum monthly energies consumed in the first group for all customers are given in Figure 9.

Similarly, Figure 10 presents energy consumption for customers in the second group where the maximum energy each month is highly swing for each. It is remarked from Figure 9 as well as from Figure 10 that, the domestic energy consumption has an oscillatory character based on the family performance although each family behaves in a similar manner. Otherwise, the computed maximum says that a sharp increasing for the utilization of electric energy is found where the oscillation phenomenon is appeared in both cases besides the model totally as drawn in Figure 11. However, the same oscillation must be presented for the maximum value of energy per each month (Figure 11) during the period of investigation.

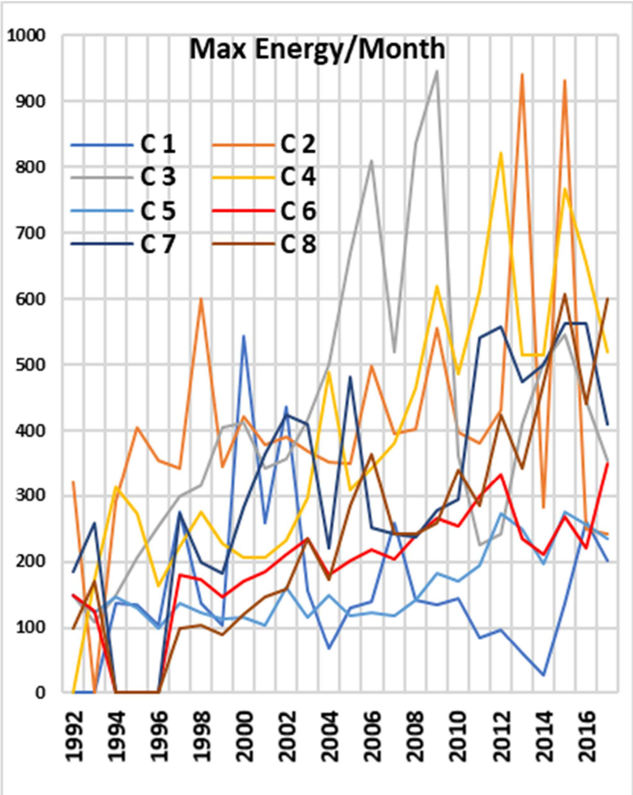

Figure 9. The maximum values (1st group).

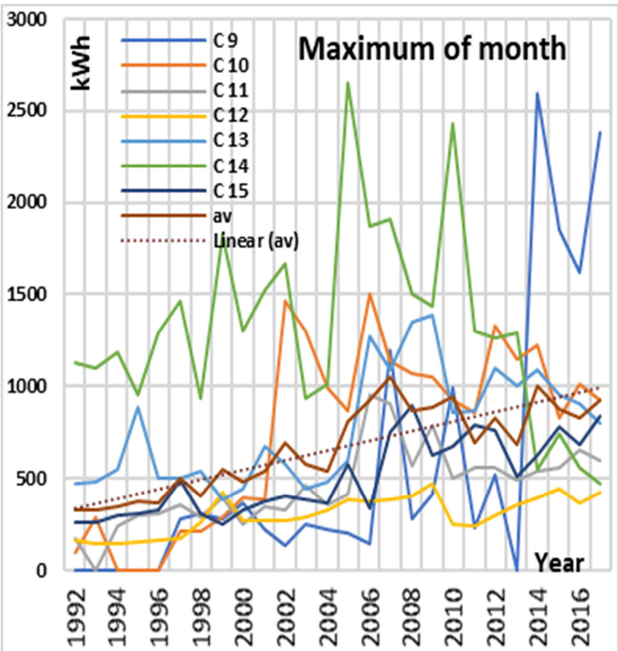

Figure 10. The estimated maximum values (2nd group).

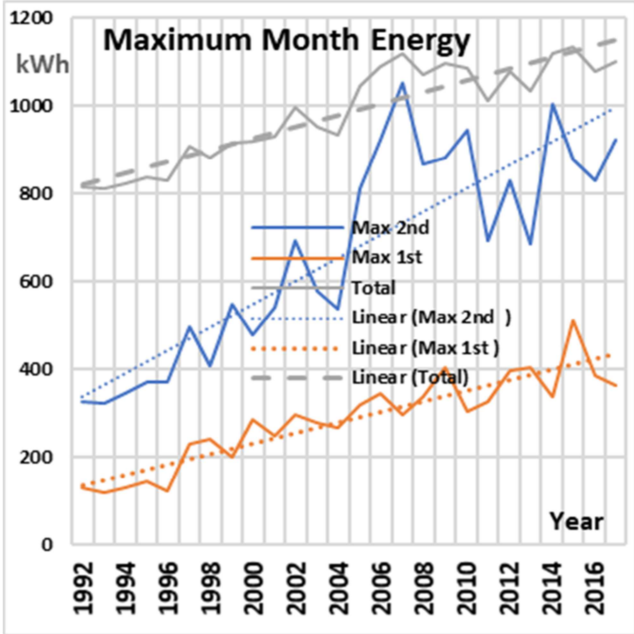

Figure 11. The estimated maximum values (both groups).

Residential loads play a significant role in balancing distribution sector of power system although demand side management is focusing on the optimum use and automatic control. Automatic scheduling of appliances based on their probabilities considering different constraints like weather, occupancy level etc. may be needed as home energy management technology where the appliances would be based on their calculated probability index to reduce the peak [16]. The maximum energy consumption is a good measure for power demand required to be ready in the generation system while the tendency of consumption increase is higher for consumers in the second group than that for the first (Figure 11).

7. Energy Growth

Planning or design is the most required item in all countries because the life doesn't stop. So, the study of a subject to get the maximum efficiency will be important so that economists and scientists are interested in such items. Then, the visibility study for a project can be the right way to be advanced since all present material equipment and machines or tools would require an improvement. The use of these items may hurt them and consequentially their life can be troubled due to bad utilization. The percentage typical distribution for domestic sector (type of customers) in advanced countries reaches 23% while in others it is 30% [17].

Food industry is one of the world's largest contributors to emissions (pollution) because of energy consumptions throughout the food life cycle. Specifically, while much effort has been placed on improving energy efficiency, appliance models used in various applications, including the food, are not updated regularly [18]. The first group has been studied for the history development, but it will be concentrated in the domestic energy consumption. Both month average and maximum energy are estimated as given in Figure 12 while it contains many other calculated parameters. Original data are treated for monthly or annual base while the tendency of future readings is controlled for each curve. Figure 12 pointed the sharp rise for actual annual readings, but it is slow for original annual energies.

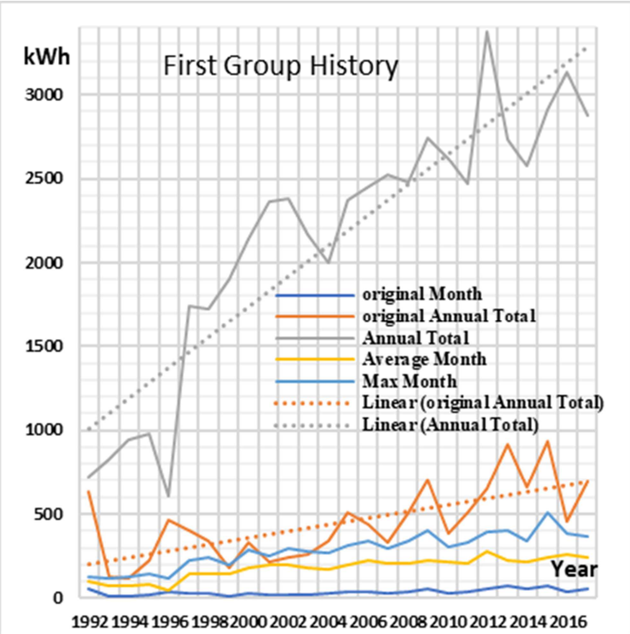

Figure 12. The History of consumption mean value (1st group).

