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Analysis of faculty of electrical engineering and informatics building energy use intensity in pardubice, czech

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Abstract. The investigation focused on analyzing the energy usage patterns of the Faculty of Electrical Engineering and Informatics in Pardubice. The recorded energy consumption data were examined and discussed. The average heating energy consumption in the Faculty of Electrical Engineering and Informatics building in 2020, 2021, and 2022 is 686.45 MWh or 57% of the total energy equivalent value. Meanwhile, the average electricity consumption in the building during the same period is 518.97 MWh or 43% of the total energy equivalent value. The average fluctuation in heating energy consumption used in the Faculty of Electrical Engineering and Informatics building tends to increase by 2.9% per year, while the average fluctuation in electricity consumption tends to increase by 3.3% per year. According to the findings, the average comprehensive energy consumption per unit area in the building was 146,03kWh/m². It was the sum of the energy use intensity for heating and the energy use intensity for electricity. The average energy use intensity value for heating in the building was 83.16 kWh/m², while the average energy use intensity value for electricity was 62.78 kWh/m².

1. Introduction

The level of energy efficiency can be assessed based on the actual energy use intensity compared to the benchmark. Energy use intensity is a parameter used to measure the energy performance of a building [1]. This performance indicator typically normalizes the total energy consumption of a building over a specific period against the total floor area of the building consuming energy [2]. Thus, this energy use intensity model is better known as a simple normalization model [3]. In this model, energy use is totaled over one year and then divided by the floor area with a unit of kWh/m²/year [4]. Several types of buildings have evaluated energy use intensity using this model to assess the performance of office buildings [5], schools [6-9], hotels [10], and hospitals [11-12].



Based on the Energy Statistical Yearbook 2021, the Czech Republic has the highest energy intensity among European Union and OECD countries group [13]. From this data, the public building sector consumes approximately 34% of the total energy consumption. Within the public building sector, school or university buildings contribute significantly to the sector's total energy consumption. Therefore, it is important to implement energy efficiency measures in buildings to reduce energy consumption [14] and subsequently lower energy intensity. Energy efficiency measures usually begin with an energy audit [15-16], followed by tangible actions such as turning off the load switch outside working hours, regulating thermostat temperature, and optimizing lighting [17]. Other practices include energy management evaluation [18], and building operation management [19]. However, before implementing energy efficiency measures in buildings as mentioned above, investigating the energy use intensity of the building is necessary to reduce energy intensity.

By analyzing the energy use intensity, it is hoped that the level of energy efficiency in the building can be determined. The results of the analysis are obtained through descriptive statistics on the regression curve of the energy use intensity data categorized according to the types of energy sources and usage. The data on energy use intensity are collected by obtaining monthly energy consumption data and building floor area data. The selection of the Faculty of Electrical Engineering and Informatics building is due to the lack of previous research studies on energy use intensity and the fact that it is one of the top three energy-consuming buildings separate from the university building complex in Pardubice, Czech Republic.

2. Method

Energy use intensity in the Faculty of Electrical Engineering and Informatics building is analyzed and investigated based on the energy consumed by the building. According to the survey results conducted in each room from the 1st to the 4th floor of the Faculty of Electrical Engineering and Informatics building, thermal and electrical energy are utilized throughout the entire building.

Data on the monthly energy consumption of the Faculty of Electrical Engineering and Informatics building, including thermal and electrical energy, for three years (2020, 2021, and 2022) were obtained by administrating the building's energy management in Pardubice. This energy consumption data was then categorized into two types: thermal energy and electrical energy. Meanwhile, the building's floor area was obtained from the staff responsible for building administration. The data were further validated using direct measurements with a laser distance meter. Hence, this research relies on secondary data collection and involves observing energy consumption in the Faculty of Electrical Engineering and Informatics building in Pardubice, Czech Republic.

3. Result and Discussion

3.1. Energy consumption analysis

The investigation results regarding energy consumption in the Faculty of Electrical Engineering and Informatics building indicate that the building has consumed various energy sources, including electricity and heating. The energy consumption in the Faculty of Electrical Engineering and Informatics building for the years 2020, 2021, and 2022 are presented in Figure 1.

