

# Electricity Consumption in Construction Projects in the Czech Republic

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**Abstract.** The paper deals with the development of electricity production in the Czech Republic and its consumption in the construction industry. The research specifies individual types of appliances - electric motors, lighting, heating, water heating and information technology in a selected newly constructed building. Construction machines with electric motors have been taken out of the itemized budget of the construction, their electric power input and time of their use have been determined. In order to determine other consumption, the equipment of a construction site, individual electrical appliances, their power input, number and time of their use have been proposed. Methods of consumption measuring and its division into the implementation costs of constructions in the way usual in the Czech Republic are presented. Furthermore the possibilities of optimizing electricity consumption costs within the project management by choosing a supplier and discussing other possible measures during the construction process have been considered.

## 1. Introduction

The place where construction projects are implemented is the construction site. Its total area is given by the sum of the built-up areas of all construction objects and by the area of land on which the facilities used for construction are located. These include production, storage, communication and social facilities. Energy resources are necessary for the implementation of technological processes. The universal energy source used to power machinery and tools as well as for lighting and heating, is electrical energy. Provision of its delivery to the construction site and its distribution to the place of consumption is the subject of the construction site project.

Electricity is not only consumed during construction. It is used in the purchase, production, processing and recycling of building materials and in the transport of materials to the construction site. [1] For buildings, the predominant operating consumption is for the whole period of use. The paper deals only with the consumption of electricity on the construction site during construction.

Firstly, the paper discusses the development of electricity production in the Czech Republic since 1989 and the structure of its consumption in the sectors of national economy. Electricity consumption in the construction industry is specified. Secondly, the research divides the electricity consumption on the construction site according to its use. Financial resources for the payment of its price, which are based on the usual budgeting process of construction works in the Czech Republic, are described. Thirdly, consumption and price of electricity for the entire construction period and its share on the price of the construction from the actual construction documents is calculated. Finally, the possibility of

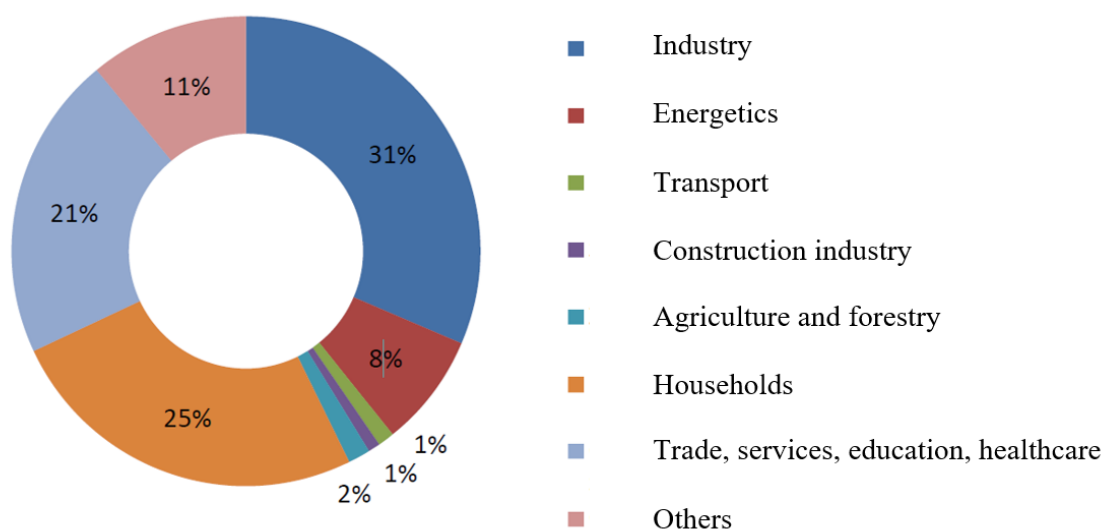


choosing an electricity supplier is considered and measures that may reduce electricity consumption are discussed.

## 2. Electricity production and its consumption in the construction industry

In 1989, the share of coal on the electricity production in the Czech Republic was 79%. Nuclear energy accounted for 11%, while water resources accounted for 10%. There were no other sources at the time. In the course of 30 years, the structure of resources has changed considerably. The importance of coal decreased significantly, its share on the electricity production in 2018 accounted only for 47%. Nuclear power, on the other hand, rose to 34%. Both gas and steam-gas power plants and renewable sources such as sun, wind, biomass and biofuels have been added, with a production volume of 17%. Hydroelectric power generation has decreased to 2%. [2]

The total installed capacity of power plants has increased from 15,230 MW in 1989 to the current 22,176 MW. In 2018, 76,305 GWh [3] were produced and 49,842 GWh were consumed in industry. Construction industry (NACE codes 41 to 43) accounted for 287 GWh, i.e. 0.6% of total consumption [4]. The share of electricity consumption by individual sectors of the national economy in 2018 is shown in Figure 1. It can be clearly seen that electricity consumption in the construction industry is very low compared to other sectors. However, it should be borne in mind that the construction industry own consumption is preceded by the consumption in the production of building materials (included in industry) and in transport.