The development of strategies that involves the participation of demand for increasing the flexibility of power systems requires defining accurate residential load models as cyclic loads, characterized by even different operating cycles. The model is developed starting from the collection of actual measurements gathered in real operating conditions in Cairo. The subsequent statistical and clustering analysis allows the model to be generalized for cyclic appliances as a target for the investigation. The actual model simulates more reliably the real behavior of cyclic loads [19]. However, the energy consumption growth is a goal for the present research so that more details can be deduced and discussed. It is noticed from all above results illustrated in the Figures that, the tends strategy for the future energy requirements must account the following remarks:

1. The tendency of the average energy utilization says that, there is a continuous growth in the domestic energy consumption so that the generating power system may be ready for such requirements.
2. The tendency of the maximum energy utilization appeared a continuous rise in the energy utilization and consequentially the maximum load could be determined in the same way. Therefore, the peak of domestic load in the city would be increased with time while the rise in the peak is greater than that of the energy applications as noticed from the above results. This means that, the generating system in the electric network would have the capability to cover such cases in the future, continuously.

These two major conclusions could be proved mathematically, but Figure 13 shows the effect of starting zeros on the energy growth. It is seen that, the three cases are drawn in Figure 13 where the treated readings, the zero-start correlation and the maximum actual for the correlation case are drawn. It is globally seen that the forthcoming energy consumption is higher for the maximum curve than that for the average so that the consideration of maximum values becomes vital.

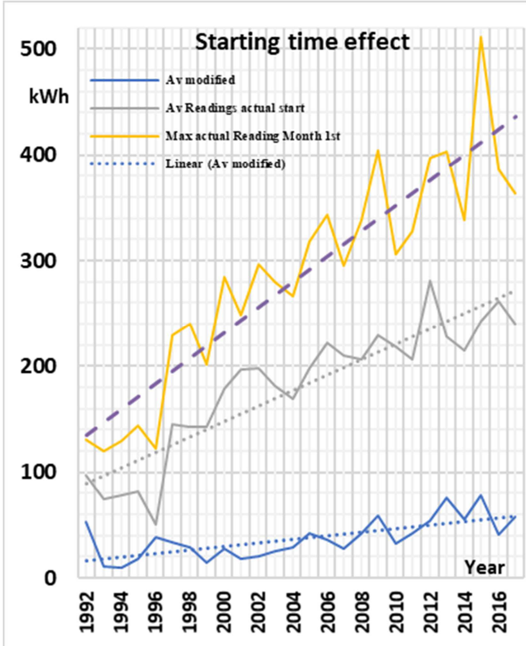

Figure 13. The modification and correlation of initial data.

7.1. Rate of Rise of Energy Consumption (RREC)

In recent years, the increment of distributed electricity generation based on renewable energy sources and improvement of communication technologies have caused the development of next-generation power grids known as smart grids. The structures of smart grids have bidirectional communication capability and enable the connection of energy generated from distributed sources to any point on the grid. They also support consumers in energy efficiency by creating opportunities for management of power consumption. The information on power consumption and load profiles of home appliances is essential to perform load management in the dwelling accurately. In this study, the power consumption data for all the basic home appliances, utilized in a three-person family as equivalent number of family. The detailed power consumption analysis and load profile were executed for each home appliance. The obtained data must be not only the average energy consumption of each appliance but also characterizes different operating modes. In addition, the impact of these devices on home energy management studies and their standby power consumptions would be analysed. The acquired data is an important source to determine the load profile of individual home appliances precisely in-home energy management studies however, the rate of energy consumption per a person should be determined as a measurement for economics related to tariff. Although the results of this study do not completely reflect the energy consumption behavior of people who live in this region, they can reveal the trends in load demands according to a real sample and customer consumption behaviour of a typical three-person family [20]. The mathematical analysis for the rate of rise of energy consumption RREC may be implemented into two parts such as monthly rise and yearly rise where the mathematical formula is expressed as:

$$RREC_i = (R_i - R_{i-1}) / R_i \qquad (6)$$

The first part of this equation can be defined as the difference between the two subsequent readings and the results of estimation are drawn in Figure 14. The results are illustrated for both first and second groups.

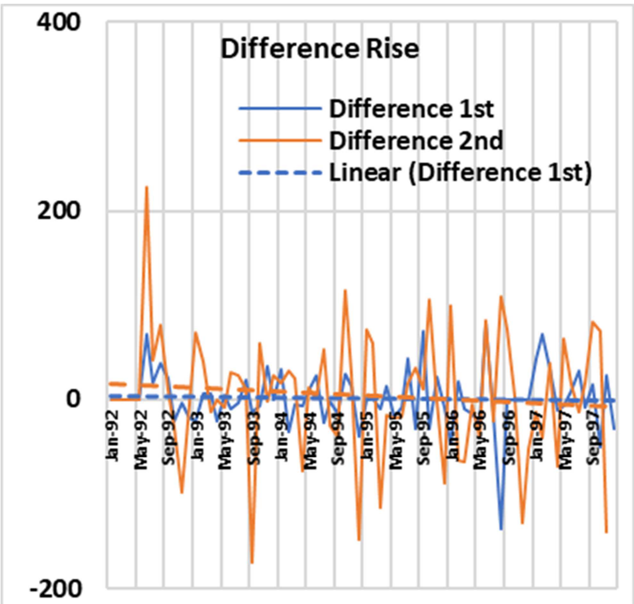

Figure 14. The computed difference dependency.

The next step appears to be the estimation of $RREC_i$ for both groups as shown in Figure 15. The high frequency change is illuminated in the Figure 15, but the goal of evaluation differs from that. It is needed to find the rate of variation in the use of home appliances if the development and rationalization of energy utilization is required.

Figure 15 is drawn for the beginning period (1992-1997) because it is the time of domestic transients due to the preparation and finishing works. It includes the wiring, piping, gas installation, decoration, water cycle system and others since the style of life and community base deals with these in discrete type of works causing a varied energy consumption. These works give the instable consumption, but later the family live comes to a stable system and the energy consumption becomes stable as indicated in Figure 16.

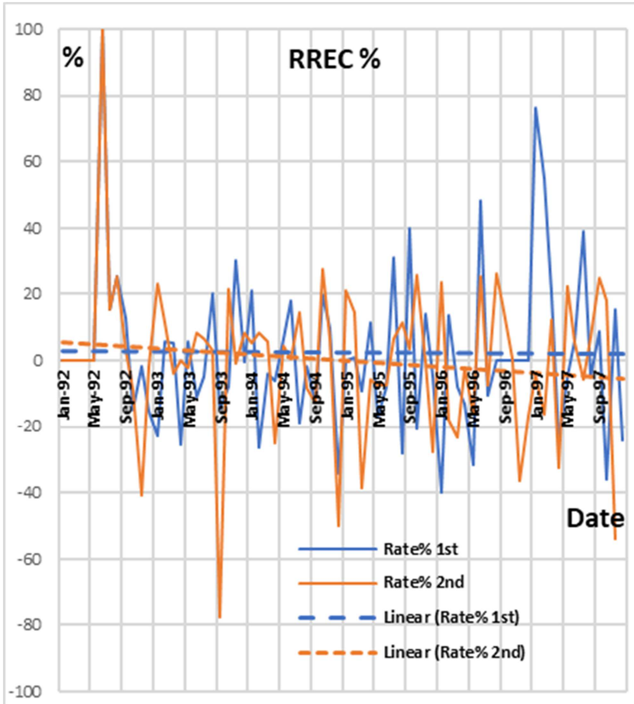

Figure 15. The deduced RREC for the model.

