Control and Cybernetics

vol. **49** (2020) No. 4

Electric power consumption forecasting for industries in Ahmednagar City: a preliminary study*

by

Riddhi Panchal[1] and Binod Kumar[2]

[1]SavitribaiPhule Pune University, Maharashtra, India
[2] JSPM'S RajarshiShahu College of Engineering, Pune, Maharashtra, India
rids.panchal@gmail.com,
binod.kumar.1970@ieee.org

Abstract: This paper reports from the study dealing with the preliminary investigations, concerning forecasting of electric power consumption of some industries from Ahmednagar city. The investigations regarding the potential energy consumption are mainly directed to three energy-related aspects or drives, namely: (i) energy policy, (ii) production of green and non-green products, and (iii) production of FMCG (fast-moving consumer goods) and non-FMCG products.

The here proposed methodology is implemented in three phases. The first, initial phase concerns the preparation of the questionnaire that clearly addresses the effects of the aforementioned drives on various industries. The issues mentioned in the questionnaire are closely related to the industries from Ahmednagar city. In the second phase, the prepared questionnaire was distributed to the industries of Ahmednagar city. In the questionnaire, all the questions are made mandatory and subsequently, the industrial authorities are demanded to fill up the precise information as much as possible. The responses from the concerned industries related to power management are then subject to analysis.

The analysis is done with the focus on correlation coefficients. Thereby, determining the correlation between different factors helps to arrive a conclusion regarding the dependencies of various factors in the potential power consumption of industries in Ahmednagar city.

Keywords: energy policy, industry, green and non-green products, FMCG and non-FMCG products, correlation analysis

1. Introduction

Long-term electricity requirements forecasting is an important part of appropriate planning of expansion and setting up of EPS (Meer, Munkhammar and

*Submitted: February 2020; Accepted: March 2021.

Abbreviations used throughout the paper in the sequence of appearance in the text

Abbreviation	**Description**
EPS	Electric Power Systems
EE	Energy Efficiency
PV	Photo Voltaic
PIs	Prediction Intervals
NPPs	Nuclear Power Plants
ANN	Artificial Neural Network
HEM	Home Energy Management
ELM	Extreme Learning Machine
ESF-ELM	Error & Self-Feedback Extreme Learning Machine
PSO	Particle Swarm Optimization
LV	Low Voltage
SCR	Self-Consumption Ratio
GBM	Gradient Boosting Machine
RMSE	Root Mean Square Error
FELM	Fuzzy ELM
FMCG	Fast Moving Consumer Goods
AMVO	Adaptive Multi-Verse Optimizer
SVM	Support Vector Machine
SCBPM	Self-Consumption Based Power Management
NN	Neural Network

Widén, 2018; Kleshchyova and Nakhabov, 2015). Actually, forecasting plays a crucial role in the planning of construction of new generation services, of the transmission lines expansion, and also of the developments in the country-wide electric power system (Collotta and Pau, 2017; Xu et al., 2018). Based on the spatial and temporal extent of the long-term predictions, the respective kinds of decisions from the administration can be distinguished (Nousdilis, Christoforidis, and Papagiannis, 2018; Touzani, Granderson and Fernandes, 2018). For example, predicting the electricity requirement for a particular distribution region will provide assistance to the respective electricity company to approximate in quantitative terms the requirements on personnel, materials and equipment (Han et al., 2018; Wang et al., 2018; Jameel and Ali, 2016).

Anyhow, in identifying and then addressing in a well-founded manner the demand for electricity it is indispensable to have adequate prediction (Shi et al., 2018; Silva et al., 2018), and this prediction has to be based on an explicit comprehensive forecasting scheme, in order to encompass and consider the entire knowledge regarding the long-term demand prediction factors and mechanisms (Wirtz et al., 2018; Al-Falahi et al., 2018; Donateo, Carlà and Avanzini, 2018; Ding, Hipel and Dang, 2018; Anand and Suganthi, 2020; Hu et al., 2019).

To ensure appropriate effectiveness of the supply systems and to minimize the amount of energy used, a significant step consists in comprehending energy requirements at comparatively high spatial resolution. A precise forecast of energy demand (Kumari and Sharma, 2016; Ioakimidis et al., 2018; Singh, Jain and Singh, 2018) could offer valuable information for formulating decisions on energy production and acquisition. Besides, a precise prediction (Zhang et al., 2018; Teixeira and Sodré, 2018) might exert a noteworthy impact on the capacity of avoiding overloading. Consequently, numerous research studies have been undertaken on developing machine learning schemes to forecast energy utilization of commercial and residential entities, using as primary inputs the features like energy bills and weather (Thangam and Muthuvel, 2020; Thangam, Muthuvel and Kazem, 2019; Swamy, Rajakumar and Valarmathi, 2013).

Prediction of future energy needs (Yoon, Singh and Min, 2018; Shi et al., 2016; Munkhammar, Widén and Rydén, 2015) for public policy makers is essential for future infrastructure enlargement, economic planning, and assessing of energy consumption. A widespread technique exploited by the state policy formulators in planning future energy requirement is to carry out a simple linear extrapolation of chronological energy-related statistics with respect to time. It is, however, indicated that such an approach might significantly over-estimate the prospective demand, owing, first of all, to the raise in energy efficiency (EE), see, e.g. Yuan (2017), which reduces the energy intensity of the economic and household sectors in the majority of countries. Moreover, this linear extrapolation approach (whatever its concrete varieties are) fails to take into consideration the interdependence of energy needs, population dynamics, fuel and energy prices, financial activity, and climate (Fiori, Ahn and Rakha, 2016; Cai, Ouyang and Yang, 2017; Nagasawa, Rhodes and Webber, 2018). Numerous manufacturing industries implement a variety of models for improved electric power forecasting and managements, and it can be stated in this context that, generally speaking, the machine learning approaches provide nowadays a much-enhanced ability for prediction, as compared to other kinds of methods.

The major contribution of this paper consists of.

1. Presentation of a new, original scenario for forecasting electric power consumption, here applied to the industries from Ahmednagar city.
2. Founding the analysis of the future energy consumption mainly on three major drivers, namely (i) energy policy, (ii) production of green and non-green products, and (iii) production of FMCG and non-FMCG products.
3. The methodology presented and implemented is composed of three phases; in the first phase, a questionnaire is prepared that clearly addresses the effect of the aforementioned drives on diverse industries; then, in the second phase, the prepared questionnaire is distributed to the industries – here: of Ahmednagar city, with all the questions being required to be filled up by the industrial authorities; the responses are then taken for analysis; finally, the analysis is performed based on statistical characteristics, mainly the correlation coefficients, helping to arrive at conclusions regarding the interdependencies among various factors.

The overall organization of the work is as follows: Section 2 portrays the literature work. Section 3 describes the proposed overall architecture of the forecasting approach. Section 4 presents the perceptions of different industries on power consumption. Section 5 provides the analytical results and Section 6 concludes the paper.

