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THE IMPACT OF ELECTRICITY CONSUMPTION LOAD GRAPHS ON THE POWER

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Abstract: This paper presents the analysis results of hourly, daily, monthly, and annual electricity costs for the textile enterprise. Data on the company's energy consumption for 2023 was collected and analyzed, revealing the dynamics of monthly, quarterly, and annual energy consumption patterns. The study also highlights the benefits of implementing time-of-use tariffs to encourage electricity consumption. Data from developed countries indicate that shifting to off-peak times can lead to significant cost savings, reduced peak demand charges, and favorable time-of-use tariffs, resulting in better load management and sustainability.

Keywords: energy consumption, industrialization, energy efficiency, tariff, rational energy use, time-varying tariffs, off-peak consumption, cost savings, energy audit.

Introduction. Recently, concerns about energy usage and its negative environmental impact have intensified. Most developing countries have transitioned from agriculture to industrialization and urbanization due to economic growth over the past few decades. The growth in the industrial sector, which promised healthy GDP increases, has significantly impacted the ability to maintain fuel supply and reserves. Introducing the concept of rational energy use aims to reduce energy consumption while optimizing the use of all limited economic resources [1]. This definition indicates that measures leading to more rational energy use show advantages over the current situation. Many sectors experience energy losses, highlighting the potential for increasing energy efficiency [2]. Thus, energy savings mean less dependence on energy imports. The increase in energy usage has caused serious concern for the Uzbek government, prompting efforts to overcome these issues by promoting final energy efficiency—using less energy for the same service level. This can be achieved by either reducing overall energy consumption or increasing production rates per unit of energy used. Different types of equipment and devices use energy with varying efficiency levels, depending on their characteristics and operating conditions. Energy audits are one method that can be used to identify and quantify how energy is used in an enterprise. Numerous studies have been published on the results of energy audits and analyses for various sectors [3]. The energy usage indicators and efficiency of the industrial sector have also been studied in various surveys across different countries [4]. However, existing literature lacks specific research quantifying energy consumption distribution in the Asian industrial sector.

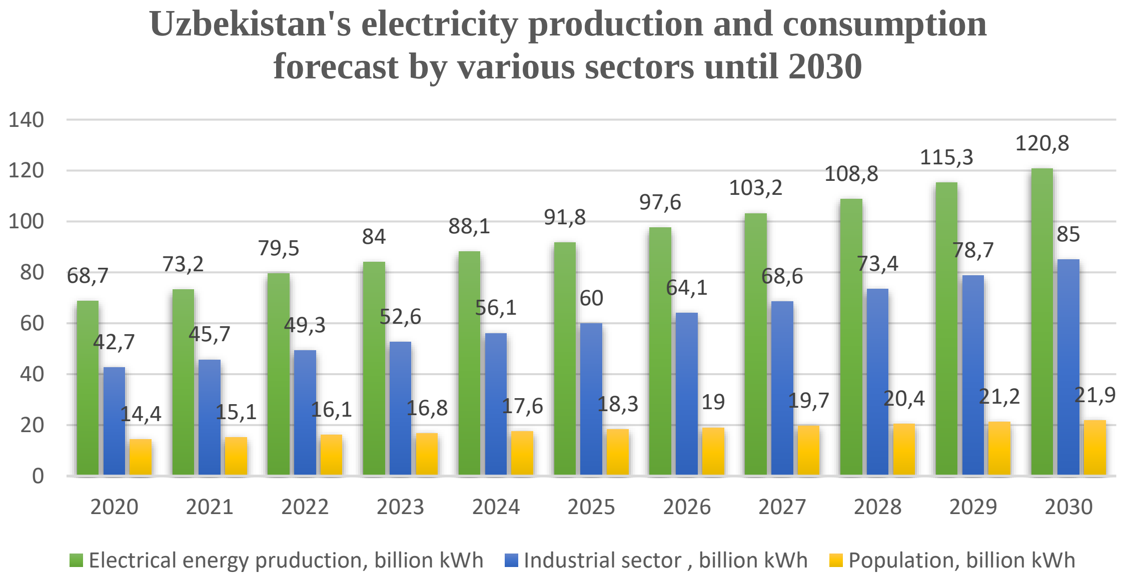

Figure 1. Uzbekistan's electricity production and consumption forecast by various sectors until 2030, billion kWh [16].

