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RESEARCH ARTICLE

Energy Management Planning According to the Electricity Tariff Models in Turkey: A Case Study

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ABSTRACT

In recent years, as a result of limited energy sources, growing populations all around the world, and increases in energy demand, many techniques penetrate into both the producer and consumer sides. One of the most important of these techniques is optimal energy management. Managing the energy use of public institutions, particularly in state universities with campus characteristics, should be an important part of local energy and climate policy. The International Organization for Standardization (ISO) 50001 standard constitutes an internationally recognized catalog of requirements for systematic energy management. Currently, this standard is mostly implemented by organizations. In this study, with reference to the ISO 50001 standard, the energy management system is handled as an energy planning which is the initial step of the ISO 50001 and also optimal tariff management study is exercised as the initial action of energy planning. Case studies are conducted to specify the optimal electricity tariffs model by analyzing different billing models in Turkey. Results show that invoice costs can be saved at the rate of 2.93%–3.71% by optimal tariff management that does not require any investment costs.

Index Terms—Energy management, electricity tariff management, ISO 50001, university campus

I. INTRODUCTION

In recent years, especially in emerging economies, the energy demand increased rapidly and became an explosive problem of the world as a result of limited energy sources, population growth, and economic development day by day [1-4]. Furthermore, as conventional energy resources such as fossil fuels, oils, natural gas, and coal are not dispersed uniformly among the world, the classification of resource-rich and resource-poor countries emerges too. Hence, countries form their foreign policies in this direction, develop methods to be competitive in the world, and tend to implement these optimally [5, 6]. In the context of severe and cascading sustainability challenges, critical strategies are shared among emerging economies [7, 8]. These countries are ascribing greater importance to energy efficiency, and energy management systems (EnMS) subtly balance the industry-driven economies and energy consumption [9–11]. These issues led numerous countries, especially in emerging economies, to take action about energy efficiency and EnMS and accelerated the steps to be taken in these regards.

In Turkey, ranked as an emerging economy, energy demand increases faster than developed countries due to its population growth, economic development, and industrialization. In addition, Turkey, whose imported energy rate is 73.21%, according to the primary energy data of 2019, is among the countries with a high external dependence on energy [12, 13]. Ultimate energy consumption was realized as 109.57 Million Tonne of Oil Equivalent (MTOE) on a sectoral basis in 2019 and increased by 39.47% in the 10-year period from 2009 to 2019. The ultimate energy consumption rates of sectors as of 2019 in Turkey are shown in Fig. 1. As illustrated in Fig. 1, the rates of ultimate energy consumptions in Turkey by sectors are as follows respectively: housing and service sector (32.58%), industry sector (31.46%), transportation sector (25.24%), agriculture and livestock (4.27%), and non-energy consumption group (6.45%) [13]. These rates clearly show that energy efficiency and EnMS have an important role in public institutions, especially in university campuses, that are placed in the housing and service sector and should be carried out in Turkey particularly. Thus, so as to energy efficiency studies to aim at sustainable and continuous improvement, it is strongly recommended that organizations in Turkey need to establish EnMS in line with the Energy Efficiency Law No 5627.

Due to the above-mentioned issues, EnMS becomes one of the popular research topics around the world and is considered the most effective way to prevent energy wastage [14]. With an EnMS,

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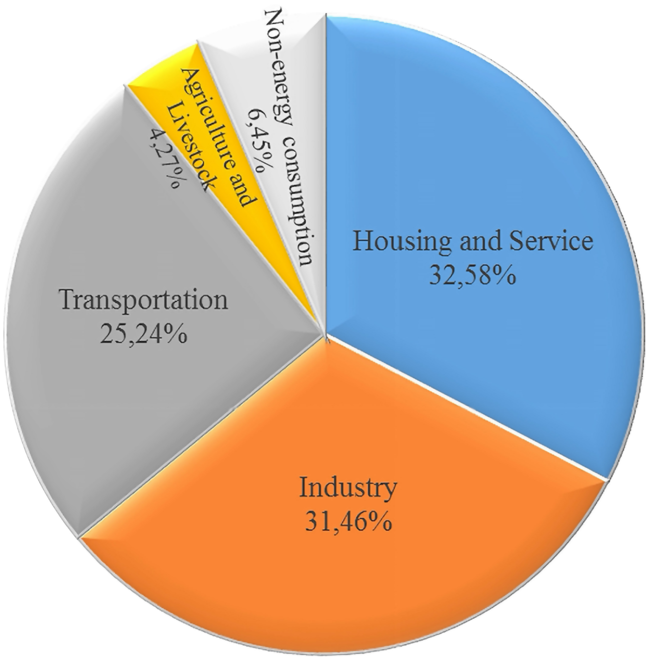

Fig. 1. Ultimate energy consumption rates on the basis of sectors in Turkey as of 2019.

an organization can specify energy targets and processes to achieve these targets [15]. Besides the energy efficiency potentials in almost all sectors, it is possible to improve the energy performance by 40% by EnMS and existing technologies, even in the countries that use energy efficiently [16]. In this regard, the International Organization for Standardization (ISO) 50001, which comprehensively gives guidance on the elements of an EnMS, is a significant standard [17]. The ISO 50001 standard defines good practice standards and guidelines for energy management and is widely applicable [11-18]. It permanently aims to enhance the energy performance of numerous organizations worldwide by ensuring them strategic practices to use their energy more optimally and effectively [19, 20–25]. A great number of studies in the literature have highlighted that significant energy efficiency gains and energy savings can be yielded cost-effectively through the long-term execution of an ISO 50001-based EnMS, even without requiring a large financial investment [18, 24–27].

Main Points

- Cost reduction without investment.
- The way of the successful initial step about energy management issue.
- Raise awareness about energy management issues in public institutions and organizations, especially in state universities that have campus zones.
- Winning the top management's trust, increasing its support, thus putting techniques into practice that require investment cost in a shorter time by the savings obtained from the actions that no need investment cost.

A great number of studies on energy efficiency and EnMS in various sectors have taken part in the literature. Most papers on EnMS deal with practices in the industrial, company, factory, and building and residence sectors that are used for various purposes and finally the transportation sector [28]. In [29], Roy studied sustainable energy management to promote energy efficiency in the public sector in Malaysia. This study makes recommendations regarding the applicability of energy management strategy in the public sector in Malaysia. In [30], the results of the research conducted among 121 German companies that are mostly (84%) from the manufacturing sector and EnMS certified by the ISO 50001 are analyzed. In this study, it is concluded that the reduction of energy costs is the main motivation of EnMS. Moreover, making use of subsidies, acceptance of EnMS by employees, and image advantages are regarded as additional motivators.

A case study in Latvia [31] recommends directions for implementing EnMS and stresses that having an energy team of employees tasked with establishing the EnMS and being equipped with the necessary instruments are a high priority. Another study on EnMS [32] concludes that having no energy manager, insufficient financial resources, and missing or incomplete data are major challenges that need to be overcome for functioning EnMS. In the case study of [33], the EnMS helps identify public buildings with high specific and absolute energy consumption and prioritize energy efficiency measures, including renovation. In this study, in 2019, the heat consumption of public buildings was 12% lower and electricity consumption was 8% lower than in 2016. In [34], the study on EnMS and clean production in the automotive sector, Ozdemir indicates that the electricity used in the factory could be reduced by 10%, thanks to energy efficiency actions. Moreover, the amount of waste could also be reduced by 40% with clean production activities. In [35], Onus, in his study on the automotive sector, indicates that the cheapest and the most effective way to reduce energy consumption, energy costs, carbon emissions, and wastes in the production process is to use EnMS standards. In studies [36–39], analyses are conducted based on energy audits to increase energy consumption transparency through a systematic investigation and for the identification of the different energy consumers within a production system. Methods in these studies allow for the identification of the most energy-consuming processes and represent a very significant step to improve the energy efficiency of the production process. Moreover, reviewing of utility bills or other operating data (e.g., rated power of the equipment and their number of operating hours) and a walk-through of the facility are analyzed in these studies.