2. Literature review

2.1. Related work

Meer, Munkhammar and Widén (2018) investigated the impact of aggregation of consumers and of the rising contribution of photovoltaic (PV) power in the net load on PIs of probabilistic forecasting techniques that were implemented for the allocation relative to the grid consumers throughout spring and winter. In addition, the training window breadth was optimized and it was demonstrated that the approach generates reliable and sharp PIs with the training set of up to three weeks. At last, the increasing contribution of PV power was found to raise the reliability and sharpness of the proposed model.

Kleshchyova and Nakhabov (2015) developed an approach, in which various applications of data analysis for predicting electric power utilization by NPPs using accurate data, were represented. Accordingly, assessment of these techniques was performed in relation to those presently in the application by NPPs.

Consequently, a technique was presented for predicting NPP power utilization for treating the requirements regarding the plants with considerably increased accuracy of prediction. At last, a series of analyses was carried out to evaluate the effectiveness and efficiency of the introduced scheme.

Collotta and Pau (2017) presented an ANN-based technique as a basis for a HEM system depending on bluetooth low energy, called BluHEMS. The implemented technique was capable of predicting the energy utilization circumstances, that is, to forecast the home energy needs at diverse periods of the day or on various days of the week. The paper offered a comprehensive explanation of the ANN arrangement, a systematic examination on the embedding constraints for the derivation of best performance values, and the evaluations, obtained through simulations.

Xu et al. (2018) suggested a new PIs technique along with ESF-ELM with PSO. In order to enhance the energy design and precision of the ELM, the input weights were assigned with the use of cosine similarity coefficients. Finally, PSO with a wide-ranging metrics was introduced to assess the probability and the mean width of PIs. The results reported demonstrate that the suggested model could produce high-quality PIs with higher probability, slender width, and supremacy in reliability and adaptability that offers the foundations for the decision-makers for increasing the profits and providing logical prospect plans.

Nousdilis, Christoforidis and Papagiannis (2018) considered a power management method for over-voltage mitigation in active LV networks. The technique evaluates the utmost permitted quantity of power supplied to the grid and, consequently, it produces a power management agenda for the procurers depending on their SCR. Here, the adopted technique was verified on an LV test system and was shown to positively differ from other, conventional schemes for voltage support. The reported results demonstrate that the application of the method increases the SCR of installation, treating at the same time prosumers, and the quality of results is improved when compared with the traditional schemes.

Touzani, Granderson and Fernandes (2018) established an energy consumption baseline approach depending on a GBM. For evaluating the performance of this technique, a novel testing process was exploited. Furthermore, the model training periods were altered and numerous forecasting quality measures were deployed to estimate the performance of the model. Altogether, the results demonstrate that by deploying the GBM-based model, the RMSE has been enhanced when compared with other approaches considered.

Hanet al. (2018) implemented a novel methodology of energy management and an optimization technique, depending on the FELM procedure. In addition, the FELM secures enhanced forecasting performance and training speediness. At last, the implemented technique was exploited to optimize and manage the energy position of the ethylene industry in China with multifaceted petrochemical manufacturing industries. The results of the study demonstrated that the adopted technique was effective and appropriate in the energy-saving prospective.

Wang et al. (2018) introduced a novel methodology, which referred to AMVO for optimizing the constraints of the SVM. The results reported indicate that the hybrid AMVO-SVM model displays superior accuracy when compared to other models. The developed hybrid AMVO-SVM technique was evaluated in terms of its prediction capability under five different setups.

Table 1 shows the methods, features, and challenges, related to the techniques oriented at the electric power consumption management.

3. The questionnaire for the forecasting model

3.1. The questionnaire content

In the here presented work, the investigation regarding industrial energy consumption is mainly directed to three primary driving aspects, namely: (i) energy policy, (ii) production of green and non-green products, and (iii) production of FMCG and non-FMCG products. First, the questionnaire was prepared, and then it was distributed in order to obtain the responses from the definite industries.

The part, dealing with energy policy comprises 18 questions, the one on production of green and non-green products includes 29 questions, and finally, the third part, on production of FMCG and non-FMCG products includes 18 questions. Thus, the questionnaire comprised altogether 65 items. The diagrammatic shorthand presentation of the questionnaire is provided in Fig. 1. Accordingly, the complete wording of the questionnaire for each of the three aspects is given in Tables 2 through 4, respectively.

3.2. The data collection procedure

The present study focused on the possibility of predicting electric power consumption of definite industries from Ahmednagar city. The investigation regarding the energy consumption are mainly directed to three aspects or drivers, already explained. For managing power consumption, every industry performs some kind of policy, to be analyzed through this research framework. The items mentioned in the questionnaire designed are closely related to the reality of industries from Ahmednagar city. The questionnaire was distributed among fifteen industries of Ahmednagar city. In the questionnaire, all the questions were considered mandatory, and the respective industrial authorities were asked to provide as much as possible the precise information. Then, the 15 responses from the concerned industries, related to power management, were taken for analytic purpose.

Table 1: Features and challenges of the state-of-the-art electric power consumption models

Reference	**Methodology**	**Features**	**Challenges**
Meer, Munkhammar & Widén (2018)	Gaussian process	Enhanced sharpness. Better reliability.	Needs further improvement in performance of prediction intervals
Kleshchyova & Nakhabov (2015)	SVM	Increased accuracy. Minimizes economic expenses.	Requires consideration of delivery and management.
Collotta & Pau (2017)	NN	Better performance of the network. Better end to end delay.	The cost of equipment and installations is high.
Xu et al.(2018)	PSO	Better reliability. Offers logical future plans.	Needs consideration of exploiting the energy sources.
Nousdilis, Christoforidis & Papagiannis (2018)	SCBPM	Better treatment of prosumers. Novel power profiles.	Proper control of storage system is required
Touzani, Granderson & Fernandes (2018)	GBM	Enhanced prediction accuracy. Minimizes the frequency of charging.	Requires consideration on GBM to be deployed in other energy efficiency issues.
Han et al. (2018)	FELM	Effective model. Can be deployed under complex conditions.	Needs improvement with data on more detailed time density to adapt the current production
Wang et al. (2018)	SVM	Better precision. Improved economic growth.	Has to be focused on different scenarios.

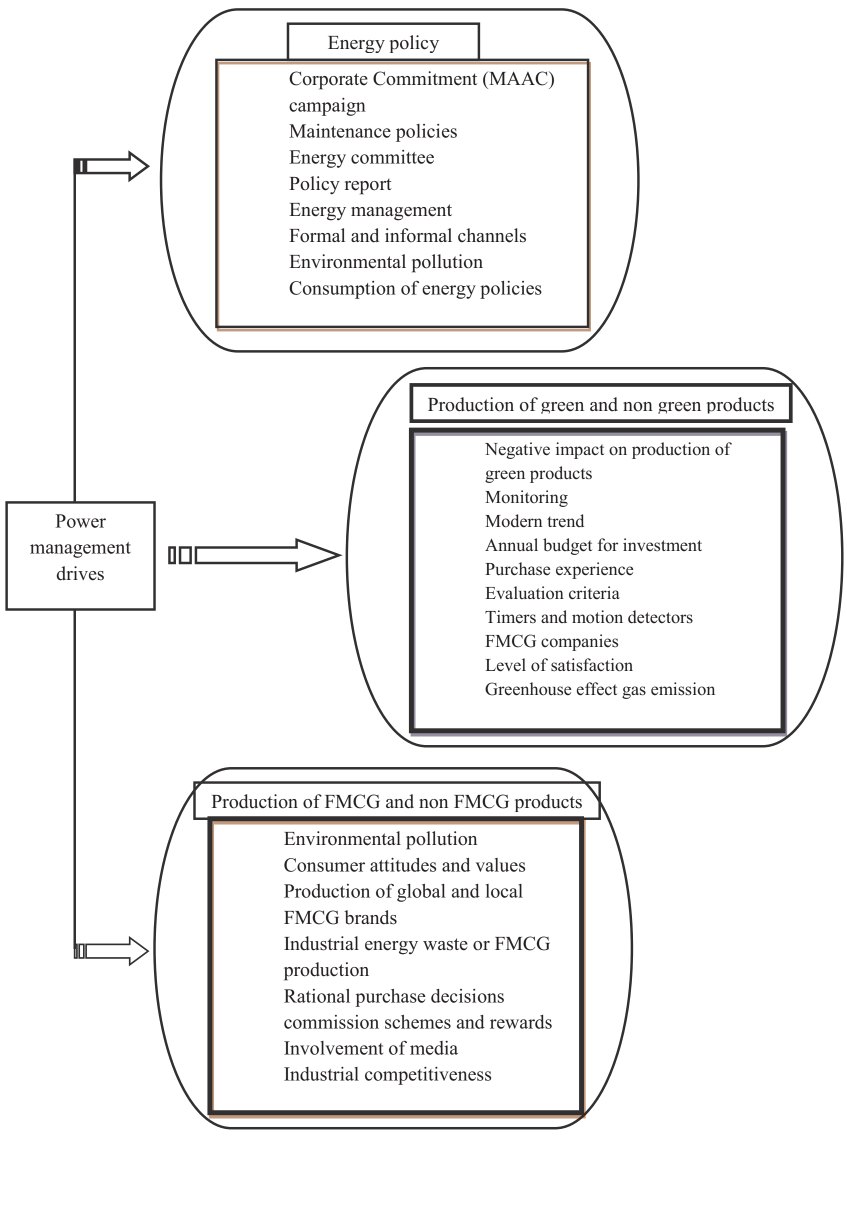

Figure 1: Representation of the questionnaire used

Table 2: The questionnaire relative to the energy policy aspect

1.	Does the industry have an energy policy?
2	Are the objectives of energy integrated into new building/refurbishment specifications?
3	Is the industry a signatory to the Making a Corporate Commitment (MAAC) campaign?
4	Are the objectives of energy integrated into maintenance policies?
5	Are the objectives of energy integrated into purchasing policies?
6	Whether there should be a need for a managing head to maintain the energy policies?
7	How many staff members have responsibility for energy management policies?
8	Approximately what percentage of time is devoted to managing the energy policies?
9	Does the industry have an energy committee?
10	Have energy audits been conducted in major policies?
11	Is an annual energy policy report produced?
12	Has the industry's energy policy had a significant impact on energy management?
13	When the information of the industry's energy management is generally recorded?
14	Does your company agree to develop more advanced policies on energy management?
15	Whether the formal and informal channels of communication are regularly exploited by the energy policy manager?
16	Whether the energy policies include cost-effectiveness and pollution-free production?
17	Are informal contacts used to promote energy efficiency?
18	Are the consumption of energy policies compared with other sector benchmarks?

Table 3: The questionnaire relative to the production of green and non-green products aspect

1	Whether the energy policy, action plan, and regular review on green product production, have a commitment as part of energy management?
2	What is the range of difficulty in obtaining information regarding the energy consumption of green/non-green products?
3	Is there any necessity to replace the existing policies or equipment that have a negative impact on the production of green products?
4	Is production of green products based on energy management monitored periodically?
5	Is the green production as per the modern trend focusing on energy management?
6	Is there an annual budget for investment in production of green and non-green products?
7	If yes, how much is it for green products?
8	If yes, how much is it for non-green products?
9	How are the product and service items satisfied based on the value in accordance with energy management?
10	How are the product and service items satisfied based on purchase experience in accordance with energy management?
11	How are the product and service items satisfied based on usage experience in accordance with energy management?
12	Are the products and services satisfactory with respect to user experience, value etc. regarding energy management?
13	Do you think that green marketing activities serve addressing energy management?
14	Specify the importance level of production of green products that should be encouraged by marketers focusing on energy management
15	What words would you use to describe the energy-aware green product manufacturing?
16	Do you think that by implementing a green marketing strategy the companies are able to gain a competitive advantage over others in terms of energy consumption?
17	Does your company have an energy-efficient production system for green products?
18	Which product is preferred more with respect to energy policies?
19	Are there any evaluation criteria for green products relative to energy management?
20	Does the industry use timers and motion detectors to optimize energy use for the production of green products?
21	Which green products utilize more energy?
22	Specify the importance level of the energy management practices that should be encouraged by green product marketers
23	Do you think FMCG companies, which can establish themselves with a green image along with energy efficiency will have a distinctive advantage in the marketplace?
24	How will you describe your level of satisfaction regarding green and non-green products based on energy management?
25	Is there any requirement to educate the people about the eco-friendly green and non-green products through some public forums?
26	Do the products minimize energy consumption at all stages of the product life cycle, including manufacturing, sales, distribution, use, and disposal?
27	Does low energy consumption design reduce the greenhouse gas emissions?
28	Is the information given on the energy usage of green/non-green product trustworthy?
29	Are there any technologies or practices to enhance energy management in producing green products?

Table 4: The questionnaire relative to production of FMCG and non-FMCG products aspect

1	Do many FMCG clients target energy as a priority in keeping costs down?
2	Whether the marketing practitioners of the FMCG sector utilize energy management strategies to minimize environmental pollution nowadays?
3	Does the FMCG manufacturing require more attention on consumer attitudes and values towards energy policies?
4	Does the production of global and local FMCG brands consume more energy?
5	On which of the factors the FMCG product usage and the opportunities for improving its energy efficiency depend on?
6	What is the contribution of industrial energy waste for FMCG production when compared with overall energy consumption?
7	Whether the younger people utilize the recommendations from their peers regarding the energy management on FMCG and non-FMCG products and services in order to make rational purchase decisions?
8	Would you like to switch your FMCG brand preference if you get some developed energy management scheme with another brand?
9	The reason for making a purchase on FMCG and non-FMCG products?
10	Are there any worthwhile commission schemes and rewards for better management of energy concerning FMCG products?
11	Is there any necessity to involve media to distribute knowledge regarding the energy policies in buying FMCG products?
12	Whether the energy policy has been extended beyond the traditional issues of availability and price to include environmental quality and industrial competitiveness in FMCG products?
13	Whether steps are taken to investigate energy management within the FMCG and non-FMCG markets to ensure satisfaction and loyalty?
14	Whether the customers evaluate the energy policies on the regular FMCG store when they tend to evaluate typical physical quality factors?
15	Is there any significant effort made to minimize energy consumption during the production of FMCG products?
16	Are there any integral energy management and efficiency solutions, tailored to the specific needs of the FMCG industry via its many technical and managerial aspects?
17	Whether the negative customer reviews related to the FMCG products regarding the energy consumption have been rectified?
18	Do the FMCG companies look to invest in energy-efficient plants to benefit society and lower the costs in the long term?

4. Perceptions of different industries regarding power consumption

4.1. Energy policy

The responses obtained from the various industries regarding the energy policies of power management drives are summarised in Table 5. From the obtained responses it can be seen that about 80% of the industries addressed have an energy policy. Similarly, for some 80% of the industries, the energy was integrated into new build/refurbishment specifications. Likewise, roughly 80% of the industries possess an energy committee.

Table 5: Summary of responses concerning energy policies

Analytical questions	**Yes %**	**No %**	**Sometimes %**
The industry has an energy policy	80	20	–
The objectives of energy are integrated into new building/refurbishment specifications	80	20	–
Industry is a signatory to the MAAC campaign	60	6.7	33.3
The objectives of energy are integrated into maintenance policies	73.3	26.7	
The objectives of energy are integrated into purchasing policies	85.7	14.3	
The industry has an energy committee	80	20	
Energy audits have been conducted for major policies	53.3	13.3	33.3
Annual energy policy reports are produced	66.7	6.7	26.7
The industry's energy policy had a significant impact on energy management	66.7	33.3	
Are the consumption of energy policies compared with other sector benchmarks?	46.7	20	33.3

4.2. Production of green and non-green products

Table 6 shows the summary of responses obtained from the various industries regarding the production of green and non-green products. From the response, it is observed, for instance, that about 66.7% of the firms have a commitment, as a part of energy management, regarding energy policy, action plan and regular review on green product production. The green marketing activities are considered good at addressing energy management in 78.6% of the firms. Then, 80% of the firms accept the view that the green products minimize energy consumption at all stages of the product life cycle, including manufacturing, sales, distribution, use, and disposal. Also, 60% of the firms apply technologies or practices meant to enhance energy management while producing green products.

Table 6: Summary of responses concerning production of green and non-green products

Analytical questions	**Yes, %**	**No, %**	**Sometimes, %**
Energy policy, action plan and regular review on green product production constitute a commitment as a part of energy management	66.7	26.7	6.7
Production of green products based on energy management is monitored periodically	53.3	13.3	33.3
Green production is focused on energy management	60	6.7	33.3
Annual budget for investment on production of green and non-green products is developed	46.7	33.3	20
Green marketing activities are good at addressing energy management	78.6	21.4	–
The company have an energy-efficient production system for green products	80	20	–
Evaluation criteria are used for each green product	73.3	26.7	–
Industry uses timers and motion detectors	53.3	33.3	13.3
Green products minimize energy consumption at all stages	80	20	–
Low energy consumption power design reduces greenhouse gas emissions	78.6	21.4	–
Information given on the energy usage of green products/non-green products is trustworthy	60	13.3	26.7
Technologies or practices for enhancing energy management while producing green products are applied	60	13.3	26.7

4.3. Production of FMCG and non-FMCG products

The results, obtained from the responses to the questionnaire, concerning the aspect of production of the FMCG and non-FMCG products, are summarized in Table 7. To cite a couple of examples from this table, for instance, the younger people in the case of 66.7% of the firms utilize the recommendations from their peers regarding the energy management on FMCG and non-FMCG products, while 26.7% of them do not. Further, 60% of the industries would like to switch their FMCG brand preference if they get some developed energy management scheme with another brand, whereas 20% of the firms would not. Steps are taken in order to investigate the energy management within the FMCG and non-FMCG markets to ensure satisfaction and loyalty in 71.4% of the firms.

On the other hand, 40% of the industries include integral energy management and efficiency solutions.

Table 7: Summary of responses concerning the aspect of production of FMCG and non-FMCG products

Analytical questions	**Yes, %**	**No, %**	**Sometimes, %**
Consideration of consumer attitudes and values	60	13.3	26.7
Energy consumption regarding the production of global and local FMCG brands	40	26.7	33.3
Recommendations from peers	66.7	6.7	26.7
Switching FMCG brand preference	60	20	20
Energy policy	66.7	6.7	26.7
Investigation of energy management	71.4	28.6	–
Minimization of energy consumption	40	26.7	33.3
Integral energy management	40	13.3	46.7
Negative customer reviews	53.3	6.7	40

5. Results from the questionnaire-based study

5.1. The procedure

On the basis of the responses to the questionnaires, which are summarized in the preceding tables, the correlation analysis was carried out, as reported in the series of tables in the sequel. Again, these tables were separated according to the three aspects or drivers here distinguished (energy policy, production of green and non-green products and production of FMCG and non-FMCG products). The respective correlation matrices are, therefore, shown separately.

The analysis was implemented in MATLAB 2018a after loading the obtained raw data, constituting the questionnaire responses from the industries. Thus, we deal with three matrices of dimensions, respectively, 18×18, 29×29, and again 18×18, according to the numbers of questions, dealing with particular aspects. So, if A and B are two lists of answers to questions from the respondents, these questions being indexed i, the correlation coefficient formula used for the computation of the matrices shown is given by Eq. (1), in which N denotes the number of responses, σ_A and μ_A denote, respectively, standard deviation and mean for A, while σ_B and μ_B denote, respectively, standard deviation and mean of B:

$$\rho_{AB} = \frac{1}{N-1} \sum_{i=1}^{N} \left(\frac{A_i - \overline{\mu_A}}{\sigma_A} \right) \left(\frac{B_i - \overline{\mu_B}}{\sigma_B} \right). \tag{1}$$

5.2. Correlation analysis for energy policy

Table 8 provides the values of the correlation coefficients, calculated conform to formula (1), for the questions, concerning energy policy. It can be easily observed that there are some questions (like, e.g. the question no. 1: "Whether the industry has an energy policy?"), the responses to which display much higher correlations than for some of the other ones. Thus, the questions with higher correlations, like the already mentioned question no. 1, but also some other ones (e.g. nos. 2, 5, 9 etc.) can be treated as essential for the given driver, determining to a high extent the content of the entire respective part of the questionnaire.

Then, there are some questions (and responses), which feature low correlations with the other ones, for instance questions nos. 6 (a very striking example!), 7 and 8, which can be, in contrast with those highly correlated ones, considered to be "unrelated", or even "spurious". The substantive conclusions therefrom, though, ought to be very careful, and should be formulated on the basis of well-based analysis of the respective issues.

5.3. Correlation analysis for production of green and non-green products

Table 9 provides the correlation coefficient values for the responses to the 29 questions, related to the production of green and non-green products. Since twenty-nine questions are analyzed, 29×29 matrix is formed as a result of correlation analysis. Here, again, we can observe the correlations, characterising the responses to particular questions, with special attention to those displaying the highest and the lowest correlations. Based on this matrix, it can be stated that the highest correlation values are observed for the question "Are the products and services satisfactory with respect to user experience, value etc. regarding energy management? "

It is interesting to note that the average values of the correlation coefficients (absolute values, of course) for the responses to individual questions vary quite considerably. The ratio between the highest average and the lowest one is higher than 3. The highest average exceeds 0.5, while the lowest one is equal only 0.16. The list below shows these averages of the correlation coefficients ranked in the decreasing order:

Questionnaire items (denoted Qi) in green/non-green product area ranked according to mean correlation value (note that the values are approximate):

1. Q23: 0.51; **2**. Q24: 0.47; **3**. Q10 & Q11: 0.46; **4**. Q12: 0.45; **5**. Q9: 0.45; **6**. Q25: 0.43; **7**. Q13 & Q26: 0.42; **8**. Q3: 0.40; **9**. Q18 & Q19: 0.39; **10**. Q2: 0.38; **11**. Q17: 0.37; **12**. Q1: 0.35; **13**. Q28: 0.34; **14**. Q29: 0.34; **15**. Q8: 0.33; **16**. Q20: 0.32; **17**. Q16: 0.31; **18**. Q22: 0.30; **19**. Q5: 0.29; **20**. Q4: 0.27; **21**. Q21: 0.25; **22**. Q27: 0.22; **23**. Q14: 0.20; **24**. Q6: 0.19; **25**. Q15: 0.18; **26**. Q7: 0.16.

Table 8: Correlation matrix (18 × 18) for the responses related to energy policy

1.00	0.58	0.50	0.45	0.78	-0.03	0.05	-0.09	1.00	0.48	0.61	0.35	0.38	0.78	0.84	0.47	0.62	0.08
0.58	1.00	0.50	0.83	0.29	-0.03	0.52	-0.09	0.58	0.11	0.23	0.00	0.23	0.44	0.43	0.33	0.31	-0.30
0.50	0.50	1.00	0.34	0.32	-0.30	0.14	0.19	0.50	0.33	0.44	0.20	-0.20	0.31	0.33	0.03	-0.02	0.12
0.45	0.83	0.34	1.00	0.21	-0.04	0.55	0.03	0.45	0.30	0.10	-0.11	0.02	0.58	0.28	0.19	0.33	-0.08
0.78	0.29	0.32	0.21	1.00	-0.20	-0.33	0.02	0.78	0.30	0.62	0.55	0.18	0.68	0.81	0.53	0.49	0.28
-0.03	-0.03	-0.30	-0.04	-0.20	1.00	0.12	-0.37	-0.03	-0.31	-0.11	-0.42	-0.02	0.07	-0.09	0.11	0.02	0.01
0.05	0.52	0.14	0.55	-0.33	0.12	1.00	-0.42	0.05	-0.12	-0.36	-0.60	0.15	0.08	-0.19	-0.22	-0.09	-0.61
-0.09	-0.09	0.19	0.03	0.02	-0.37	-0.42	1.00	-0.09	0.55	-0.02	0.53	-0.10	0.13	0.26	-0.01	0.03	0.10
1.00	0.58	0.50	0.45	0.78	-0.03	0.05	-0.09	1.00	0.48	0.61	0.35	0.38	0.78	0.84	0.47	0.62	0.08
0.48	0.11	0.33	0.30	0.30	-0.31	-0.12	0.55	0.48	1.00	0.23	0.62	-0.04	0.55	0.52	0.04	0.34	0.13
0.61	0.23	0.44	0.10	0.62	-0.11	-0.36	-0.02	0.61	0.23	1.00	0.48	-0.15	0.37	0.47	0.33	0.14	0.36
0.35	0.00	0.20	-0.11	0.55	-0.42	-0.60	0.52	0.35	0.62	0.48	1.00	-0.04	0.29	0.61	0.31	0.22	0.11
0.38	0.23	-0.20	0.02	0.18	-0.02	0.15	-0.10	0.38	-0.04	-0.15	-0.04	1.00	0.20	0.40	0.43	0.61	-0.46
0.78	0.44	0.31	0.58	0.68	0.07	0.08	0.13	0.78	0.55	0.37	0.29	0.20	1.00	0.76	0.37	0.63	0.12
0.84	0.43	0.33	0.28	0.81	-0.09	-0.18	0.26	0.84	0.52	0.47	0.61	0.40	0.76	1.00	0.44	0.54	-0.07
0.47	0.33	0.03	0.19	0.53	0.11	-0.22	-0.01	0.47	0.04	0.33	0.31	0.43	0.37	0.44	1.00	0.48	0.05
0.62	0.31	-0.02	0.33	0.49	0.02	-0.09	0.03	0.62	0.34	0.14	0.22	0.62	0.63	0.54	0.48	1.00	0.09
0.08	-0.30	0.12	-0.08	0.28	0.01	-0.61	0.10	0.08	0.13	0.36	0.11	-0.46	0.12	-0.07	0.05	0.09	1.00

Table 9: Correlation matrix (29 × 29) for the responses related to production of green and non-green products

1	0.3	0.4	0.4	0.6	0.4	-0.2	0.2	0.2	0.2	0.3	0.2	0.8	0	-0.1	0.5	0.4	0.6	0.6	0.1	-0.3	-0.3	0.6	0.5	0.4	0.8	0	0.2	0.2
0.3	1	0.2	0.3	0.4	0.3	0.3	0.5	0.5	0.5	0.5	0.5	0.4	-0.1	-0.1	0.2	0	0.2	0.2	0.4	-0.6	-0.6	0.5	0.3	0.5	0.4	0.4	0.6	0.8
0.4	0.2	1	0.4	0.2	0	-0.4	0.6	0.6	0.6	0.6	0.7	0.4	-0.2	-0.3	0.4	0.8	0.6	0.6	0.1	-0.3	-0.3	0.6	0.7	0.6	0.4	0	0.1	0.1
0.4	0.3	0.4	1	0.3	0.5	0	0.3	0.5	0.5	0.6	0.5	0.1	0.1	0.2	0.5	0.1	0	0	0	0	0	0.2	0.5	0.7	0.1	0.1	0.3	0.4
0.6	0.4	0.2	0.3	1	0.4	-0.1	0.1	0.3	0.3	0.4	0.3	0.5	0	0.1	0.2	0.1	0.3	0.3	0.2	-0.3	-0.3	0.3	0.2	0.3	0.5	0.1	0.6	0.3
0.4	0.3	0	0.5	0.4	1	0.3	0	-0.1	0	0	-0.1	0.3	0	0	0.2	-0.1	0.1	0.1	-0.2	-0.2	-0.2	0.1	0.3	0.2	0.3	0.1	0.4	0.5
-0.2	0.3	-0.4	0	-0.1	0.3	1	-0.1	0	0	0	0.1	0.1	0.3	0.4	0	-0.3	-0.1	-0.1	0.1	0.1	0.1	-0.2	-0.3	-0.1	0.1	0	0.2	0.6
0.2	0.5	0.6	0.3	0.1	0	-0.1	1	0.5	0.6	0.5	0.5	0.1	-0.3	-0.5	0	0.3	0.4	0.4	0.2	-0.4	-0.4	0.5	0.5	0.3	0.1	-0.3	-0.1	0.4
0.2	0.5	0.6	0.5	0.3	-0.1	0	0.5	1	1	1	1	0.4	-0.2	0	0.5	0.5	0.4	0.4	0.6	-0.1	-0.1	0.7	0.7	0.8	0.4	0.2	0.4	0.5
0.2	0.5	0.6	0.5	0.3	0	0	0.6	1	1	1	0.9	0.4	-0.3	0	0.5	0.5	0.4	0.4	0.6	-0.2	-0.2	0.7	0.7	0.8	0.4	0.2	0.4	0.5
0.3	0.5	0.6	0.6	0.4	0	0	0.5	1	1	1	1	0.4	-0.3	0	0.4	0.5	0.4	0.4	0.6	-0.1	-0.1	0.7	0.7	0.8	0.4	0.2	0.4	0.5
0.2	0.5	0.7	0.5	0.3	-0.1	0.1	0.5	1	0.9	1	1	0.4	-0.2	0	0.4	0.5	0.4	0.4	0.6	-0.2	-0.2	0.7	0.6	0.8	0.4	0.2	0.4	0.5
0.8	0.4	0.4	0.1	0.5	0.3	0.1	0.1	0.4	0.4	0.4	0.4	1	0	0	0.5	0.6	0.8	0.8	0.3	-0.4	-0.4	0.8	0.5	0.4	1	0.2	0.4	0.4
0	-0.1	-0.2	0.1	0	0	0.3	-0.3	-0.2	-0.3	-0.3	-0.2	0	1	0.5	0.3	-0.2	-0.2	-0.2	-0.6	0.2	0.2	-0.4	-0.5	-0.2	0	-0.2	0	0
-0.1	-0.1	-0.3	0.2	0.1	0	0.4	-0.5	0	0	0	0	0	0.5	1	0.4	-0.2	-0.2	-0.2	-0.1	0.2	0.2	-0.3	-0.3	0	0	0.3	0.4	0.1
0.5	0.2	0.4	0.5	0.2	0.2	0	0	0.5	0.5	0.4	0.4	0.5	0.3	0.4	1	0.4	0.3	0.3	-0.1	0	0	0.4	0.4	0.6	0.5	0.1	0.3	0.2
0.4	0	0.8	0.1	0.1	-0.1	-0.3	0.3	0.5	0.5	0.5	0.5	0.6	-0.2	-0.2	0.4	1	0.8	0.8	0.3	-0.2	-0.2	0.6	0.6	0.4	0.6	0.2	0.2	0
0.6	0.2	0.6	0	0.3	0.1	-0.1	0.4	0.4	0.4	0.4	0.4	0.8	-0.2	-0.2	0.3	0.8	1	1	0.3	-0.4	-0.4	0.7	0.5	0.2	0.8	0.1	0.2	0.2
0.6	0.2	0.6	0	0.3	0.1	-0.1	0.4	0.4	0.4	0.4	0.4	0.8	-0.2	-0.2	0.3	0.8	1	1	0.3	-0.4	-0.4	0.7	0.5	0.2	0.8	0.1	0.2	0.2
0.1	0.4	0.1	0	0.2	-0.2	0.1	0.2	0.6	0.6	0.6	0.6	0.3	-0.6	-0.1	-0.1	0.3	0.3	0.3	1	-0.3	-0.3	0.5	0.3	0.2	0.3	0.5	0.4	0.4
-0.4	0.4	0.1	0.2	0.1	-0.2	0.2	0.3	0.3	0.3	0.3	0.4	-0.4	-0.1	0.2	-0.1	-0.2	-0.3	-0.3	0.3	-0.2	-0.2	-0.1	0	0.2	-0.4	0.2	0.3	0.3
-0.3	-0.6	-0.3	0	-0.3	-0.2	0.1	-0.4	-0.1	-0.2	-0.1	-0.2	-0.4	0.2	0.2	0	-0.2	-0.4	-0.4	-0.3	1	1	-0.5	-0.4	-0.2	-0.4	-0.4	-0.4	-0.3
0.6	0.5	0.6	0.2	0.3	0.1	-0.2	0.5	0.7	0.7	0.7	0.7	0.8	-0.4	-0.3	0.4	0.6	0.7	0.7	0.5	-0.5	-0.5	1	0.9	0.7	0.8	0.2	0.2	0.3
0.5	0.3	0.7	0.5	0.2	0.3	-0.3	0.5	0.7	0.7	0.7	0.6	0.5	-0.5	-0.3	0.4	0.6	0.5	0.5	0.3	-0.4	-0.4	0.9	1	0.8	0.5	0.2	0.2	0.2
0.4	0.5	0.6	0.7	0.3	0.2	-0.1	0.3	0.8	0.8	0.8	0.8	0.4	-0.2	0	0.6	0.4	0.2	0.2	0.2	-0.2	-0.2	0.7	0.8	1	0.4	0.3	0.4	0.4
0.8	0.4	0.4	0.1	0.5	0.3	0.1	0.1	0.4	0.4	0.4	0.4	1	0	0	0.5	0.6	0.8	0.8	0.3	-0.4	-0.4	0.8	0.5	0.4	1	0.2	0.4	0.4
0	0.4	0	0.1	0.1	0.1	0	-0.3	0.2	0.2	0.2	0.2	0.2	-0.2	0.3	0.1	0.2	0.1	0.1	0.5	-0.4	-0.4	0.2	0.2	0.3	0.2	1	0.8	0.2
0.2	0.6	0.1	0.3	0.6	0.4	0.2	-0.1	0.4	0.4	0.4	0.4	0.4	0	0.4	0.3	0.2	0.2	0.2	0.4	-0.4	-0.4	0.2	0.2	0.4	0.4	0.8	1	0.6
0.2	0.8	0.1	0.4	0.3	0.5	0.6	0.4	0.5	0.5	0.5	0.5	0.4	0	0.1	0.2	0	0.2	0.2	0.4	-0.3	-0.3	0.3	0.2	0.4	0.4	0.2	0.6	1

5.4. Correlation analysis for production of FMCG and non-FMCG products

Table 10 shows the correlation coefficients, calculated for the responses to the 18 questions, concerning production of FMCG and non-FMCG products. Like in the preceding two cases, analysis can be performed, oriented at identification of the most important among the issues (questions) considered, and those that can be altogether neglected. One can notice a differentiation of these indices, very much like in the preceding case, the ratio between the highest average and the lowest one being this time equal 3.40 (in the preceding case it was equal $0.51/0.16 = 3.19$).

