J. Civil Eng. Architect. Res.
Vol. 4, No. 4, 2017, pp. 1963-1974
Received: May 17, 2017, Published: April 25, 2017

Journal of
Civil Engineering
and Architecture Research

An Explorative Study on Assessing Onsite Energy Use during the Construction of Residential Buildings

Bram Entrop, Robin de Graaf and Rogier Janssen

Department of Construction Management and Engineering, University of Twente, Enschede 7500AE, the Netherlands

Corresponding author: Bram Entrop (a.g.entrop@utwente.nl)

Abstract: The assessment of energy use in buildings is widely incorporated into building energy regulations, energy certifications and standards. The majority of these assessments focuses on a building's operational energy use and, sometimes, on the indirect energy embodied in building materials. However, there is little research on the energy use during the construction stage. Current interpretations, quantification and analysis procedures of energy used for onsite construction activities are unclear and real-life data are lacking. Further, due to the increased focus on lowering operational energy use, the relative share of energy used in the construction stage is increasing. This paper presents the results of an explorative study on energy use during onsite activities for the construction of family houses. A protocol was developed to structure data gathering and was applied to several residential building projects. The data gathered were analyzed to explore relationships between project characteristics and energy use in onsite construction activities. In the analysis, the authors use scatter plots and statistics. Significant strong positive correlations were found between onsite electricity use and three basic project characteristics: construction period in working days, gross floor area and gross building volume. Based on the findings, this paper concludes with a proposed research agenda.

Keywords: Energy use, electricity, onsite construction activities, residential building projects, construction stage

1. Introduction

Worldwide, the building sector accounts for more than 30% of the total final energy use across all economic sectors [1]. In the European Union, the proportion is even slightly higher, with buildings responsible for around 40% of total energy use [2]. In Europe (EU-28), households account for around 25% of the final energy use [3]. Consequently, building energy regulations, energy performance standards and the certification of buildings have evolved over the years [4-6]. Particularly in the context of sustainability assessments, there is a vast number of methods and instruments that address the energy use of buildings [7-8].

Recently, there has been a growing emphasis that a lifecycle perspective is required to understand a building's environmental impacts [9]. Within a lifecycle perspective, the energy use associated with buildings is usually split into operational energy and embodied energy. Operational energy is the energy used for heating, cooling, lighting and operating appliances in buildings. Most energy performance assessments of buildings focus on this operational aspect. "The embodied energy in a product comprises the energy to extract, transport and refine the raw materials and then to manufacture components and assemble the product" [10]. Although definitions of operational and embodied energy are to an extent debated, in particular about where to draw system boundaries and the types of energy to be included in embodied energy analysis [11-12], the basic differentiation is generally acknowledged.

Until recently, research has tended to focus on operational energy, because this is seen as representing the largest proportion of a building's total lifecycle energy consumption. For residential buildings, in particular, operational energy is considered to represent 80-90% of total lifecycle consumption [13]. Further, several studies have noted that the relative share of embodied energy is increasing substantially, because operational energy use has reduced significantly over time [12, 14-20]. This reduction in operational energy use is, in part, due to effective energy-efficient building designs [21], new technology, more efficient systems, onsite electricity generation [22] and the move towards low (operational) energy buildings or even zero (operational) energy buildings [19, 23]. As a consequence, research is increasingly focusing on both operational and embodied energy. Decreasing both operational and embodied energy components can significantly reduce the overall energy use, thereby minimizing the energy footprint of buildings [18] and greenhouse gas emissions [12].

Consequently, as embodied energy becomes increasingly significant, the non-use stages and aspects of a building's lifecycle, such as manufacturing, construction, maintenance, refurbishment and demolition, become more important [6, 12, 21, 24]. That is, to further reduce the energy use of buildings, all stages of the lifecycle should be considered, and not just the operational stage [20]. One of the lifecycle stages of buildings that is especially gaining in importance, due to its energy implications, is the construction stage. Factors that influence on-site energy use include lighting systems on the construction site, fuel consumption of construction vehicles, use of heating to dry concrete and plaster [25-27].

Despite the relevance of energy use during onsite construction processes, and its growing importance, there are very few data sources available to support the assessment and quantification of embodied energy consumption throughout the whole construction process [26, 28]. In fact, only one study seems to have specifically addressed this topic [28]. As such, the need for reliable and good quality data to analyse energy use in the construction stage, identified by Ref.[29], and to further quantify the environmental impacts of onsite construction activities [20, 28, 30] remains. Moreover, protocols or standards are needed, especially in complex construction projects, to guide data analysis in calculating embodied energy [12].