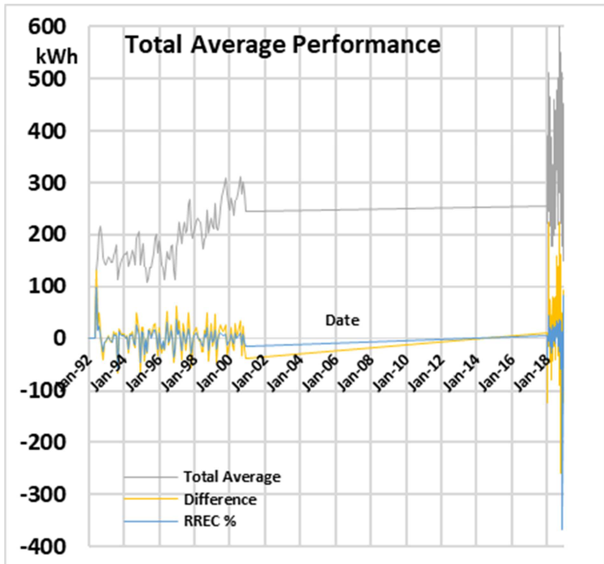

Figure 16. The stable and transients' profile in domestic energy

On the other side, the oscillations at beginning and end of the curves are presenting the transients of energy consumption while the straight line represents the stable time. The first beginning transients are occurred due to the community character in general or sometimes. Sequentially, oscillations at the end of curves may be happened because of the new appeared cost on energy consumption according to the tariff development policy. Otherwise, the average of total energy consumption lies in a high scale relative to the others two so that the separate curve may be illustrated individually. Thus, the average curve will be eliminated from and the other two (difference and RREC) can be drawn as shown in Figure 17.

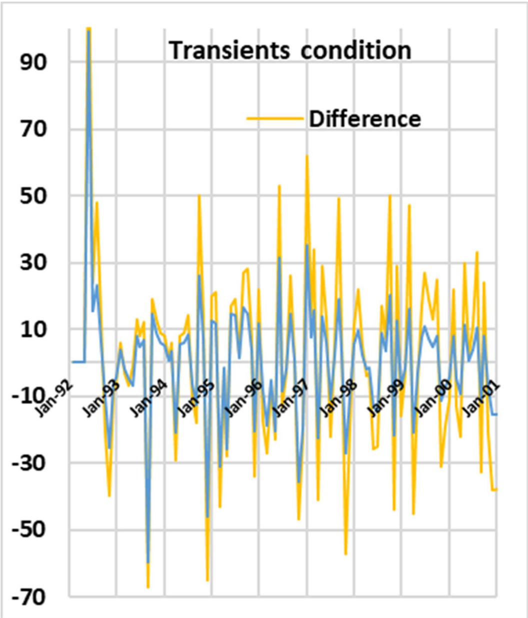

Figure 17. The transients at starting part (model).

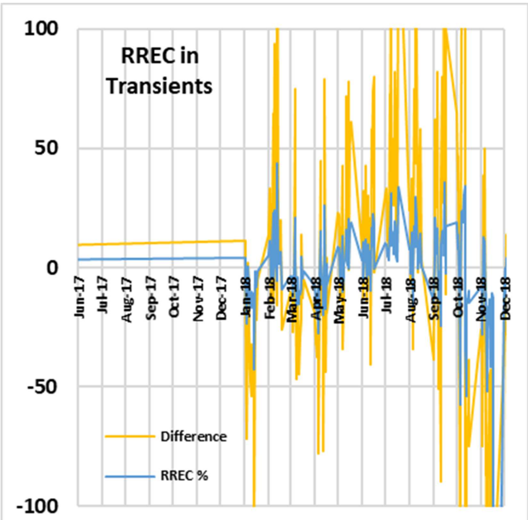

Figure 18. The transient characteristics at the end time.

The variation in curves of the studied model in Figure 17 is occurred within (-60 - 100) at the starting time, but it dropped from -40 to 30 at the beginning of the stable zone. This indicates a family stability with respect to the domestic power consumption because the income of family should cover all requirements in life. This reason may be miscellaneous from consumer to another based on the community classes or levels and national traditions. Similarly, the last part of transients due to the increased cost of energy, with a trial to go to stability condition, can be derived in Figure 18 where the stable part is appeared at the start position. It is valuable to find the details of the straight line in Figure 17 since Figure 18 presents the stable condition for each consumer. The straight line (Figure 18) would be transformed into small steps (scale) as illustrated in Figure 19 at lower oscillation level.

Figure 19 proves that, the oscillation in the steady state of energy consumption is varied between -100 and 100% although in the transient circumstances it was in less margin at very small value of original energy. This means that, the domestic energy consumption is normally stable while with the price variation a disturbance may be floated. A rationalization tendency for the domestic energy may be required for next future if the country decided to control and save the fuel for a maximum time.

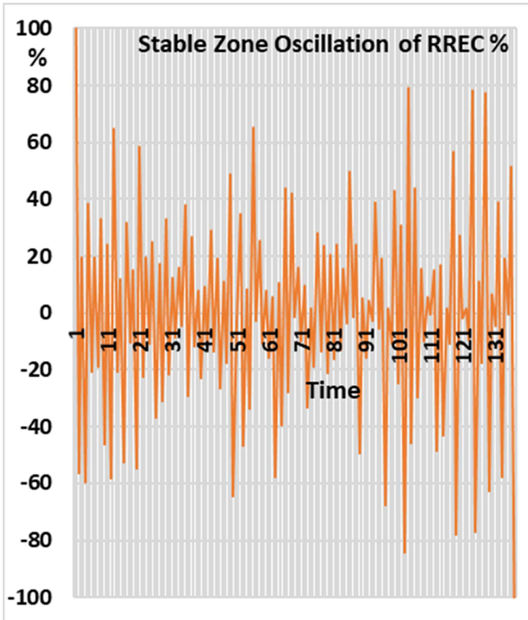

Figure 19. The stable oscillation in the period (1997-2016).

7.2. The Peak Load (L_{max})

Planning of an item, in general, depends on the forecasting all future values for the subject under study. Good planning is that study including too, the emergency and all probabilities, even, the non-predictable events. In attention of electric energy, the forecasting is required for the installation of new power stations, substations and transmission lines. Electric loads will float above due its characteristics in variety response. So, the designer in the field of electric power networks may need to concentrate on these electric loads as a major factor since this forecasted load reflects the real conditions. Thus, the study of electric loads has a major target to bring its vital duty in the operation of power systems in forward.

Nowadays, the fuel saving is the superintendent strategy in the world for two reasons: the storing of permissible fuel for next generations and have a cleaner environment for healthy (Green Zone). Thus, the present paper studies the domestic energy consumption although the peak load means the demand power. The theoretical relationship between both energy and power load (Demand) may be expressed as:

$$\text{Load (kW)} = \text{Energy (kWh)} / \text{Time (h)} \quad (7)$$

To enable demand power response in the residential sector, home energy management algorithms are needed. Many recent publications present a variety of algorithms for appliance-level demand response. In most studies, appliance power consumption is constant at its rated power without any cycling or variation during its operation. The main reason under lying the flat appliance power consumption assumption is the lack of knowledge about detailed appliance operating characteristics, and most importantly the lack of publicly available measurement data. Variation in appliance power consumption is an intrinsic characteristic for most major household appliances. Using realistic load profile, to find individual appliances for such studies, will lead to more accurate research findings and analyses. To date, there are only a few comprehensive sources of energy use data at a household level.

These include a free forum for the public, to share their energy usage data for a varying time interval (1-s, 1-min, 5-min, etc.) obtained from different individuals using assorted measuring devices, which may not be calibrated to provide consistent results. When a circuit supplies different types of appliances, it is categorized by its main type of appliance. This indicates that, electrical load profiles of individual appliances may not always be available. A few other publications discussed the operating characteristics of household appliances based on real-world measurement data where in these papers, very limited number of appliances were discussed [9, 14].