Acosta, in [40], does scientific research on the 66 public schools in Louisiana and indicates that 70% of the energy consumed in schools is for heating–cooling, 22% for lighting, and 8% for office and kitchen needs. Moreover, in this study, it is also stated that the energy-saving potential is higher in schools with a large number of students and a wide usage area. Thus, in this study, it is concluded that energy consumption and costs can be reduced by 25% by implementing an EnMS in schools. In [41], Lee forms an EnMS model to evaluate the building energy performance by analyzing scenario-based case studies in 30 buildings that serve cross purposes on the campus of Georgia Technical University. The proposed model in the study aims to improve the energy and environmental performance of the buildings on the campus and concludes that it is economized energy consumption and prevents negative environmental effects as a result of the implementation of these specified scenarios. In [42], saving methods to reduce the energy costs of mosques are analyzed by Akdag. In this study, it is concluded that approximately 30% of energy savings could be achieved by applying thermal insulation to the mosques that are no thermal insulation studied. In addition, it is concluded that the lighting costs could be reduced by 75% by replacing the existing lighting in the examined mosques with energy-saving compact fluorescent or LED lamps. Sinha, in [43], develops a real-time energy performance model to reduce energy consumption and costs in residential buildings. This model is employed for controlling and forecasting the energy consumption of heating–cooling equipment, and 30% of energy saving has been achieved in the residences in this way.

It is clearly seen that the above-mentioned studies are the output of EnMS. In general, these studies aim to reduce both the negative environmental effects and provide financial saving opportunities as a result of actions that needed investment costs in small and medium-sized enterprises. However, the practicing rates of these studies in real life are surprisingly minimal since the proposed EnMS studies in the literature generally include issues that needed initial investment costs. As can be seen in Fig. 2, an organization can save about 3%–5% financially only through the energy reviewing process [44]. Therefore, the top management expectation of the organizations for EnMS, particularly public institutions subject to public funding, is to be given priority applications with no or very low investment costs in action plans.

In this study, firstly, an organizational EnMS flowchart that specifies all steps step by step is proposed in Fig. 3. As can be seen in Fig. 3, the proposed EnMS include the stages of planning, implementation, control, and taking precautions specified in the ISO 50001 standard. Next, the energy reviewing process, which is one of the initial steps of EnMS, given in Fig. 3 is performed as a case study. Thus, opportunities in EnMS are specified by energy consumption analysis on a zonal basis and costs. As shown in Fig. 2, financial opportunities that are approximately 3%–5% only through the energy reviewing process are the main motivation of this study. Thus, the main purpose of this study is to analyze the opportunities that do not need any investment costs but have financial returns within the scope of EnMS. Within this context, in our study, [45] is taken as a reference, the electrical energy consumed by the six campuses of Bogazici University located in different locations are analyzed and important consumption zones are specified for the years 2019–2020. Next, as a case study, scenario-based invoice cost (IC) analysis of the North Campus which is specified as one of the important consumption zones is conducted. As a result, the optimal tariff management strategy of the campus is specified, and it is concluded that there is a financial savings opportunity of 2.93%–3.71% per year by this strategy. The main contributions of this study are as follows:

(1) raising awareness about energy management issues in public institutions and organizations, especially in state universities that have campus zones;
(2) specifying important consumption zones and energy mapping of the organization;
(3) scrutinizing the tariff models in Turkey in electricity energy billing and specifying optimal tariff management of an organization;
(4) specifying opportunities that do not need any investment cost in EnMS, and analyzing the financial gain potential of the organization in line with these opportunities;
(5) winning the top management's trust, increasing its support, and thus implementing the applications that require investment cost in a shorter time by the savings obtained from the EnMS applications that do not require investment costs.

The paper is organized as follows. Section II explains the method and materials of the study. In section III, as a case study, scenarios are

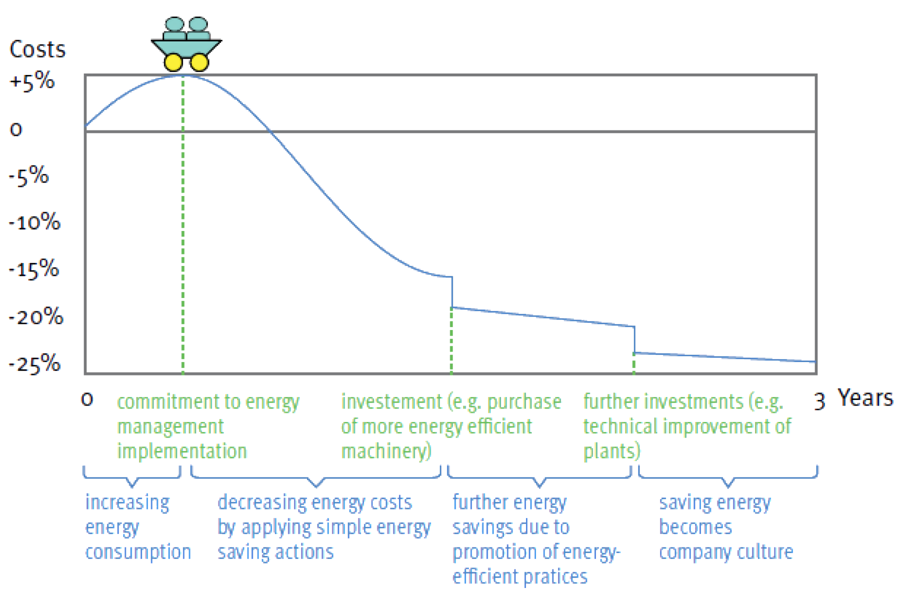

Fig. 2. Impact of EnMS on cost reduction [16].

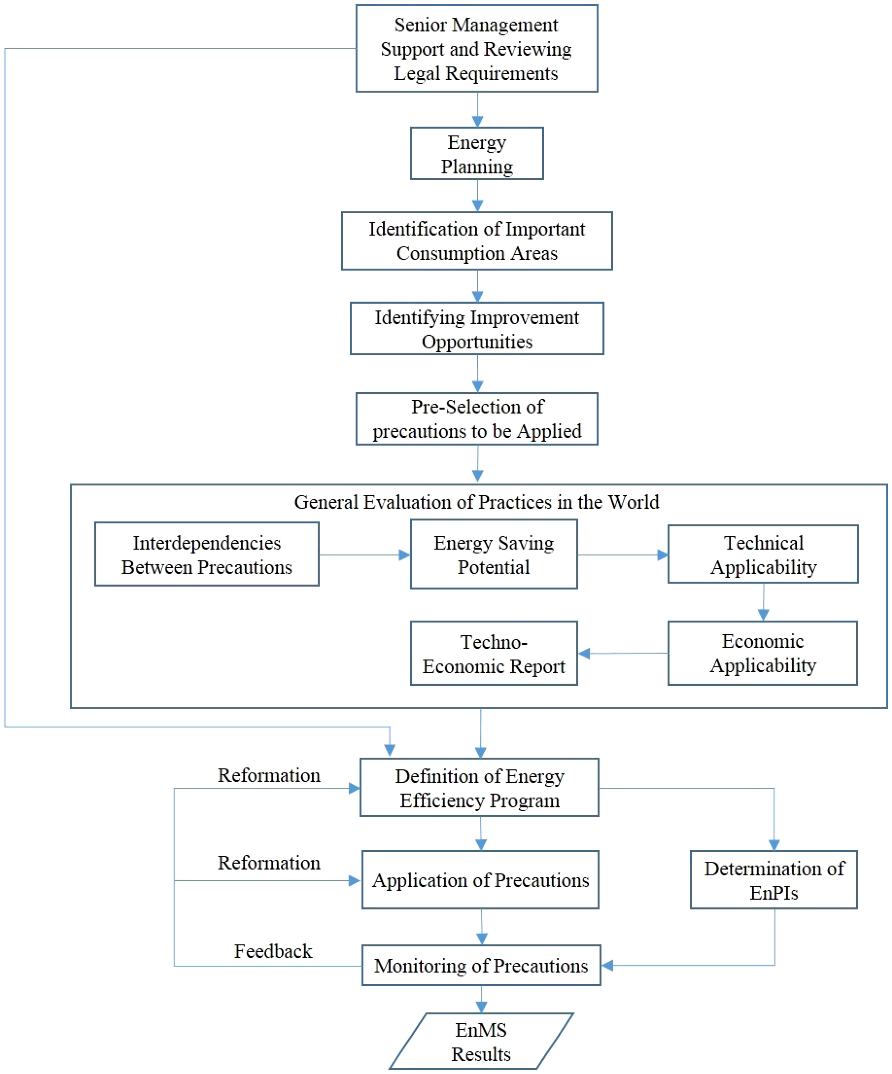

Fig. 3. Proposed EnMS flow chart.