This paper specifically explores the energy use during one particular stage of a residential building's lifecycle: the construction stage. This research contributes to existing knowledge by quantifying and interpreting energy use in onsite construction activities. We will explore whether relationships exist between project characteristics and the energy used during construction. Section 2 describes the research method and introduces a protocol for structuring data gathering. This protocol was applied to a sample of residential building projects leading to the results presented in Section 3 and then analysed in Section 4. In Section 5, we discuss the results, and in the final section, Section 6, conclusions, the implications of our research for practice, and proposed research agenda are presented.

2. Research Method

In our research, we used a four-step research approach, consisting of the following steps:

(1) Determine variables to characterize projects;
(2) Determine variables to measure energy use;
(3) Collect data from a set of building projects;
(4) Analyze the data collected.

This research was commissioned by VGD (Vastgoed Groep Drienerlo, which can be translated as Real Estate Group Drienerlo). VGD is responsible for real estate developments for the University of Twente. To provide information to use in its procurement processes, VGD was interested in variables related to energy use during the construction of buildings. To identify appropriate variables to characterize projects and energy use, a user group was formed consisting of VGD's clients and contracting parties that are active in the residential sector. The role of the user group was to ensure access to the housing projects, to give feedback on the research and to safeguard the practical relevancy of the research. The user group provided some valuable suggestions regarding the project characteristics that could be used to relate to onsite energy use during construction. The user group selected these characteristics on the basis that these could be retrieved efficiently or were already collected for other purposes and available from archival sources.

2.1 Project Characteristics

The selection process to determine project characteristics resulted in the following list:

- Construction period: measured in days and defined as the number of days that were actually used for construction on the site, from site preparation to cleaning up the site. Weekends are excluded, except when construction took place during weekends;
- Gross floor area of the building: measured in m^2 and defined by Ref. [31]. This norm defines the gross floor area of a building as the sum of all gross floor areas of the inner rooms within a building. The gross floor area of an inner room is defined as the surface or the room, measured at floor level, and alongside the outer edges of the walls or facade. Also included in the gross floor area are the surface areas required for stairs, elevator shafts and shafts for cables and pipes;
- Gross building volume: measured in m^3 and defined by Ref. [31]. This norm defines the gross building volume as the sum of all gross volumes of inner rooms within a building. The gross volume of an inner room is defined as the product of the gross floor area and the gross height of that room. The gross height is the distance between the finished upper layer of the floor of a room and the finished upper layer of the floor of the room above, or in case of a roof, the top of the roof;
- Average building height: measured in meters from the finished ground level located at the main entrance of the building and the top of the roof, excluding antennas and chimneys;
- Deployment of staff: measured in hours and defined by the actual hours made by employees of different companies and subcontractors on the construction site. Excluded are incidental visits as these are often not registered. Also excluded are preparations done off site.

2.2 Energy Use

The scope of this research is limited to onsite construction activities, from site preparation, to the construction itself and cleaning the site. Energy used for transportation of materials, equipment and personnel to and from the construction site is not included. Onsite energy is usually available in the forms of gasoline and diesel fuel, electricity, and natural gas [26]. Therefore, the following energy variables were taken into account when assessing the energy use of onsite construction activities:

- Electricity use, measured in kWh, equivalent to 3.6 MJ/kWh;
- Diesel use, measured in liters, with an energy content of approximately 40 MJ/dm^3;
- Petrol use, measured in liters, with an energy content of approximately 34 MJ/dm^3;
- Natural gas use, measured in m^3, with an average caloric value of approximately 33.4 MJ/m^3.

2.3 Collecting Data from the Building Projects

Having determined the variables of interest, the next step was to identify a sample of residential building projects. The user group, consisting of ten contractors, was asked to provide residential building projects that satisfied two criteria: (1) they had to have been recently finished to ensure they were representative of current construction practice; and (2) data on the identified project and energy variables were available. Regarding the current construction practice, it is important to shortly explain what building materials are commonly used in the Netherlands. Mostly concrete is used in foundations, the outer leaf consists of brickwork and the inner leaf consists of sand-lime bricks or aerated blocks. Glass wool or mineral wool often provides the thermal resistance required by the national Building Code. Covered with roof tiles, pitched roof structures often include a timber frame that contains the insulation and that at the inside as well as outside is finished off with wooden plates.

