Reducing the carbon footprint of temporary site structures

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Abstract

The paper focuses on minimizing the carbon footprint associated with temporary buildings on site through the identification and implementation of sustainable measures. Experimental work on two of the sites studied revealed high levels of night-time heating consumption in temporary buildings, highlighting the need for more efficient heating and insulation technologies. The analysis of the consumption showed significant opportunities for energy savings, with critical areas identified that allow for the implementation of improvements in energy management, with a potential positive impact on the overall sustainability of the construction industry.

Keywords: *Carbon footprint, energy consumption, temporary buildings, construction traffic.*

Introduction

The construction industry is facing an increasingly urgent challenge in the form of environmental impacts and the need to reduce its carbon footprint [1]. One of the key aspects of this issue is temporary buildings on site, which often consume significant amounts of energy and contribute to high greenhouse gas emissions.

Construction production consumes many inputs that are involved in the realization of the construction work. The incorporation of materials results in the generation of construction waste, which is a significant environmental problem in the construction industry [2]. Many studies have investigated this issue, but the energy required to run construction production also needs to be addressed [3].

Electricity is required to power the machinery and equipment on site [4]. Furthermore, electricity is converted to create working conditions in the premises for the site personnel. Currently, temporary buildings are mostly powered by electricity, which is needed for lighting, heating, cooling, ventilation and powering all electrical appliances [5]. The analysis of electricity consumption at the surveyed construction sites showed significant opportunities for energy savings. Critical areas where improvements in energy management can be implemented were identified, and these modifications could have a positive impact on the overall sustainability of the construction industry.

An expert perspective on the topic should contribute to forming a better understanding of the impact of temporary buildings on the environmental sustainability of the construction sector. In this way, we consequently open up the debate on the need and possibilities of implementing sustainable approaches in the construction industry and contribute to the creation of innovative solutions with regard to the future of this sector.

Basic hypothesis

The basic hypothesis of this study is that the implementation of sustainable measures, innovative technologies and efficient energy strategies for temporary site buildings can lead to a significant reduction in the carbon footprint of the construction industry.

It is anticipated that the heating analysis and identification of critical high consumption areas will provide valuable information for the design and implementation of specific measures to minimize the environmental impacts of temporary structures. Focus on innovative technologies, smart energy management and new practices that can lead to significant emission reductions and energy efficiency improvements.

Contemporary literature

The dependence of the construction industry on electricity has been investigated in several researches and provides valuable insights into energy consumption and greenhouse gas emissions [6,7]. In particular, the focus is on buildings where non-negligible consumption occurs. In buildings throughout their lifetime, conditions are created that must be met by electricity. For example, the study by Yu Mishin et al. deals with the energy consumption patterns in buildings and provides insights into energy efficiency [8]. However, it already highlights the significant impact of construction on sustainability and explores the impacts in protecting the natural environment through resource and water use [9].

Research in the United States has identified key barriers to the promotion of sustainable construction and offered practical solutions to overcome the barriers and one of these was electricity consumption [10]. In the context of emissions, it has been argued that even small changes in the operation of temporary structures can have a significant impact on the surrounding environment as well as on long-term behaviour [11]. In the current context, the existing literature reflects on several key aspects, addressing sustainability issues in the construction industry, but quantitative data of the real behaviour of construction offices is not evident.

An analysis of greenhouse gas emissions in construction offices will provide insight and prompt the search for more effective solutions [12]. In the planning of temporary offices and changing rooms, demands are placed on the typological division and the creation of an environment according to the requirements of the planned construction [13]. At the same time, research into new technologies in insulation, energy management and renewable energy present opportunities for energy efficiency improvements. These new practices should gradually make their way into the literatures related to the design of building organization.

Methodology

The study procedure involves a combination of data collection, the use of statistical methods and the design of optimization measures. Smart metering devices have been installed on site to monitor the electricity consumption of temporary buildings. These devices have the ability to provide detailed and accurate data on electricity consumption, which has enabled a better understanding of energy usage patterns and helps to identify areas of high consumption and potential energy saving opportunities. The data collected from these devices can be analyzed using statistical methods to identify trends, patterns, and correlations in electricity consumption.