In modern energy systems, factors such as fluctuations in renewable energy sources, uncertainty in electricity demand, insufficient ramping of thermal blocks, low spinning reserves, and others can lead to cascading outages and widespread blackouts. Therefore, implementing Demand-Side Management (DSM) strategies plays a significant role in optimizing the operation of electrical distribution networks [4]. According to the definition provided by the U.S. Department of Energy, DSM schemes aim to alter the energy consumption patterns of residential, commercial, and industrial loads, considering changes in electricity tariffs and incentive payments [5]. Generally, demand response programs are categorized into two types: time-based approaches and incentive-based approaches. In this context, the authors in [6] developed a time-based demand response program for production services. Time-of-use tariffs allow production networks to shift the electricity consumption process from peak hours to non-peak periods, lowering monthly electricity bills and creating an energy-saving, load-sensitive approach. For example, in Singapore's residential and commercial sectors, game theory-based strategies are used for half-hour real-time pricing, time-of-use, and day-night pricing strategies [7]. In [8], the economic benefits of real-time pricing depend on consumer participation and their willingness to restrict their electricity consumption patterns. Thus, production companies offer lower electricity prices when consumers participate in real-time pricing-based demand management strategies, and conversely for inflexible loads. In [9], a real-time pricing-based demand response policy is applied to flexible consumers to incentivize energy savings in load aggregator transactions. This study uses time-of-use rates to improve the economic performance of the system under investigation. In energy systems with high wind turbine penetration, the application of incentive-based DRPs to cover uncertainties related to wind power plants and prepare reserve capacities was studied in [10]. A 25% cost savings was achieved after applying time-based and incentive-based DRPs. In [11], a two-stage risk-aware stochastic model for purchasing electricity for large consumers with an energy storage unit, PV, wind turbines, geothermal energy generator, slow and fast DSM, bilateral contracts, and pool market is proposed. Studies in China have shown that peak demand durations are very short (only 1.6% of total hours in a year). Peak demand usually occurred at 7:00 PM in most provinces of China. Multi-energy DR applications for data centers, electric vehicles, and air conditioning loads were developed in [12]. Similarly, the analysis of electricity consumption in textile enterprises in our country has been studied in several scientific publications [13, 14]. This paper presents the results of hourly, daily, monthly, and annual electricity cost analysis of the textile enterprise. Instrument measurements are performed to determine the hourly regime of electricity consumption in the enterprise. Data on the company's energy consumption for 2023 were collected and analyzed, revealing the dynamics of monthly, quarterly, and annual energy consumption patterns.

Methodology & empirical analysis. This study investigates energy consumption patterns and efficiency improvements in an industrial setting, focusing on a textile factory in Tashkent, Uzbekistan. The methodology involves a walkthrough energy audit to collect data on energy usage. The audit team recorded the power ratings and operating hours of all equipment on the production floor, consulting with responsible personnel to estimate total working days per year.

Key data collected include:

Power ratings and operation times of energy-consuming equipment and machinery.

Fossil fuel and other energy sources usage.

Production figures.

Peak and off-peak tariff usage behavior.

Power factor trends.

Due to time and budget constraints, the data collection relied on manual methods rather than metering devices. Similar approaches have been used in previous studies to estimate energy use in various industries.

Results. This study presents the results and analysis of walkthrough energy audit on textile factory in industrial sector located in Tashkent, Uzbekistan. During the walkthrough audit in a factory, the audit team counted all the equipments on the production floor, and took notes on rated power from technical specifications on the equipments and operating hours per working day. The audit team has also estimated total working days in a year in consultation with responsible person of the production process.

The most important data that have been collected during walkthrough audit are power rating and operation time of energy-consuming equipments, machineries; fossil fuel and other sources of energy use; production figure; peak and off-peak tariff usage behavior and power factor. Using these data, an analysis has been carried out to investigate the breakdown of end-use equipments machineries energy use, the peak and off-peak usage behavior, power factor trend, specific fossil fuel energy and specific electricity use.

It may be mentioned that data collection by meter (such as power meter, electric pliers) or experimental investigation would be the best one. The authors are very much aware of this matter. However, due to time and budget constrains and nature of the audit (i.e. walkthrough audit), the data have been collected using the technique mentioned earlier. It may also be noted that several other works found in the published literatures in different countries used similar approaches to estimate equipment, applicances energy use [13,14].