The contractors offered 22 projects that initially seemed to satisfy the selection criteria. All the projects are located in the Netherlands having the advantage that they all comply to the same Building Code, and that all are subjected to the Dutch moderate climate with an annual average temperature of approximately 10 °C and solar irradiation of 1000 kWh/m^2 per year. When it became apparent that a full set of figures on energy use in onsite construction activities was not available, three projects were removed from the sample at an early stage, resulting in 19 potential projects. Data on the four types of energy used in onsite construction activities plus the six identified project characteristics were collected by reading energy meters, reviewing bills, inspecting architectural drawings, looking into archives and accessing time recording systems. As such, secondary data were used throughout. This made the study feasible in terms of time and available skills, but it also involved risks as one is reliant on the archival sources providing reliable and accurate information. Given this concern, the usefulness of the data was critically reviewed.

A data-collection table (Appendix A) was created as an instrument for collating the values of the variables. The user group indicated that the data-collection table was not always unambiguous in its interpretation, and therefore we added operational definitions to make it clear how to measure the variables. By providing sharper definitions, the risk of misunderstanding was minimized. Based on the operational definitions, the data-collecting table and instructions for its completion were explained to students who would collect, albeit under the supervision of the researchers, the actual data during an internship at the participating contractors. According to the contractors involved, all data requested were present as part of their administration and easily accessible.

However, it transpired that it was much more difficult than expected to collect all the data initially requested. For example, data was fragmented throughout the organization and registered in different systems. It took much time to exactly locate where data could be found and then to combine data from these systems into a coherent whole. The students communicated specific difficulties and problems to the researchers, who then contacted the relevant contractors. In the end this solved several problems but nevertheless, we still lacked much data on key variables.

3. Results

After collecting the data, they were prepared for analysis, which resulted in removing several projects and variables due to missing data. The remaining data are analyzed by visually exploring relationships using scatter plots, before correlation coefficients are calculated to assess the strength of each relationship.

The basic project characteristics and energy use in the onsite construction activities of nineteen residential building projects are shown in Table 1. Due to their specific physical identities, two types of residential projects are distinguished: single-family housing, and blocks of flats. The set of cases ranges from a small project of just one family house with a gross floor area of 167 m^2, up to large projects of more than one hundred houses with a total gross floor area of 27,000 m^2. Four cases, Projects 4, 6, 7 and 8, had very similar construction periods but differed substantially in terms of floor area and building volume. These differences are not unexpected given that building projects vary in terms of building speed, for example, because construction companies can speed up or slow a project based on the demands for manpower on other projects,

Table 1 Collected values on the project characteristics and energy use.

(No.) project type	Constr. period	Gross floor area	Built area	Gross building volume	Average building height	Deployment of staff	Electricity use	Diesel usage	Gasoline use	Natural gas use
	(days)	(m^2)	(m^2)	(m^3)	(m)	(hours)	(kWh)			(m^3)
(1) Apartments	180	914	369	2630	7,13	4380	969			0
(2) Apartm. & houses	380	6529	3502	22890	6,54	23632	180901			8255
(3) Houses	135	886		2658	8,2		2891	15		
(4) Houses	91	1832		4600	9,3		2875	0		
(5) Houses *	180	4927		13816	10,5			0		
(6) Single house	90	298	114	851	10,1	1700	189	700		124
(7) Single house	90	167	63	444	9,39	550	80	360		492
(8) Single house	90	184	105	573	9,81	900	281	400		
(9) Apartments	420	17824		54989	21		323633			
(10) Apartments	335	10804		33291	15,3		129148			
(11) Apartments	275	9822		29035	9,42		103606			
(12) Apartments	205	1230	1230	2952	8,77		4192			
(13) Apartments	220	1248	1248	3306	10		6600			
(14) Houses	130	1554	583	5599	9,6	1358	1457			
(15) Houses *		27000	10000	330	9,7	22200	98955	2400		12619
(16) Houses *		1710	1500	333	2,9					
(17) Houses *			3600		2,9					
(18) Houses *		306	420	295	2,9					
(19) Apartm. & houses*		2540	2320	386	2,9					

* Projects that were not used for data analysis

and adverse weather conditions can also slow progress. As such the differences shown in Table 1 are not unexpected and highlight the difficulty in comparing projects.