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

Description of the investigated sites

The construction sites that were analyzed by the study are located in the city of Bratislava. In both operations, the support system of the planned building was reinforced concrete and lifting mechanisms were deployed to carry out heavy construction works. Temporary buildings were placed for the site personnel to serve various purposes, including operational, social and sanitary needs [4].

Each construction site had temporary objects placed in one part of the plot according to the project documentation of the construction organization project. Site "A" had 10 temporary objects, where the central object consisted of 8 containers and 2 containers were placed next to each other. Site 'B' had 13 temporary objects, where the central object consisted of 10 containers and 3 were also located in close proximity. The year of manufacture of the temporary site objects for "A" was 2008 and the age was 15 years, for "B" the year of manufacture was 2016 and the age was 7 years. The average number of workers on site "A" was 23 and on site "B" was 31 during working days.

The wiring at the construction sites was branch-wired, which means that the temporary buildings were powered by a separate branch via a 3pole B 50 A circuit breaker and the site operation also had a separate branch. The site power supply via the 3pole circuit breaker formed the node for consumption metering. The site was designed to capture the consumption of all site facilities. The metering equipment installed met the basic criteria of recording and evaluating electricity consumption at hourly intervals and storing the data on remote storage. The same type of metering equipment was used for each construction site with factory calibrated with 99 % accuracy.

Data processing

The research started with the processing of data from consumption measurements at selected construction sites for a time period of 365 days from 1 September 2022 to 31 August 2023. The aim was to obtain detailed and accurate information on the amount of energy consumed at temporary buildings and to identify areas of high energy consumption.

Table 1: Consumption of the study areas

Month	Site A		Site B	
	Consumption of temporary objects (kWh)	**Site operation consumption (kWh)**	**Consumption of temporary objects (kWh)**	**Site operation consumption (kWh)**
September´22	3,260.0	1,413.0	1,902.0	736,5
October´22	3,984.0	1,931.5	3,511.3	1,088.7
November´22	4,502.1	1,609.0	4,155.1	2,014.0
December´22	4,807.7	1,208.5	6,907.8	3,076.1
January´23	5,307.9	1,208.5	7,231.1	2,217.0
February´23	6,307.5	1,208.5	6,677.0	2,560.9
March´23	4,919.1	1,945.7	6,010.0	1,882.0
April´23	2,323.2	1,360.3	4,310.8	2,125.7
May´23	2,049.1	928.1	2,769.3	1,246.8
June´23	1,062.5	458.9	1,328.0	514.0
July´23	880.6	256.3	1,378.9	535.0
August ´23	877.0	768.5	1,245.0	709.2
Total	**40,280.7**	**14,296.8**	**47,426.3**	**18,705.9**
Total	**54,577.5**		**66,132.2**	

Tab. 1 provides a detailed view of the monthly consumption of the two sites. For better orientation and comparison of site consumption, the data are recorded separately for the temporary structures area and the site operations area in the table. Comparing the consumption between sites 'A' and 'B' allows for the identification of differences in the energy behavior of each site.

The results show that temporary facilities represent a significant part of the total energy consumption at both sites, accounting for more than 70 % of the total consumption. Seasonal variations are also observed, with winter months showing an increase in consumption, while summer months show a decrease.

Identification of critical areas

Based on the data, the energy intensity of the temporary buildings was identified. The analysis showed that site 'A' had a higher consumption per container of 4,028.07 kWh per year than site 'B' with a consumption of 3,648.17 kWh per year, but with a larger number of containers and personnel. The first critical area demonstrated is the age of the temporary building.

Comparing the highest and lowest consumption values creates an important indicator that points to increased energy consumption. This trend is strongest in the winter months when climate conditions are more challenging and heating is needed in work areas. Conversely, in summer, temperatures are higher and there is a decrease in energy consumption. This effect is further accentuated by the long daylight hours, the need for artificial lighting in temporary buildings is not required. Conversely, on days with shorter daylight hours, energy consumption also increases due to the illumination of the premises. The second proven critical area is heating.

Proposal for optimisation measures

Based on the identification of critical areas, the research established proposals for optimization measures to mitigate the energy intensity of temporary buildings. Prospective opportunities for electricity savings are a key aspect in the quest for more efficient and sustainable use of resources on construction sites.

