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ANALYSIS OF ENERGY DEMAND BY A 24-HOUR STORE

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Abstract. The paper presents the balance of electricity consumption and fuel oil consumption of a medium-sized 24-hour store. Measurements of the electricity consumption of the various components of the balance were made for air conditioning, refrigeration, fast food, and especially for indoor and outdoor lighting. Their shares over the 12-month period of measurements were determined. Opportunities to reduce electricity consumption by changing the type of lighting of the facility were identified. Replacement of lighting reduced electricity consumption by 38535.8 kWh, which represented a total reduction of 21.2% in the store's annual electricity consumption.

Keywords: energy efficiency, electricity consumption, lighting.

JEL Classification: Q42, Q55.

Introduction

Energy generation in Poland has been a matter of course for many years. The vast reserves of coal and lignite used as fuel in our power plants meant that, for decades, people were relatively unconcerned about energy consumption in their daily lives. Electricity was cheap and at one point, also readily available to almost every resident. In our daily lives, we use electricity to power virtually every goto household appliance. A similar situation occurred with heat generation. Heating with coal was a well-known and easy-to-use technique, and the availability of the fuel was high and at a good price. Therefore, the vast majority of entrepreneurs and owners of domestic farms, wishing to avoid wrong decisions and high initial costs, chose traditional coal or, at a later stage, electric heating as the heat source in their facility. Only changes in the EU's 3×20 package forced a change in approach to reduce CO_2 emissions, increase energy efficiency and increase the share of renewable energy sources. Electricity in Poland is produced primarily in utility thermal power plants. In 2020, the volume of production at these facilities amounted to 120.5 TWh, which accounted for 76.3% of total production. The share of thermal utility power plants in production has decreased by 11.6 percentage points since 2014. The efficiency of public thermal power plants has remained at a similar level for years, and amounted in 2020. 42,6%. Industrial power plants generated in 2020. 16.8 TWh, which accounted for 10.7% of total generation. In this case, a significant increase in production and efficiency can be observed, which reached 57.5% in 2020. The remaining production of electricity is the result of independent power plants, mainly wind power. In 2020, the structure of energy generation in Poland, unfortunately, was still largely based on hard coal and lignite. The most important fuel for electricity generation in 2020 was hard coal, with a share of 44.1%, and lignite with a share of 24,1%. The share of these fuels in production decreased by 13.2 percentage points since 2014. Production from renewable energy sources accounted for 17.9% and increased by 5.4% since 2014 (Statistics Poland, 2021). The most important carriers in this group were wind energy and biomass and biogas. Solar energy has the smallest share, but has the highest growth rate. Increasing energy efficiency is related to performing energy audits. An energy audit of various types of facilities is now a mandatory activity for various types of facilities (Mukhopadhyay & Haberl, 2014). Conclusions of the energy consumption analysis are presented to users with proposals to reduce energy intensity for the facility within the framework of reasonable economic solutions (Rusowicz & Grzebielec, 2014; Rusowicz et al., 2014; Grudzień et al., 2019; Rusowicz, Ruciński & Laskowski, 2017; Rusowicz, Grzebielec & Laskowski, 2017). IT systems are also proposed to optimize the energy consumption of facilities (Ziąbka et al., 2020; Yaqub et al., 2016; Nilsson et al., 2018).

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The study analyzed the electricity consumption of a 24-hour store that also provides fast food sales services. Energy consumption was metered over a 12-month period (July 2019–June 2020). The studied facility is representative of a large chain of medium-sized stores, amounting to almost 1,100 facilities in Poland. The analysis of consumption makes it possible to isolate the components of electricity consumption and propose to increase their energy efficiency.

1. Analyzed object

The medium-sized store that opens 24 hours a day, also offering café services in the Warsaw area, was analyzed. The heated area of the store is 313 m^2, while the area available to customers is 120 m^2. There is an illuminated parking lot in front of the store. Heating and cooling of the facility is provided by compressor air-conditioning units with a heat pump. Domestic hot water and supplementary heating are provided by an oil furnace.

Electricity and fuel oil consumption were measured from July 2019 to June 2020. During this period, the number of customers visiting the store was 33,500 people or an average of about 2,800 people per month. Electricity consumption was measured for indoor and outdoor lighting, air conditioning, refrigeration equipment, and equipment for the cafeteria (fast food). Nonmetered equipment represents the difference between total electricity consumption and that of metered equipment.

The outdoor lighting was sodium lamps, while the indoor lighting was fluorescent lamps in open fixtures. The measured electricity consumption for the lighting is presented in Figure 1.