analyzed and results and discussions are considered. Finally, the conclusion is drawn in section IV.

II. MATERIALS AND METHODS

In this section, the electrical energy consumed by the six different campuses of Bogazici University indicated in Table I was systematically measured and monitored (MM) between 2019 and 2020. Thus, important consumption zones (campuses) have been specified. MM was carried out via Otomatik Sayaç Okuma Sistemi (OSOS) system which does not need any investment cost at the transformer points, and recorded consumptions have been analyzed within the framework of the following points:

(1) energy consumptions on a monthly and seasonal basis;
(2) energy consumptions on a three-time tariff basis;
(3) peak load demands on a monthly basis;
(4) existing billing model versus alternative electricity tariffs models.

TABLE I.
BOGAZICI UNIVERSITY CAMPUSES WHERE ELECTRICAL ENERGY CONSUMPTION IS MEASURED AND MONITORED

Campus	Total Closed Area (m^2)	Attribute of Subscriber
South	58,783.85	2000 kVA, MV*
North	99,661.25	2000 kVA, MV
		1600 kVA, MV
Uçaksavar	37,304.42	1600 kVA, MV
Hisar	13,529.13	LV*
Sarıtepe	45,748.37	1600 kVA, MV
Kandilli	43,613.06	1600 kVA + 2500 kVA, MV

*MV is the medium voltage; LV is the low voltage.

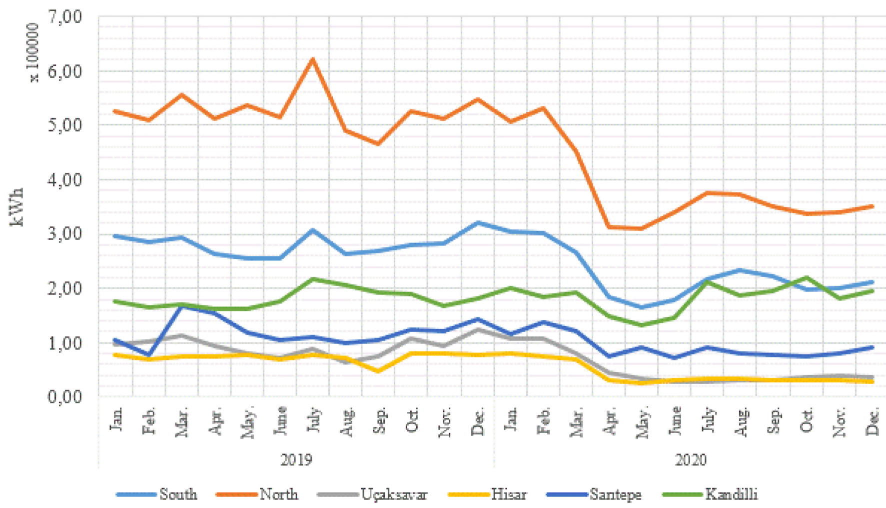

Fig. 4. Monthly basis campus consumptions of 2019–2020 years.

Thus, the second and third steps of the EnMS workflow diagram indicated in Fig. 3 have been carried out. These data are shown in Fig. 4 and Fig. 5. At this point, the main purpose is to determine the important consumption zones and the next step is to improve opportunities by making a preliminary study of the electrical energy consumption of the institution within the scope of EnMS. In this study, the priority of improvement opportunities is to identify actions with low investment costs but high impact and include these in the action plan of EnMS. Thus, as illustrated in Fig. 2, it is aimed to initially reduce energy costs by 3%–5% by simple measures and actions and to take the first step to ensure its continuity. Moreover, it is also aimed to win the top management's trust and to increase the awareness and support of EnMS through actions that need low investment costs but have a high financial incoming impact.

As can be seen clearly in Fig. 4 and Fig. 5, the highest total electrical energy consumption occurs in the North Campus by 40%. This is followed by South Campus by 23%, Kandilli Campus by 16%, Sarıtepe Campus by 10%, Uçsavar Campus by 6%, and Hisar Campus by 5%, respectively. When Fig. 4 is analyzed carefully, it is clearly seen that, since February 2020, electricity consumption has been decreased by nearly 32% as a result of online education throughout the university due to the coronavirus disease 2019 epidemic. Since this issue is important in terms of IC analysis, which is the main subject of our study, it is especially discussed.

Another indicator used in this study to specify the important consumption zones is the energy performance indicators (EnPI) of the campuses. In our model, as the EnPI, kWh/m^2, that is, the amount of energy consumed per unit closed area is used. Campus energy performances for the years 2019–2020 were calculated by using the closed area values specified in Table I and the consumption data in Fig. 4, and results are illustrated graphically in Fig. 6. As can be seen in Fig. 6, campuses with the worst energy performance are North, Hisar, Kandilli, South, Sarıtepe, and Uçaksavar campuses, respectively. As illustrated in Fig. 4–6, it is clearly concluded that the North Campus is the most critical campus in terms of both consumption and performance. Therefore, a case study on optimal IC analysis is conducted in the North Campus. We would like to point out in particular that other EnMS issues such as performance evaluation, the best and worst periods analysis, hourly consumption analysis, energy production rates, EnPI targets, etc., are not discussed because these lie outside the scope of the study.

A. Electricity Billing Tariffs in Turkey

The electrical energy billing tariffs in force in Turkey are shown in Table II briefly. As can be seen in this table, the electricity tariffs in Turkey are primarily categorized as Low Voltage (LV) and Medium Voltage (MV). Next, sub-categorization is made based on monomial (M) and binomial (B) regarding term type, based on fixed-time (FT) and three-time (3T) regarding the time of use (ToU), and finally user types. We would like to point out that since the green tariff specified in Table II entered into force as of date October 2020, it is not taken into consideration in the case study.

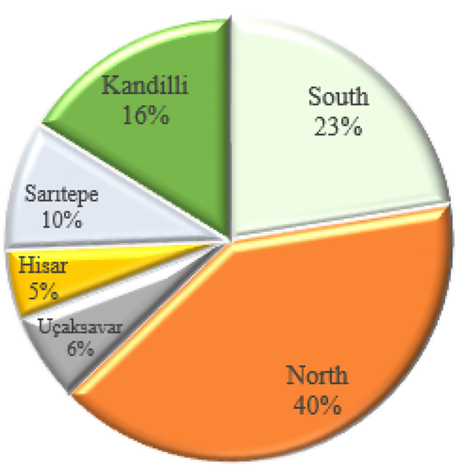

Fig. 5. The percental rates of the total electrical energy consumption in 2019–2020 by campuses.