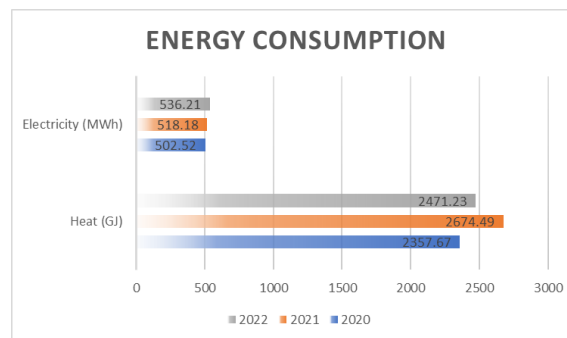


Figure 1. Energy Consumption in the Faculty of Electrical Engineering and Informatics Building

The monthly energy consumption for heating in the Faculty of Electrical Engineering and Informatics building remains relatively constant throughout the years 2020, 2021, and 2022. On the other hand, the electricity consumption in the Faculty of Electrical Engineering and Informatics building shows fluctuations, with increases and decreases occurring monthly in 2020, 2021, and 2022. The graph depicting the monthly heating and electricity consumption in the Faculty of Electrical Engineering and Informatics building for the years 2020, 2021, and 2022 is presented in Figure 2.

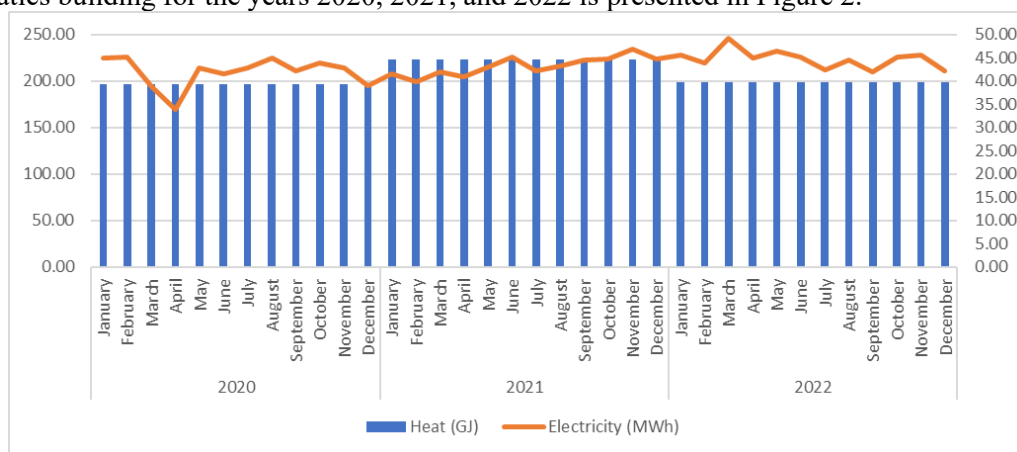


Figure 2. Monthly Energy Consumption Graph for Heating and Electricity

In this study, researchers analyzed the energy consumption characteristics in the Faculty of Electrical Engineering and Informatics building, which showed significant variations in building energy consumption on a monthly basis due to academic activities. However, the total electricity consumption in the Faculty of Electrical Engineering and Informatics building tends to increase because researchers identified the need for additional equipment in laboratories, classrooms, and research centers as the areas that consume the most electricity due to high-energy-demanding equipment. Additionally, teaching computer rooms and information rooms also contribute significantly to electricity consumption.

The energy units were converted uniformly to the standard consumption unit of MWh to facilitate energy consumption analysis. The results of the energy consumption conversion in the Faculty of Electrical Engineering and Informatics building for the years 2020, 2021, and 2022 are presented in Table 1.

Table 1. Energy Consumption Conversion (2020-2023)

Years	Heat (MWh)	Electricity (MWh)
2020	654.91	502.52
2021	742.91	518.18
2022	661.54	536.21

Based on the table above, the heating and electricity consumption in the Faculty of Electrical Engineering and Informatics building in 2020 was 654.91 MWh and 502.52 MWh, respectively. In 2021, the heating and electricity consumption were 742.91 MWh and 518.18 MWh, respectively. In 2022, the heating and electricity consumption were 661.54 MWh and 536.21 MWh, respectively. Looking at the energy consumption from 2020 to 2022, it can be observed that heating energy usage is the largest energy source compared to electricity consumption. The average heating consumption in the Faculty of Electrical Engineering and Informatics building for the years 2020, 2021, and 2022 is 686.45 MWh. On the other hand, the average electricity consumption in the building for the same period is 518.97 MWh. The average heating and electricity consumption in the Faculty of Electrical Engineering and Informatics building is shown in Table 2.

Table 2. Average Heating and Electricity Consumption

Item	Heat (MWh)	Electricity (MWh)	Total (MWh)
Average (2020 – 2022)	686.45	518.97	1205.42

The proportion of energy consumption in the Faculty of Electrical Engineering and Informatics building in 2020, 2021, and 2022 is presented in Figure 3.

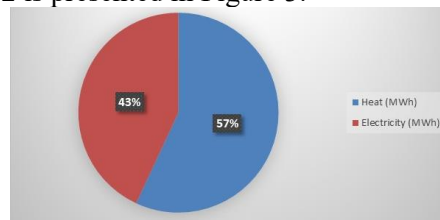


Figure 3. Energy Consumption Proportions in the Building

Based on the above figure, the researchers analyzed energy consumption proportions in this study. The research findings indicate that the equivalent total value of energy consumption used for communal heating in the Faculty of Electrical Engineering and Informatics building is the highest, accounting for approximately 57% of the total equivalent energy value. The second largest energy consumption in the Faculty of Electrical Engineering and Informatics building, accounting for around 43% of the total equivalent energy value, is electricity used for elevators, lighting, computers, printers, and other electrical equipment in the building (including classrooms, laboratories, offices, and the cafeteria). Furthermore, from an energy conservation perspective, the researchers recommend that heating energy consumption be a primary area of focus for energy conservation. It is also important to take steps to reduce heating energy consumption, such as implementing smart thermostat technology. The Faculty of Electrical Engineering and Informatics building can reduce energy costs and contribute to a more sustainable future by taking these measures.

3.2. Energy consumption characteristics

Although the equivalent total value of energy consumption used for communal heating in the Faculty of Electrical Engineering and Informatics building is higher than the electricity consumption, the energy consumption for both heating and electricity fluctuates annually. The following table 3 presents the tabulation of energy consumption fluctuations in the Faculty of Electrical Engineering and Informatics building in 2020, 2021, and 2022.

Table 3. Energy Consumption Fluctuations.

Years	Heat (GJ)	Electricity (MWh)
2021	13.4%	3.1%
2022	-7.6%	3.5%
Average	2.9%	3.3%

Based on the table above, the researchers analyzed the fluctuation of heating energy consumption. In 2021, the heating energy consumption in the Faculty of Electrical Engineering and Informatics building increased by 13.4% compared to 2020. However, in 2022, there was a decrease of 7.6% in heating energy consumption compared to 2021. Nevertheless, the average fluctuation of heating energy consumption in the Faculty of Electrical Engineering and Informatics building tends to increase by 2.9% per year. Regarding the analysis of electricity consumption fluctuation, in 2021, the electricity consumption in the Faculty of Electrical Engineering and Informatics building increased by 3.1% compared to 2020.

Similarly, in 2022, there was a further increase of 3.5% in electricity consumption compared to 2021. Thus, the average fluctuation of electricity consumption in the Faculty of Electrical Engineering and Informatics building tends to increase by 3.3% per year. The trend of energy consumption in the Faculty of Electrical Engineering and Informatics building in 2020, 2021, and 2022 is presented in Figure 4.

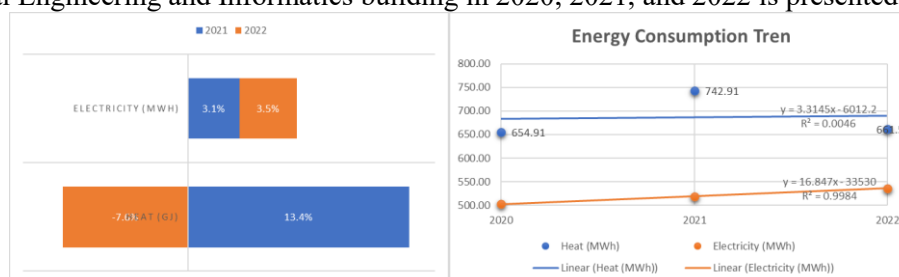


Figure 4. Energy Consumption Trend (2020, 2021, and 2022)

Based on the above graph, heating and electricity consumption show an annual increase trend. However, according to the correlation value with time, the trend in heating energy consumption is not strong or, in other words, other factors affect heating energy consumption apart from time itself. In contrast, electricity consumption has a strong correlation with time.

Therefore, by studying the increasing trend and correlation with time, the researchers highlight the importance of addressing the electricity consumption that inevitably increases. As a result, the researchers recommend taking measures to reduce electricity consumption, such as implementing energy-efficient technologies and practices. By doing so, it can reduce costs and contribute to global efforts in conserving energy and protecting the environment. One achievable step is implementing energy-efficient technologies and practices, such as LED lighting.

3.3. Energy use intensity

The researchers studied the energy use intensity in the Faculty of Electrical Engineering and Informatics building. The research findings indicate that the total energy use intensity in the years 2020, 2021, and 2022 are 140.21 kWh/m², 152.77 kWh/m², and 145.10 kWh/m², respectively. Over the three years, the average energy use intensity in the Faculty of Electrical Engineering and Informatics building is 146.03 kWh/m². The total energy use intensity in the Faculty of Electrical Engineering and Informatics building is the sum of the energy use intensity for heating and the energy use intensity for electricity. The detailed values are presented in Table 4.