**Figure 1.** Share of individual sectors of the national economy on the total electricity consumption in the Czech Republic in 2018, taken from [5].

Construction industry output in the Czech Republic in 2018 amounted at CZK 487,526 million at current prices [6]. The production volume of CZK 1 million corresponds to the consumption of 1.7 MWh of electricity.

## 3. Electricity on the construction site

Construction site equipment represents a place for construction implementation and includes operational, manufacturing, social and sanitary facilities. In all these areas, electrical appliances are used which are divided into light, heat and rotating. Outdoor lighting appliances serve for illumination of construction site area, indoor lighting appliances serve for illumination of indoor workplaces for administration, production, storage and maintenance. Heat appliances are represented by heaters and

boilers for water heating. Rotating machines are represented by electric motors in large construction machines (e.g. cranes, elevators, cement-mixers, pumps, cutters) as well as in the small hand tools. A special group of appliances consists of IT, communication and other equipment.

For trouble-free power supply to the construction site, it is necessary to calculate the maximum required current input (kW) and to propose the dimension of the main automatic circuit breaker of the construction connection in amperes (A). Its amount needs to be optimized, as the flat monthly payments for providing the required performance increase in the relation with increase in its amount. Based on the signed "Contract for Associated Services of Electricity Supply" between the customer - the contractor of the construction and the supplier, the customer is obliged to pay the price for the electricity consumed in the form of regular payments to the supplier with an agreed periodicity.

In the Czech Republic, the price of electricity consists of:

- prices for electricity supply according to the price list
- prices for related services in the electricity sector (system services, market operator activities, support of electricity from supported energy sources)
- electricity tax and value added tax

#### **4. Sources of financing electricity consumption on the construction side**

In the market economy of the Czech Republic, the price of the construction work is determined by the contractual relationship between the client (investor) and the contractor (construction company). Price determination is based on traditional methods used for decades. The partial price of the actual construction is given by the sum of the prices of individual building constructions and works and is referred to as the basic budgetary costs (BBC). The list of all these works forms the budget. The price of the individual building structure is calculated according to the so-called calculation formula. It is the sum of partial costs of materials, wages, labour of machines and insurance, which create the so-called direct costs. Indirect costs consist of so-called production overheads (costs incurred on the construction site not included in direct costs) and so-called administrative overheads (costs of management and operation of the construction company). The total cost of building construction and labour is created by the sum of direct and indirect costs and profit.

The total construction cost is the sum of the BBC and the so-called ancillary budgetary costs (ABC). ABC consists of costs related to the location of the construction. These include, for example, construction site costs, operating and territorial impacts and transport costs.

In addition to the price of construction, it is necessary to add the price of so-called engineering activities. They are represented by planning and management of the construction, the creation of studies, documentation, surveys, the aim of the construction and public negotiations.

The payment of electricity prices has two sources in the system used. They are

1a – BBC, where the price of construction work includes also the price of consumed electricity. This applies to large construction machines with electric motors.

1b – BBC, where the overhead of production includes also electricity consumed by small mechanisms and information technology

2 – ABC, where the price of construction site equipment includes the price of electricity used for lighting, heating, water heating and other appliances not mentioned elsewhere

Within the construction of the electrical connection, the construction site is equipped with a single meter of consumption - an electricity meter. The price for electricity supply is then paid by a single amount according to meter readings. According to the above described sources of reimbursement of electricity prices, only the consumption from ABC should be included in the operation costs of the construction site equipment. Further consumption and thus its price have already been included in the BBC. Consequently, a secondary metering of electricity consumption should be established at the construction site, which would separate the consumption of BBC and ABC. In fact, this can only be provided for the consumption of the BBC of large construction machines. It is practically impossible to divide the distribution of electricity for small tools and information technology from heat and light appliances.

## 5. Electricity consumption in the model construction

### 5.1. Types of electrical appliances

The first group of costs of electricity consumption consists of electric motors. The so-called machine limit which indicates the time of use of each machine on the construction site can be compiled in computer applications from the construction budget. According to the description, machines with an electric motor, in which the power (kW) is determined, are chosen. The multiplication of the time of use and the power of the engine represents the electricity consumption (kWh). The sum of the consumption of all machines represents the consumption (and thus the price) included in the price calculation of construction works (BBC).

The second group of costs of electricity consumption is based on the design and operation of the construction site equipment. These are represented by heating, lighting and water heating. To put it simply, they are directly proportional to the duration of construction work and the number of workers. Their consumption is determined by the product of the number of appliances, their output and the operating time.