5.5. Overall correlation analysis

Table 11 shows the values of the correlation coefficients for the junction of the three parts of the questionnaire, related to, energy policy, production of green and non-green products, and production of FMCG and non- FMCG products. Here, the correlation analysisis concerns the most correlated three questions from the respective parts of the questionnaire, namely, 1. "Whether the industry has an energy policy?", 2. "Are the products and services satisfactory with respect to user experience, value etc. regarding energy management?" and 3. "Are there any worthwhile commission schemes and rewards for better management of energy concerned FMCG products?" It can again be seen that the highest correlations characterise the question: "1. Whether the industry has an energy policy?"

6. Conclusion

This paper presents a study, oriented at the analysis of some prerequisites for the forecasting of electricity demand from the industry, with focus on Ahmednagar city, primarily related to three considered types of demand drivers, and namely (i) energy policy, its existence and significance, (ii) the presence and the role of production of green and non-green products, and (iii) production of FMCG and non-FMCG products. In this study, three phases were carried out. First, a questionnaire was prepared, addressing the potential effect of the aforementioned drivers on various industries. In the subsequent phase, the prepared questionnaire was distributed to the industries of Ahmednagar city and the filling up of the individual responses was required and monitored. The responses obtained were then taken for analysis. Finally, the analysis was performed consisting in summarising the characteristics of the responses and in calculating the correlation coefficients inorder to arrive at conclusions, concerning the dependencies of diverse factors, to be potentially used in a proper forecasting study. It can be seen from the analysis reported that the highest correlations were noted for the responses to the "1. Whether the industry has an energy policy?". Although this might be treated as next to trivial, it shows two important aspects, i. the correct construction of the questionnaire, and ii. the implied

Table 10: Correlation coefficient matrix (18×18) for the responses relative to production of FMCG and non- FMCG products

1.00	0.45	0.71	0.31	-0.02	-0.31	0.52	0.29	0.62	0.56	0.58	0.10	0.66	0.39	0.58	0.56	0.26	0.55
0.45	1.00	0.25	-0.03	-0.14	-0.35	0.17	0.13	0.48	0.59	0.62	0.17	0.31	0.70	0.47	0.48	0.25	0.60
0.71	0.25	1.00	0.42	-0.03	-0.13	0.78	0.48	0.62	0.42	0.67	0.44	0.40	0.10	0.33	0.69	0.19	0.30
0.31	-0.03	0.42	1.00	-0.14	-0.68	0.23	0.45	0.29	0.07	0.31	0.05	-0.13	-0.04	0.45	0.34	0.40	0.12
-0.02	-0.14	-0.03	-0.14	1.00	0.37	0.21	0.15	0.44	0.36	-0.16	0.36	0.22	-0.19	0.01	-0.22	0.02	0.26
-0.31	-0.35	-0.13	-0.68	0.37	1.00	0.10	-0.03	-0.02	-0.24	-0.33	0.10	-0.05	-0.22	-0.48	-0.34	-0.51	-0.40
0.52	0.17	0.79	0.23	0.21	0.10	1.00	0.72	0.78	0.43	0.54	0.66	0.45	-0.12	0.23	0.60	0.41	0.30
0.29	0.13	0.48	0.45	0.15	-0.03	0.72	1.00	0.66	0.26	0.44	0.53	0.11	-0.07	0.35	0.31	0.63	0.26
0.62	0.48	0.62	0.22	0.44	-0.02	0.78	0.66	1.00	0.70	0.63	0.60	0.63	0.23	0.45	0.44	0.43	0.69
0.56	0.59	0.42	0.07	0.36	-0.24	0.43	0.26	0.71	1.00	0.44	0.68	0.43	0.37	0.33	0.29	0.36	0.74
0.58	0.62	0.67	0.31	-0.16	-0.33	0.54	0.44	0.63	0.44	1.00	0.26	0.56	0.64	0.24	0.59	0.30	0.64
0.10	0.17	0.44	0.05	0.36	0.10	0.66	0.53	0.60	0.68	0.26	1.00	0.10	-0.12	0.05	0.28	0.41	0.30
0.66	0.31	0.40	-0.13	0.22	-0.05	0.45	0.11	0.63	0.43	0.56	0.10	1.00	0.32	0.22	0.28	0.24	0.72
0.39	0.70	0.10	-0.04	-0.19	-0.22	-0.12	-0.07	0.23	0.37	0.64	-0.12	0.32	1.00	0.15	0.21	-0.07	0.51
0.58	0.47	0.33	0.45	0.01	-0.48	0.23	0.35	0.45	0.33	0.24	0.05	0.22	0.15	1.00	0.59	0.56	0.31
0.56	0.48	0.69	0.34	-0.22	-0.34	0.60	0.31	0.44	0.29	0.59	0.28	0.28	0.21	0.59	1.00	0.39	0.17
0.26	0.25	0.19	0.40	0.02	-0.51	0.41	0.63	0.43	0.36	0.30	0.41	0.24	-0.07	0.56	0.39	1.00	0.50
0.55	0.60	0.30	0.12	0.26	-0.40	0.30	0.26	0.69	0.74	0.64	0.30	0.72	0.51	0.31	0.17	0.50	1.00

Table 11: Correlation coefficients calculated for the selected questions from the three parts of the questionnaire

Questions from the three parts of the questionnaire	*1*	*2*	*3*
1	1	0.5385	0.5714
2	0.5385	1	0.31
3	0.5714	0.31	1

high probability of obtaining relevant responses, which may serve well for the construction of the forecasting model.

References

Al-Falahi, M.D.A., Nimma, K.S., Jayasinghe, S.D.G., Enshaei, H. and Guerrero, J.M. (2018) Power management optimization of hybrid power systems in electric ferries. *Energy Conversion and Management*, 172, 50-66.

Anand, A. and Suganthi, L. (2020) Forecasting of electricity demand by hybrid ANN-PSO models. In: *Deep Learning and Neural Networks: Concepts, Methodologies, Tools, and Applications*, IGI Global, 865-882.