To explore the energy use of onsite construction activities, our intention was to investigate how the six project characteristics we had identified and collected were associated with the four energy use variables. The data collected were first checked for appropriateness and completeness. Given that the participating contractors had asserted that providing data on the selected variables would not be difficult, the large number of gaps was disappointing. Of the 19 projects that were originally offered by the contractors to the researchers, it was apparent that Projects 16, 17, 18 and 19 could not be analyzed further because no data on energy use were available. Further, Project 15 was deleted from the sample set because construction work had not been completely finished in time.

After removing these projects, the remaining fourteen projects were scanned again. This highlighted that none of the projects seemed to have used petrol, which can be easily explained by its relatively high price in the Netherlands compared to another common engine fuel; diesel. Unfortunately, only a few figures on diesel and natural gas usage were unlocked. Values for the deployment of staff were also missing for some projects. Therefore, we decided to limit our analysis to four project characteristics (gross floor area, gross building volume, construction period and average building height) and a single energy variable (electricity use). At this stage, Project 5 was also removed since it lacked data on electricity use. Based on this data assessment, four relationships are considered viable for further analysis, and we start with the following presumptions:

- the greater the construction period, the greater the electricity use;
- the greater the gross floor area, the greater the electricity use;
- the greater the gross building volume, the greater the electricity use;
- the greater the average building height, the greater the electricity use.

4. Analysis

The four distinguished relationships are first explored visually in Section 4.1, before correlation coefficients are calculated in Section 4.2. The findings are then interpreted and discussed in Section 4.3.

4.1 Visually Exploring the Four Relations

As explained in Section 3, four relationships between project characteristics and electricity use form the basis of the analysis. Each relationship was explored using the SPSS statistical package. First, scatter plots (Figs. 1-4) were drawn to visualize the data and enable us to determine the apparent type of relationship (if any), and if certain cases stood out as not fitting with a general pattern [32]. Since our dataset included both very small and very large values, a logarithmic scale was used in the graphical presentations.

The scatter plot (Fig. 1) of Relationship A suggests a relationship between the variables construction period and electricity as a straight line can be drawn through the points in the graph. The scatter plots of Relationships B and C are not dissimilar to Fig. 1, with Fig. 2 shows a relationship between electricity use and gross floor area, and Fig. 3 shows a similar trend between electricity use and gross building volume. Fig. 4 shows a much less clear relationship between electricity use and average building height, although one could perhaps deduce that the construction of lower buildings tends to (but not always) use less electricity.

As such, Figs. 1-3 suggest positive relationships between the variables, meaning that larger values of the project characteristic variables tend to be associated with greater electricity use.

4.2 Calculating the Strength of the Four Relationships

Given that the scatter plots for Relationships A, B and C suggest the existence of positive relationships, correlation coefficients were calculated to determine

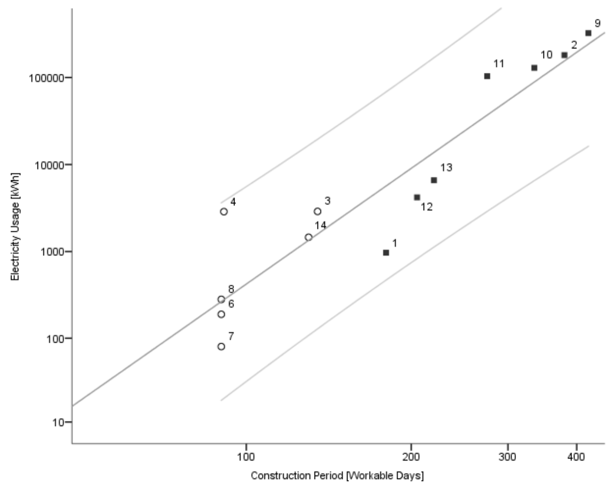

Fig. 1 Scatter plot of relation A between electricity use and construction period.

