

OPTIMISING ELECTRICITY CONSUMPTION ON CONSTRUCTION SITE USING A MONITORING SYSTEM

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Abstract

This research focuses on the optimization of electricity consumption on a construction site through the implementation of a monitoring system. The construction industry is known for its high energy demands and therefore, efficient electricity management is a key element for the economic sustainability of projects and the reduction of environmental impact. In this research, a monitoring system is deployed to collect real electrical energy data at the construction site. This data is then analysed to identify consumption patterns and develop algorithms for the optimal management of electrical loads. As a result of this work, electricity costs will be reduced and the negative impact on the environment will be reduced.

Keywords

Consumption optimization, construction site, electricity consumption

1 INTRODUCTION

In the current context of the global construction industry, which is in a constant process of growth and transformation, site operations play an indispensable role. Not only is it an important segment of the construction industry, but it also has a significant impact on the economies of many countries. The industry ranges from infrastructure projects to commercial construction [1] and is characterised by high energy requirements, especially during periods of increased construction activity. Electricity supply is a vital foundation for operations on construction sites, without which these projects could not exist [2].

Germany is known for its innovative approach to energy and its commitment to sustainable development. In line with this commitment, it is increasingly striving to use energy efficiently also on construction sites and to reduce greenhouse gas emissions. This includes not only traditional sectors but also the construction sector, which deserves special attention. One of the key factors that requires careful analysis is the electricity consumption of construction sites.

Construction operations have the potential to have a significant impact on the overall electricity consumption of a country, not only in quantitative terms but also in terms of the quality of electricity supply. Effective management of electricity consumption on construction sites can contribute significantly to reducing energy costs for construction companies, which has a positive impact on their competitiveness in this sector. At the same time, reducing electricity consumption on construction sites can help achieve environmental goals and reduce greenhouse gas emissions, which is in line with global efforts to combat climate change.

It is widely acknowledged that construction sites are energy-intensive, as a result of the use of different equipment and machinery. The International Energy Agency (IEA) estimates that the construction sector accounts for a significant proportion of global electricity consumption, around 36% of total final energy consumption worldwide [3]. These figures clearly show the significant potential for reducing electricity consumption within the construction sector.

Effective management of electricity consumption on construction sites brings several benefits to construction companies. Firstly, it can lead to significant cost savings through reduced energy expenditure. The Construction Industry Institute (CII) highlights that energy management methods can help construction companies achieve savings of up to 30% on energy costs [4]. These savings can significantly increase the competitiveness of construction companies, especially in this highly competitive sector.

In addition, effective management of electricity consumption can have a positive impact on the long-term sustainability and environmental goals of the construction industry. By reducing energy costs, companies can contribute to reducing their carbon footprint and achieving environmental standards. In doing so, they support the fight against climate change and are in line with global sustainability efforts.

The importance of efficient management of electricity consumption in the construction industry is therefore twofold, taking into account not only economic considerations but also environmental aspects, which are increasingly important in today's world.

2 METHODOLOGY

A monitoring system can be put in place to optimise electricity consumption on the construction site. This system can provide real-time monitoring of the construction site environment and determine the exact prefills of electricity consumption [5].

The analytical approach of this study involves a combination of the analysis of electricity consumption on a construction site in Germany and the use of statistical methods. Smart metering devices were installed at the construction site to monitor electricity consumption. Each of these devices monitored consumption in different parts of the construction site. These devices were selected for their ability to provide detailed and accurate data on electricity consumption, allowing for a better understanding of the energy requirements on site.

The use of smart metering devices allows real-time monitoring of electricity consumption in different parts of the site. This provides a comprehensive view of energy consumption patterns and helps to identify areas of high consumption or potential energy-saving opportunities. The data collected from these devices can be analysed using statistical methods to identify trends, patterns and correlations in electricity consumption.