7.3. Daily Load Curve

Since the load is continuously varied, the consumed energy will not be a constant always. So, a new correlation factor may be required to adjust the performance of tariff as well as to bring the economic pricing in the right margin. Also, this process appears to be a direct reflection for the statistical type of variation, and consequently, it may be taken according to the load curves of network either in the end locations or in the city as a whole [10, 11]. The case of end users is analysed above while the next part of work considered the load curves in north of Cairo [12] as an example for the idea of correlation. This leads to the importance of statistical parameters to cover the probable values during the period of study. The major factors may be essential to represent all readings as they are tailored into the following items.

The subject of load curves is useful for engineers, economists and IT designers because it is a statistical problem. The load curves are investigated through real readings too, in addition to the standard load curves as original readings. The statistical base has been introduced since the load is always varying in all directions. *Domestic energy* can be expressed for the personal behaviour on the universe while each performance in each field of life may be studied and analysed. The variety of performance would be happened in a wide range so that the statistical base may be implemented. This view should be the major factor in the analysis of loads although it depends on the level of development either for a person or the country. Contrary, the load may be changed according to the geographical state for the same similar person. This means that, a hill would cause a different load for a citizen if he lives in a simple homogenous land. Also, a sea zone would give another shape for the variation of loads (*Domestic Electrical*) where the desert zone makes a third shape.

Loads can be defined as a periodic function in a constant cycle of time (a day) where it is like the sinusoidal wave of electric current. Also, the variation is repeating in the same manner relative to the value or time. This means a constant repeating manner for both (value and time) where the wave is known as cyclic. This means that, a point (a) is the beginning point of the function and its end too. The same variation is presented in the behaviour of a person because his life is always repeated every day. Since this characteristic is viewed, the load applied from a person should be seen daily. The load variation does not be smooth in all times while it can be discrete or highly change in some points. The personal loads differ from a field to another for a certain person although it may widely vary from a person to another.

A good planning gives benefits as: (a) power is generated and consumed locally (for islanded operation), and transmission losses are reduced; (b) daily load profiles are usually well known for microgrids and can be used as a priory information for frequency control systems; (c) information from smart sensors (which measure frequency deviations, power disturbances and other quantities) transmitted via local communication system with minimal delay can also be used for active control of power generators; and many others. Also, variability and uncertainty associated with: (a) renewable energy sources, such as wind and solar power; (b) load fluctuations due to changing weather conditions, temperature, humidity, economic factors like energy prices, disturbances from the utility grid and others can significantly challenge the performance. These technical disturbances result in voltage and frequency variations (since the desired grid frequency is maintained when the generated power matches the grid load) in microgrids [15].

Electric loads (L) mean the electric amount of either energy or power or even others so that the study of load curves in absolute meaning will be better than a specific one. Generally, load curves may be inserted for many items (not for energy only. So, a load curve can be considered for the number of cars crossing a bridge or the number of people upstairs a ladder in a governmental building or the quantity of a material consumed in the market in a regular period. Also, the loading on phone networks and entering the internet system can be estimated as a kind of load curves. These are examples while there are a lot to state here. Electric loads mean the use of electricity either in work or in home, day time or evening or the loading daily or annually. Then, the loads are defined as a technical approach as "LOAD CURVES" which must be analysed. Thus, the load curves will be the major subject where the value of a load can be either a power or an energy or sometimes the current. All these fundamental load curves can be defined as "standard load curves" because its behaviour is approximately the same in all fields. This load characteristic would be referred to the time. Therefore, the starting point should be a unit system for representation since to the standardization concept for the analysis is a fact. Then, the classification of standard load curves would be the goal although the values must be absent depending on the absolute percentage values. This means that the standard load curve is a periodic percentage curve and unit less values.

The mathematical determination for a load curve becomes the target although it is a difficult process. The formulation depends on the load curve characteristic based on the direct relationship between load and energy. Since the area under the load curve is the energy consumption per day, the theoretical formulation can be given as:

$$\sum L_i = \sum P_i \quad (8)$$

The negative direction will be proposed if estimation of the load curve is the goal. Thus, the total energy for all consumers in the ideal model can be effortlessly deduced and consequentially the value of (□ P_i) is found. The equivalent value of (□ L_i) cannot be possible directly, but the standard domestic load curve must be the way to the mathematical derivation for actual load curve [17]. Therefore, the standard load curve [17] may be stated for the equivalent one (point to point) to find the actual corresponding points of aimed load curve for the studied energy curves in the Cairo model. The standard daily load curve (Figure A6 in the Appendix) is the same as average as the monthly load curve and so, the determination of either the monthly load curve or the daily load curve will lead a good result. Thus, the computational processing instigates with the corresponding standard values, but the ratio of transformation may be implemented after the application of Equation 7 as:

$$L_i\,(h) = [\sum L_i\,(\text{Average}) / \sum P_i\,(\text{Average})] \times P_i\,(h) \quad (9)$$

Therefore, the actual load curve corresponding to the energy curve would be estimated for each hour where the monthly load curve is deduced and then given in Figure 20 for the monthly values according to the original input monthly data.

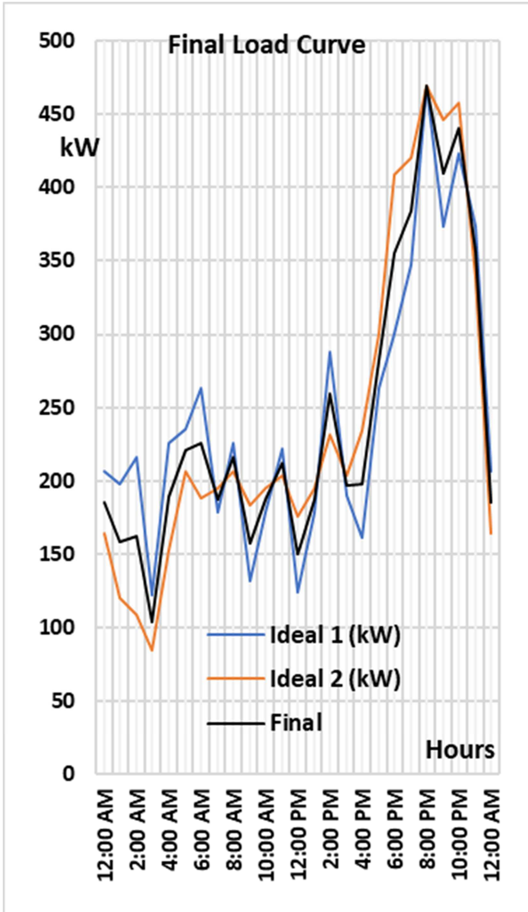

Figure 20. The estimated ideal monthly load curve for Cairo north.

It is seen from Figure 20 for the monthly load curve that, there are two deduced load curves for the same energy calculated because the standard load curve for the domestic load is expressed in two limits for utilization. Thus, the two limits curves are determined but the equivalent single load curve representative the case is estimated as the final load curve. Since the values used in computations are the monthly, the inferred single load curve will be also for the monthly load curve. Therefore, the daily load curve can be evaluated based on the mathematical equation of daily load L_i (kW):

$$L_i = L_i\ (\text{Month}) / \text{No. of month Days} = L_i / 30 \quad (10)$$

Then, the daily load curve can be assessed simply according to the extracted monthly load curve in Figure 20 as given in Figure 21.