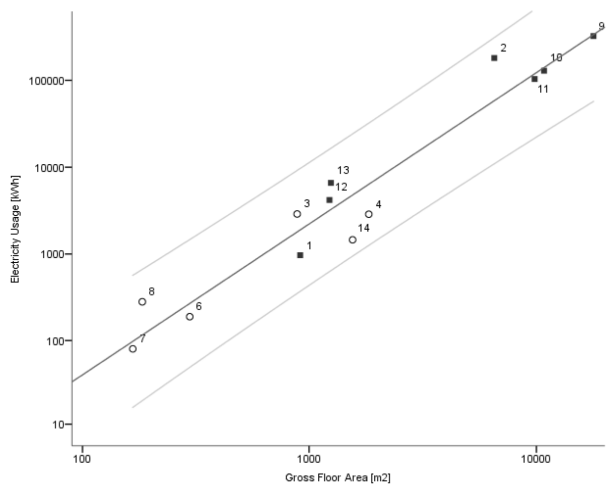

Fig. 2 Scatter plot of relation B between electricity use and gross floor area.

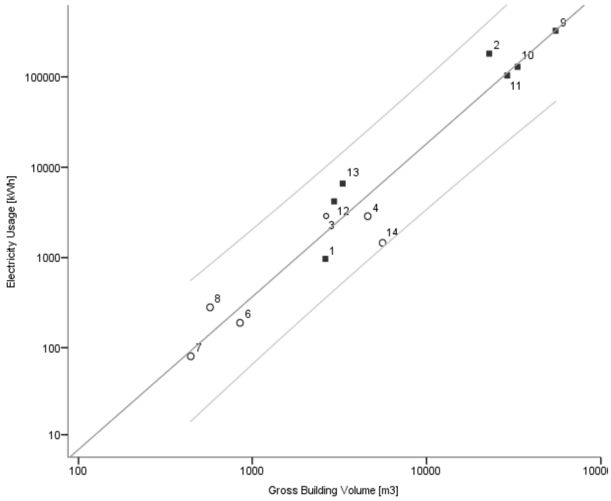

Fig. 3 Scatter plot of relation C between electricity use and gross building volume.

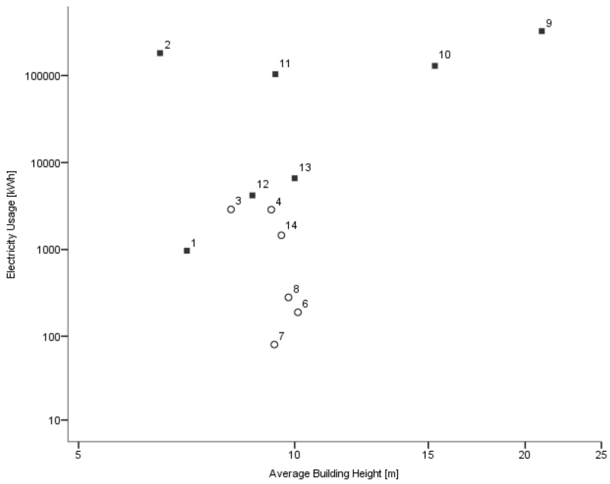

Fig. 4 Scatter plot of relation D between electricity use and average building height.

the strength of these relationships between the project characteristics and electricity use. Before such a calculation, the distribution of the data (for the four project characteristics and electricity use) should be tested for normality. Using a box plot routine in SPSS, it was found that all the variables showed skewness and none were normally distributed. Given that the data were non-normally distributed, that one of the four relationships appeared to be not a relationship at all based on visual inspection, and because the sample size (N) was quite small, Spearman's rho was selected as the appropriate test for the significance of the calculated correlation coefficients [32]. As part of this test, a Spearman's correlation coefficient (r_s) is calculated using the following Eq. (1) [33]:

$$r_s = 1 - \frac{6D}{N(N^2-1)}\ \text{, with } D = \sum_{i=1}^{n} d_i^2 \qquad (1)$$

In this formula, N is the number of paired observations and d_i is the difference between the rank numbers of x and that of y for observation pair (x_i, y_i). The null hypothesis, H0, is that X and Y are independent. This hypothesis is rejected when, for a chosen significance level (α), the absolute value of r_s equals or exceeds the critical value. This critical value can be obtained from tables that are included in most statistical books and articles [34, 35].

Using SPSS, four Spearman correlation coefficients (r_s) were calculated and the results are presented in Table 2. These correlations coefficients have to be compared with the critical values to determine if the null hypothesis, that X and Y are independent, can be rejected. As the number of paired observations (N) is 13, and the chosen significance level (α) is 0.01, the critical value (r_c) is 0.648 [34]. This means that the null hypothesis (H0) has to be rejected if r_s equals or exceeds this value.