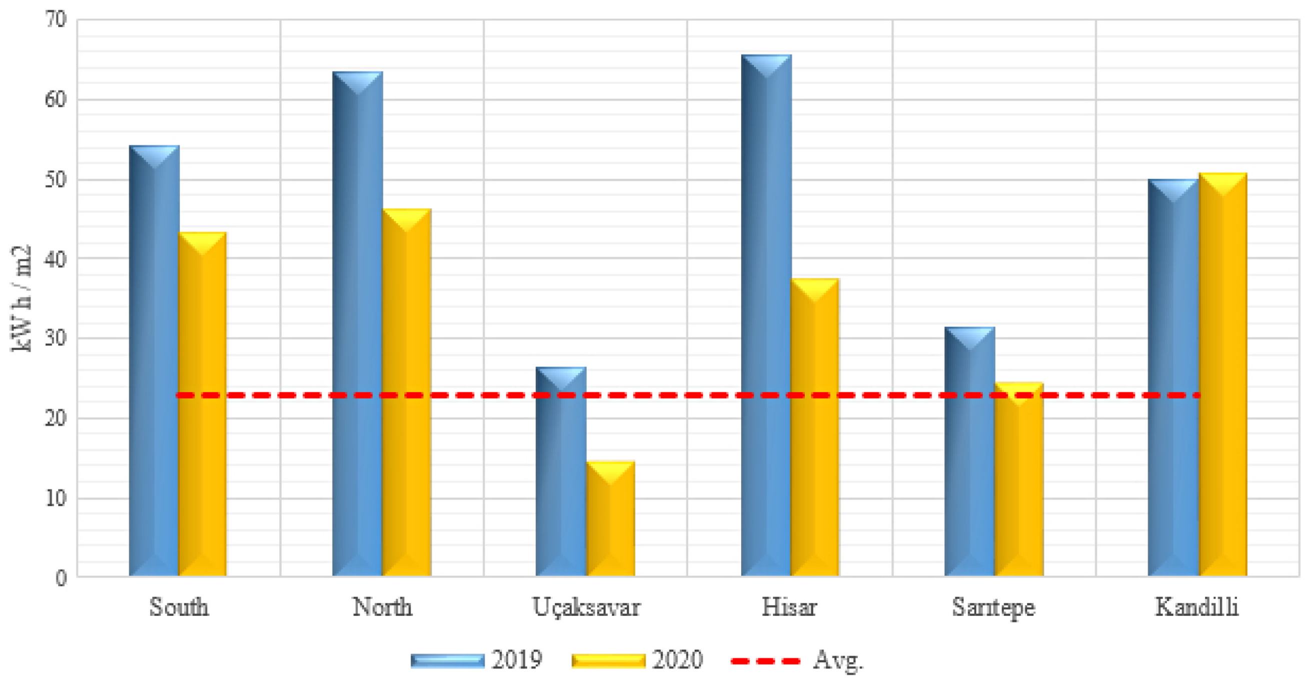

Fig. 6. Yearly basis campus EnPIs of 2019–2020 years and the reference line.

1) Monomial Tariff
In this tariff model, only the amount of electricity consumed (kWh) is used for IC [45]. In this tariff, Eq. (1) is used for calculating IC.

2) Binomial Tariff (Demand Charge Tariff)
In this tariff model, in other words, demand charge tariff (DCT), IC is calculated via both contract power (CP) (kW) that is promised not to exceed by the consumer during 1 month and monthly-based active power consumption of the consumer [45]. Customers subject to this tariff model can change their contract power up to three times in a calendar year [46]. The purpose of DCT is to know the demanded power (DP) of the customers and to keep this power ready for them by agreements made with consumers who demand high power [45]. A certain power fee (PF) is charged in this tariff model; however, a discount is also made on the active energy unit cost consumed. The most important issue in this tariff model is the determination of the CP optimally because the selected high value of the CP can cause more power cost and can remove the advantage of the tariff. On the

TABLE II.
THE ELECTRICAL ENERGY BILLING TARIFFS IN FORCE IN TURKEY

	Normal Tariff								Green Tariff							
	LV				MV				LV				MV			
	M		B		M		B		M		B		M		B	
Consumer Groups	FT	3T	FT	3T	FT	3T	FT	3T	FT	3T	FT	3T	FT	3T	FT	3T
Industry	✓	✓			✓	✓	✓	✓	✓				✓		✓	
Business	✓	✓			✓*	✓	✓	✓	✓				✓		✓	
Household	✓	✓			✓	✓	✓	✓	✓				✓		✓	
Agricultural Irrigation	✓	✓			✓	✓	✓	✓	✓				✓		✓	
Lighting	✓				✓		✓		✓				✓		✓	
Families of Martyrs and War Veteran	✓															
General Lighting	✓															

* The current (base) tariff class of the North Campus for which the case study is conducted.

contrary, when this power is exceeded as a result of which the CP is specified low value, the extra power overrun fee is applied and the customer is penalized. Therefore, the system should be analyzed very carefully for determining the optimal CP. In this tariff model, IC is calculated by using Eq. (2).

3) ToU Tariff as Fixed-Time and Three-Time

In the FT tariff model, ToU is fixed. On the contrary, in the 3T tariff model, ToU is categorized as follows: T1 is the normal price time slot between 06:00 and 17:00 hours, T2 is the higher price time slot between 17:00 and 22:00 hours, and T3 is the lower price time slot between 22:00 and 06:00 hours. In the 3T tariff model, the IC of electricity consumed specified time slots above are calculated separately. These time periods have been determined by considering the daily load curve of the Turkish electricity system by the Energy Market Regulatory Authority (EMRA). The main purpose of this model is to encourage the use of electrical home appliances that consume a lot of energy, such as washing machines, dishwashers, irons, after 22:00 hours. Because, at T2 time slot overlapping of various loads such as lighting, industry, generally the highest demand power occurs and this power needed should be provided by electricity generation companies. In this case, the power plants with the highest operating costs are commissioned and the production cost naturally increases. Thus, the electrical energy selling price in this model reaches the highest value at the T2 time slot. In this tariff model, for calculating ICs, Eq. (3) is used for M tariff and Eq. (4) is used for B tariff, in other words, DCT:

$$IC = \frac{1}{100} \times \sum_{t=1}^{n} \left(\exists_i \times \aleph \right) \tag{1}$$

$$IC = \frac{1}{100} \times \left[\left(\sum_{t=1}^{n} \left(\exists_i \times \aleph \right) \right) + \left(CP \times PF \right) \right] \tag{2}$$

$$IC = \frac{1}{100} \times \sum_{t=1}^{n} \left[\left(\exists_{T1_t} \times \aleph_{T1} \right) + \left(\exists_{T2_t} \times \aleph_{T2} \right) + \left(\exists_{T3_t} \times \aleph_{T3} \right) \right] \tag{3}$$

$$IC = \frac{1}{100} \times \left[\left(\sum_{t=1}^{n} \left(\exists_{T1_t} \times \aleph_{T1} \right) + \left(\exists_{T2_t} \times \aleph_{T2} \right) + \left(\exists_{T3_t} \times \aleph_{T3} \right) \right) + \left(CP \times PF \right) \right] \tag{4}$$

Where $\exists$ denotes the active energy consumption (kWh) and $\aleph$ denotes the energy unit cost of the relevant class (krş/kWh). *PF* is (krş/Month/kW) basis. Subscripts denoted *t* and *n* are periods of IC. Where time slots denoted as *t* and *n* are handled on a daily basis while ICs are calculated monthly.