Daily load curve with the fundamental parameters is defined as peak value of 15.667 kW and average load of 8.106 kW while the monthly energy consumption for each consumer is 202.6495 kWh. These parameters are very needed for the future planning to cover the energy requirements in Cairo while other big cities may be similar, too. Otherwise, the total daily energy consumption in Cairo can now be introduced for future planning according to the formulae:

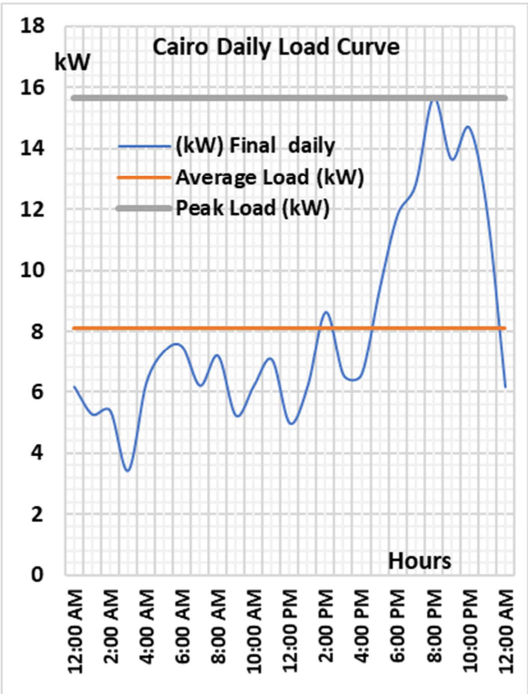

Figure 21. The ideal Daily load curve for Cairo north.

$$\text{Daily energy consumption (Cairo)} = \text{Daily Energy (kWh)} \times \text{No. of Consumers} \quad (11)$$

Whatever, the characteristics of some consumers in the studied model may be distracted from the ideal standard load curve whenever the diversion can be evaluated and then correlated. Thus, the deduced daily load curve in Figure 21 should be considered and proposed for the *Electric Distribution Company* to be implemented as a unity performance for consumers in Cairo as average. Since the data of number of consumers are absent, the tabulation system may be computed as listed in Table 1. It contains the total domestic energy consumption, the peal load and equivalent demand corresponding to the number of consumers connected to the distribution network in Cairo. The demand factor can be considered as 1.1 [17].

Finally, the economic factor of electric energy per capita (Wh) can be calculated as a function of the total population energy consumption in (Wh/Year) according to the expression:

$$\text{energy/capita} = \text{Total consumption/population} \quad (12)$$

This equation can be averagely modified according to the process proposed in the present paper. Since the average members / family is supposed as 4 persons and consequentially, the electric energy per capita will be evaluated as:

P_{av} (Daily) × 365 / 4 persons = 8106 W × 365 / 4 = 2026.5 × 365 = 739672.5 Wh = 739.673 kW

This value depends on the mathematical analysis for the consumers in the north of Cairo.

Table 1. The daily parameters of load in Cairo for different populations

No. of Consumers	Domestic Energy	Peak Load	Demand Load
(Million)	(MWh)	(MW)	(MW)
1	8106	15667	17233.7
2	16212	31334	34467.4
5	40530	78335	86168.5
10	81060	156670	172337
20	162120	313340	344674

7.4. Energy Management

Energy management in residential buildings is one of the major keys for achieving the ambitious goals of efficient energy consumption, minimum carbon footprint, and reduced consumers energy expenditures [21]. It is known that; the application of standard optimization concept requires huge computational complexity and therefore, a conversion of the original problem into an equivalent mathematical model with reduced number of constraints and decision variables. This significantly reduces the computational effort and time while standard optimization methods can be utilized for finding its optimal solution. The vast growing electricity demand affects the reliable electricity supply, which in turn causes fluctuations in power system, where the renewable energy insertion could be suitable [22]. To curtail the unpredictability and fluctuation of the power system, the demanded load curve should be deduced within the allowable range. Electric consumption in consumers premises would be increased day by day [21].

Although there are several concepts and methods for the energy management around the world according to the national style of energy pricing, the present work indicates that there are a few principle bases for the real and good energy management, especially in the developing countries. It should be said that, energy management appears as one of the vigorous factors to go to the effective rationalization for the energy consumption, but fundamental goal would be wider vision. Then, the aimed protocol must depend on:

1. Elimination of the impurities in the running system of energy management
2. Achievement of optimal flow in the network
3. Smart control for the energy consumption at end users (Consumers)
4. Minimization of all types of energy loss in the distribution system
5. Creation of a new dispatching center for smart recording of energy readings for each
6. Schedule implementation of the capital and routine maintenances under control
7. Regular fine inspection and upgrading of specification of all house appliances
8. Quick replacing for new innovations related
9. Attention clarifying for population
10. Support policy for renewable energy to reach clean
11. Continuous modification for the operation characteristics of the united electric network
12. Application of all requirements (mentioned above and others) through a single manager for energy management

8. Conclusion

Since the load curve characteristic has a periodic cycle (Daily, Monthly or Annual), its statistical factors can express the overall performance. Therefore, the determination of an ideal load curve for a city will have a significant meaning if statistical application would be needed for forthcoming planning. This item is a main goal for the subject of energy consumption because the rationalization strategy appears to be the policy for all countries on the Glob. Thus, the subject is vital, and the deduced unique load curve is a precious work.

Recently, the energy consumption takes the space of research and implementation in dissimilar countries, especially, the advanced one. The analysis for all consumers has impracticable meaning so that the statistical study based on the sampling concept might be the right way. Otherwise, the analysis of energy consumption in a city could be incomprehensible if the details for economics and costing are the target. Then, the analysis of energy curves for a model representing the city leads to accurate results needed for the planning and development. The original data are digital values while the correction for readings must be accounted. Thus, the types of correction for both the multi-month reading distribution equally and the starting energy utilization evaluation (occupied houses) are implemented for all original data. The resulting energy curves indicated actual and real vision so that the deduced curves are classified into two groups for the statistical purpose.

However, the determined single ideal daily load curve for Cairo (capital of Egypt) directed the calculation to appraise the energy consumption / year / person as the economic main factor (energy per capita) in a simple way. The population concept may be difficult to utilize, but each consumer represents a family that have 4 members in Mega cities and may be 6 in villages. The present work deduces the energy per capita with the assumption of 4 persons in each family (consumer). Therefore, the number of consumers connected to a network through the company can be simply accounted without the need for the population problem.

Since the energy curves presents the energy consumption per month, the regular estimation for either the energy cost or the number of consumers each month will be known simply. So, the paper illuminated on the simplicity of some complex problems with population and elucidates the energy requirement in the present time or even in future using the extrapolation principle. On the other hand, the maximum values for readings represents the installed capacity for the demand resolve the generating power system. Nevertheless, the rate of rise of the energy consumption is computed for both groups either for the average values or the maximum where the results illuminated on the fluctuation up and down. The difference between each sequential couple appeared a vacillation while the rate of rise of energy consumption gives less. The tendency of future variation is rising in a blaze shape where the average rate of rise is determined showing a growth of energy consumption for the present consumers without new addition daily.

Acknowledgements

The authors express thanks to Eng. Nagi Aref (The President of Elec. Distrib. Co.) and his staff members for help.

Appendix

Table A1. The Published Data for the Economic measurements (Average energy per capita).