In this study the maximum emphasis was given to find out the end-use electricity used in the industrial production process for the year 2006. Based on the analyzed data, it has been found that electrical motors used the highest amount of energy (47%) followed by pumps (14%), air compressors (9%), air-conditioning systems (7%), workshop machines (6%,), lighting (6%), overhead cranes (3%), ventilation (2%), furnace (1%), conveyor system (1%), boiler (1%), refrigeration system (1%) and other equipments (4%). Figure 2 and figure 3 active and reactive power consumption of "BIRYUZA GROUP" enterprise during winter and summer peak days.

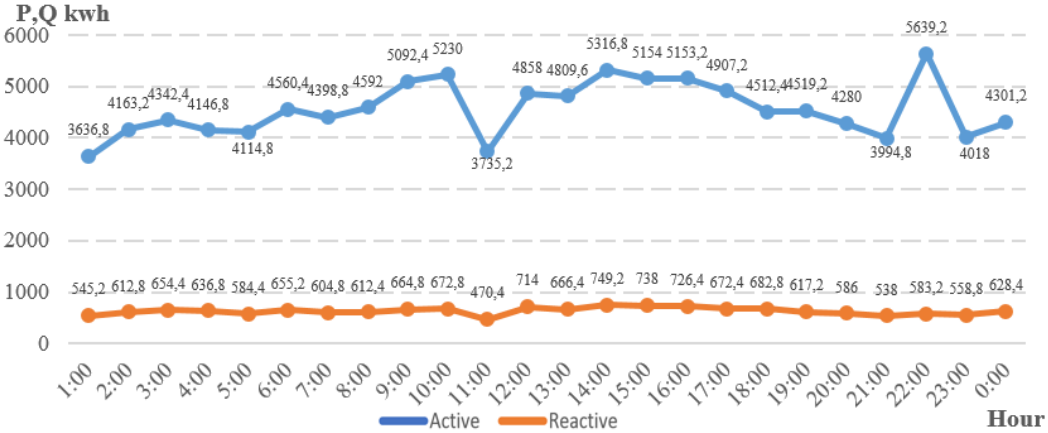

Figure 2. Shows active and reactive power consumption of "BIRYUZA GROUP" enterprise in winter.

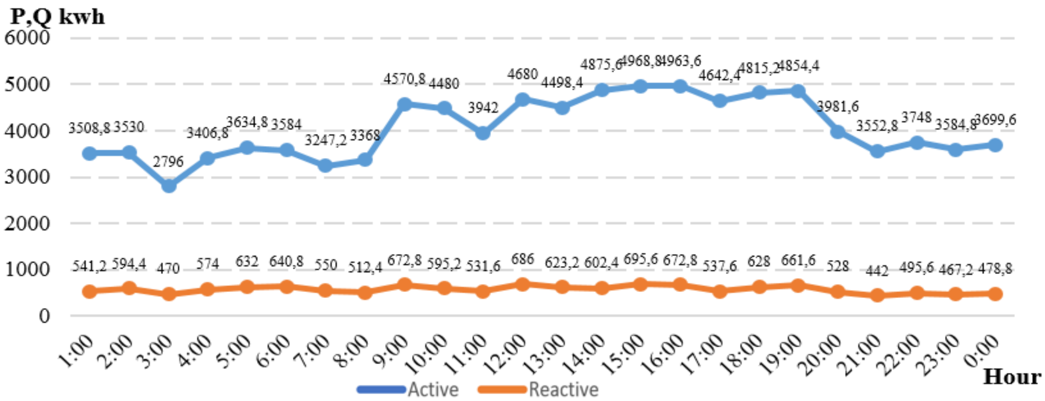

Figure 3. Shows active and reactive power consumption of "BIRYUZA GROUP" enterprise in the summer period.

The company's electricity demand in winter was observed to be higher than the daily consumption in summer. Based on daily consumption data, a graph of the company's monthly electricity consumption for 2023 was created (Figure 4).