Electricity consumption presents a stabilized consumption throughout the year with an average value of about 2,000 kWh/month. Interior lighting is practically not correlated with the length of the day, while exterior lighting is clearly correlated with the length of the day (Doulos et al., 2019; Jakubowsky & de Boer, 2022).

As for the electricity consumption of refrigeration equipment, which are 3 refrigeration counters, an open front refrigerator, an ice maker and a freezer, there is a stabilized consumption throughout the year, with an average of 2844 kWh/month. The situation is similar for cafe equipment (oven, coffee maker, microwave oven). The average monthly consumption of electricity is 443 kWh/month. Nonmetered appliances are mainly electrical outlets to which various current consumers (e.g., vacuum cleaners, hand dryers) are connected periodically. A summary of the electricity consumption of groups of appliances during the year is shown in Figure 2.

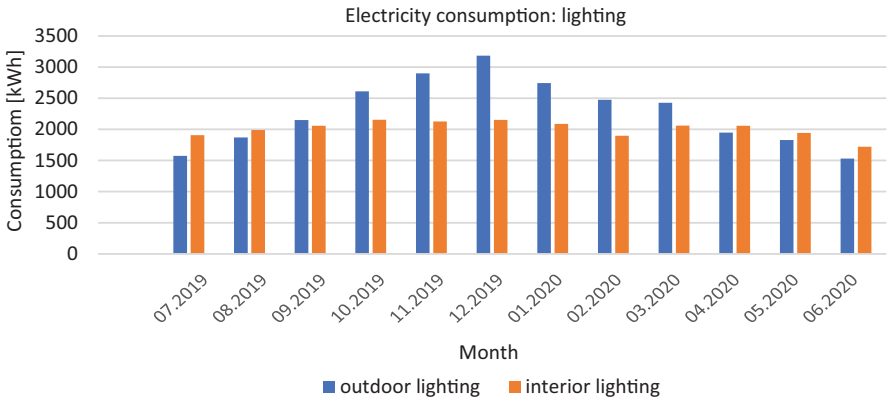

Figure 1. Electricity consumption of lighting during the study period

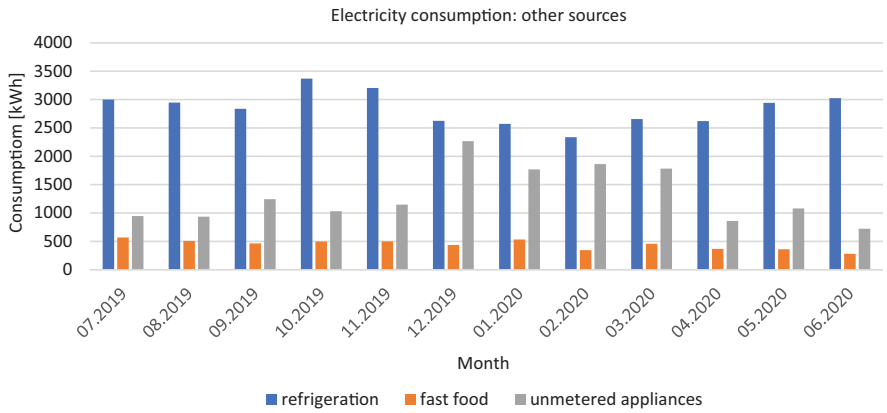

Figure 2. Electricity consumption by various sources during the study period

In the case of air conditioning in the store, compressor air-conditioning units with heat pump function were used. Electricity consumption of air-conditioning is presented in Figure 3. It can be seen that electricity consumption is clearly higher in the summer months. In the other months, consumption is at an average level of 1500 kWh/month.

Domestic hot water and main heating in winter is provided by an oil furnace. Figure 4 shows oil consumption throughout the year. The highest consumption is in the winter months (December–April).

The share of electricity consumption by the source is presented in Figure 5. Interior and exterior lighting consumes 28.3% of the electricity needed for this store.