Statistical methods used in the analysis may include descriptive statistics such as calculating averages, standard deviations and ranges of electricity consumption. In addition, regression analysis can be used to identify factors that influence electricity consumption, such as weather conditions, working hours, or the number of workers on site [6].

The combination of analysis and statistical methods provides a comprehensive understanding of electricity consumption on a construction site. This approach enables evidence-based decision-making on energy management and the implementation of energy conservation measures.

The research methodology included the following steps:

1. Selecting a monitoring system: The first step was to select an appropriate system to monitor electricity consumption on the construction site.
2. Installation of smart metering devices: We then installed smart metering devices on the construction site.
3. Setup and calibration: We properly set up and calibrated the devices for accurate measurements.
4. Real-time monitoring: We started monitoring electricity consumption in real-time at various locations on the site.
5. Analysis and Statistical Methods: We analysed the collected data using statistical methods to identify patterns and trends in electricity consumption.
6. Decision making and measures: Based on the analysis, we proposed specific measures to optimize electricity consumption.

Description of the investigated construction site

The construction site analysed by the study is located near the city of Magdeburg, Germany. It is an infrastructure work that will play an important role in the dispatching and communication system of the electricity transmission network, in order to ensure the stability of the power system's operation. The planned facility has two storeys and uses a reinforced concrete support system. Two lifting mechanisms have been deployed to carry out heavy construction work. Thirteen temporary buildings were constructed to serve various purposes for the personnel working on site, including operational, social and sanitary needs. This construction site has a complex infrastructure and requires a reliable source of electricity to operate and provide comfort for the staff.

The site's wiring is branch-circuited, meaning that the temporary buildings are fed through separate branches with fuses with a capacity of up to 100 A, and the site operations also have a separate branch with fuses with a capacity of up to 125 A. The site's electrical system was designed to be branch-circuited. The main tapping point, which supplies the entire site with electricity, is fused to a maximum capacity of 160 A. This thorough provision of on site electrical service is essential to ensure the smooth running of construction work and day-to-day operations on this complex site.

Tab. 1 Electrical consumers in site operation.

Electric tools	Quantity	Motor power		Active power
		Individual 400 V	Entire 400 V	Entire 230 V
Self-propelled crane	1	21.0 kW	21.0 kW	
Self-propelled crane	1	23.0 kW	23.0 kW	
Table saw	1	2.0 kW	2.0 kW	
Lighting – 120 W	4			0.5 kW
Video monitoring – 500 W	2			1.0 kW
Concrete Vibrator – 1 500 W	1			1.5 kW
CEE 16A	1	10.0 kW	10.0 kW	
Socket – 2 000 W	2			4,0 kW
Total			56.0 kW	7.0 kW

Tab. 2 Electrical tools in temporary containers.

Electric tools	Quantity	Motor power		Active power
		Individual 400 V	Entire 400 V	Entire 230 V
Lighting – 180 W	13			2.4 kW
Heater – 2 000 W	13			26.0 kW
Water heating	2			3.0 kW
IT technology – 100 W	6			0.6 kW
Socket – 2 000 W	13			26.0 kW
Total				58.0 kW

Tab. 1 and 2 contain information on the electrical consumers on site, showing the quantity and electrical output of the various tools and equipment used on site. The tables provide details of each appliance, including its quantity, motor power and active power consumption. These tab. 1 and 2 offer crucial insights into on site electrical equipment, aiding in a comprehensive understanding of energy requirements for effective management.

Time limit

The installation of metering equipment to monitor electricity consumption was carried out during the course of rough construction in mid-June. The electricity consumption analysis focuses on the first 108 days from June 15, 2023 to September 30, 2023. This method of analysis allows for the identification of recurring patterns of electricity consumption as well as long-term time series trends. Through this analysis, it is possible to pinpoint which months and periods were characterized by increased or decreased electricity consumption at the site. This information is essential for the effective planning and management of energy resources on the site throughout its lifetime.