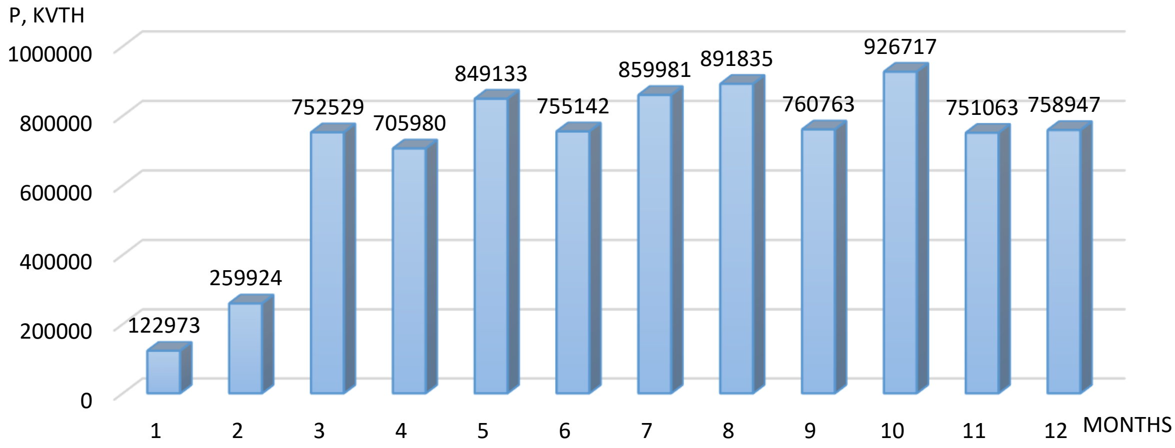

Figure 4. "BIRYUZA GROUP" Energy demand in the months of 2023.

The annual load graph shows that the company's electricity consumption was almost 80 kWh for nearly 90% of the year. Using the above graphs helps identify hourly consumption, peak load hours for the power system, and monthly and seasonal load periods. Analyzing the data revealed specific patterns of electricity consumption at different times and seasons. The analysis showed that 46% of total electricity consumption occurred during the summer period, likely due to increased cooling demands. Additionally, 24% of winter electricity consumption occurred during peak hours, while 30% of total consumption took place during peak hours, indicating higher usage during these times due to heating needs and increased indoor activities. Moreover, 19% of summer electricity consumption occurred during off-peak hours, differing from the winter period, where 27% of consumption happened during busy hours.

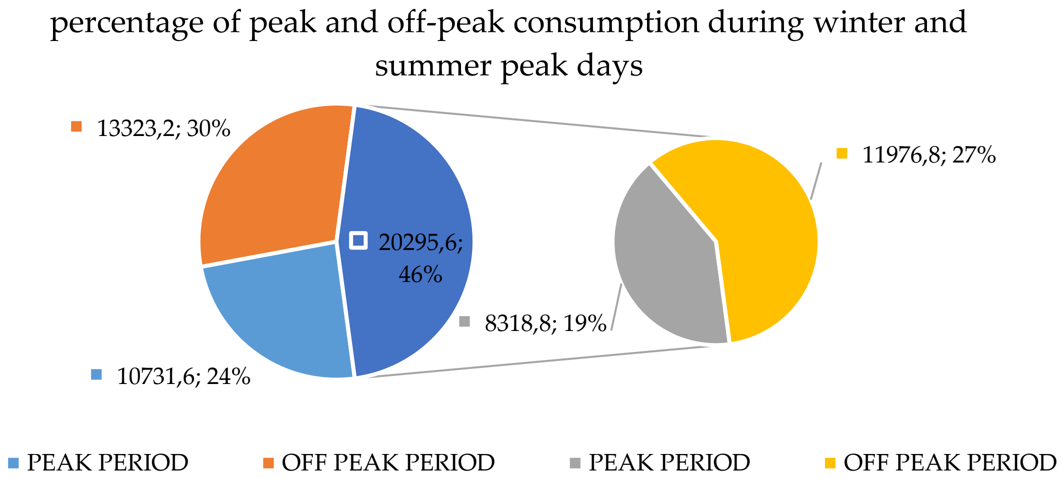

Figure 5. Percentage of peak and off-peak consumption during winter and summer peak days.

These consumption rates during peak hours highlight potential cost-saving opportunities by better managing the load and shifting some usage to these periods. The changing patterns of electricity consumption emphasize the importance of seasonality and time of day in energy management. Figure 5 illustrates these consumption trends, providing a visual representation of data distribution across different periods and hours. This emphasizes the need for targeted strategies to optimize electricity use and efficiency.