Cai, Y., Ouyang, M.G., Yang, F. (2017) Impact of power split configurations on fuel consumption and battery degradation in plug-in hybrid electric city buses. *Applied Energy*, 188, 257-269.

Collotta, M. and Pau, G. (2017) An Innovative Approach for Forecasting of Energy Requirements to Improve a Smart Home Management System Based on Ble. *IEEE Transactions On Green Communications And Networking*, **1**(1), 112-120.

Ding, S., Hipel, K.W and Dang, Y.G. (2018) Forecasting China's electricity consumption using a new grey prediction model. *Energy*, 149: 314-328.

Donateo, T., Carlà, A. and Avanzini, G. (2018) Fuel consumption of rotorcrafts and potentiality for hybrid electric power systems. *Energy Conversion and Management*, 164, 429-442.

Fiori, C., Ahn, K. and Rakha, H.A. (2016) Power-based electric vehicle energy consumption model: Model development and validation. *Applied Energy*, 168, 257-268.

Han, Y., Zeng, Q., Geng, Z. and Zhu, Q. (2018) Energy management and optimization modeling based on a novel fuzzy extreme learning machine: Case study of complex petrochemical industries. *Energy Conversion and Management*, 165, 163-171.

Hu, Y., Li, J., Hong, M., Ren, J., Lin, R., Liu, Y., Liu, M. and Man, Y. (2019) Short term electric load forecasting model and its verification for process industrial enterprises based on hybrid GA-PSO-BPNN algorithm - A case study of papermaking process. *Energy*, 170: 1215-1227.

Ioakimidis, C.S., Thomas, D., Rycerski, P. and Genikomsakis, K.N. (2018) Peak shaving and valley filling of power consumption profile in non-residential buildings using an electric vehicle parking lot. *Energy*, 148, 148-158.

Jameel, A.S. and Mohammed Ali, M. (2016) Factors affecting customer loyalty towards yes company in Malaysia. *International Journal Of Advanced Research in Engineering & Management (IJAREM)*, **2**(1), 1-7.

Kleshchyova, M.A. and Nakhabov, A.V. (2015) Prediction of electric power consumption by nuclear power plants for covering plant needs using data mining methods. *Nuclear Energy and Technology*, **1**(4):243-247.

Kumari, A. and Sharma, A.K. (2016) Analyzing the causal relations between electric power consumption and economic growth in India. *The Electricity Journal*, **29**(4):28-35.

Meer, D.W., Munkhammar, J. and Widén, J. (2018) Probabilistic forecasting of solar power, electricity consumption and net load: Investigating the effect of seasons, aggregation and penetration on prediction intervals. *Solar Energy*, 171, 397-413.

Munkhammar, J., Widén, J. and Rydén, J. (2015) On a probability distribution model combining household power consumption, electric vehicle home-charging and photovoltaic power production. *Applied Energy*, 142, 135-143.

Nagasawa, K., Rhodes, J.D. and Webber, M.E. (2018) Assessment of primary energy consumption, carbon dioxide emissions, and peak electric load for a residential fuel cell using empirical natural gas and electricity use profiles. *Energy and Buildings*, **178**, 242-253.

Nousdilis, A.I., Christoforidis, G.C. and Papagiannis, G.K. (2018) Active power management in low voltage networks with high photovoltaics penetration based on prosumers' self-consumption. *Applied Energy*, 229, 614-624.

Shi, K., Chen, Y., Yu, B., Xu, T. and Wu, J. (2016) Detecting spatiotemporal dynamics of global electric power consumption using DMSP-OLS nighttime stable light data. *Applied Energy*, 184, 450-463.

Shi, K., Yu, B., Huang, C., Wu, J. and Sun, X. (2018) Exploring spatiotemporal patterns of electric power consumption in countries along the Belt and Road. *Energy*, 150, 847-859.

Silva, L., Valdés-Lozano, D., Escalante, E. and Gasca-Leyva, E. (2018) Dynamic root floating technique: An option to reduce electric power consumption in aquaponic systems. *Journal of Cleaner Production*, 183, 132-142.

Singh, G., Jain, V.K. and Singh, A. (2018) Adaptive network architecture and firefly algorithm for biogas heating model aided by photovoltaic thermal greenhouse system. *Energy & Environment*, **29**(7): 1073-1097.

Swamy, S.M., Rajakumar, B.R. and Valarmathi, I.R. (2013) Design of Hybrid Wind and Photovoltaic Power System using Opposition-based Genetic Algorithm with Cauchy Mutation. In: *IET Chennai Fourth Intcer-*

national Conference on Sustainable Energy and Intelligent Systems (SEISCON 2013), Chennai, India. IET, 504-510.

Teixeira, A.C.R. and Sodré, J.R. (2018) Impacts of replacement of engine powered vehicles by electric vehicles on energy consumption and CO2 emissions. *Transportation Research Part D: Transport and Environment*, 59, 375-384.

Thangam, T. and Muthuvel, K. (2020) Parametric Analysis on Optimized PFoPID control design of a Grid-connected PV inverter for MPPT. In: *2020 4th International Conference on Trends in Electronics and Informatics (ICOEI)*, 48184: IEEE, 236-241.

Thangam, T., Muthuvel, K. and Kazem, H.A. (2019) Research perspectives and state-of-the-art methods in photovoltaic microgrids. *World Journal of Engineering*, **17**(2), 223-235.

Touzani, S., Granderson, J. and Fernandes, S. (2018) Gradient boosting machine for modeling the energy consumption of commercial buildings. *Energy and Buildings*, 158, 1533-1543.

Wang, X., Luo, D., Zhao, X. and Sun, Z. (2018) Estimates of energy consumption in China using a self-adaptive multi-verse optimizer-based support vector machine with rolling cross-validation. *Energy*, 152, 539-548.

Wirtz, A., Meiner, M., Wiederkehr, P. and Myrzik, J. (2018) Simulation-assisted Investigation of the Electric Power Consumption of Milling Processes and Machine Tools. *Procedia CIRP*, 67, 87-92.

Xu, Y., Zhang, M., Ye, L., Zhu, Q. and Han, Y. (2018) A novel prediction intervals method integrating an error & self-feedback extreme learning machine with particle swarm optimization for energy consumption robust prediction. *Energy*, **164**, 137-146.

Yoon, H.-S., Singh, E. and Min, S. (2018) Empirical power consumption model for rotational axes in machine tools. *Journal of Cleaner Production*, 196, 370-381.

Yuan, X., Zhang, C., Hong, G., Huang, X. and Li, L. (2017) Method for evaluating the real-world driving energy consumptions of electric vehicles. *Energy*, 141, 1955-1968.

Zhang, S., Gajpal, Y., Appadoo, S.S. and Abdulkader, M.M.S. (2018) Electric vehicle routing problem with recharging stations for minimizing energy consumption. *International Journal of Production Economics*, 203, 404-413.