Consumption measurements

Measurement of electricity consumption on the investigated construction site was carried out by means of smart metering devices installed during the rough construction. The assessment of electricity consumption at the investigated construction site showed significant seasonal and temporal fluctuations. Increased consumption was observed during active construction periods and work shifts, mainly associated with the use of heavy construction machinery and lifting mechanisms. The opposite trend was observed during less intense periods of construction activity and out-of-hours. These findings allow the planning and management of electricity supply based on work schedules and seasonal changes, leading to more efficient use of energy and reduced costs. These findings contribute to a more sustainable and efficient use of electricity on site and provide valuable information for future projects on implementing an Industry 4.0 approach to improve energy efficiency [7].

Tab. 3 Consumption of electricity.

	Temporary facilities [kWh]	Operation [kWh]	Total [kWh]	Consumption ratio (temporary facilities and operation)	
June '23 (from 15.6.)	446.2	431.5	877.7	50.8%	49.2%
July '23	768.5	428.2	1 196.8	64.2%	35.8%
August '23	771.3	508.8	1 280.2	60.3%	39.7%
September '23	886.6	485.6	1 372.2	64.6%	35.4%
Total	2 872.7	1 854.2	4 726.8	60.8%	39.2%

Tab. 3 provides information on electricity consumption at the investigated construction site in Germany during different months in 2023. The electricity consumption is divided into two categories: "Temporary facilities [kWh]" and "Operation [kWh]." The total consumption is shown in the column "Total [kWh]." In addition, the ratio of these two categories to the total consumption is shown as a percentage in two columns, with the first column indicating the ratio of temporary facilities to total consumption and the second column indicating the ratio of operations to total consumption.

During the 108 days on site, electricity consumption was investigated in two parts: site operations and the containers. Site operations consumed a total of 1,854.15 kWh of electricity, representing 39.23% of the total consumption. On the other hand, the containers recorded a consumption of 2,872.68 kWh, accounting for 60.77% of the total consumption.

The average daily consumption of site operations was 17.16806 kWh, while containers had an average daily consumption of 26.59886 kWh. Among the significant data is information on days with extreme consumption. The day with the highest site operation consumption was September 14, 2023, with a daily consumption of 63.03 kWh. Containers recorded the highest daily consumption on September 26, 2023, with a value of 72.75 kWh.

In the case of minimum electricity consumption, site operations stood out by having 10 days with zero consumption. All the zero consumption days were during weekdays. Containers achieved the lowest daily consumption on August 26, 2023, when they consumed 9.43 kWh. This data provides important information about the patterns and distribution of electricity consumption on the site, which can be key in planning and managing the site's electrical infrastructure.

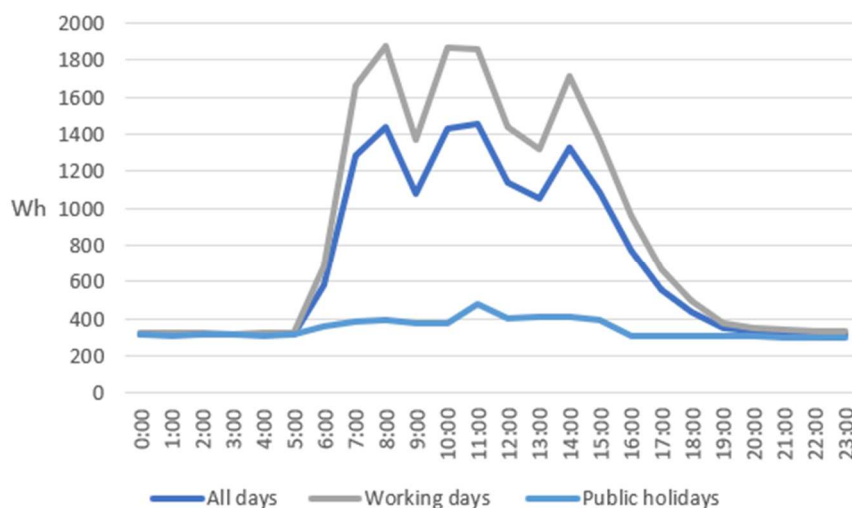


Fig. 1 Averaged electricity consumption of site operation.

Fig. 1 shows the analysis of electricity consumption in different time categories. It provides important insights into consumption patterns and dependencies. The total daily electricity consumption reached its maximum between 7:00 and 8:00 a.m., with a value of 1,288.97 Wh, and the lowest values were recorded in the evening between 8:00 and 11:00 p.m., hovering around 320 Wh. These significant variations in consumption during the day can serve as a basis for effective management and planning of electricity consumption on the site.

In addition, it was evident that there are differences in electricity consumption between working days and non-working days. Rest days tended to have lower electricity consumption compared to working days, which can be important when planning and managing electricity inventory at different time periods. These findings can help in effectively managing the electrical infrastructure on site and optimizing electricity consumption.

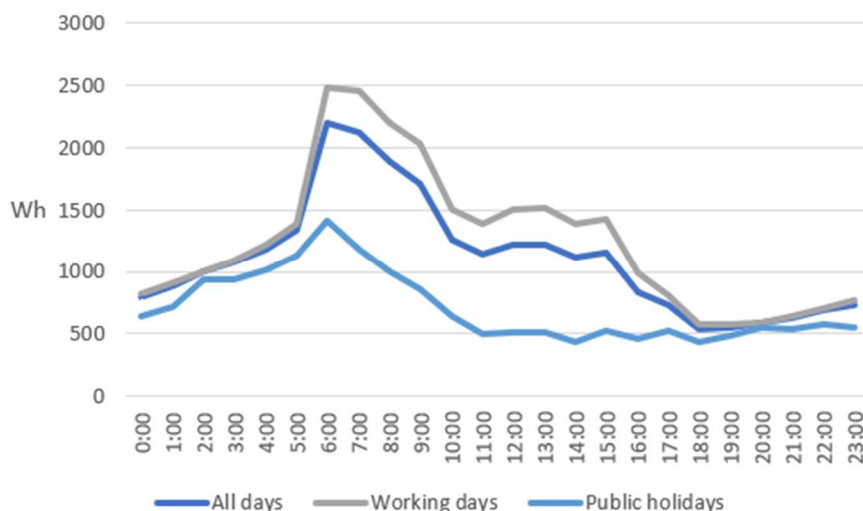


Fig. 2 Averaged electricity consumption of temporary facilities.

The provided Fig. 2 highlights electricity consumption at different time categories, namely all days, weekdays and days off, revealing significant patterns and differences over the course of the day and week. Interestingly, the maximum electricity consumption was recorded mainly in the morning, between 6:00 a.m. and 7:00 a.m., reaching a value of 2,192.12 Wh. On the contrary, the minimum consumption was recorded in the late afternoon, between 5:00 p.m. and 6:00 p.m., when it reached a value of 536.44 Wh. This reveals significant fluctuations in the consumption during the course of a typical day.

On weekdays, total electricity consumption was usually higher than on other days. Peak values were recorded between 6:00 a.m. and 7:00 a.m., with values around 2,480.21 Wh, while minimum values on weekdays were observed between 6:00 p.m. and 7:00 p.m., reaching a value of 575.07 Wh. This reflects the obvious impact of weekdays on electricity consumption.

Days off, on the other hand, showed the lowest electricity consumption, with maximum values observed in the same morning time window between 6:00 am and 7:00 am, reaching a value of 1,408.31 Wh. Minimum consumption on these days was observed late in the evening, namely between 8:00 p.m. and 9:00 p.m., when it reached a value of 555.73 Wh.

These data offer important information regarding electricity consumption on the construction site. One significant finding is that daily electricity consumption showed significant fluctuations throughout the day. The maximum consumption was in the morning hours between 6:00 a.m. and 7:00 a.m., while the minimum consumption was in the evening hours between 8:00 p.m. and 11:00 p.m. These data suggest that it is possible to identify 'peaks' and 'troughs' in electricity consumption, which can be important in managing and planning electricity supply on site.

3 RESULTS

The obtained results contain key information about electricity consumption on the construction site. The averaged daily consumption shows significant fluctuations, with maximum consumption in the morning hours and minimum consumption in the late evening hours. This is due to the working activity of the site operation, where, based on the consumption pattern, a time period of activity from 6 a.m. to 6 p.m. has been identified.

A comparison of consumption during non-working days, such as weekends and holidays, between site operations and temporary buildings shows that although construction production is stopped, there is still an increase in consumption of temporary buildings during the day. This is due to the provision of activities such as security, monitoring and cleaning.

An analysis of electricity consumption of operational and temporary facilities on site reveals several significant aspects. Seasonal differences in consumption show a significant weather effect, with temporary facilities having lower consumption in the summer months than in the autumn month. Another aspect identified is the site personnel. Additionally, there are electrical appliances such as kettles, microwaves and fridges in the temporary buildings, which are mainly used by site staff for personal use when they arrive at work. Therefore, the highest consumption is recorded in the morning hours.

These findings are in line with the recommendations of the German Standards Institute, which emphasizes the need to systematically identify areas of energy waste, implement energy-efficient technologies and practices, and continuously monitor and improve energy performance [8].

4 DISCUSSION

Based on the investigation results provided, we can observe interesting patterns in the electricity consumption of the investigated site in Germany in 2023. The data in Table 3 clearly shows that there is a significant difference between the electricity consumption of the site operation and that of the containers. There is a need to further investigate these two areas, and therefore, further investigations on electricity consumption on similar construction sites in Slovakia and Slovenia are being carried out.

First of all, it is interesting to note that the site operation consumed only 39.23% of the total consumption, while containers accounted for the majority of the consumption with 60.77%. This finding may be surprising, as one might have expected that the on site operation, where construction activities take place, might have a higher electricity consumption compared to containers. However, it should be pointed out that the presented results from measurements in Slovakia, where temporary facilities accounted for a larger part of the total consumption. At three different construction sites, temporary objects had a share ranging from 67.9%, 71.7% to 73.5% [9]. It should be pointed out that the data are from annual measurements and the results from the German site are for a shorter period of time.

Furthermore, it is important to note that the average daily consumption in the on site operation was lower than in the containers. This difference may be due to the different technological processes and equipment in the two areas of the construction site. In particular, the consumption in containers is due to appliances that are in operation for longer periods of time such as heaters, IT technologies, lighting and thermal water treatment.

The extreme consumption values on some days are also interesting. For example, the highest daily consumption of site and container operations occurred on different days but in the same month with the coldest average temperature, which may indicate that some phases of construction or activity are affected by the weather. Also, the pattern of electricity consumption during the day may be of interest from a renewable energy perspective. In particular, electricity production from photovoltaics is concentrated during sunshine, which can be an interesting solution to optimise when compared to the consumption pattern in temporary buildings.

5 CONCLUSION

This study clearly demonstrates that the analysis of electricity consumption on construction site operations is of paramount importance for managing energy costs and increasing efficiency in the construction industry. It is essential to pay attention to the temporary facilities on the construction site, such as containers, which have shown significant differences in consumption patterns and their shares of the total electricity consumption. These findings pave the way for more efficient management of electricity consumption, cost reduction, and improved energy efficiency on the construction site. Another important aspect is the consideration of seasonal patterns and factors influencing consumption in the planning and management of the electrical infrastructure on the construction site.

Reducing electricity consumption at construction sites offers not only economic benefits but also a positive environmental impact. The construction sector represents a significant share of global greenhouse gas emissions, and thus, the adoption of energy-efficient practices and the reduction of electricity consumption can help construction companies mitigate their environmental footprint and contribute to global emissions reduction goals. The United Nations Environment Programme (UNEP) underscores the importance of these efforts in the fight against climate change and environmental protection [10].

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