One of the main prospective savings opportunities is the optimisation of electricity consumption through alternative energy sources. Data has shown that there are specific time periods when electricity consumption in temporary buildings on construction sites is significantly higher during the day than at night. Therefore, it is proposed to implement 5 kWp photovoltaic panels that could be installed on the roof of construction containers for on-site electricity generation. The electricity generation from the PV panels is only during the sunshine hours and the construction production has been carried out during the day time.

Table 2: Overview of electricity production and consumption

Month	**Site A**		**Site B**	
	Production (kWh)	**Consumption (kWh)**	**Production (kWh)**	**Consumption (kWh)**
September´22	581.9	3,260.0	581.9	1,902.0
October´22	424.7	3,984.0	424.7	3,511.3
November´22	251.5	4,502.1	251.5	4,155.1
December´22	197.6	4,807.7	197.6	6,907.8
January´23	219.3	5,307.9	219.3	7,231.1
February´23	306.2	6,307.5	306.2	6,677.0
March´23	531.7	4,919.1	531.7	6,010.0
April´23	679.3	2,323.2	679.3	4,310.8
May´23	685.9	2,049.1	685.9	2,769.3
June´23	623.4	1,062.5	692.2	1,328.0
July´23	587.9	880.6	718.69	1,378.9
August ´23	521.41	877.0	669.26	1,245.0
Sum	**5,610.81**	**40,280.70**	**5,958.25**	**47,426.34**
Percentage saving	**14 %**			**13 %**

Tab. 2 gives us the production and consumption values in each month. The modeling software program SOLAR PRO was used to simulate the production, in which the possible quantities of optimal electricity production with respect to the consumption of a specific construction site were evaluated. The program processed the consumption during the eventual production at the investigated site and evaluated the possible electricity savings in a given month. A 5 kWp generating plant would produce more than the consumption during the summer months, but for the specific consumption at the temporary sites, no storage in batteries or sale of electricity to the grid was considered. For the temporary buildings on site 'A' and site 'B' there would be an eventual electricity saving of 14 % and 13 % respectively.

The second optimization solution on the investigated construction sites can be the control of the heating consumption. Electric heaters were used to condition the indoor environment in all temporary buildings.