Rank	Country	$Energy_{Av}$ / Capita kW/person/year	Rank	Country	$Energy_{Av}$ / Capita kW/person/year	Rank	Country	$Energy_{Av}$ / Capita kW/person/year
—	World	2,674	9	Finland	14,732	42	France	6,448
1	Iceland	50,613	10	Sweden	12,853	48	Denmark	5,720
2	Liechtenstein	35,848	11	USA	12,071	55	Greece	4,919
3	Norway	24,006	16	Korea, South	9,720	59	UK	4,795
4	Kuwait	19,062	37	Germany	6,602	61	Italy	4,692

Rank	Country	Energy$_{Av}$ / Capita kW/person/year	Rank	Country	Energy$_{Av}$ / Capita kW/person/year	Rank	Country	Energy$_{Av}$ / Capita kW/person/year
5	Bahrain	18,130	17	Saudi Arabia	9,658	62	China	4,475
6	U A E	16,195	26	Russia	7,481	124	Egypt	1,510
7	Qatar	15,055	29	Oman	7,450	218	Chad	16
8	Canada	14,930	30	Japan	7,371	219	Gaza Strip	0.1

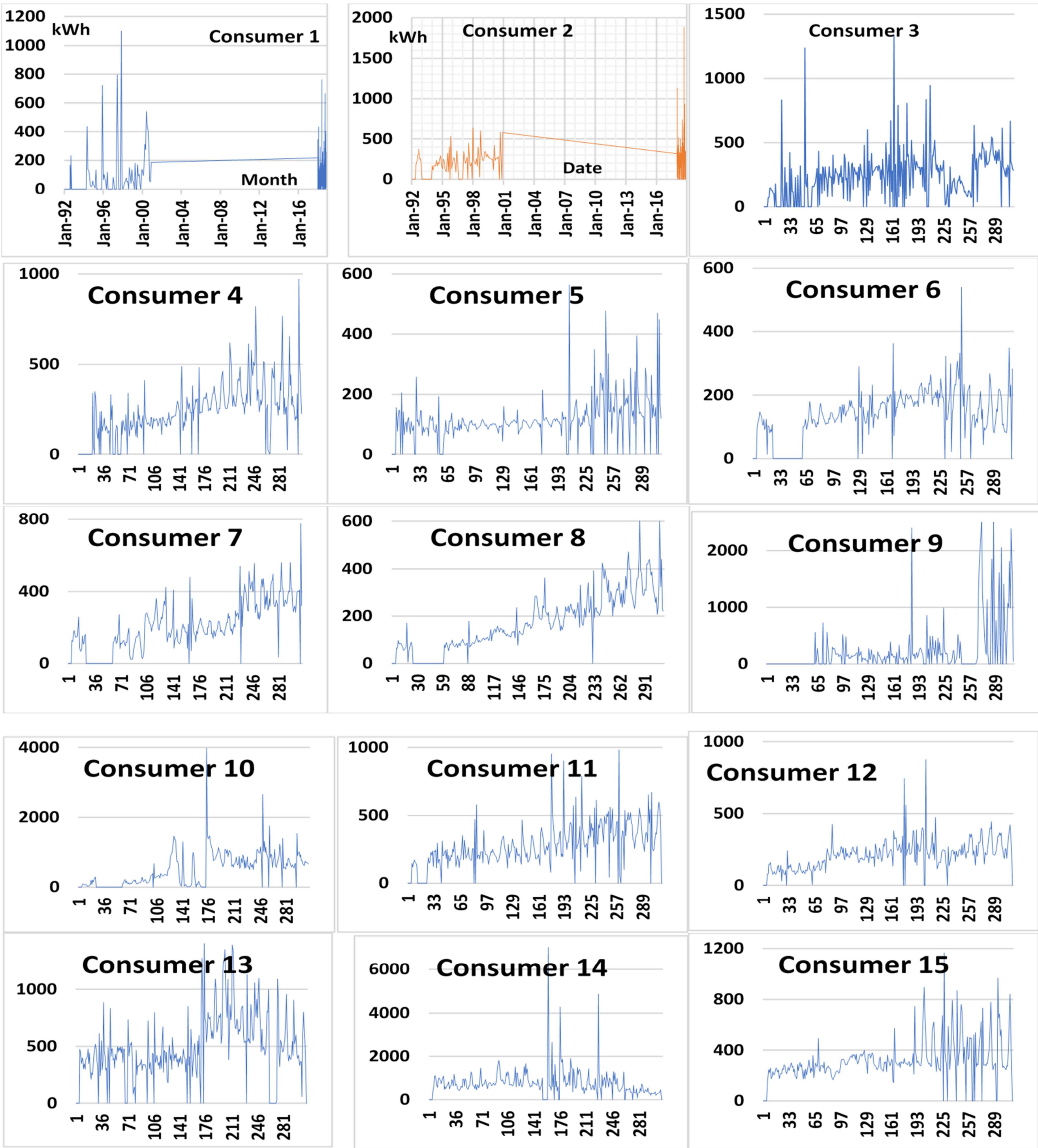

Figure A1. Readings for the ideal Samples (Jan 1992 – Jan 2018).

Source: Wikipedia pages
Source. North Cairo Electricity Distribution Company.

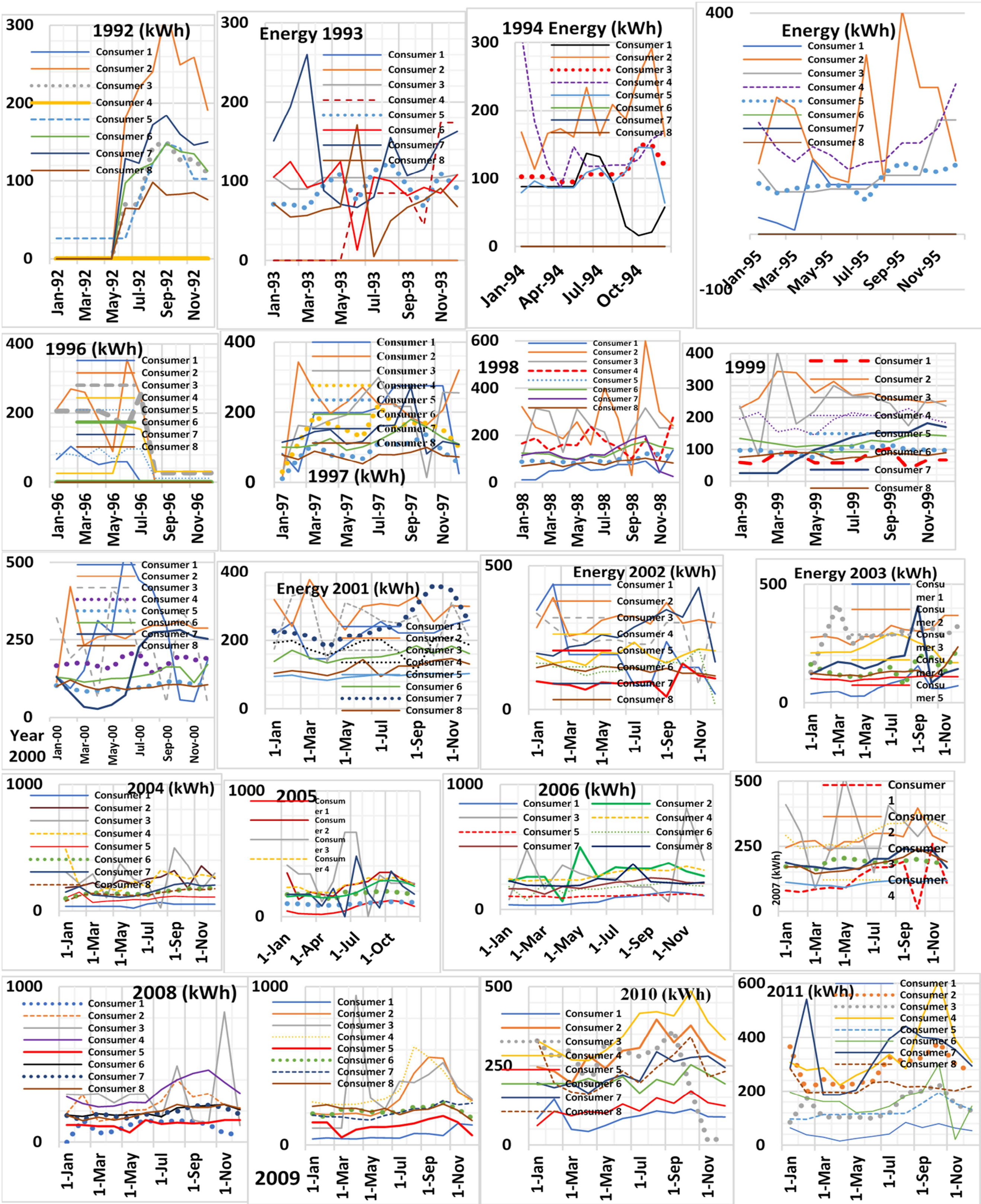

Figure A2. Treated Energy consumption for the first group (1992-2011).

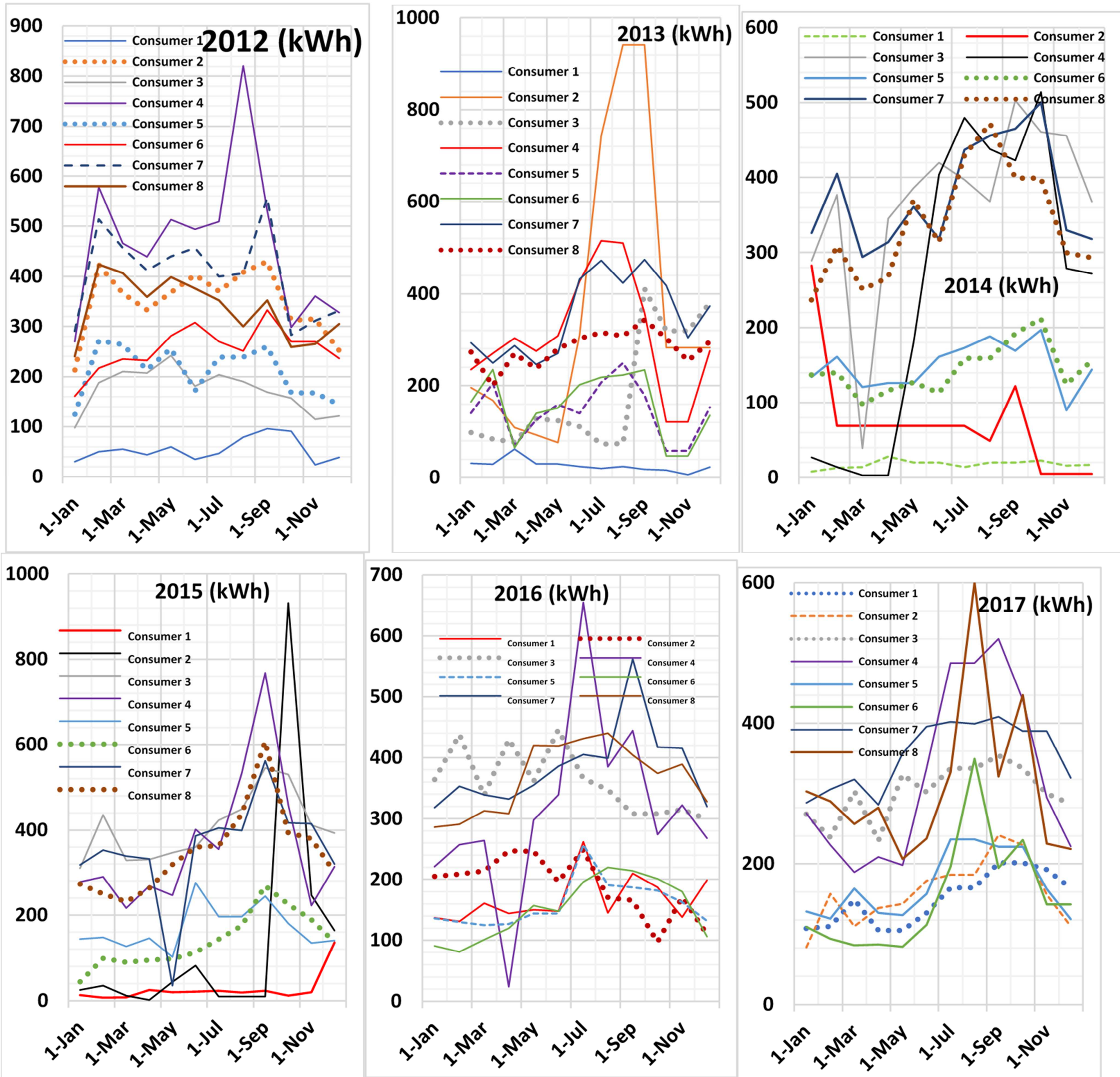

Figure A3. Treated Energy consumption for the first group 19922- Jan 2003.

Table A2. The basic tariff for the domestic sector in Egypt.

Energy	100	200	300	400	500	1000	2000	3000	4000
Tariff base	180	480	860	1280	1740	5290	15290	27290	39290
Pav (/ kWh)	1.8	2.4	2.86	3.2	3.48	5.29	7.645	9.096	9.82
RRP (base)	1	1.33	1.58	1.77	1.93	2.93	4.24	5.05	5.69
RRP (stripe)	1	1.33	1.19	1.11	1.08	1.52	1.44	1.18	1.07

Table A3. The basic tariff for the commercial (industrial) sector in Egypt.

Energy	100	200	300	400	500	1000	2000	3000	4000
tariff base	210	570	1210	1970	2850	7850	19850	33850	46850
Pav (/ kWh)	2.1	2.85	4.03	4.925	5.7	7.85	9.925	11.28	1.96
RRP (base)	1	1.35	1.91	2.34	2.71	3.73	4.72	5.37	5.69
RRP (stripe)	1	1.35	1.41	1.22	1.15	1.37	1.26	1.13	1.06