The third group of electricity consumption costs, which is represented by small hand tools and information technology, can only be estimated. Implemented construction site equipment of comparable buildings shows that daily consumption can reach several kWh.

### 5.2. Calculation of electricity consumption

The construction of a multi-dwelling house was chosen for the analysis of electricity consumption (classification code CZ-CC 112216 Four- and multi-dwelling buildings - non-standard). The building has no basement, has three floors and an attic. Land area is 2,902 m<sup>2</sup> and the built-up area is 343 m<sup>2</sup>, usable area of flats is 842 m<sup>2</sup>, total usable area of apartment building is 1,095 m<sup>2</sup> and living area of flats is 447 m<sup>2</sup>.

The foundation structures are made of monolithic reinforced concrete belts and the foundation slab. Vertical structures are made of burnt brick. Some partitions are made of lightweight plasterboard. The ceiling structures are made of prefabricated reinforced concrete hollow or prestressed panels. The staircase is prefabricated from reinforced concrete. The roof construction consists of a wooden saddle truss with ceramic roofing.

The total price of the BBC is CZK 26 886 thousand excluding VAT at the 2019 price level. The ancillary budgetary costs (ABC) are set at a percentage of BBC of 2.5% and amount to CZK 672 thousand. The construction takes 12 months from the takeover of the construction site to its handover to the investor. Social and sanitary facilities are designed for a maximum of twenty workers. Table 1 shows the calculation of total electricity consumption over the construction period.

**Table. 1.** Calculation of electricity consumption on the construction site

Type of appliances	Appliance	Number	Power input. [kW]	Operation [h]	Operation [day]	Consumption [kWh]
Machines	Tower crane	1	18	160	-	2 880
	Cutter	1	14	85	-	1 190
	Mixer	1	1.5	400	-	600
	Building lift	1	5.5	70	-	385
	Welder	1	7	40	-	280
	Submersible vibrator	1	1.6	20	-	32
	Mortiser	1	2.5	10	-	25
	Compressor	1	1.5	20	-	30
	Bending machine	1	0.5	16	-	8
<b>Total machines (BBC)</b>			<b>52.1</b>			<b>5 430</b>

Interior lighting	LED source	10	0.01	4	330	132
Exterior lights	Halogen source	4	0.5	3	180	1 080
Heating containers	Heater	4	2	6	130	6 240
Water heating	Boiler	2	2.2	6	330	8 712
<b>Total lighting and heating</b>			<b>14.5</b>			<b>16 164</b>
Other appliances	Small tools	2	0.5	5	30	150
	Computing technology	1	0.05	8	330	132
	Information technology	10	0.005	6	330	99
<b>Total other appliance</b>			<b>1.1</b>			<b>381</b>
<b>Total ABC</b>			<b>15.6</b>			<b>16 545</b>
<b>Total consumption</b>						<b>21 975</b>

Source: own elaboration

Thus, the ratio between the consumption of BBC and ABC is approximately 1: 3.

The results of the economic analysis shows positive values of indicators, so from the point of view of the economic cash-flow the project it is possible to considered as efficient.

### 5.3. Valuation of electricity supply

To determine the price of electricity supply, it is necessary to first calculate the required dimension of the main circuit breaker. For its calculation it is necessary to know the value of the total apparent electricity power input. The adjusted formula [7] shall apply:

$$S = 1.1 \cdot ((0.5 \cdot P_1 + 0.8 \cdot P_2 + P_3 + P_4 + 0.8 \cdot P_5)^2 + (0.7 \cdot P_1)^2)^{\frac{1}{2}} \quad [\text{kW}] \quad (1)$$

Where:  $S$  ... apparent electricity power input [kW]

1.1 ... reserve coefficient for unforeseen power increase

0.5, 0.7, 0.8 and 1.0 ... concurrence coefficients

$P_1$  ... installed power of machines [kW]

$P_2$  ... installed power of interior lighting [kW]

$P_3$  ... installed power of exterior lighting [kW]

$P_4$  ... installed power for heating and hot water [kW]

$P_5$  ... installed power of other appliances [kW]

After substituting values from Table 1 to equation (1):

$$S = 1.1((0.5 \cdot 52.1 + 0.8 \cdot 0.1 + 2 + 12.4 + 0.8 \cdot 1.1)^2 + (0.7 \cdot 52.1)^2)^{\frac{1}{2}} \quad [\text{kW}]$$

$$S = 60.698 \quad [\text{kW}]$$

It is now possible to calculate the required dimension of the main three-phase circuit breaker according to the formula: [8]

$$I = S \cdot \left( \frac{1}{3^{\frac{1}{2}}} \cdot U \cdot \cos \varphi \right)^{-1} \quad [\text{A}] \quad (2)$$

Where:  $I$  ... electric current value [A]

$S$  ... total power input of appliances [W]

$U$  ... line-to-line voltage [V]

$\cos \varphi$  ... power factor [-]

After substituting known values to equation (2):

$$I = 60 \cdot 698 \cdot \left( \frac{1}{3^2} \cdot 400 \cdot 0.8 \right)^{-1}$$

$$I = 109.5 \text{ [A]}$$

The main three-phase circuit breaker must have the dimension closest to the highest of the series produced, i.e. 125 A.