Table 4. Energy Use Intensity in the Faculty of Electrical Engineering and Informatics Building

Years	Area (m ²)	EUI Heat (kWh/m ²)	EUI Electricity (kWh/m ²)	EUI Total (kWh/m ²)
2020	8254.88	79.34	60.88	140.21
2021		90.00	62.77	152.77
2022		80.14	64.96	145.10
Average		83.16	62.87	146.03

The energy use intensity for heating in the years 2020, 2021, and 2022 are 79.34 kWh/m², 90.00 kWh/m², and 80.14 kWh/m², respectively. Over the three years, the average energy use intensity for heating in the Faculty of Electrical Engineering and Informatics building is 83.16 kWh/m². When

analyzed against the Best Practice heating demand of the building in the Czech Republic, which is 102 kWh/(m² .a), the existing energy use intensity for heating in the Faculty of Electrical Engineering and Informatics building still complies with the standard.

According to the findings, the average comprehensive energy consumption per unit area in the building was 145,10 kWh/(m² a), with an average electricity consumption of 64.96 kWh/(m² a) in 2022. In 2021, the average comprehensive energy consumption per unit area was 152,77 kWh/(m² a), along with an average electricity consumption of 62.77 kWh/(m² a). Similarly, in 2020, the average comprehensive energy consumption per unit area was 140,21 kWh/(m² a), and the average electricity consumption was 60.88 kWh/(m² a). Comparatively, it was observed that the energy consumption per unit area in 2021 exceeded the average consumption from 2020 to 2022, which was 146.03 kWh/(m² a). Based on the data in the graph of total energy use intensity in the years 2020, 2021, and 2022, the research findings indicate a trend of increasing values in energy use intensity. The graph depicting the change in total energy use intensity for electricity is shown in Figure 5.

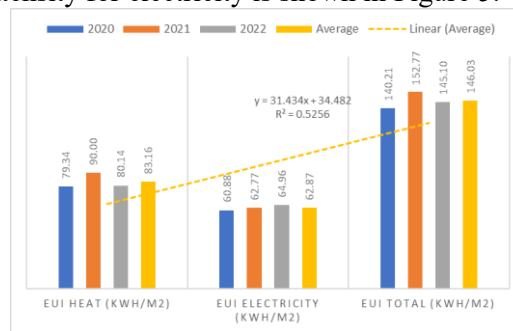


Figure 5. Total Energy Use Intensity Change Graph

If the existing value of Energy Use Intensity in the Faculty of Electrical Engineering and Informatics building is compared with the forecasted results for the Europe region from 2018 to 2024, which is 139 kWh/(m² .a), the existing value was above the standard. Therefore, it is important to carefully monitor and control the energy consumption in the expanded area to avoid energy wastage. The reduction of energy consumption per unit area in the Faculty of Electrical Engineering and Informatics building can be achieved by using energy-efficient equipment technology and improving thermal resistance in the walls.

4. Conclusion

(1) In this article, researchers discuss the issue of energy consumption in the Faculty of Electrical Engineering and Informatics building. The study results show that the building consumes various energy sources, including electricity and heating. The heating energy consumption in the Faculty of Electrical Engineering and Informatics building tends to be relatively constant on a monthly basis. However, electricity consumption fluctuates depending on academic activities. Nevertheless, energy consumption in 2020, 2021, and 2022 shows an increasing trend. This increase can be attributed to the addition of equipment in laboratories, classrooms, and research centers. Furthermore, the computer teaching rooms and information rooms also contribute significantly to electricity consumption.

(2) The researcher's analysis reveals the energy consumption from 2020 to 2022, where heating energy usage becomes the largest energy source compared to electricity consumption. The average heating energy consumption in the Faculty of Electrical Engineering and Informatics building in 2020, 2021, and 2022 is 686.45 MWh or 57% of the total energy equivalent value. Meanwhile, the average electricity consumption in the building during the same period is 518.97 MWh or 43% of the total energy equivalent value. Considering energy conservation, the researcher recommends that heating energy consumption is the main area that needs attention in energy conservation efforts. Additionally, steps should be taken to reduce heating energy consumption, such as implementing smart thermostat

technology. By taking these measures, the Faculty of Electrical Engineering and Informatics building can reduce energy costs and contribute to a more sustainable future.

(3) The average fluctuation in heating energy consumption used in the Faculty of Electrical Engineering and Informatics building tends to increase by 2.9% per year, while the average fluctuation in electricity consumption tends to increase by 3.3% per year.

(4) The total Energy Use Intensity value in the Faculty of Electrical Engineering and Informatics building 146,03kWh/m². It was the sum of the Energy Use Intensity for heating and the Energy Use Intensity for electricity. The average Energy Use Intensity value for heating in the building was 83.16 kWh/m², while the average Energy Use Intensity value for electricity was 62.78 kWh/m².

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