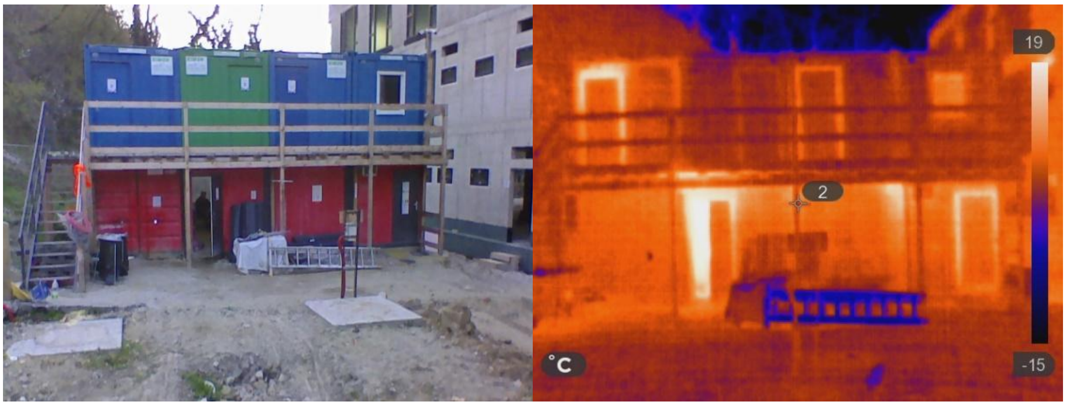

Figure 1:Thermal assessment of temporary structures on site A

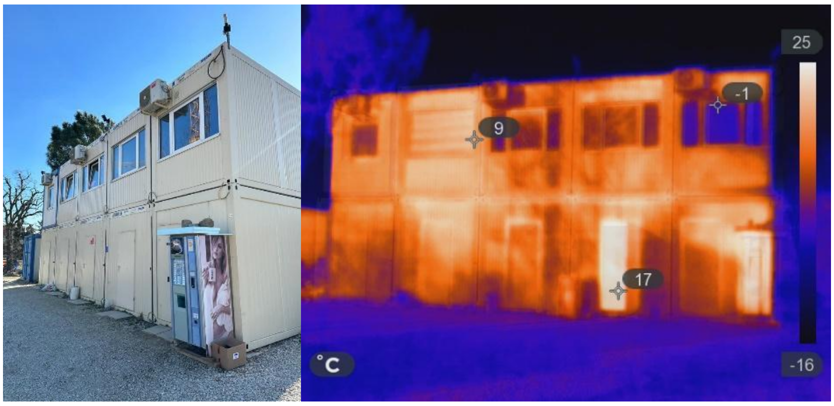

Figure 2:Thermal assessment of temporary structures on site B

In Fig. 1 and 2, the operation of these devices was demonstrated, which caused an increase in consumption. An important piece of information was that the heating of the containers was also during night hours. This effect can be thought of as a waste of energy as no one was on the sites at the time. The staff had the area heated during the night hours as during the day.

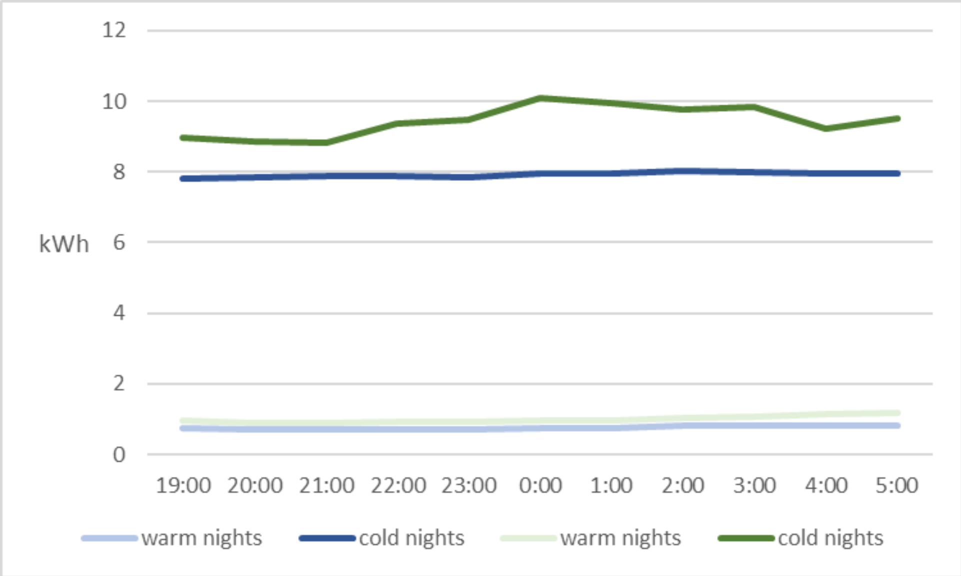

Figure 3: Comparison of consumption trajectories

Fig. 3 confirms and highlights the difference in averaged consumptions during warm and cold nights. The cool nights show consumption during the nighttime hours of 7:00 p.m. to 5:00 a.m. for the coldest months of December, January, and February. For comparison, values during the summer months of June, July, and August are shown. This difference is mainly due to heating in the temporary buildings, on site 'A' there was an increase over the summer months to a value of 87.04 kWh per night and on site 'B' there was an increase to a value of 103.89 kWh per night.