E.ON Energie, a.s. was chosen as an electricity supplier. The construction site is one of the offtake points without significant representation of electric storage or direct-heating appliances with higher consumption. This corresponds to the distribution rate marked "C 03 d. for customers of the C category - Entrepreneurs" valid since 1 January 2019 [9]. It lists the following items and prices:

Electricity supply of CZK 1 857/MWh as a monthly payment for power input according to the main circuit breaker rated current above 3×125 A and up to 3×160 A including CZK 7 005/month, fixed monthly payment of CZK 65/month, distribution rate CZK 1 200.97/MWh, electricity tax CZK 28.30/MWh, price for system services CZK 76.19/MWh, price for market operator activity CZK 6.93/offtake point/month, price for support of electricity from supported energy sources CZK 10 890/22 MWh (calculation added).

The price for electricity supply, assuming the construction period of 12 months after all the above-listed prices have been taken into account, makes  $12 \cdot (7\,005 + 65 + 6.93) + 22 \cdot (1\,857 + 1\,200.97 + 28.30 + 76.19) + 10\,890 = 165\,387$  CZK without VAT. The price of 1 MWh after rounding is CZK 7 526. When this unit price is used, the price of electricity included in the BBC is CZK 40 866 and the price of electricity included in the ABC is CZK 124 517.

At the total price of the construction (BBC + ABC = 26 886 + 672) CZK 27 558 thousand, the price of electricity is 0.60%. The share of the price of all the electricity on the total ABC represents 24.6%. The share of electricity price contained only in ABC represents 18.6% of the total ABC.

## 6. Conclusions

It can be concluded from the numerical valuation of the electricity price on the price of used construction that the percentage share of the electricity price is very low (0.60%). It can be assumed that the average consumption during the construction itself represents approximately 1% of the construction price. It depends on the type of construction, its size and the technology used. As a part of the optimization of the electricity supply in the Czech Republic, it is possible to choose between companies with different prices of electricity supply. However, the other components of the price are regulated and are the same for all suppliers. Supply prices do not differ much among companies and lower price is usually saturated in a different way. The greatest electricity consumption on the construction site is represented by heat appliances - heaters and water heaters. Under certain conditions on the construction site it is possible to replace them with the gas ones. However, lower energy costs are compensated by higher installation costs and lower operation safety. Concerning the large machines, it is possible to consider the replacement of a stationary tower crane with a mobile crane, for example, the use of a mixer for the supply of ready semi-finished products. Such considerations must always be supported by a specific economic calculation at the project planning phase. According to statistical data, the construction industry accounts for less than 1% of the energy consumption of the entire national economy of the Czech Republic. In this respect, the hard-won savings in electricity consumption in the construction industry are negligible in relation to the whole and will only result in an increase in energy intensity in another area. Low electricity consumption in construction poses only a small threat to the sustainability of the development of human society. It is necessary to promote the principles of sustainable construction, which include the use of renewable and recyclable resources, the reduction of energy consumption and waste generation, the creation of a healthy environmentally friendly environment and the protection of the natural environment. [10]

It is possible that electricity consumption on construction sites will increase in the future, similar to what is now in transport. Internal combustion engines of construction machines will be replaced by electric motors powered by electricity from lithium batteries or hydrogen cells. [11]

The paper also broadly discusses the way of including the electricity price into the price of the construction work. The inclusion of the electricity consumption of large construction machinery, which is included in the BBC, in the construction site costs (ABC) is certainly wrong. This incorrect method can be replaced by a detailed budgeting of the installation, operation and disposal of the construction site equipment and not include the price of the BBC in it. In order to invoice electricity to the investor, it is then necessary to deduct the consumption of this large machinery from the total construction site consumption. This can be provided by ancillary consumption measurement. However, this issue is negligible and imperceptible if the price of the construction site equipment and other ancillary budgetary costs (ABC) is determined as a percentage rate. Increasing the rate by several tenths of a per cent will eventually cover the deducted electricity consumption in the BBC.

Interviewing contractors shows that most of them are aware of the theory of including the electricity price in the price of construction. However, few use it. The simpler method is usually chosen in order not to deal with the different method of budgeting and to determine the cost of the building site equipment as a percentage rate.

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