As can be seen in Table 2, we can reject the null hypothesis for our first three relationships. In other words, there is a statistically significant correlation between the variables. The fact that the rank correlation coefficients were positive confirms what was apparent from the scatter plots: that as one variable increases, the other variable also increases. Although our analysis shows a correlation between pairs of variables, these relationships do not formally indicate causality. Further, as Fig. 4 suggested, there is no statistically significant relationship between building height and electricity used in construction.

Table 2 Correlation coefficients of the bivariate relations.

Independent variable	r_s	r_c	H0: (Independent)	Conclusion correlation
Construction period	.956	.648	Rejected	Significant*
Gross floor area	.879	.648	Rejected	Significant*
Gross building volume	.890	.648	Rejected	Significant*
AVG building height	.121	.648	Not rejected	Insignificant

* Correlation is significant at the 0.01 level (directional) N = 13

4.3 Interpretation of the Findings

Given the data limitations, four directional relationships were considered logical and open to analysis in this research. The analysis, based on the data from the sample projects, provided empirical evidence for the existence of three of the expected relationships. As anticipated, the three strong positive relationships mean that the greater (in terms of construction period, gross floor area and gross building volume) a project, the greater its electricity use. However, based on the sample data, no relationship was found between average building height and the electricity used in its construction. Although we had expected that taller buildings would require more electricity (lifting materials to higher floors), our sample did not indicate a simple relationship between height and electricity used during a building project. Although no strong relationship was identified, it is possible that height does influence energy use but in combination with other variables (such as gross floor area).

When looking at the results, it is important to recall that the sample included both small and large projects, resulting in quite some differences in the values of the project characteristic variables and in electricity use. The electricity use per square metre of gross floor area ranged from 0.5 to 3.3 kWh/m^2 (1.8-11.9 MJ/m^2) for houses, and from 1.1 to 18.2 kWh/m^2 (4.0-65.5 MJ/m^2) for apartments. In the Netherlands, the overall average efficiency of electricity production and distribution is 39% [36]. In terms of primary energy, the electricity consumption therefore amounts to 4.7-30.5 MJ/m^2 for houses, and 10.1-168.0 MJ/m^2 for apartments.

5. Discussion

In this section, we will indicate which parts of the research warrant caution and discussion. First, in this research, we initially identified five variables with which to characterize construction projects plus four variables for assessing different forms of energy use during onsite construction activities. Unfortunately, we could only access sufficient data to analyse four project variables and one energy variable. However, it can be debated whether projects can be characterized by only these variables. Nevertheless, we did find some significant relationships between three of the project variables and electricity usage across a broad range of project magnitudes. This suggests that our basic concept of relating energy consumption during the construction stage to building characteristics has potential.

Second, some caution is needed with regard to the variables construction period, average building height and the deployment of staff we used. Construction periods are commonly expressed by the number of working days. However, equipment such as pumps and heaters may also run on non-working days (e.g., at weekends). This means that in terms of electricity use, the construction period can be considered longer. Regarding the variable average building height, it is expected that the taller a building is, the more energy that will be needed for its construction. However, using an average building height, and thus assuming that all buildings in a project are of this height, may not be an accurate representation or reality. Finally, the variable deployment of staff needs some caution as it appeared difficult to get reliable data on this variable. The worked hours of on-site personnel could be derived from administrative records, but hours spent on the project by project managers and project planners were hard to identify since such people often work on multiple projects. The time registration systems used do not always distinguish between different projects.

Finally, some caution is also required regarding data analysis and data interpretation. The results show that three project variables (construction period, gross floor area and gross building volume) were significantly and positively correlated with electricity use. However, one cannot assume that the project variables necessarily caused this variation in electricity use. It is possible that other, measured or unmeasured, variables influence electricity consumption—a phenomenon known as the third-variable problem. Although proving causality is a major challenge without a set of rules or criteria, in general, the more robust a correlation, the more likely it is to reflect causation.

6. Conclusions and Research Agenda

This research started with the goal of exploring possible relationships between project characteristics and energy use. Based on the data collected, we were able to explore four relationships between project characteristics and electricity use. With the help of scatter plots and Spearman's rho tests, three significant and strong positive correlations were identified between three project characteristics and onsite electricity use. Based on the Spearman correlation coefficients, onsite electricity use has a statistically significant correlation with construction period in working days, gross floor area and gross building volume. However, there was no statistically significant correlation between electricity use and the average building height.