Table 3: Optimizing heating during the winter months

Month	**Site A**		**Site B**	
	Heating reduction at night (kW)	**Consumption (kW)**	**Heating reduction at night (kW)**	**Consumption (kW)**
September´22	-	3,260.0	-	1,902.0
October´22	-	3,984.0	-	3,511.3
November´22	-	4,502.1	-	4,155.1
December´22	2,698.1	4,807.7	3,220.7	6,907.8
January´23	2,698.1	5,307.9	3,220.7	7,231.1
February´23	2,437.0	6,307.5	2,909.0	6,677.0
March´23	-	4,919.1	-	6,010.0
April´23	-	2,323.2	-	4,310.8
May´23	-	2,049.1	-	2,769.3
June´23	-	1,062.5	-	1,328.0
July´23	-	880.6	-	1,378.9
August ´23	-	877.0	-	1,245.0
Total	**7,833.2**	**40,280.7**	**9,350,4**	**47,4263**
Percentage saving		**19 %**		**20 %**

Based on Tab. 3, the savings by controlling the heating during the 3 coldest months are quantified. Over a 90 day period, 19 % savings can be achieved by controlling heating during night hours on site 'A' and up to 20 % savings on site 'B'. In order not to reduce the thermal comfort of the workers, it is planned to heat the rooms for an hour before the arrival of the workers.

Results

The research first shows the high electricity consumption at the surveyed construction sites. For site A a consumption of 54,557.5 kWh was recorded and for site B a consumption of 66,132.2 kWh was recorded, with construction offices accounting for 70 % of the consumption on both sites.

The high energy consumption was also confirmed by the thermal photographs which showed high internal temperature of around 17 ^{0}C and high thermal leakage. A key finding was the unnecessary heating during the night when nobody was in the premises.

The research sought to find optimisation practices where consumption could be reduced. Suggested optimization measures include the implementation of photovoltaic panels on the roof of temporary buildings and heating controls. Simulations suggest that these measures could contribute to savings of 13,444.01 kWh at Site A and 15,308.65 kWh at Site B.

Discussion

The results achieved are significant for the construction industry. The critical areas identified, such as the age of temporary buildings and heating systems, highlight the need for innovative solutions to minimise the carbon footprint. Seasonal fluctuations in energy consumption indicate the importance of adapting energy strategies and creating pressure for more energy efficient containers. Improvements should focus on thermal insulation properties and on more energy efficient appliances.

The implementation of photovoltaic panels and the management of heating consumption appear to be promising measures. Photovoltaic panels could cover time periods with significant electricity consumption, while heating control at night could minimise consumption. Furthermore, on-site generation plants could increase the electricity supply by a storage and use system in the evening.

Several studies examining the emissions of different process operations count only the process itself, not including offices or changing rooms, which are needed for workers.

Discussions need to be opened on legislative measures and incentives that could encourage the implementation of sustainable approaches. The insights provided could shape the approach of policy interventions and regulatory frameworks to create pressure to change the production process in the construction industry. For example, the study by Dalirazar and Sabzi looks at support such as financial incentives, low-interest loans and tax breaks for sustainable buildings. They appear to be effective ways to increase the demand for sustainable buildings and to encourage investors in the market to construct sustainable buildings [14]. However, these incentives need to precede the identification of areas and some research highlights.

Conclusion

The study highlights the need and opportunities to improve the environmental sustainability of the construction industry by minimizing the carbon footprint of temporary buildings. The critical areas identified present a challenge but also an opportunity for the implementation of innovative measures.

The proposed optimization steps in the form of photovoltaic panels and heating management could contribute to significant energy savings, which would have a positive impact on the overall sustainability of the building industry. The debate on these measures should be continued in order to promote their implementation and stimulate further research on eco-innovation in the building sector. Overall, these adjustments could contribute to positive changes in the sector and to a better integration into the current trend of environmental sustainability.

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Znižovanie uhlíkovej stopy dočasných objektov staveniska

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Abstrakt

Článok sa zameriava na minimalizáciu uhlíkovej stopy spojenej s dočasnými objektmi na stavenisku prostredníctvom identifikácie a implementácie udržateľných opatrení. Experimentálna činnosť na dvoch sledovaných staveniskách odhalila vysokú mieru spotreby na vykurovanie počas noci v dočasných objektoch, zdôrazňujúc potrebu efektívnejších technológií vykurovania a izolácie. Analýza spotreby ukázala na výrazné možnosti úspor energie, pričom identifikované kritické oblasti umožňujú implementáciu zlepšení v riadení spotreby energie, s potenciálnym pozitívnym vplyvom na celkovú udržateľnosť stavebného priemyslu.

Kľúčové slová: *Uhlíková stopa, spotreba energie, dočasné objekty, stavebná prevádzka*