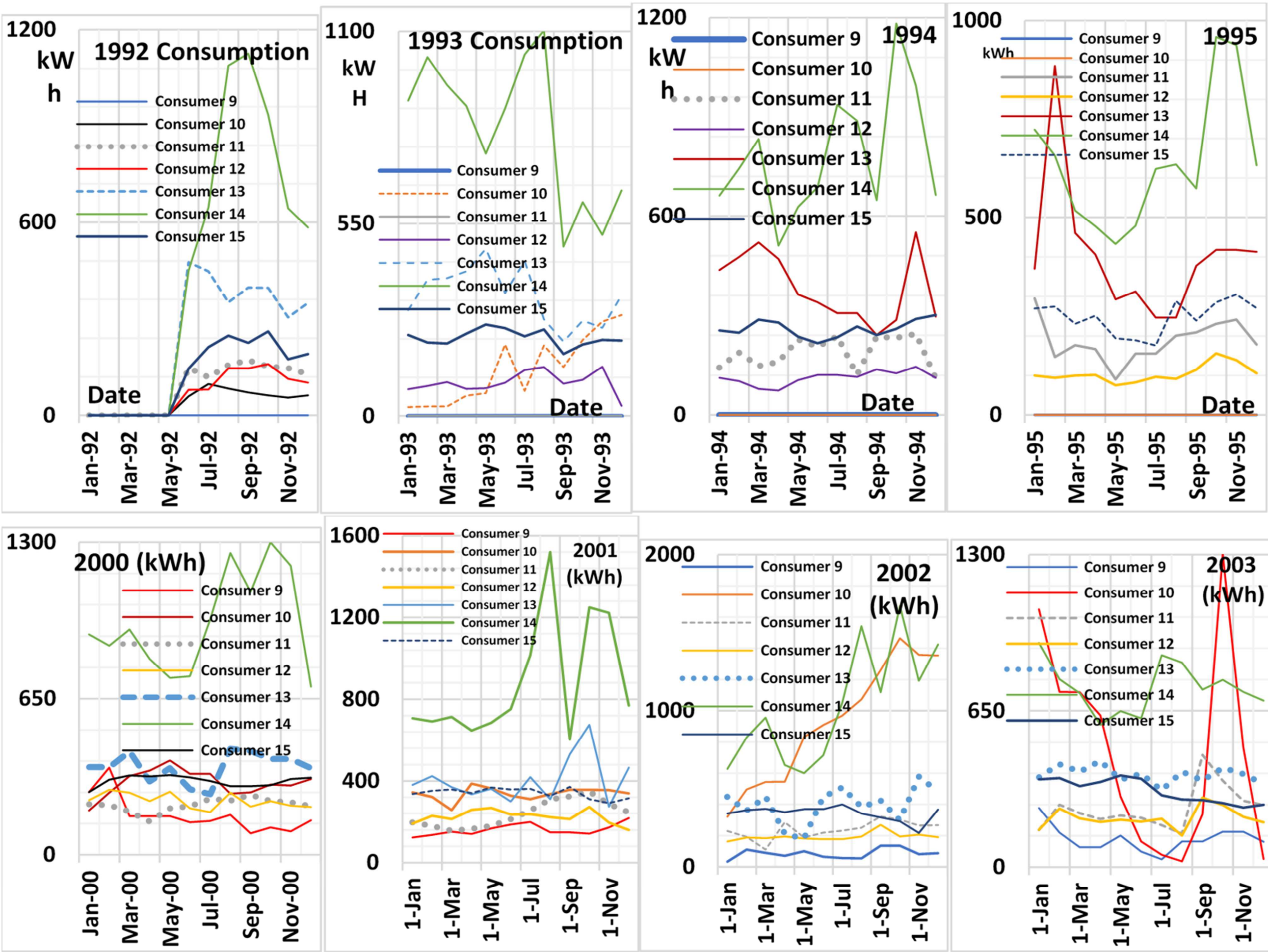

Figure A4. Modified Energy consumption of the second Group (1992-2003).

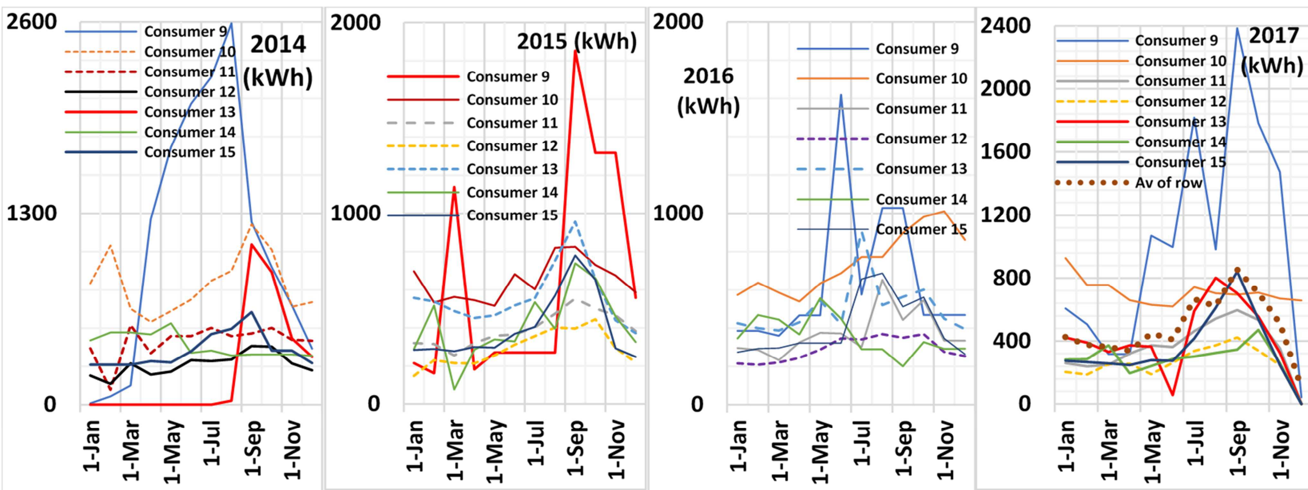

Figure A5. Modified Energy consumption of the second Group Jan 2014 - Jan 2018.

Table A4. The last tariff for the domestic sector in Egypt (L E / kWH).

Price	Triple stage Strip	Price	Double stage Strip	Price	Single stage Strip	Strip
0 - 50		0.05	First Stage	0.075		0.11
51 - 100	Ascending price	0.13		0.145	First Stage	0.19
101- 200		0.13	Second Stage			0.19
201 - 350		0.215			Second Stage	

Price	Triple stage Strip	Price	Double stage Strip	Price	Single stage Strip	Strip
0 - 200				0.16		0.215
201 - 350		0.19		0.24		0.42
351 - 650		0.29		0.34		0.55
351 - 650						0.55
651 - 1000		0.53		0.60		0.95
651 - 1000		0.95		0.95		0.95
Above 1000		0.67		0.74		0.95
0 - 1000					Third Stage	0.95

Source: North Cairo Electricity Distribution Company

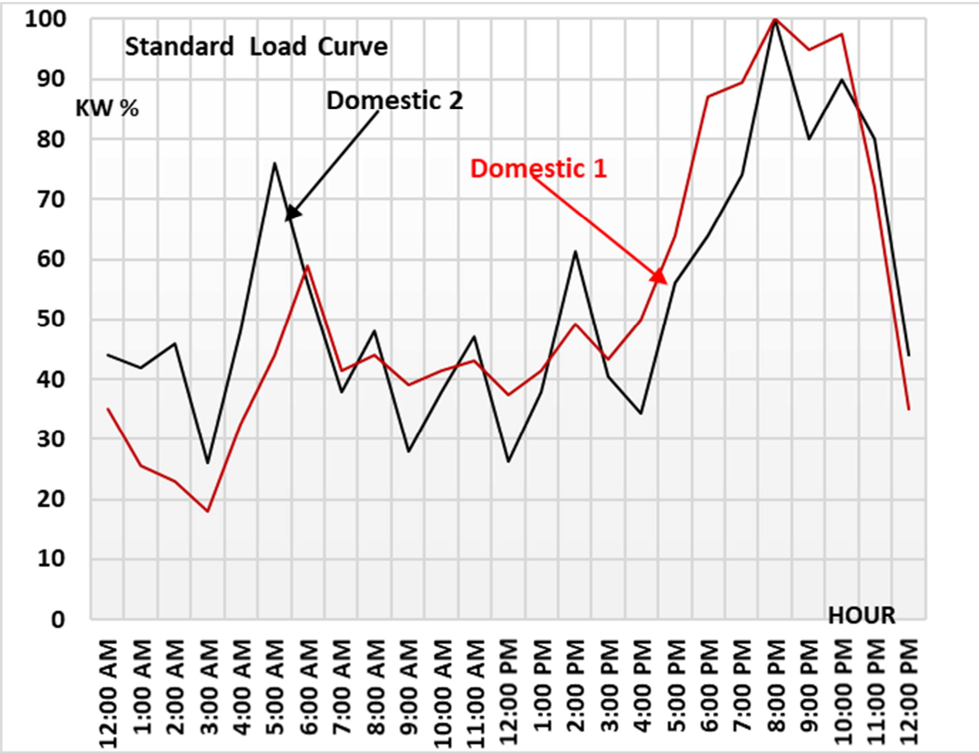

Figure A6. The standard domestic load curve [17].

Nomenclature

Symbol	*Meaning*	*Symbol*	*Meaning*
C	*Class interval of median class*	kWh_i	*Energy reading for the* i^{th} *month*
E_t	*Total energy consumed*	X	*Mean value of the population measurements*
P_o	Average month reading	$RREC_i$	*Rate of Rise of Energy Consumption (Year/Month)*
P_i	*Instant reading for the* i^{th} *month*	$n_{0\text{-months}}$	No. Of past zero reading months
S	*Standard deviation for the population*	μ	*Mean value of the samples*
X_w	*Weight load mean*	X_i	*Reading at the* i^{th} *month or day or hour*
X_g	*Grouped mean*	E_i	*Energy Consumption in the* i^{th} *(Month/Year)*
N	*Number of populations*	L_i	*Load at moment i*
n	*Number of samples (n < N)*	L_{max}	*Peak /Maximum load*
σ	*Standard deviation for the samples*	W_i	*Weight of reading of the* i^{th} *month or day or hour*

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