III. SYSTEM DESCRIPTION AND DATA'S

As shown in Table I, the power of the North campus is supplied through two separate transformer subscriptions named North-TR1 and North-TR2. Load profiles and DP data of these subscriptions are shown in detail in Fig. 7, Fig. 8, Table III, and Table IV. Where $\ddot{Y}$ denotes the closest to the highest demand power (DP) value occurred during the years 2019–2020 and the safest maximum DP value that is not exceeded. On the other hand, λ denotes the safest maximum DP value that is closest to and does not exceed the highest DP value occurring in the periods specified in Table III and Table IV in 2019 and 2020. Another issue we would like to point out here is that the consumption of the North Campus illustrated in Fig. 4 is the sum of the consumption of these two subscriptions given in Fig. 7 and Fig. 8 during the same periods. For instance, the total consumption of January 2019 of the North Campus illustrated in Fig. 4 is equal to the sum of January 2019 consumptions in Fig. 7 and Fig. 8.

IV. CASE STUDY

Case studies are conducted on specifying the optimal tariff model analyzed through using electrical energy consumption data of the North Campus between 2019 and 2020 years. The current model, as a base case, is analyzed by being compared with the five alternative

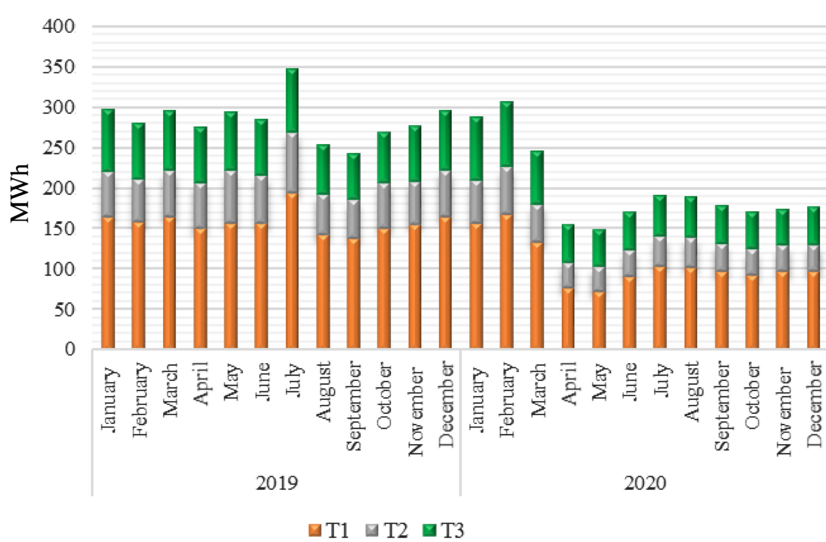

Fig. 7. Load profile of North-TR1.

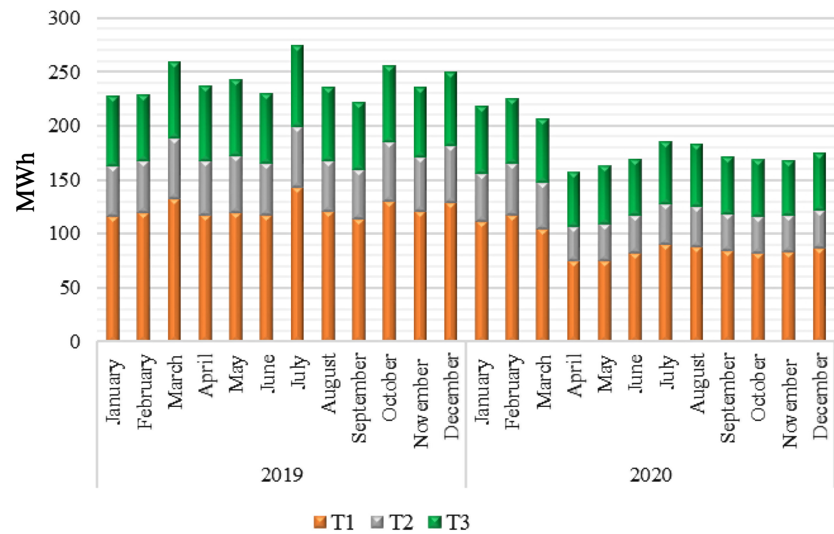

Fig. 8. Load profile of North-TR2.

scenario-based billing models. The case studies carried out in this section are briefly described below.

(1) Case 1: Base case: In this case, the ICs of the analyzed campus are carried out via the current tariff model named medium voltage monomial fixed time (MV-M-FT). Thus, a benchmark is specified for the pros and cons of other scenarios compared to the current model.
(2) Case 2: Scenario of medium voltage monomial three time (MV-M-3T) tariff model: In this scenario, the ICs of the North campus is analyzed as if the MV-M-3T model was utilized during the same period of the base case.
(3) Case 3: Scenario of medium voltage binomial fixed time (MV-B-FT) tariff model using $\ddot{Y}$ values: In this scenario, the ICs of the North campus is analyzed as if the MV-B-FT model was utilized during the same period of the base case. In this scenario, DP is not changed during the period.
(4) Case 4: Scenario of medium voltage binomial fixed time (MV-B-FT) tariff model using λ values: In this scenario, the ICs of the North campus is analyzed as if the MV-B-FT model was utilized during

TABLE III.
DP DATA OF NORTH-TR1

	DP (kW)		Ÿ (kW)		λ (kW)	
Months	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**
January	756.2	728.6	≤1000	≤1000	≤800	≤800
February	750.7	772.8	≤1000	≤1000	≤800	≤800
March	695.5	684.4	≤1000	≤1000	≤800	≤800
April	656.5	309.1	≤1000	≤1000	≤800	≤500
May	723.1	270.4	≤1000	≤1000	≤800	≤500
June	966	402.9	≤1000	≤1000	≤1000	≤500
July	966	458.1	≤1000	≤1000	≤1000	≤500
August	817	463.6	≤1000	≤1000	≤1000	≤500
September	684.4	469.2	≤1000	≤1000	≤750	≤500
October	712	425	≤1000	≤1000	≤750	≤500
November	645.8	419.5	≤1000	≤1000	≤750	≤500
December	673.4	408.4	≤1000	≤1000	≤750	≤500

TABLE IV.
DP DATA OF NORTH-TR2

	DP (kW)		Ÿ (kW)		λ (kW)	
Months	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**
January	529.92	463.68	≤800	≤800	≤600	≤600
February	574.08	507.84	≤800	≤800	≤600	≤600
March	552.00	507.84	≤800	≤800	≤600	≤600
April	518.88	342.24	≤800	≤800	≤600	≤400
May	529.92	298.08	≤800	≤800	≤600	≤400
June	717.60	331.20	≤800	≤800	≤800	≤400
July	750.72	375.36	≤800	≤800	≤800	≤400
August	618.24	353.28	≤800	≤800	≤800	≤400
September	529.92	353.28	≤800	≤800	≤600	≤400
October	540.96	342.24	≤800	≤800	≤600	≤400
November	507.84	342.24	≤800	≤800	≤600	≤400
December	507.84	353.28	≤800	≤800	≤600	≤400

the same period of the base case. On the contrary of Case 3, in this scenario, DP is changed three times during the period.

(5) Case 5: Scenario of medium voltage binomial three time (MV-B-3T) tariff model using $\ddot{Y}$ values: In this scenario, the ICs of the North campus are analyzed as if the MV-B-3T model was utilized during the same period of the base case. Different from Case 3, on the contrary, in this scenario, ToU is 3T.

(6) Case 6: Scenario of medium voltage binomial three time (MV-B-3T) tariff model using λ values: In this scenario, the ICs of the North campus are analyzed as if the MV-B-3T model was utilized during the same period of the base case. Different from Case 4, on the contrary, in this scenario, ToU is 3T.

The prices used for the calculations of the ICs do not include VAT. For the unit prices, the 2019 and 2020 EMRA Tariff Tables of Electricity Bills [47-54] are used. All scenarios in the case studies are calculated based on the Central Bank of the Turkish Republic monthly average effective selling USD rates [55] of the relevant consumption period.[1]

A. Case 1 Base case

In this case, for being made a benchmark rightly, the ICs belonging to the campus consumption are analyzed as a base case via the current billing model of the campus, named the MV-M-FT. The ICs of this case are calculated via Eq. (1) using the unit prices of this model given in [47-54]. The results of the ICs of the current model are \$675.432.6 and \$475.511.7 for the years 2019 and 2020, respectively, and the total IC is \$1.150.944.2.

B. Case 2 Scenario of the MV-M-3T tariff model

In this scenario, the ICs of the campus consumptions are analyzed via the MV-M-3T tariff model. The ICs of this scenario are calculated via Eq. (3) using the unit prices of this model given in [47–54]. The main purpose of this scenario is to analyze the pros and cons of the ToU model with 3T versus the current model with FT. The results of the ICs in this scenario are \$680.924.5 and \$473.102.1 for the years 2019 and 2020, respectively, and the total IC is \$1.154.026.6. As can be seen from the results, ICs increase by \$3.082.42 compared to the base case. It can be concluded that the load profile of the North campus is unsuitable for this scenario, and thus, this model is not optimal for the North campus consumption.

C. Case 3- Scenario of the MV-B-FT tariff model using Ÿ values

In this scenario, the ICs of the campus consumptions are analyzed via the MV-B-FT tariff model. The ICs of this scenario are calculated via Eq (2) using the unit prices of this model given in [47-54]. As a CP, $\ddot{Y}$ values given in Table III and Table IV are used. In this scenario, during the periods of 2019–2020, CPs are the $\ddot{Y}$ values as stated in Table III and Table IV and are fixed. The main purpose of this scenario is to analyze the pros and cons of the B model versus the current model. The results of the ICs in this scenario are \$651,100.9 and \$466,163.1 for the years 2019 and 2020, respectively, and the total IC is \$1,117,264.0. These results show that ICs decrease by \$33.680.20 compared to the base case. It can be concluded that the load profile of the North campus is suitable for this scenario even if CP equals to $\ddot{Y}$ values, which are fixed and the peak DP during the period of the years 2019 and 2020.

D. Case 4- Scenario of the MV-B-FT tariff model using λ values

In this scenario, the ICs of the campus consumptions are analyzed via the MV-B-FT tariff model. The ICs of this scenario are calculated via Eq. (2) using the unit prices of this model given in [47–54]. As a CP, λ values given in Table III and Table IV are used. In this scenario, during the periods of 2019–2020, CPs are the λ values as stated in Table III and Table IV and are not fixed. In other words, CPs, or λ values, indicated in Table III and Table IV are changed three times a year in accordance with [46]. The main purpose of this scenario is to analyze how CP, which is being changed three times a year in the B model, affects the ICs and the pros and cons of this strategy versus the current model and B model with fixed CP. The results of the ICs in this scenario are \$648,817.9 and \$459,301.5 for the years 2019 and 2020, respectively, and the total IC is \$1,108,119.4. These results show that ICs decrease by \$42,824.80 and \$9,144.6 compared to the base case and case 3, respectively. It can be concluded that the load profile of the North campus is more suitable for this scenario than the before ones if the CP equals λ values. Moreover, CPs which are being changed optimally three times a year as a result of careful analysis of the load profile could further decrease the ICs.

E. Case 5- Scenario of the MV-B-3T tariff model using Ÿ values

In this scenario, the ICs of the campus consumptions are analyzed via the MV-B-3T tariff model. The ICs of this scenario are calculated via Eq (4) using the unit prices of this model given in [47–54]. As such in case 3, in this scenario too, CPs are the $\ddot{Y}$ values given in Table III and Table IV. The only difference in this scenario is that the ToU model is 3T. The main purpose of this scenario is to analyze how 3T affects the ICs and the pros and cons of this strategy versus the other cases. The results of the ICs in this scenario are \$656,594.1 and \$463,753.9 for the years 2019 and 2020, respectively, and the total IC is \$1.120.347.9. These results show that ICs decrease by \$30,596.29 and \$33,678.71 compared to case 1 and case 2, respectively. However, on the contrary, ICs increase by \$3,083.91 and \$12,228.51 compared to case 3 and case 4, respectively. So, it can be concluded that the 3T in model B causes to lose its advantage in both cases, that is, when CP is both $\ddot{Y}$ and λ.

F. Case 6- Scenario of the MV-B-3T tariff model using λ values

In this scenario, the ICs of the campus consumptions are analyzed via the MV-B-3T tariff model. The ICs of this scenario are calculated via Eq. (4) using the unit prices of this model given in [47–54]. As such in case 4, in this scenario too, CPs are the λ values given in Table II and Table III. The only difference in this scenario is that the ToU model is 3T. The main purpose of this scenario is to analyze how 3T affects the ICs and the pros and cons of this strategy versus the other cases. The results of the ICs in this scenario are \$654,311.1 and \$456,892.2 for the years 2019 and 2020, respectively, and the total IC is \$1,111,203.3. These results show that ICs decrease by \$39,740.89, \$42,823.31, \$6,060.69, \$9,144.6 compared to case 1, case 2, case 3, and case 5 respectively. However, on the contrary, ICs increase by \$3.083.91 compared to case 4. So, it can be concluded that the 3T model still continues its advantages

1 Based on [55], the average effective selling USD rate for 2019 and 2020, 1 USD = 5.67 TL and 1 USD = 7.00 TL, respectively.

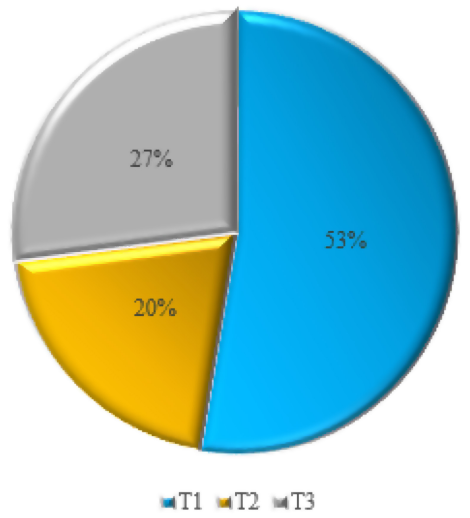

Fig. 9. Consumptions of The North campus in 3T periods.

against all other cases apart from case 4, on the condition that the CPs are specified as λ values. But, 3T in model B still causes to lose its advantage when CP is λ.

The results of the case studies above mentioned are given in Table V as a summary and also illustrated graphically in Fig. 10. It can be concluded that;

- In case 2, ICs are getting increase by 0.27%. Therefore, this model is not optimal for the North Campus.
- All the 3T models in case 2, case 5, and case 6 compared to all FT models in case 1, case 3, and case 4 respectively are worse by approximately 0.28%.
- 3T models are not optimal for consumers with load profiles in the 3T periods shown in Fig. 7.

TABLE V.
SUMMARIES OF CASE STUDIES

Scenario	Total IC of 2019–2020 ($)	Profit Amount ($)	Profit Rate
Base case	1,150,944.21		
S2	1,154,026.63	−3,082.42	−0.27%
S3	1,117,264.00	33,680.20	2.93%
S4	1,108,119.41	42,824.80	3.72%
S5	1,120,347.92	30,596.29	2.66%
S6	1,111,203.32	39,740.89	3.45%

- Unless the rate of load consumed in the T2 period is lower than 20% of all consumption or contrary unless the rate of load consumed in the T3 period is higher than 27% of all consumption 3T tariff models should be analyzed carefully for the related consumer.

The tariff model named B, or DCT, is the best suitable model for the North campus load profile. By using these tariff models, ICs are getting decrease between rates of 2.93% and 3.72% by case 3 and case 4, respectively. Opportunities to earn a total of $39,000–$43,000 in 2 years are available for case 4 and case 6 by this tariff model. Therefore, these cases, particularly case 4, are more optimal for the North Campus.

V. CONCLUSIONS

This study has focused on a crucial but seldom thoroughly investigated domain in public institutions and organizations, especially in state universities that have a campus: energy management on a non-technological and organizational, especially financial opportunities, aspect. In accordance with this purpose, initially, the importance of

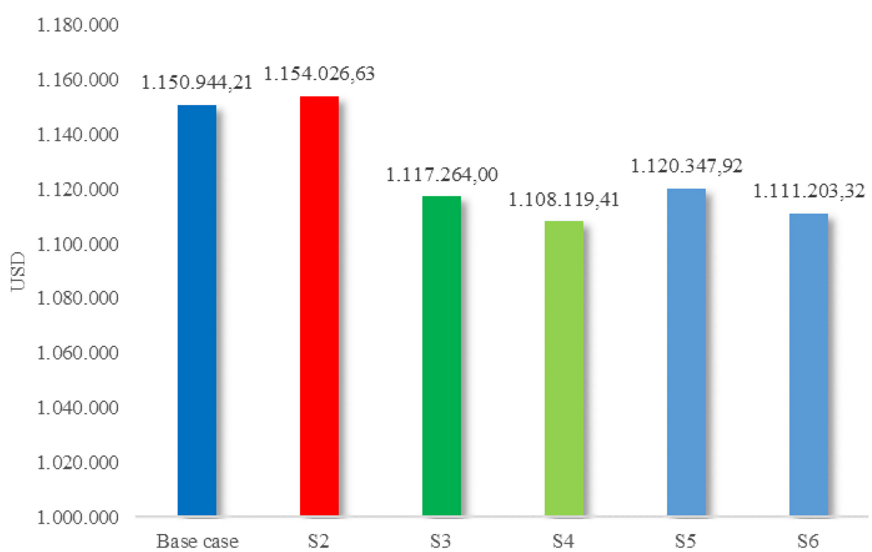

Fig. 10. Summary of the base case versus alternative scenarios.

EnMS and actions in various sectors in the literature are mentioned, and then, with reference to the ISO 50001 standard, the flow chart in Fig. 3 is proposed as an organizational EnMS. As illustrated in the proposed flow chart, after the support of the top management and reviewing legal requirements, the next step of the EnMS has been specified as energy planning. Because the sustainability of EnMS can only be ensured by successful actions in the planning step. Hence, it is highly essential to give priority to actions with both minimum investment costs and high yield in EnMS action plans for improvement activities. With this approach, as a planning step of EnMS, for performance evaluation based on specifying optimal billing model, in terms of the economy, scenario-based case studies were conducted on the IC analysis of Boğaziçi University's electricity consumption, which does not need any investment cost.

In these scenario-based case studies, the ICs of the North Campus, which is the most critical campus of Bogazici University in terms of EnPI, have been analyzed by using different tariff models in Turkey through electrical energy data that was consumed by this campus during 2019–2020 years. In this direction, initially, as a base case, the current billing model of the campus has been analyzed. The main purpose of the base case study is to make a reference point in order to analyze the pros and cons of the other five alternative tariff models against the current situation. Moreover, the pros and cons of each case study against the other ones are discussed in detail and the results are summarized. To sum up these cases, ICs increase by 0.27% in case 2 while decrease between rates of 2.93%, 3.72%, 2.66%, and 3.45% by case 3, case 4, case 5, and case 6, respectively. Thus, via the tariff models in cases 4 and 6, a total savings of $39,000.0–$43,000.0 is available for 2 years. We would like to emphasize in particular that these sums could be saved without any investment costs. These are great opportunities for organizations at the start and thus it is strongly suggested that it must be considered in the EnMS action plans as an initial step. Moreover, the opportunities on behalf of organizations to implement energy-efficient techniques that could be financed via these savings are also particularly important for their future action plans in EnMS. With reference to this study, we strongly suggest that the optimal tariff management strategy should be analyzed in public institutions, especially in universities campuses where energy is consumed intensively. Consequently, we hope that our study is a roadmap for the EnMS issue which started in 2018 at public institutions and state universities in Turkey and contributes to the gap in the literature by creating awareness.

There are many subjects to be investigated as future works. In the present study, we only analyze the ICs considering electricity tariff models in Turkey as an initial step of EnMS. However, to make the research closer to globally, different electricity tariff models in developed or developing countries can be conducted as case studies. In this way, electricity tariff models in Turkey can vary optimally on behalf of both producer and consumer. Moreover, the green tariff model in Turkey, not handled in this study because of its immaturity, can be considered as an alternative model in future works. Thus, the pros and cons of this model can be analyzed for consumer types and load profiles. As a continuation of this study, as the next step of EnMS, our future thought is to forecast the load profiles of the buildings in Bogazici University campuses, especially the peak load demands, by using forecasting-based methods. Thus, we are of the opinion to gain more profit maximization by using the B, or DCT, tariff model, as a result of peak load shaving optimally.

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REFERENCES

1. G. A. Kiliç, K. Al., E. Dağtekin, and Ü. Ünver, “Technical, economic and environmental investigation of grid-independent hybrid energy systems applicability: a case study,” *Energy Sources Part Recover Util. Environ. Eff.*, vol. 00, no. 00, pp. 1–16, 2020. [CrossRef]
2. A. Imran *et al.*, “Heuristic-based programable controller for efficient energy management under renewable energy sources and energy storage system in smart grid,” *IEEE Access*, vol. 8, pp. 139587–139608, 2020. [CrossRef]
3. Y. Fernando, P. S. Bee, C. J. C. Jabbour, and A. M. T. Thomé, “Understanding the effects of energy management practices on renewable energy supply chains: Implications for energy policy in emerging economies,” *Energy Policy*, vol. 118, pp. 418–428, 2018. [CrossRef]
4. S. K. Mangla, S. Luthra, S. Jakhar, S. Gandhi, K. Muduli, and A. Kumar, “A step to clean energy - Sustainability in energy system management in an emerging economy context,” *J. Clean. Prod.*, vol. 242, p. 118462, 2020. [CrossRef]
5. E. Koç, and E. Kaplan, “General Energy situation-I world assessment in the world and in Turkey,” *J. Thermodyn.*, vol. 187, pp. 70–80, 2008.
6. M. Haseeb, S. A. A. Kazmi, M. M. Malik, S. Ali, S. B. A. Bukhari, and D. R. Shin, “Multi objective based framework for energy management of smart micro-grid,” *IEEE Access*, vol. 8, pp. 220302–220319, 2020. [CrossRef]
7. M. A. Moktadir *et al.*, “Key factors for energy-efficient supply chains: Implications for energy policy in emerging economies,” *Energy*, vol. 189, p. 116129, 2019. [CrossRef]
8. R. Martin, M. Muûls, L. B. De Preux, and U. J. Wagner, “Anatomy of a paradox: Management practices, organizational structure and energy efficiency,” *J. Environ. Econ. Manag.*, vol. 63, no. 2, pp. 208–223, 2012. [CrossRef]
9. Energy and Natural Resources Ministry. *National Energy Efficiency Action Plan 2017–2023*. Ankara: Energy and Natural Resources Ministry, 2017.
10. M. S. Alam, and S. A. Arefifar, “Energy management in power distribution systems: Review, classification, limitations and challenges,” *IEEE Access*, vol. 7, pp. 92979–93001, 2019. [CrossRef]
11. Y. Jin *et al.*, “An energy management maturity model for China: Linking ISO 50001:2018 and domestic practices,” *J. Clean. Prod.*, vol. 290, p. 125168, 2021. [CrossRef]
12. General Directorate of Energy Affairs, “2009 National Energy Balance Sheet,” Ankara, 2010. [Online]. Available: https://enerji.enerji.gov.tr//Media/Dizin/EIGM/tr/Raporlar/PRP/UEDT/741828-2009_yili_genel_enerji_dengesi_2016__r1.xlsx.
13. General Directorate of Energy Affairs, “2009 National Energy Balance Sheet,” Ankara, 2020. [Online]. Available: https://enerji.enerji.gov.tr//Media/Dizin/EIGM/tr/Raporlar/Ulusal_Enerji_Denge_Tablolari/2019.xlsx.
14. D. Lee, and C. C. Cheng, “Energy savings by energy management systems: A review,” *Renew. Sustain. Energy Rev.*, vol. 56, pp. 760–777, 2016. [CrossRef]
15. J. Kaselofsky *et al.*, “Getting municipal energy management systems ISO 50001 certified: A study with 28 European municipalities,” *Sustainability*, vol. 13, no. 7, 2021. [CrossRef]

16. UNIDO, *Practical Guide for Implementing an Energy Management System*. Vienna: United Nations Industrial Development Organization, 2015.
17. International Organization for Standardization Energy Management Systems. *Requirements with Guidance for Use; (ISO Standard No. 50001:2018)*. Vernier, Switzerland: ISO, 2018.
18. B. Jovanović, and J. Filipović, "ISO 50001 standard-based energy management maturity model – Proposal and validation in industry." *J. Clean. Prod.*, vol. 112, pp. 2744–2755, 2016. [CrossRef]
19. C. Naden, "ISO 50001 for Energy Management Gets a Boost." Available: https://www.iso.org/news/ref2316.html.
20. L. G. Mkhaimer, M. Arafeh, and A. H. Sakhrieh, "Effective implementation of ISO 50001 energy management system: Applying Lean Six Sigma approach," *Int. J. Eng. Bus. Manag.*, vol. 9, pp. 1–12, 2017. [CrossRef]
21. R. Uriarte-Romero, M. Gil-Samaniego, E. Valenzuela-Mondaca, and J. Ceballos-Corral, "Methodology for the successful integration of an energy management system to an operational environmental system," *Sustainability*, vol. 9, no. 8, pp. 5–8, 2017. [CrossRef]
22. M. R. Teixeira, P. Mendes, E. Murta, and L. M. Nunes, "Performance indicators matrix as a methodology for energy management in municipal water services," *J. Clean. Prod.*, vol. 125, pp. 108–120, 2016. [CrossRef]
23. F. Marimon, and M. Casadesús, "Reasons to adopt ISO 50001 Energy Management System," *Sustainability*, vol. 9, no. 10, pp. 1–15, 2017. [CrossRef]
24. A. McKane *et al.*, "Predicting the quantifiable impacts of ISO 50001 on climate change mitigation," *Energy Policy*, vol. 107, pp. 278–288, 2017. [CrossRef]
25. UNIDO, *Practical Guide for Implementing an Energy Management System*. Vienna: United Nations Industrial Development Organization, 2015.
26. T. Y. Chiu, S. L. Lo, and Y. Y. Tsai, "Establishing an integration-energy-practice model for improving energy performance indicators in ISO 50001 energy management systems," *Energies*, vol. 5, no. 12, pp. 5324–5339, 2012. [CrossRef]
27. T. Fiedler, and P. M. Mircea, "Energy management systems according to the ISO 50001 standard - Challenges and benefits," *Int. Conf. Appl. Theor. Electr. ICATE 2012 - Proc.*, 2012. [CrossRef]
28. H. Kanneganti *et al.*, "Specification of energy assessment methodologies to satisfy ISO 50001 energy management standard," *Sustain. Energy Technol. Assess.*, vol. 23, pp. 121–135, 2017. [CrossRef]
29. A. K. Roy, *Public Sector Energy Management: A Strategy for Catalyzing Energy Efficiency in Malaysia*. Delaware: University of Delaware, 2001.
30. P. Karcher, and R. Jochem, "Success factors and organizational approaches for the implementation of energy management systems according to ISO 50001," *TQM J.*, vol. 27, no. 4, pp. 361–381, 2015. [CrossRef]
31. K. Beihmanis, and M. Rosa, "Energy management system implementation in Latvian municipalities: From theory to practice," *Energy Procedia*, vol. 95, pp. 66–70, 2016. [CrossRef]
32. A. Kamenders, M. Rosa, and K. Kass, "Low carbon municipalities. The impact of energy management on climate mitigation at local scale," *Energy Procedia*, vol. 128, pp. 172–178, 2017. [CrossRef]
33. A. Jekabsone, A. Kamenders, and M. Rosa, "Implementation of certified energy ManagementSystem in municipality. Case study," *Environ. Clim. Technol.*, vol. 24, no. 2, pp. 41–56, 2020. [CrossRef]
34. Ö. Özdemir, "Energy management and cleaner production in an automotive supply industry," İzmir: Dokuz Eylül Univ, 2014.
3s5. C. O. Onus, *Continual Energy Management Dynamics: Energy Efficiency in US Automotive Manufacturing Indsustry*. Walden University, 2014.
36. R. Kannan, and W. Boie, "Energy management practices in SME — Case study of a bakery in Germany," *Energy Conversion and Management*, vol. 44, no. 6, pp. 945–959, 2003.
37. A. Boharb *et al.*, "Auditing and analysis of energy consumption of an industrial site in Morocco," *Energy*, vol. 101, pp. 332–342, 2016. [CrossRef]
38. A. Kluczek, and P. Olszewski, "Energy audits in industrial processes," *J. Clean. Prod.*, vol. 142, 3437–3453, 2017. [CrossRef]
39. M. Tunc, K. Kaplan, S. Sisbot, and U. Camdali, "Energy management and optimization : Case study of a textile plant in Istanbul, Turkey," *World J. Eng.*, vol. 13, no. 4, pp. 348–355, 2016. [CrossRef]
40. D. T. Acosta, *Energy Management in Louisiana's Public School Districts*. Louisiana State University, 1993.
41. S. H. Lee, *Management of Building Energy Consumption and Energy Supply Network on Campus Scale*. Georgia Institute of Technology, 2012.
42. A. R. Akdağ, *Energy Management and Energy Saving in Mosques in the Case of Buildings Used for Gathering Purposes*. Karabük: Karabük Üniversity, 2013.
43. M. N. Sinha, *Intelligent Demand Side Management of Residential Building Energy Systems*. United States of America: The University of North Carolina at Charlotte, 2013.
44. N. C. and N. S. (BMU) Federal Ministry for the Environment. "*Energy Management Systems in Practice - ISO 50001: A Guide for Companies and Organisations. Berlim: Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. (BMU) - Division: ZG III 2*," 2012.
45. S. İşçan, "Creating and modeling the energy management system of Metro Istanbul and its evaluation," *Yalova Üniversity*, 2019.
46. "EMRA," *Procedures and Principles regarding Tariff Applications of Distribution Licensee Legal Entities and Responsible Supply Companies*, *Türkiye*, 2015.
47. "EMRA," *Electricity Tariff Tables Valid as of 1/1/2019*, *Türkiye*, 2019.
48. "EMRA," *Electricity Tariff Tables Valid as of 01/04/2019*, *Türkiye*, 2019.
49. "EMRA," *Electricity Tariff Tables Valid as of 1/7/2019*, *Türkiye*, 2019.
50. "EMRA," *Electricity Tariff Tables Valid as of 01/10/2019*, *Türkiye*, 2019.
51. "EMRA," *Electricity Tariff Tables Valid as of 01/01/2020*, *Türkiye*, 2020.
52. "EMRA," *Electricity Tariff Tables Valid as of 1/4/2020*, *Türkiye*, 2020.
53. "EMRA," *Electricity Tariff Tables Valid as of 1/7/2020*, *Türkiye*, 2020.
54. "EMRA," *Electricity Tariff Tables Valid as of 1/10/2020*, *Türkiye*, 2020.
55. "The Central Bank of the Republic of Turkey," *Monthly Basis Effective Exchange Rates*. Available: https://evds2.tcmb.gov.tr/index.php?/evds/serieMarket/#collapse_2.