Peak hours show a higher percentage of electricity consumption because industries realize that the costs associated with overtime payments for off-peak operations outweigh the savings from reduced electricity rates. Additionally, minor equipment is often operated during peak hours for regular production and administrative tasks. Most audited factories use off-peak hours for running major production equipment, with some having agreements with labor union to fully shift operations to off-peak times. Large and medium-scale factories tend to run their production plants during off-peak hours, whereas small-scale industries avoid off-peak production due to the high costs of employee overtime.

The experiments revealed significant potential for savings on electricity costs by shifting consumption to off-peak periods, especially in comparison to summer peak periods. The following statements summarize the key findings and provide supporting evidence with reference to current tariffs in developed countries:

Cost Savings Potential:

Shifting electricity consumption to off-peak periods can result in substantial cost savings. For instance, in the United States, off-peak electricity rates can be as low as 50% of peak rates, highlighting the financial benefits of this practice.

Reduced Peak Demand Charges:

Many developed countries impose demand charges based on peak usage. By reducing peak demand through off-peak consumption, businesses can significantly lower these charges. For example, in Germany, demand charges during peak hours can be three times higher than those during off-peak hours.

Time-of-Use Tariffs:

Time-of-use (TOU) tariffs incentivize off-peak usage. In the UK, TOU tariffs can offer up to a 40% discount for electricity consumed during off-peak periods, compared to peak times. This encourages consumers to adjust their consumption patterns.

Energy Efficiency Programs:

Many developed countries have energy efficiency programs that reward consumers for off-peak usage. In Australia, some programs offer rebates or reduced rates for shifting consumption to off-peak periods, resulting in direct financial savings.

Load Management:

Effective load management through off-peak consumption can help businesses avoid higher costs associated with peak-hour surcharges. In France, peak-hour surcharges can increase the electricity bill by 20% to 30%, making off-peak consumption a more economical option.

Lower Wholesale Prices:

Electricity prices in wholesale markets are generally lower during off-peak periods. In Canada, the difference between peak and off-peak wholesale prices can be as much as 30%, translating to lower overall electricity costs for consumers who adjust their usage accordingly.

Sustainability Incentives:

Many developed countries offer sustainability incentives for off-peak consumption, such as lower tariffs for using renewable energy sources during off-peak hours. In Japan, tariffs for renewable energy consumption can be reduced by up to 25% during off-peak periods, providing both cost savings and environmental benefits.

These findings underscore the importance of optimizing electricity consumption by leveraging off-peak periods, thereby reducing costs and taking advantage of favorable tariffs in developed countries.

Based on expert opinions, a tariff system was introduced in our country to promote off-peak electricity consumption. This article analyzes electricity consumption graphs for industrial enterprises using a time-varying tariff system. Various entities such as residential areas, industrial enterprises, manufacturing firms, factories, and other electricity-consuming organizations can benefit from reduced electricity prices by using time-varying tariffs during non-peak hours. For instance, if a consumer uses electricity at night, the cost per kWh can be 1.5 times lower than the daytime rate. This reduction in electricity costs decreases production expenses for consumers. Consequently, power generation and supply organizations can ensure the long-term stability of the network and transformers, reduce peak load periods, and provide high-quality electricity to consumers].

Conclusions. In conclusion, this study highlights the significant benefits of shifting electricity consumption to off-peak periods, both in terms of cost savings and operational efficiency. The research findings demonstrate that leveraging off-peak periods can result in substantial financial benefits, particularly in comparison to peak summer periods. key observations include these cost savings potential, reduced peak demand charges, time-of-use tariffs, energy efficiency programs, load management, lower wholesale prices, sustainability incentives. The introduction of a tariff system to promote off-peak consumption in our country has shown that various sectors, including residential areas, industrial enterprises, and manufacturing firms, can benefit from reduced electricity prices. For example, consumers who use electricity at night can pay 1.5 times less per kWh than during the day. This reduction in costs decreases production expenses, ensuring long-term network stability, reducing peak load periods, and providing high-quality electricity to consumers.Overall, these findings underscore the importance of optimizing electricity consumption by leveraging off-peak periods to reduce costs and take advantage of favorable tariffs available in developed countries. The implementation of time-varying tariffs and energy-efficient practices not only promotes economic benefits but also contributes to environmental sustainability by reducing greenhouse gas emissions.

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