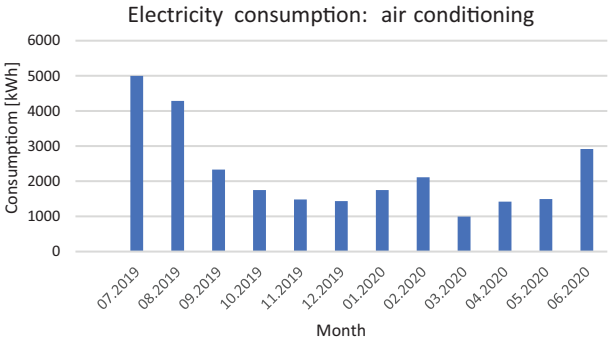

Figure 3. Electricity consumption of air conditioning and heat pumps during the study period

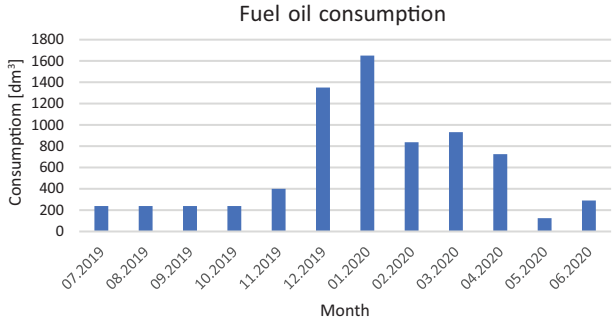

Figure 4. Fuel oil consumption during the study period

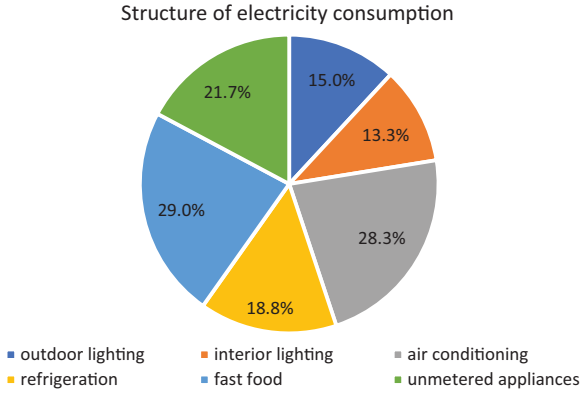

Figure 5. Structure of electricity consumption in the study period

The same level of consumption is for air-conditioning equipment – 28.3%. In the case of the analyzed store, the air-conditioning and refrigeration equipment and for fast food are relatively new equipment.

Based on a preliminary analysis, it can be concluded that improving energy efficiency can focus primarily on lighting replacement. Based on the literature on road lighting (Djuretic & Kostic, 2018; Yoomak & Ngaopitakkul, 2018; Polzin et al., 2016), there is an existing potential to reduce the electricity consumption of outdoor parking lot lighting. According to [0], replacing the installation of high-pressure sodium lamps with high-efficiency LED lighting results in electricity consumption savings of 31% while maintaining uniform luminance levels. Similar values of a 21.9% reduction in electricity consumption are presented by (Byun et al., 2013). The use of an additional multi-stage dimming system reduces electricity consumption by a further 20% over the year. Similar values for savings from the use of dimming systems are presented by (Farahat et al., 2015), noting an increase in installation costs by a similar 30%. In the case of road lighting, sodium lamps are preferred due to their lighting quality (Yoomak & Ngaopitakkul, 2018), the use of LED lamps does not always result in savings in electricity consumption when high lighting standards are needed. The use of LED lighting generates reactive power consumption. The occurrence of reactive power causes an increase in current, which increases electricity losses in AC power generation and transmission equipment (generators, transmission lines and transformers). The use of electronic dimming systems in LED lighting additionally, further increases the generation of reactive power (Byun et al., 2013; Farahat et al., 2015). The analysis of increasing the energy efficiency of the store assumes a 25% reduction in electricity consumption for lighting. In a year, 38535.8 kWh is consumed for lighting. At an electricity price of 0.15 Euro/kWh, savings of 5780 Euro/year were obtained. In the current year, electricity prices in Poland for entrepreneurs are four times higher than in the analyzed 2020.

Conclusions

The paper presents the balance of electricity consumption in a 24-hour store. Measurements were carried out from July 2019 to June 2020. Various components of electricity consumption were analyzed in conjunction with the existing state of the equipment. Refrigeration, has a stabilized consumption, averaging 2844 kWh/month, which is 18.8% of the average consumption during the year. Air conditioning (with heat pump function) consumes 28.3% of electricity during the year. The air conditioners are modern units and there is no need to replace them. Fast food units consume 29% of electricity and there is no need to replace them either. To improve the energy efficiency of the facility, it was proposed to replace the lighting from fluorescent lamps inside the store

and sodium lamps in the parking lot. For the parking lot, dimming systems were not used due to the cost of replacement and the increased generation of additional reactive power. As a result of the lighting replacement, electricity consumption was reduced by 38535.8 kWh, a total reduction of 21.2% in the store's annual electricity consumption. In 2020, savings of 5780 Euro/year were achieved. In the current year, electricity prices in Poland for entrepreneurs are four times higher than in the analyzed 2020.

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