These relationships are a promising basis for parties that would like to benchmark, or even estimate, the energy use in onsite construction activities. Formulas could be derived through a regression analysis of our data to estimate the energy use in onsite construction activities based on project characteristics. However, as this research was only an initial exploration, with a very limited number of cases, we consider it more appropriate to first follow the research agenda presented below before deriving formulas for further use.

The results also show that the highest values we found for primary electricity use during onsite construction activities related to apartment buildings, where an amount equivalent to roughly 1.5% of the embodied energy over the lifecycle of residential buildings was used. Based on these findings, we would conclude that the energy used in onsite construction activities is not negligible, as is often assumed, but also not that substantial. However, our findings only relate to electricity consumption and so the significance would increase somewhat when diesel, petrol and natural gas are taken into account.

Therefore, we would stress the value of further research on this topic. To derive reliable formulas for energy use during onsite construction activities based on project characteristics, the following research agenda is proposed:

(1) Collect more data, preferably automatically using accurate sensor technology, on onsite energy use during the construction of residential buildings together with the key characteristics of these building projects to complement our research;

(2) Collect data on non-residential building projects to be able to place the outcomes of this research in a broader context, e.g., schools, hospitals, offices;

(3) Increase the number of project characteristics included so as to be better able to define projects more accurately and to study possible correlations that were beyond the scope of this research. This is also in line with the recommendations of Davies et al. [28];

(4) Broaden the range of energy use variables and try to automate their measurement. Although our study was eventually limited to electricity use, future research should endeavour to include other forms of energy (diesel, petrol and natural gas) usage;

(5). Conduct research into the mechanisms behind the relationships between project characteristics and energy use to determine causality;

(6). Once a better understanding of the relationships and their strengths is achieved, consider the possibilities for reducing energy use in on-site construction activities, such as by rethinking construction principles, adopting photovoltaic systems to power construction equipment and stimulating environmental awareness among construction workers.

Besides this research agenda, our findings are also relevant for practice, because

- They lead to awareness as it appeared that electricity usage is not negligible. This may lead to improved registration of electricity use and other variables by contractors. As we have seen that these variables are currently not considered that relevant;
- We collected and distributed key indicators such as electricity use per m^2 or m^3. Such values were not publicly available, until now. These key indicators can be used by contractors beforehand to estimate the costs of electricity use and hence contributes to improved cost and risk management. Moreover, these key indicators can be used in tendering processes. For example, clients striving after sustainable products and production, could set requirements for electricity use and use these to assess offers of contractors;
- The values of our study can be used for benchmark purposes. Contractors can see how well they perform compared to others.

The final conclusion we want to make is that despite extensive preparatory efforts for data collection, it still proved difficult, and often impossible, to get accurate and reliable data on energy use in the construction stage, a finding which is in keeping with those of Ref. [17]. This research has contributed to existing knowledge in three ways. First, we have found significant correlations between three project characteristics and energy use in onsite construction activities. Second, we have determined the amount of electrical energy typically used in onsite construction activities. Third, we have developed a protocol to guide data gathering and analysis of energy use in onsite construction activities.

Acknowledgment

The authors would like to express their gratitude to ir.Marien Florijn of Vastgoed Groep Drienerlo for taking the initiative to start the research project and for providing valuable support during the research process. Furthermore, the contractors that participated in the research project are acknowledged for granting access to information on their projects.

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Appendix A The data collection instrument

The form, Table A1, was used to collect data in the construction projects. Other researchers are warmly welcomed to use it and to further develop it.

Table A1 Data collection form.

	Project characteristics and energy usages	Project:
		Contractor Contact:
		Data collector:
Project	Building's (main) function:	Start of construction (month-year):
	Number of units built:	Finish of construction (month-year):
	Main construction method:	
	Construction period (working days):	Source:
	Gross Project Floor Area (m^2):	Source:
	Gross Project Volume (m^3):	Source:
	Average Building Height (m):	Source:
	Deployment of Staff (hours):	Source:
Energy	Electricity use (kWh):	Source:
	Diesel usage (l):	Source:
	Petrol usage (l):	Source:
	Natural gas usage (m^3):	Source: