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Correlation Analysis of the Spread of Household-Sized Photovoltaic Power Plants and Various District Indicators: A Case Study

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Abstract: As efforts are made worldwide to meet the growing energy needs of the population in a more sustainable way, harnessing weather-dependent renewable energy sources is becoming more and more important. One of the available technologies is photovoltaic energy production. In the last decade, there has been a growing need among households, institutions, and businesses to reduce the use of fossil-fuel-based electricity from the public grid. In order to meet their electricity demand in Hungary, investors prefer using household-sized photovoltaic power plant (HMKE) systems. The novelty of this study is that it examines the number and total power of photovoltaic HMKEs at the district level in the service areas of different electricity distributors, taking into account the social, economic, infrastructural, and welfare dimensions of these districts as well. The study seeks to uncover whether there is a correlation between the number and total power of these types of power plants and the indicators of the districts, and if so, how strong these relationships are. The examination of the relationships also involved, in addition to correlations by pairs, the relationships of the ranking of the districts according to the complex indicators created from the district indicators and the ranking of the districts based on the number and power of photovoltaic HMKEs per 1000 members of the population. By exploring correlations, the paper seeks to establish a regression model for the number of photovoltaic HMKEs and the territorial (district) indicators.

Keywords: economic and infrastructural indicators of the districts; Hungary; photovoltaic system; small-scale power plant; solar energy

1. Introduction

1.1. The Global Aspects of Photovoltaic Technology

In the last decade, climate change has posed a significant challenge to countries around the world. One solution to the problems that arise is the use of renewable energy sources: By 2017, more than 150 countries had committed themselves to using alternative energy sources. This will automatically lead to the gradual expansion of the utilization of renewable energy sources worldwide. It is estimated that renewable energy sources (RESs) will provide 60% of total energy consumption by 2050 [1] and more than 60% of the newly installed global electricity capacity by 2040 [2,3]. All this shows that while more and more countries are facing the negative, harmful effects of climate change, its mitigation has become a global goal. Today, the question is no longer whether we need to take action to reduce the problem, but what measures have to be taken. At the global level, the goal is to limit the temperature rise to less than 2 °C above pre-industrial temperatures, which means that humankind must aim at a maximum increase of 1.5 °C to attain that [4].

The above objective can be achieved by developing energy systems aimed at reducing the greenhouse effect, in which weather-dependent renewable energy sources (VREs) also play an increasing role. Thanks to the rapidly evolving technology, more and more solutions that use solar energy as an alternative energy source with ever-increasing efficiency are being developed [5]. A significant proportion of the world's population lives in cities, so it is an important result that many cities around the world have launched their own solar energy programs for the purpose of protecting the environment and promoting sustainable development. Solar energy is gaining ground, on the one hand, because it is essential for many processes in nature, and on the other hand, because it is a clean, abundant, sustainable, and—most importantly—universally available resource [6–14]. What is more, the amount of solar energy reaching the surface of our planet is thousands of times greater than the current energy need of the population [15–17]. Thanks to all this, recently, an expansion of solar systems (photovoltaic (PV)) can be observed: Their total capacity worldwide was already about 627 GW by the end of 2019, which played a key role in the global efforts for sustainability, green growth, and a higher share of low-carbon economy. Over the last decade, the support schemes (e.g., the Feed-in-Tariff system), on the one hand, and a decline in initial capital expenditures due to the boom in innovation and technology, on the other hand, have had a positive impact on the spread of solar systems [18]. Examining the map of the global annual PV power generation potential, it can be concluded that the annual amount of PV energy that can be produced varies, on average, between 700 and 2400 kWh/kWp by geographical location (Figure 1). In the case of Hungary, values vary between 1050 and 1250 kWh/kWp (Figure 1) [19].

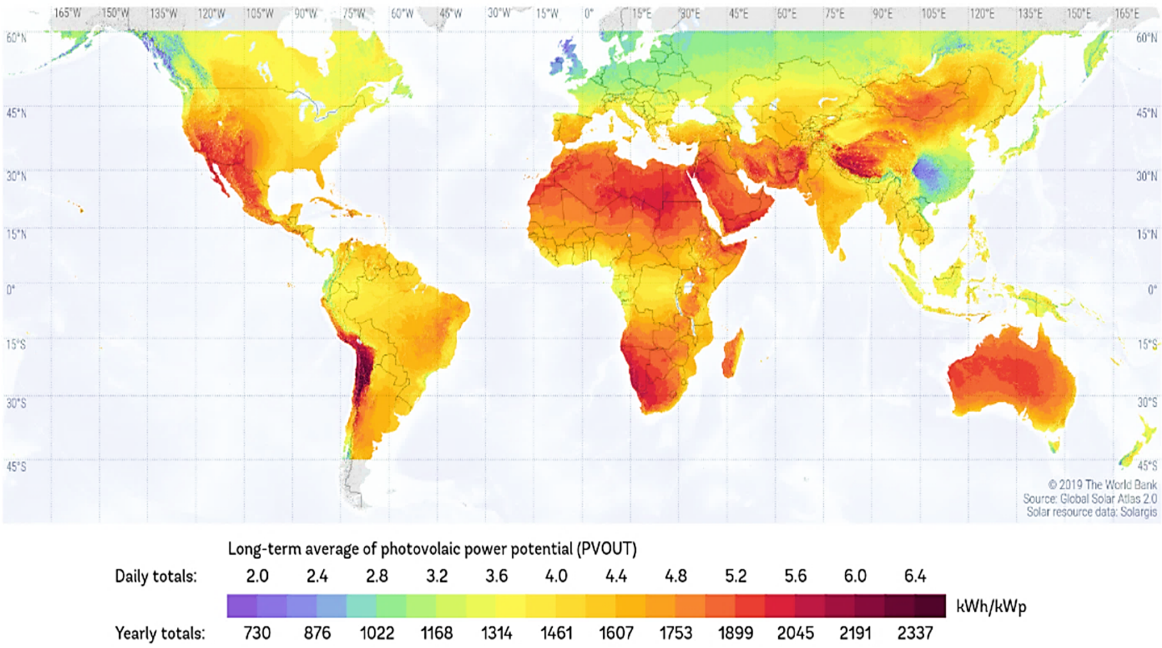

Figure 1. The photovoltaic power potential—world [19].

In Hungary, according to data from the last three years, the total installed PV capacity was approximately 0.3 GWp, 0.7 GWp, and 1.3 GWp in 2017, 2018, and at the end of December 2019, respectively, representing a growth of over 400%, mainly due to legislative amendments [20,21]. In the long term, the spread of PV systems is expected to increase significantly in Hungary as well: The Hungarian transmission system operator has prepared three different scenarios, based on which the PV capacity is projected to reach 2.5–6.7 GWp in 2030 and 4.3–12 GWp in 2040 [22–24].

1.2. The Regulatory Environment of Photovoltaic Technology in Hungary—Overview

In the last decade, green-energy-related subsidies have become more and more widespread around the world. However, the regulatory environment varies considerably from country to country. This problem is further compounded by the fact that, with the spread of weather-dependent technology, support systems change in every country year by year [25]. Hungary is no exception; the Renewable Energy Support Scheme (METÁR) was established on the 1st of January 2017, aiming to support electricity production from renewable energy sources. Under the METÁR scheme, only those renewable energy generation investments are eligible for support that have not yet started at the time of the application. The contracting and coordinating authority is the Hungarian Energy and Public Utility Regulatory Authority (MEKH), and the first call for tenders was published in September 2019. The majority of the applications were related to PV technology [26]. Another feature of the regulatory environment is that mixed-fuel and waste incineration plants can only receive support for the proportion of the use of renewable energy sources. It is important to note, however, that household-sized photovoltaic power plant (HMKE) schemes are not eligible for support in this form. Under the METÁR system, one of the conditions is that the applicant must be entitled for green-premium-type support during the application process. Under the premium-type scheme, the electricity producer sells electricity to the Hungarian Transmission System Operator (MAVIR) and receives support as a paid premium over the market reference price, provided that it undertakes to bear the costs of deviating from the 15-min scheduling.

One of the domestic instruments for encouraging energy production from renewable energy sources and waste in Hungary is the Hungarian scheme for supporting green energy from renewable energy sources (KÁT). Under the KÁT scheme, electricity can be sold at a price specified by law, which is currently higher than the market price. By determining the amount of electricity that can be fed into the grid and the duration of the subsidized period, the KÁT system guarantees that electricity producers can receive support up to an amount equal to a full return on their investments. If more support is given to a power plant, the subsidized period decreases proportionally. As a result of some legislative changes, entitlement to KÁT support can no longer be awarded for applications submitted after 1 January 2017 [26].

In Hungary, in addition to the METÁR and KÁT schemes, the HMKE system is becoming more and more popular among electricity producers: According to official data in the last quarter of 2019, a total of 4644 HMKEs were newly connected to the grid, with a total installed power of 36.58 MW. A total of 99.5% of the installed HMKEs were PV systems. The average installed power of the new solar HMKEs was 7.88 kWp during the indicated period (Figure 2) [27].

The connection power of an HMKE system at one connection point does not exceed 50 kVA. Users of HMKEs, regardless whether they are individuals, institutions, or businesses, have the opportunity to use the system to reduce the amount of electricity they receive from the public grid. The most important contributing factors to the spread of HMKEs are, first, that electricity producers are not required to keep the 15-min scheduling, and, secondly, that the basis of the settlement of accounts is the difference between the amount of energy received from the public grid and the amount fed into the network [26].

In Hungary, the spread of HMKEs is of great importance in terms of both environmental and economic policy, and this is exactly why it is necessary to examine which economic, social, and infrastructural district indicators influence it. The appropriate design of regional energy strategies and energy policies in the case of the less-developed regions requires the identification of those district indicators whose improvement could result in positive changes.

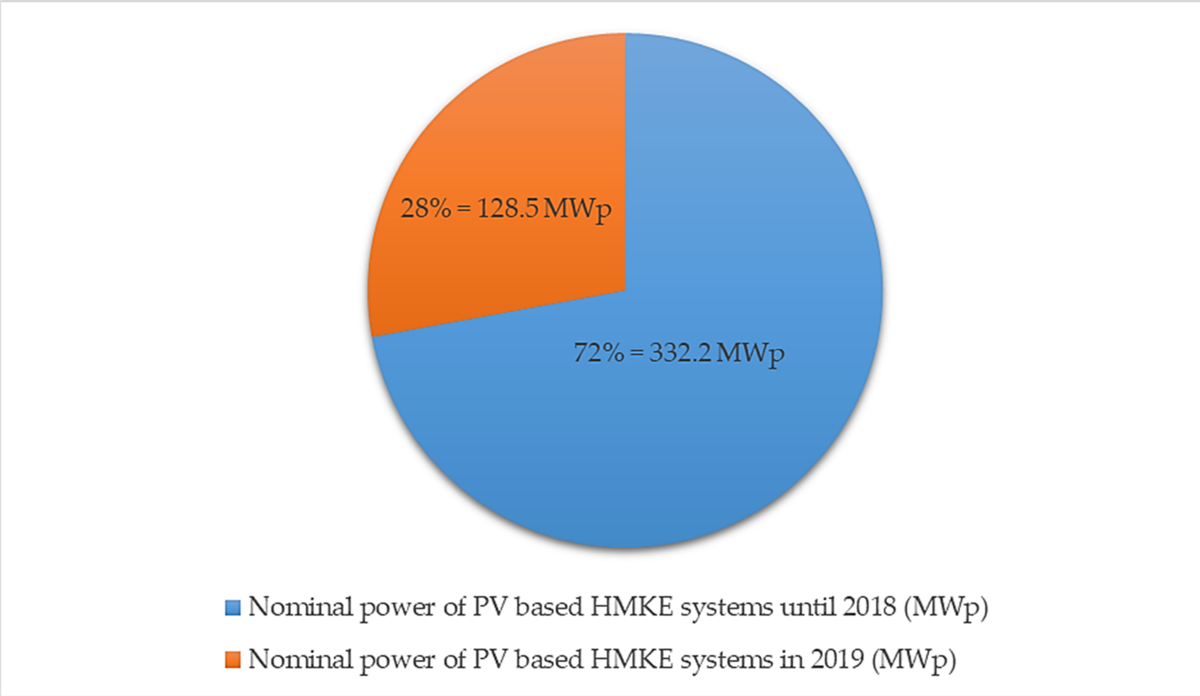

Figure 2. The total installed photovoltaic (PV) power of the Hungarian household-sized photovoltaic power plant (HMKE) systems [27].

1.3. The Evolution of the Methodology for Territorial Development Indicators in Hungary

In our research, we sought to prove our hypothesis that the development-related and other indicators of Hungarian districts have an effect on the number of HMKEs. To do this, it was first necessary to compile a database containing economic, social, and infrastructural indicators of the districts in Hungary. Such indicators were first developed and applied in regional development surveys in Hungary in the mid-1980s (by the National Planning Office in 1985 and the Ministry of Environment and Regional Development between 1988 and 1995). In 1993, the methodological definition of the development of regions and the classification of their underdevelopment was given a legal framework when the first legislation was passed (Resolution of the National Assembly No. 84/1993 (XI. 11.) [28]). However, this was only the first step; since then, both the set of indicators and the methodology have been constantly changing and evolving, along with the development of the regions.

Currently, two government decrees are in force: Government Decree 290/2014 (XI. 26.) on the classification of beneficiary districts [29] and Government Decree 105/2015 (IV. 23.) on the classification of beneficiary districts and classification conditions [30].

Experts dealing with regional development research pointed out the importance of reliable and accurate data at the regional level and drew attention to the fact that the development of an area and the trends behind it need to be examined from several aspects in order to get a complete picture. To that end, it is essential to apply a wide range of district indicators [31,32]. When analyzing data, researchers should remember that the publication of regional data takes a long time, and a delay of as much as 1–2 years may occur.

This study is unique in the sense that, in Hungary, no earlier research has been done to analyze the relationships between the penetration of HMKEs and the district indicators. Nevertheless, creating well-grounded energy strategies at the level of the national economy as well as that of the districts requires not only the analysis of factual data, but also the reasons behind them. This necessitates, above all, suitable databases.

The research was based on (i) indicators of the districts of Hungary (Central Statistical Office (KSH) [33] and the database of the National Regional Development and Spatial Planning Information System (TEIR; [34])) and (ii) the HMKE databases received from electricity suppliers, such as ELMŰ-ÉMÁSZ Zrt. (ELMŰ-ÉMÁSZ), E.on Hungária Zrt. (EON), and NKM Energy Zrt. (NKM). The analyses were performed by using mathematical–statistical methods and regional analysis tools for the year 2019. Our hypotheses were as follows:

- Each of the indicators of the districts is suitable for detecting relationships regarding the number and power of PV HMKEs.
- The ranking of the districts according to the complex indicators created from the district indicators correlates with the ranking of the districts based of the number and power of PV HMKEs/1000 people in Hungary.
- It is possible to create a regression model with the help of which the quantity of PV HMKEs in the districts can be determined.

2. Material and Methods

2.1. Methods

As part of a correlation and regression analysis, one examines the relationship between two quantitative criteria, where one criterion is considered an independent explanatory variable and the other one is a dependent outcome variable [35]. Pearson's correlation (parametric) can be used for criteria measured on a ratio scale, and Spearman's (nonparametric) correlation can be used for variables measured on an ordinal scale. The first step in the relationship test is to create a scatterplot in order to draw conclusions for the strength and direction of the relationship from the arrangement of the points in the diagram. If one wants to quantify the strength of the correlation, the value of the correlation coefficient (r) for linear relationships and that of the correlation index (I) for non-linear relationships have to be determined. When interpreting the obtained results, it should be borne in mind that the correlation coefficient can be between -1 and 1, and the closer the absolute value of r is to 1, the stronger the correlation is. If $|r|$ equals 1, it indicates a functional relationship; if it is 0, it signals independence [36]. If the indicator is between 0 and 0.2, there is a weak relationship; if it is greater than 0.2 and lower than or equal to 0.7, it is a moderately strong relationship; and if it is above 0.7, then there is a very strong relationship between the criteria. Additional information can be obtained by observing not only the magnitude, but also the sign of the indicator, because if r is a positive number, the relationship has a positive direction; otherwise the direction of the relationship is negative. However, it is important to know that a correlation can only be talked about in the case of a significant result ($p < 0.05$). In addition to the correlation coefficient, we can determine its square, the coefficient of determination, which shows the percentage of the differentiation of the dependent variable that is explained by the independent variable [37].

It may be the case that although the correlation coefficient shows that there is a correlation between the criteria, this correlation is not caused by their interaction, but by a background variable, so after the correlation coefficient has been determined, it is worth determining the partial correlation coefficient when the indicator shows a significant moderately strong or stronger relationship. The difference between a partial correlation coefficient and a pairwise coefficient is that the partial correlation coefficient eliminates the effect of the controlled variable. The relationship between a selected independent variable and the dependent variable is strong if the effects of all other independent variables are filtered out from both the examined factor variable and the outcome variable. The partial correlation coefficient has a positive sign for a positive correlation and a negative sign for a negative correlation, with an absolute value between 0 and 1. The indicator is not interpreted per se, but its value is compared to the correlation coefficient. If the controlled variable has no effect, then the two correlation coefficients are the same, but if the partial correlation coefficient is 0, then there is an apparent relationship between the controlled variable and the original variable. The square of the partial correlation coefficient can also be determined; this will be the partial coefficient of determination. The partial coefficient of determination seeks the answer to what proportion can be explained by the explanatory variable *Xj* of such proportion of the scatter of the dependent variable *Y* that cannot be explained by the variables *X*1, *X*2, . . . , *Xp* [38].

In addition to demonstrating the effect of an independent variable (district indicator), creating a complex indicator (hereinafter, CI) allows the quantification of differences between districts. As the regional economic and infrastructure indicators are defined in different measurement units, the complex indicator is developed only after a normalization procedure involving transformation to a scale of the same range based on the following formula (Government Decree 290/2014 (XI.26.) [29], Government Decree 105/2015 (IV. 23.) [30] (see Equation (1)):

$$\mathrm{fa}_{\mathrm{i,j\ norm}} = \frac{\mathrm{fa}_{\mathrm{i,j}} - \min(\mathrm{fa}_{\mathrm{i,j}})}{\max(\mathrm{fa}_{\mathrm{i,j}}) - \min(\mathrm{fa}_{\mathrm{i,j}})} \times 100 \quad (1)$$

where $\mathrm{fa}_{\mathrm{i,j}}$ is the normalized basic indicator, $\min(\mathrm{fa}_{\mathrm{i,j}})$ is the minimum value of the basic indicator, and $\max(\mathrm{fa}_{\mathrm{i,j}})$ is the maximum value of the basic indicator.

The complex indicators are obtained by taking the average of the normalized indicators, which form the basis of the ranking of districts, by assigning the ranking of 1 to the district with the highest complex indicator. Districts are also ranked according to the individual HMKE indicators; here, again, the ranking of 1 is assigned to the district with the highest value. After that, the relationship can be explored with the help of rank correlation, where the first step of the process is assigning a ranking from 1 to n to the districts based on district indicators and based on the prevalence of HMKEs. By determining Spearman's rank correlation coefficient (ρ) as part of the method, the extent to which the ranking numbers of the variables of the same observation units are identical is examined. The value of the indicator is between −1 and 1; if it is 0, then there is no relationship between the criteria. If the value is close to 1, the two orders can be considered the same; a value close to −1 indicates that the two orders are inverse; the closer it is to 1, the stronger the relationship is [38].

The regression calculation describes the stochastic relationship between quantitative criteria in the form of a function. Using multivariate regression analysis, one can examine the effect of several criteria on the outcome variable. The relationship can be linear or nonlinear, depending on the type of function.

If the nonlinear relationship between the outcome variable and the explanatory variables is exponential, it can be described by the following formula (see Equation (2)):

$$Y = \beta_0 \times x_i^{\beta i} \times \ldots\ x_n^{\beta n}. \quad (2)$$

If the relationship between the outcome variable and the explanatory variables is linear, it can be represented by the following formula (see Equation (3)):

$$Y = \beta_0 + x_1\beta_1 + \ldots\ x_n\beta_n, \quad (3)$$

where x_1 to x_n are independent variables, Y is the dependent variable, β_1 is the regression coefficient of variable x_1, and β_n is the regression coefficient of variable x_n.

It was a goal of this research to produce an optimal model that includes the variables that have a significant effect on the dependent variable, and to do this, the model was significantly improved by including further variables. Step-by-step regression techniques provided a solution for this. There are basically three types of stepwise regression techniques [39]: forward selection, backward elimination, and stepwise regression. Each method is based on examining the possible variables one by one and deciding individually whether the particular variable is needed in the model. To determine whether the incorporation of a variable into the model brings a significant improvement compared to the situation one step before, an F-test is used. Furthermore, the significance of the coefficient of the variable to be incorporated is tested by a *t*-test.

The forward selection procedure examines the possible explanatory variables one by one, and thus, one can decide whether to include them or not. Backward selection is just the opposite. At the beginning of the study, all possible independent variables are included in the model, and then in each iteration step, the variables that have the least effect on the dependent variable are left out. The stepwise method is a combination of the above two methods. In each iteration step, a new variable is included so as to cause a significant improvement in the model, and then, it is examined whether one of the variables already included can be omitted to avoid statistically measurable deterioration in the adequacy of the model [37]. Of the procedures above, the stepwise method was used in the examinations herein.

2.2. Material

In Hungary, from the point of view of regional development, the delimitation of beneficiary areas is regulated by government decrees. Beneficiary districts are regulated in Government Decree 290/2014 (XI.26.), which entered into force on 1 January 2015 [29]. The classification of districts is based on their territorial development, which is measured by a complex indicator formed based on social, demographic, housing (and living conditions), local economic, labor market, infrastructural, and environmental indicators. The beneficiaries, i.e., the districts that are to be developed with or without a complex program, are determined based on these complex indicators. The classification of beneficiary districts and the system of conditions for classification is regulated by Government Decree 105/2015 (IV. 23.), which entered into force on 1 January 2017 [30]. This study was based on these two government decrees, and the formula used for calculating the complex indicator is found in their appendixes. For the purposes of regression calculation, some selected district indicators were examined, as listed in Table 1. In addition, the research was extended to economic and infrastructural indicators that may play an important role in the spread of HMKEs in Hungary (Table 2). Examining the indicators in Table 2, two important questions can be answered. The first is the question of how strong the correlation is between these district indicators and the number and total power of HMKEs; and secondly, how strong the relationship is between the ranking of districts based on these indicators and their ranking based on the number and total power of HMKEs. To compile the indicators for the districts, we used the Regional Statistics of the Information Database of the Central Statistics Office (KSH) [33] and the database of the National Spatial Development and Spatial Planning Information System (TeIR) [34]. For the study, we used the indicators for 2018 (due to the time lag in the spatial data, data for 2018 are the most recent; Tables 1 and 2).

The photovoltaic HMKE database was created based on the 2019 data of three Hungarian electricity suppliers (ELMŰ-ÉMÁSZ, EON, and NKM). In 2019, the regions of the electricity suppliers were redesigned; the database used herein already corresponds to the new division, which is illustrated in Figure 3. Experience shows that in the case of territorial indicators, there is no significant change from one year to the next, unless there is a significant economic or social crisis. Between 2018 and 2019, the aforementioned change did not occur, which allowed the use of the latest (2018) data in the case of the district indicators in the studies and their comparison with the latest 2019 HMKE data.

The Nomenclature of Territorial Units for Statistics (NUTS) system was set up for statistical purposes to identify the administrative units of EU Member States. In Hungary, large regions belong to the NUTS 1, regions belong to the NUTS 2, and counties to the NUTS 3 level. Until 2016 the NUTS system was complemented with two levels of Local Administrative Units (LAUs), which were used to identify additional local administrative units. LAU 1 included districts and LAU 2 included municipalities. A Hungarian district, járás in Hungarian, is a local administrative unit that comprises a group of municipalities within a given county. The tasks of the district offices, their competences, administrative bodies, and professional management, as well as their registered seats and their areas of competence, are regulated by Government Decree 218/2012 (VIII. 13) [40]. This provides the legal basis for a total of 198 districts; 23 of these districts are located in the capital (in a territorial division corresponding to the metropolitan districts of the city of Budapest). This research focused only on rural areas, and the capital's metropolitan districts were not included in the present study.

Table 1. Economic, infrastructural, social, and employment indicators used in the regression calculation.

x_1	Mortality rate, per mille (average of the last 5 years)	x_8	Proportion of registered jobseekers in the population, %
x_2	Number of places available in nurseries per 10,000 permanent residents aged 0–2, pcs	x_9	Proportion of registered long-term job-seekers in the population, %
x_3	Number of recipients of regular child protection benefits in the population aged 0–29	x_{10}	Number of operating enterprises per 1000 population, pcs
x_4	Number of recipients of employment replacement subsidy per 1000 population	x_{11}	The proportion of the current yearxs total municipal revenue from local taxes, %
x_5	Number of recipients of subsidies from active labor market policy instruments per 1000 population (individuals)	x_{12}	The proportion of homes connected to the public sewer network, %
x_6	Proportion of the total number of homes at the end of the period built in the last five years, %	x_{13}	Proportion of public streets/roads maintained by the municipalities that is paved, %
x_7	Number of cars per 1000 population, pcs		

Table 2. Economic and infrastructure indicators used in regression and correlation analyses.

x_{14}	Number of registered economic entities per 1000 population (Pcs)
x_{15}	Number of registered businesses per 1000 population (pcs)
x_{16}	Total budget revenues of local governments per 1000 population (HUF 1000)
x_{17}	Total budget expenditures of local governments per 1000 population (HUF 1000)
x_{18}	Number of household electricity consumers per 1000 population (pcs)
x_{19}	Amount of electric energy provided for households per 1000 population (1000 kWh)
x_{20}	Number of electricity consumers per 1000 population (pcs)
x_{21}	Amount of total electric energy provided per 1000 population (1000 kWh)
x_{22}	Length of low-voltage electricity distribution network per 1000 population (km)
x_{23}	Number of operating places of commercial accommodation (hotels, pensions, campsites, rental holiday homes, communal accommodation) units per 1000 population (pcs)
x_{24}	Number of catering units per 1000 population (pcs)

Based on data of differing levels of detail from the electricity suppliers, the investigation was divided into two parts:

1. ELMŰ-ÉMÁSZ, EON (146 districts):
    - Total power of all HMKEs per 1000 population (kW),
    - Total power of residential HMKEs per 1000 population (kW),
    - Total power of business-owned HMKEs per 1000 population (kW),
    - Total number of HMKEs per 1000 population (pcs),
    - Total number of residential HMKEs per 1000 population (pcs),
    - Total number of business-owned HMKEs per 1000 population (pcs).
2. ELMŰ-ÉMÁSZ, EON, NKM (168 districts):
    - Total number of HMKEs per 1000 population (pcs).

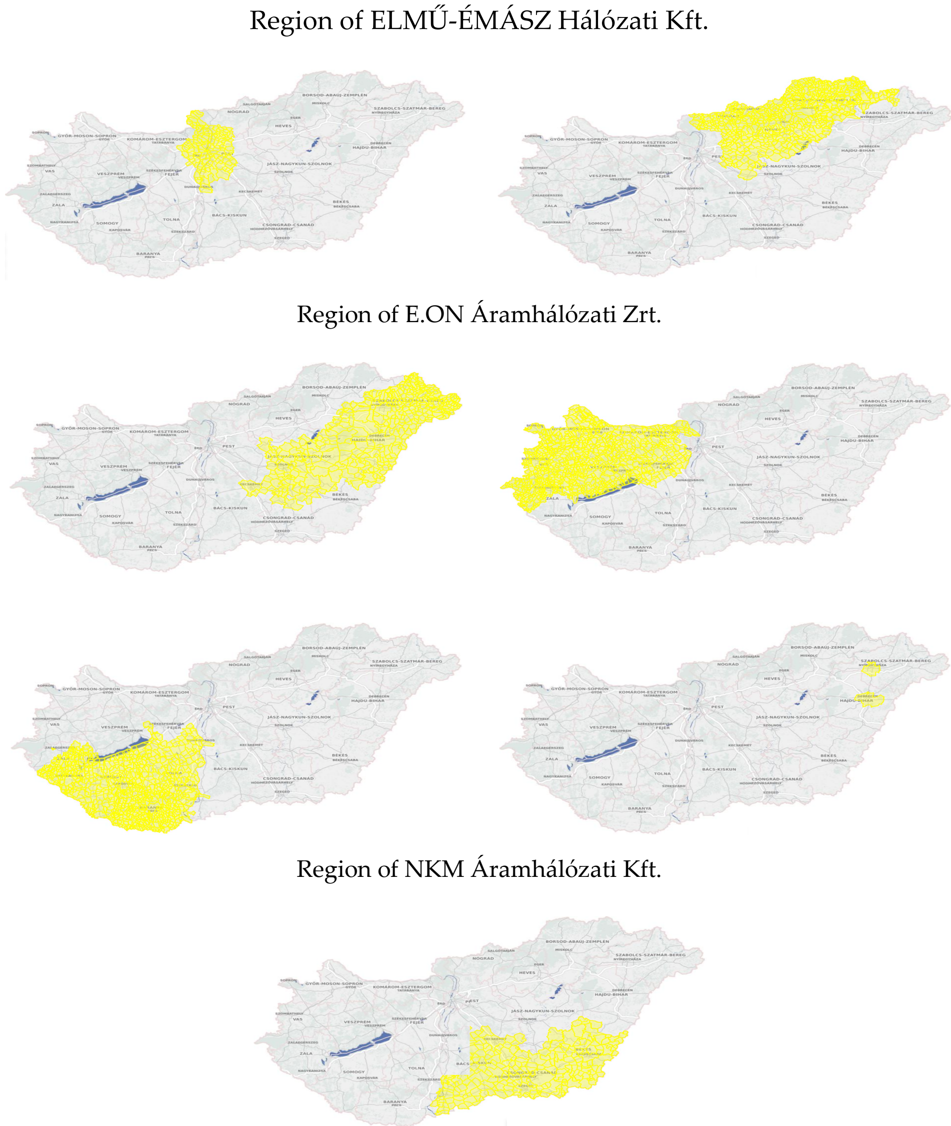

Figure 3. The service regions of the Hungarian electricity suppliers based on [41].

3. Results and Discussion of the Analysis of the Relationship between the Number and Total Power of HMKEs and the Development of the Districts

First and foremost, the present research was aimed at answering the question of whether the number and total power of HMKEs in the various districts of Hungary correlate with the districts' economic and infrastructural dimensions, and if so, how strong the relationships are.

First, the analyses were focused on the 168 districts where there are HMKEs and electricity is supplied by ELMŰ-ÉMÁSZ, EON, or NKM.

The regression function describing the relationship between the 13 social, economic, infrastructural, and welfare indicators of the districts (Table 1) and the total number of HMKEs per 1000 population was as follows (see Equation (4)):

$$Y = \beta_0 \times x_6^{\beta 6} \times x_{13}^{\beta 13} = 1.586 \times x_6^{0.261} \times x_{13}^{0.217} \quad (4)$$

where x_6 is the proportion of the total number of homes at the end of the period built in the last five years in %; x_{13} is the proportion of public streets/roads maintained by the municipalities that are paved in %. It was found that both the exponential regression model and the parameters were significant (p = 0.000), and based on the value of R (0.578), there is a moderately strong correlation between the two parameters (the proportion of the total number of homes at the end of the period built in the last five years, and the proportion of public streets/roads maintained by the municipalities that is paved) and the number of HMKEs per 1000 population; these two indicators can explain the differentiation of the district-level volumes of HMKEs to a degree of 33%.

Continuing the examinations, the effects of that group of district indicators (Table 2) that do not belong to the indicators signaling the level of development of the districts according to the government decree, yet may affect the total number of HMKEs per 1000 population, were analyzed. The linear regression function was the following (see Equation (5)):

$$Y = \beta_0 + \beta_{20}x_{20} + \beta_{17}x_{17} = -4.212 + 0.013x_{20} + 0.0000098x_{17} \tag{5}$$

where x_{20} is the number of electricity consumers per 1000 population in pcs; x_{17} is the total budgetary expenditure of the municipalities per 1000 population in HUF 1000. It was established that both the regression model and the parameters were significant (p = 0.000), and based on the value of R (0.556), there was a moderately strong correlation between the explanatory variables of the model and the number of HMKEs per 1000 population, and the indicators explain the differentiation of the district-level volumes of HMKEs to a degree of 31%.

Regarding the districts, it was found that among the districts' indicators in the examined period, there was a positive weak–moderate relationship between the total budget expenditures of local governments per 1000 population, the amount of electricity supplied to households per 1000 population, and the number of HMKEs per 1000 population. There was a stronger but still moderate correlation between the number of household electricity consumers per 1000 population, the total number of electricity consumers per 1000 population, the number of operating commercial accommodation units per 1000 population, and the number of HMKEs per 1000 population (Table 3). The partial correlation coefficients show that, in most cases, the controlled variable has some effect on the strength of the correlation; however, this effect does not significantly modify the relationship.

The ranking of the districts based on the complex indicator developed from district indicators and the ranking based on the number of HMKEs per 1000 population show a weak–moderate relationship in the positive direction (ρ = 0.295, p = 0.000). The relationship is still moderate, although stronger than previously (ρ = 0.393, p = 0.000) if only those district indicators are used for establishing the district ranking of which each indicator separately moderately correlates with the number of HMKEs per 1000 population.

In the next stage of the project, the 146 districts where ELMŰ-ÉMÁSZ and EON operate as electricity suppliers were analyzed. In these districts, not only the number of HMKEs, but also the total power of the HMKEs could be analyzed both in terms of the household and business consumers.

It was found that, of all the indicators for the districts, a moderate positive relationship was shown in the examined period between the total budgetary expenditures of local governments per 1000 population, the length of the low-voltage electricity distribution network per 1000 population, and the total number and power of HMKEs per 1000 population. There is also a weak positive correlation between the number of registered economic organizations per 1000 population, the number of registered enterprises per 1000 population, and the total number of HMKEs per 1000 population, as well as the total budget revenues of local governments per 1000 population, the amount of electricity supplied to households per 1000 population, the number of operating commercial accommodation units per 1000 population, and the total power of all HMKEs per 1000 population. There is a stronger but still moderate relationship between the number of household electricity consumers per 1000 population, the number of electricity consumers per 1000 population, and the number and total power of all HMKEs per 1000 population. The correlation between the total number of HMKEs per 1000 population and the amount of electricity supplied to households per 1000 population, as well as the number of operating commercial accommodation units per 1000 population, is also moderately positive. The number of registered economic organizations per 1000 population, the number of registered enterprises per 1000 population, and the power of all HMKEs per 1000 population are also moderately closely correlated (Tables 4 and 5). The partial correlation coefficients show that, although the controlled variable has some effect on the strength of the correlation in most cases, this effect does not significantly modify the relationship.

The ranking of the districts established on the basis of the complex indicator developed from district indicators and the ranking based on the number* and total power ** of HMKEs per 1000 population show a moderate positive and a weak to moderate relationship, respectively (* $\rho = 0.442$, $p = 0.000$; ** $\rho = 0.369$, $p = 0.000$). The relationship is still moderate, but stronger than previously (*** $\rho = 0.502$, $p = 0.000$; **** $\rho = 0.488$, $p = 0.000$), when only those district indicators are used for establishing the district ranking that are separately moderately correlated with the number *** and total power **** of HMKEs per 1000 population.

There is a weak to moderate correlation between the number and total power of residential HMKEs per 1000 population and the length of the low-voltage electricity distribution network per 1000 population, the number of registered economic entities per 1000 population, the number of registered enterprises per 1000 population, and the number of operating commercial accommodation units per 1000 population. A stronger but still moderately positive correlation was found between the number and total power of residential HMKEs per 1000 population and the number of household electricity consumers per 1000 population, the amount of electricity supplied to households per 1000 population, and the number of electricity consumers per 1000 population (Appendix A, Tables A1 and A2). The partial correlation coefficients show that, in most cases, although the controlled variable has some effect on the strength of the correlation, this effect does not significantly modify the relationship.

The ranking of districts based on the complex indicator developed from district indicators and the ranking of districts based on the number * and total power ** of residential HMKEs per 1000 population show a weak positive relationship (* $\rho = 0.387$, $p = 0.000$; ** $\rho = 0.362$, $p = 0.000$). The correlation is still moderate, though stronger than previously (*** $\rho = 0.438$, $p = 0.000$; **** $\rho = 0.430$, $p = 0.000$), if only those district indicators are used for establishing the ranking of the districts that are separately moderately correlated with the number *** and power **** of residential HMKEs per 1000 population.

A weak moderate correlation in the positive direction was found between the number and total power of business-owned HMKEs per 1000 population and the length of the low-voltage electricity distribution network per 1000 population, the number of registered economic entities per 1000 population, and the number of registered enterprises per 1000 population. A similar correlation in strength and direction was found between the number of business-owned HMKEs per 1000 population and the amount of electricity supplied to households per 1000 population, as well as the operating commercial accommodation units per 1000 population. A weak to moderate correlation was found between the total budget revenues of local governments per 1000 population, the total budget expenditures of local governments per 1000 population, and the total power of business-owned HMKEs per 1000 population; and a stronger relationship, a moderately strong correlation, was found between the volume of business-owned HMKEs per 1000 population and local government revenues and expenditures (Appendix A, Tables A3 and A4). The partial correlation coefficients show that, although the controlled variable has some effect on the strength of the correlation in most cases, this effect does not significantly modify the relationship.

Table 3. The strength of the relationship between the total number of HMKEs per 1000 population and district indicators (Pearson's correlation coefficient/p value; if $p < 0.05$, then there is a significantly confirmed relationship between the two variables). (In the table, for the correlation coefficient, a white background refers to a non-significant relationship, a gray background refers to a weak relationship, a yellow background refers to a weak–moderate relationship, and a purple background refers to a moderately strong relationship. For partial correlation, a white background refers to an insignificant relationship, a red background to a partially distorted relationship, a blue background to a partial explanation (the controlled variable only partially explains the relationship between variables i and j), and a black background refers to an irrelevant comparison).

Description	Correlation Coefficient	Partial Correlation Coefficient				
	Number HMKEs Per 1000 Population (Pcs) ELMŰ-ÉMÁSZ, EON, NKM	Total Budget Expenditures of Local Governments Per 1000 Population (HUF 1000)	Number of Household Electricity Consumers Per 1000 Population (Pcs)	Amount of Electricity Supplied to Households Per 1000 Population (1000 kWh)	Number of Electricity Consumers Per 1000 Population (Pcs)	Number of Commercial Accommodation Units Per 1000 Population (Pcs)
Total budget revenues of local governments per 1000 population (HUF 1000)	0.190/0.014	0.184/0.018	0.448/0.000	0.390/0.000	0.476/0.000	0.416/0.000
Total budget expenditures of local governments per 1000 population (HUF 1000)	0.257/0.001		0.465/0.000	0.406/0.000	0.490/0.000	0.404/0.000
Number of household electricity consumers per 1000 population (pcs)	0.468/0.000	0.250/0.001		0.110/0.157	0.276/0.000	0.191/0.013
Amount of electricity supplied to households per 1000 population (1000 kWh)	0.333/0.000	0.349/0.000	0.363/0.000		0.400/0.000	0.372/0.000
Number of electricity consumers per 1000 population (pcs)	0.496/0.000	0.240/0.002	0.206/0.008	0.093/.0.231		0.150/0.052
Total amount of electricity supplied per 1000 population (1000 kWh)	0.068/0.383	0.254/0.001	0.464/0.000	0.332/0.000	0.493/0.000	0.446/0.000
Length of low voltage electricity distribution network per 1000 population (km)	0.059/0.444	0.253/0.001	0.505/0.000	0.362/0.000	0.532/0.000	0.445/0.000.
Number of registered enterprises per 1000 population (pcs)	0.139/0.073	0.246/0.001	0.451/0.000	0.306/0.000	0.481/0.000	0.428/0.000
Number of registered economic organizations per 1000 population (pcs)	0.168/0.029	0.240/0.002	0.443/0.000	0.296/0.000	0.474/0.000	0.421/0.000
Number of commercial accommodation units per 1000 population (pcs)	0.444/0.000	0.163/0.035	0.250/0.000	0.215/0.005	0.288/0.000	

Table 4. The strength of the relationship between the total number of HMKEs per 1000 population and the district indicators (Pearson's correlation coefficient/p value; if $p < 0.05$, then there is a significantly confirmed relationship between the two variables). In the table, for the correlation coefficient, a white background refers to a non-significant relationship, a yellow background to a weak–moderate relationship, and a purple background to a moderately strong relationship. For the partial correlation, a white background refers to a non-significant relationship, a red background refers to a partially distorted relationship, a green background is used where the background variable did not modify the strength of the correlation, a blue background refers to a partial explanation (the controlled variable only partially explains the relationship between variables i and j), and a black background refers to an irrelevant comparison.

Description	Correlation Coefficient	Partial Correlation Coefficient							
	Number of HMKEs Per 1000 Population (Pcs) ELMŰ-ÉMÁSZ, EON	Total Budget Expenditure of Local Governments Per 1000 Population (HUF 1000)	Number of Household Electricity Consumers Per 1000 Population (Pcs)	Amount of Electricity Supplied to Households Per 1000 Population (1000 kWh)	Number of Electricity Consumers Per 1000 Population (Pcs)	Length of Low-Voltage Electricity Distribution Network Per 1000 Population (Km)	Number of Registered Enterprises Per 1000 Population (Pcs)	Number of Registered Economic Or-ganizations Per 1000 Population (Pcs)	Number of Operational Commercial Accommoda-Tion Units Per 1000 (Pcs)
Total budget revenues of local governments per 1000 population (HUF 1000)	0.1770./033	0.150/0.210	0.527/0.000	0.558/0.000	0.539/0.000	0.363/0.000	0.316/0.000	0.335/0.000	0.378/0.000
Total budget expenditure of local governments per 1000 population (HUF 1000)	0.205/0.013		0.537/0.000	0.572/0.000	0.547/0.000	0.366/0.000	0.306/0.000	0.326/0.000	0.375/0.000
Number of household electricity consumers per 1000 population (pcs)	0.543/0.000	0.181/0.029		0.269/0.001	0.157/0.000	0.007/0.938	0.215/0.010	0.221/0.008	0.027/0.0746
Amount of electricity supplied to households per 1000 population (1000 kWh)	0.496/0.000	0.381/0.000	0.364/0.000		0.379/0.000	0.218/0.008	0.241/0.004	0.266/0.001	0.248/0.003
Number of electricity consumers per 1000 population (pcs)	0.556/0.000	0.168/0.043	0.071/0.395	0.258/0.002		0.009/0.910	0.208/0.012	0.211/0.011	0.002/0.980
The amount of total electricity supplied per 1000 population (1000 kWh)	0.053/0.524	0.201/0.015	0.542/0.000	0.496/0.000	0.554/0.000	0.397/0.000	0.348/0.000	0.371/0.000	0.407/0.000
Length of low-voltage electricity distribution network per 1000 population (km)	0.386/0.000	0.156/0.061	0.414/0.000	0.395/0.000	0.433/0.000		0.248/0.003	0.268/0.001	0.252/0.002
Number of registered enterprises per 1000 population (pcs)	0.332/0.000	0.155/0.063	0.494/0.000	0.450/0.000	0.507/0.000	0.321/0.000		0.302/0.000	0.341/0.000
Number of registered economic organizations per 1000 population (pcs)	0.355/0.000	0.141/0.090	0.482/0.000	0.446/0.000	0.494/0.000	0.310/0.000	0.272/0.001		0.326/0.000
Number of operational commercial accommoda-tion units per 1000 (pcs)	0.406/0.000	0.118/0.159	0.396/0.000	0.391/0.000	0.415/0.000	0.214/0.010	0.241/0.003	0.256/0.002	

Table 5. The strength of the relationship between the total power of HMKEs per 1000 population and the district indicators (Pearson's correlation coefficient/p value; if $p < 0.05$, then there is a significantly confirmed relationship between the two variables). In the table, for the correlation coefficient, a white background refers to a non-significant relationship, a gray background to a weak relationship, and a yellow background to a weak–moderate relationship. For the partial correlation, a white background refers to a non-significant relationship, a green background is used where the background variable did not modify the strength of the correlation, a red background refers to a partially distorted relationship, a blue background refers to a partial explanation (the controlled variable only partially explains the relationship between variables i and j), and a black background refers to an irrelevant comparison.

Description	Correlation Coefficient	Partial Correlation Coefficient								
	Power of HMKEs Per 1000 Population ELMŰ-ÉMÁSZ, EON	Total Budget Revenues of Local Governments Per 1000 Population HUF 1000)	Total Budget Expenditure of Local Governments Per 1000 Population (HUF 1000)	Number of Household Electricity Consumers Per 1000 Population (pcs)	Total Amount of Electricity Supplied To Households Per 1000 Population (1000 kWh)	Number of Electricity Consumers Per 1000 Population (Pcs)	Length of Low-Voltage Electricity Distribution Network Per 1000 Population (Km)	Number of Registered Enterprises Per 1000 Population (Pcs)	Number of Registered Economic Organizations Per 1000 Population (Pcs)	Number of Operational Commercial Accommoda-Tion Units Per 1000 Population (Pcs)
Total budget revenues of local governments per 1000 population (HUF 1000)	0.281/0.001		0.173/0.038	0.424/0.000	0.410/0.000	0.437/0.000	0.315/0.000	0.409/0.000	0.423/0.000	0.312/0.000
Total budget expenditure of local governments per 1000 population (HUF 1000)	0.326/0.000	0.004/0.962		0.449/0.000	0.432/0.000	0.459/0.000	0.324/0.000	0.395/0.000	0.410/0.000	0.309/0.000
Number of household electricity consumers per 1000 population (pcs)	0.454/0.000	0.220/0.008	0.318/0.000		0.082/0.326	0.167/0.045	0.056/0.503	0.345/0.000	0.354/0.000	0.061/0.465
Total amount of electricity supplied to households per 1000 population (1000 kWh)	0.320/0.000	0.382/0.000	0.436/0.000	0.349/0.000		0.368/0.000	0.253/0.002	0.375/0.000	0.398/0.000	0.266/0.001
Number of electricity consumers per 1000 population (pcs)	0.470/0.000	0.209/0.012	0.309/0.000	0.099/0.234	0.068/0.420		0.038/0.647	0.340/0.000	0.347/0.000	0.033/0.692

Table 5. *Cont.*

Description	Correlation Coefficient	Partial Correlation Coefficient								
	Power of HMKEs Per 1000 Population ELMŰ-ÉMÁSZ, EON	Total Budget Revenues of Local Governments Per 1000 Population HUF 1000)	Total Budget Expenditure of Local Governments Per 1000 Population (HUF 1000)	Number of Household Electricity Consumers Per 1000 Population (pcs)	Total Amount of Electricity Supplied To Households Per 1000 Population (1000 kWh)	Number of Electricity Consumers Per 1000 Population (Pcs)	Length of Low-Voltage Electricity Distribution Network Per 1000 Population (Km)	Number of Registered Enterprises Per 1000 Population (Pcs)	Number of Registered Economic Organizations Per 1000 Population (Pcs)	Number of Operational Commercial Accommoda-Tion Units Per 1000 Population (Pcs)
Total amount of electricity supplied per 1000 population (1000 kWh)	−0.029/0.730	0.284/0.001	0.330/0.000	0.464/0.000	0.321/0.000	0.477/0.000	0.355/0.000	0.429/0.000	0.451/0.000	0.364/0.000
Length of low-voltage electricity distribution network per 1000 population (km)	0.355/0.000	0.225/0.006	0.292/0.000	0.308/0.000	0.197/0.017	0.331/0.000		0.362/0.000	0.380/0.000	0.217/0.009
Number of registered enterprises per 1000 population (pcs)	0.427/0.000	0.249/0.002	0.279/0.001	0.380/0.000	0.239/0.004	0.396/0.000	0.267/0.001		0.294/0.000	0.274/0.001
Number of registered economic organizations per 1000 population (pcs)	0.449/0.000	0.232/0.005	0.264/0.001	0.362/0.000	0.233/0.005	0.376/0.000	0.254/0.002	0.255/0.002		0.255/0.002
Number of operational commercial accommoda-tion units per 1000 population (pcs)	0.364/0.000	0.203/0.014	0.262/0.001	0.297/0.000	0.196/0.018	0.320/0.000	0.200/0.016	0.358/0.000	0.373/0.000	

The ranking of districts established based on the complex indicator developed from district indicators and the ranking based on the number * and total power ** of business-owned HMKEs per 1000 population show a weak to moderate correlation in the positive direction (* $\rho = 0.278$, $p = 0.001$; ** $\rho = 0.216$, $p = 0.009$). The correlation is still moderate, though stronger than previously (*** $\rho = 0.315$, $p = 0.000$; **** $\rho = 0.340$, $p = 0.000$), if only those district indicators are used for establishing a district ranking that are separately moderately correlated with the number *** and power **** of business-owned HMKEs per 1000 population.

The three hypotheses formulated at the beginning of the investigations were confirmed, as can be seen here below. The following were proven:

- In the case of the districts, there are certain district indicators, each of which separately shows a correlation with the quantity and power of PV HMKEs. These relationships could be detected regardless of the service regions of the particular electricity suppliers. There was a moderately strong correlation between the total budget expenditures of local governments per 1000 population, the number of household electricity consumers per 1000 population, the quantity of electricity supplied to households per 1000 population, the number of electricity consumers per 1000 population, the number of operating commercial accommodation units per 1000 population, and the total number of PV HMKEs per 1000 population. Furthermore, the power of total PV HMKEs per 1000 population also indicated moderately strong correlations with almost all the district indicators (except for the amount of supplied electricity per 1000 population).
- The ranking of the districts based on the complex indicator created from the district indicators signaled a moderately strong correlation with the ranking of the districts based on the number and power of the Hungarian photovoltaic PV HMKEs per 1000 population.
- Two regression models were created from the districts' database containing data from all three electricity supplier regions. The first model demonstrates the effects of the district indicators that are legally regarded as the dimensions of regional development in Hungary by Government Decree 105/2015 (IV. 23.) [30]). In this case, the quantity of PV HMKEs per 1000 population was explained by the proportion of the total number of homes at the end of the period built in the last five years and the proportion of public streets/roads maintained by the municipalities that are paved. In the second model, one can observe the effects of the indicators that do not belong to the regional development dimension in the strict sense of the word, but influence the spread of PV HMKEs. Thus, it can be stated that the model includes the number of PV HMKEs per 1000 population as an outcome variable and the number of electricity consumers per 1000 population and the total budget expenditure of local governments per 1000 population as explanatory variables.

4. Conclusions

Based on the results of the study, it was established that there are certain district indicators that are in a moderately strong relationship with both the quantity and power of HMKEs per 1000 population.

It was found that, considering both examination aspects (districts with ELMŰ-ÉMÁSZ, EON, NKM, or ELMŰ-ÉMÁSZ and EON as their electricity suppliers), the quantity of total HMKEs per 1000 population showed moderately strong correlations with the total budget expenditure of local governments per 1000 population, the number of household electricity consumers per 1000 population, the quantity of electricity supplied to households per 1000 population, the number of electricity consumers per 1000 population, and the number of operating commercial accommodation units per 1000 population, out of all the district indicators.

Regarding only the service area of ELMŰ-ÉMÁSZ and EON, the power of total HMKEs per 1000 population showed moderately strong relationships with almost all of the district indicators (except the quantity of supplied electricity per 1000 population).

The quantity and power of residential HMKEs per 1000 population were also in moderately strong relationships with the number of household electricity consumers per 1000 population, the quantity of electricity supplied to households per 1000 population, the number of electricity consumers per 1000 population, the number of registered economic organizations per 1000 population, the number of registered enterprises per 1000 population, and the number of operating commercial accommodation units per 1000 population.

The quantity and power of business-owned HMKEs per 1000 population correlated moderately strongly with the total budget expenditure of self-governments per 1000 population, the total budget revenue of self-governments per 1000 population, the length of the low-voltage distribution system per 1000 population, the number of registered economic organizations per 1000 population, and the number of registered enterprises per 1000 population.

It was established that the ranking of the districts based on the economic and infrastructural indicators and the ranking according to the quantity and power of HMKEs per 1000 population showed a moderately strong correlation. It was also revealed that two regression models can be created on the basis of the district indicators that influence the quantity of total HMKEs per 1000 population.

The usefulness of this study is manifold. It not only offers help with the design of energy policy and energy strategy concerning the factors that play a part in the spread of HMKEs, but also inspires researchers—including the authors of this paper—to carry out further analyses. The goals of further investigations will focus, on the one hand, on other regional levels (NUTS 2, NUTS 3, LAU 2) and, on the other hand, on the processing of the data of the year 2020 to make it possible to observe changes over time, too.

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Abbreviations

The following abbreviations are used in this manuscript:

ELMŰ-ÉMÁSZ	ELMŰ-ÉMÁSZ Energiaszolgáltató ZRT. /ELMŰ-ÉMÁSZ Energy Distributor Private Limited Company
EON	E.ON Hungária Zrt./E.ON Hungária Private Limited Company
$fa_{i,j}$	Normalized basic indicator
HMKE	Household-sized power plant
CDI	Complex development index
KÁT	Kötelező átvételi tarifa/Hungarian system of supporting green energy from renewable energy sources
KSH	Központi Statisztikai Hivatal/Hungarian Central Statistical Office
MAVIR	Magyar Villamosenergia-ipari Átviteli Rendszerirányító Zártkörűen Működő Részvénytársaság/Hungarian Transmission System Operator Private Limited Company

METÁR	Megújuló Energia Támogatási Rendszer/Renewable Energy Support Scheme
$\min(fa_{i,j})$	The lowest value of the basic indicator
$\max(fa_{i,j})$	The highest value of the basic indicator
NKM	NKM Energia Zrt./NKM Energy Private Limited Company
p-Si	Polycrystalline
PV	Photovoltaic
TEIR	Országos Teületfejlesztési és Területrendezési Információs Rendsze/National Regional Development and Spatial Planning Information System
x_i to x_n	Represent independent variables
Y	Dependent variable
β_1	The regression coefficient of variable x_1
β_n	The regression coefficient of variable x_n

Appendix A. Relationship between the Number and Total Power of Residential, Business-Owned, and Public HMKEs and the Development Indicators

Table A1. The strength of the relationship between the number of residential HMKEs per 1000 population and district indicators (Pearson's correlation coefficient/p value; if $p < 0.05$, then there is a significantly confirmed relationship between the two variables). In the table, for the correlation coefficient, a white background refers to a non-significant relationship, a gray background to a weak relationship, a yellow background to a weak–moderate relationship, and a purple background to a moderately strong relationship. For the partial correlation, a white background refers to non-significant relationship, a red background refers to a partially distorted relationship, a blue background refers to a partial explanation (the controlled variable only partially explains the relationship between variables i and j), and a black background refers to an irrelevant comparison.

Description	Correlation Coefficient	Partial Correlation Coefficient						
	Number of Residential Hmkes Per 1000 Population (Pcs) ELMŰ-ÉMÁSZ, EON	Number of Household Electricity Consumers Per 1000 Population (Pcs)	Amount of Electricity Supplied To Households Per 1000 Population (1000 kWh)	Number of Electricity Consumers Per 1000 Population (Pcs)	Length of Low-Voltage Electricity Distribution Network Per 1000 Population (Km)	Number of Registered Enterprises Per 1000 Population (Pcs)	Number of Registered Economic Organizations Per 1000 Population (Pcs)	Number of Commercial Accommoda-Tion Units Per 1000 Population (Pcs)
Total budget revenue of local governments per 1000 population (HUF 1000)	0.050/0.546	0.565/0.000	0.598/0.000	0.573/0.000	0.349/0.000	0.302/0.000	0.322/0.000	0.389/0.000
Total budget expenditure of local governments per 1000 population (HUF 1000)	0.066/0.426	0.560/0.000	0.605/0.000	0.567/0.000	0.346/0.000	0.299/0.000	0.320/0.000	0.384/0.000
Number of household electricity consumers per 1000 population	0.563/0.000		0.366/0.000	0.106/0.204	0.077/0.359	0.177/0.033	0.178/0.000	0.028/0.735
Amount of electricity supplied to households per 1000 population (1000 kWh)	0.571/0.000	0.350/0.000		0.357/0.000	0.140/0.094	0.197/0.018	0.219/0.008	0.195/0.019
Number of electricity consumers per 1000 population	0.569/0.000	0.016/0.848	0.360/0.000		0.086/0.302	0.172/0.039	0.169/0.042	0.052/0.532
Total electricity supplied per 1000 population (1000 kWh)	0.125/0.132	0.555/0.000	0.574/0.000	0.563/0.000	0.374/0.000	0.338/0.000	0.356/0.000	0.391/0.000
Length of low-voltage electricity distribution network per 1000 population (km)	0.351/0.000	0.475/0.000	0.496/0.000	0.485/0.000		0.227/0.006	0.243/0.003	0.250/0.002
Number of registered enterprises per 1000 population	0.306/0.000	0.520/0.000	0.534/0.000	0.526/0.000	0.288/0.000		0.259/0.002	0.326/0.000
Number of registered economic organizations per 1000 population	0.326/0.000	0.510/0.000	0.531/0.000	0.515/0.000	0.278/0.001	0.232/0.005		0.314/0.000
Number of operating commercial accommoda-tion units per 1000 population	0.388/0.000	0.443/0.000	0.487/0.000	0.455/0.000	0.180/0.031	0.216/0.009	0.226/0.006	

Table A2. The strength of the relationship between the total power of residential HMKEs per 1000 population and district indicators (Pearson's correlation coefficient/p value; if $p < 0.05$, then there is a significantly confirmed relationship between the two variables). In the table, for the correlation coefficient, a white background refers to a non-significant relationship, a gray background to a weak relationship, a yellow background to a weak–moderate relationship, and a purple background to a moderately strong relationship. For the partial correlation, a white background refers to a non-significant relationship, a red background refers to a partially distorted relationship, a blue background refers to a partial explanation (the controlled variable only partially explains the relationship between variables i and j), and a black background refers to an irrelevant comparison.

	Correlation Coefficient	Partial Correlation Coefficient						
Description	**Total Power of Residential Hmkes Per 1000 Population (kW) ELMŰ-ÉMÁSZ, EON**	**Number of Household Electricity Consumers Per 1000 Population**	**Amount of Electricity Supplied to Households Per 1000 Population (1000 kWh)**	**Number of Electricity Consumers Per 1000 Population**	**Length of Low-Voltage Electricity Distribution Network Per 1000 Population (Km)**	**Number of Registered Enterprises Per 1000 Population (Pcs)**	**Number of Registered Economic Organizations Per 1000 Population (Pcs)**	**Number of Operating Commercial Accommoda-Tion Units Per 1000 Population (Pcs)**
Total budget revenue of local governments per 1000 population (HUF 1000)	0.072/0.391	0.546/0.000	0.580/0.000	0.552/0.000	0.346/0.000	0.323/0.000	0.341/0.000	0.384/0.000
Total budget expenditure of local governments per 1000 population (HUF 1000)	0.113/0.173	0.543/0.000	0.595/0.000	0.547/0.000	0.341/0.000	0.315/0.000	0.333/0.000	0.374/0.000
Number of household electricity consumers per 1000 population (pcs)	0.548/0.000		0.341/0.000	0.097/0.247	0.056/0.504	0.210/0.011	0.210/0.011	0.009/0.914
Amount of electricity supplied to households per 1000 population (1000 kWh)	0.548/0.000	0.341/0.000		0.347/0.000	0.152/0.068	0.229/0.006	0.249/0.003	0.204/0.014
Number of electricity consumers per 1000 population (pcs)	0.553/0.000	0.010/0.904	0.335/0.000		0.064/0.442	0.204/0.014	0.202/0.015	0.031/0.713
Total amount of electricity supplied per 1000 population (1000 kWh)	0.115/0.168	0.540/0.000	0.549/0.000	0.547/0.000	0.373/0.000	0.359/0.000	0.376/0.000	0.391/0.000
Length of low-voltage electricity distribution network per 1000 population (km)	0.352/0.000	0.451/0.000	0.468/0.000	0.460/0.000		0.252/0.002	0.267/0.001	0.249/0.003
Number of registered enterprises per 1000 population (pcs)	0.328/0.000	0.500/0.000	0.506/0.000	0.505/0.000	0.284/0.001		0.246/0.003	0.322/0.000
Number of registered economic organizations per 1000 population (pcs)	0.347/0.000	0.489/0.000	0.503/0.000	0.493/0.000	0.274/0.001	0.216/0.009		0.308/0.000
Number of operating commercial accommodation units per 1000 population (pcs)	0.388/0.000	0.419/0.000	0.458/0.000	0.429/0.000	0.181/0.029	0.242/0.003	0.251/0.002	

Table A3. The strength of the relationship between the amount of business-owned HMKEs per 1000 population and district indicators (Pearson's correlation coefficient/p value; if $p < 0.05$, then there is a significantly confirmed relationship between the two variables). In the table, for the correlation coefficient, a white background refers to a non-significant relationship, a gray background to a weak relationship, and a yellow background to a weak–moderate relationship. For the partial correlation, a white background refers to a non-significant relationship, a red background refers to a partially distorted relationship, a blue background refers to a partial explanation (the controlled variable only partially explains the relationship between variables i and j), and a black background refers to an irrelevant comparison.

	Correlation Coefficient	Partial Correlation Coefficient						
Description	**Number of Business-Owned Hmkes Per 1000 Population (Pcs) ELMŰ-ÉMÁSZ, EON**	**Total Budget Revenues of Local Governments Per 1000 Population (HUF 1000)**	**Total Budget Expenditure of Local Governments Per 1000 Population (HUF 1000)**	**Total Amount of Electricity Supplied Per 1000 Population (1000 kWh)**	**Length of Low-Voltage Electricity Distribution Network Per 1000 Population (Km)**	**Number of Registered Enterprises Per 1000 Population (Pcs)**	**Number of Registered Economic Organizations Per 1000 Population (Pcs)**	**Number of Operating Commercial Accommoda-Tion Units Per 1000 Population (Pcs)**
Total budget revenues of local governments per 1000 population (HUF 1000)	0.510/0.000		0.279/0.001	−0.315/0.000	0.180/0.030	0.164/0.049	0.166/0.046	0.082/0.330
Total budget expenditure of local governments per 1000 population (HUF 1000)	0.562/0.000	0.055/0.507		−0.341/0.000	0.207/0.013	0.130/0.120	0.134/0.107	0.084/0.317
Number of household electricity consumers per 1000 population (pcs)	0.121/0.145	0.500/0.000	0.557/0.000	−0.259/0.000	0.247/0.003	0.182/0.028	0.201/0.015	0.173/0.038
Total amount of electricity supplied to households per 1000 population (1000 kWh)	−0.092/0.271	0.504/0.000	0.558/0.000	−0.236/0.004	0.334/0.000	0.242/0.003	0.263/0.001	0.272/0.001
Number of electricity consumers per 1000 population (pcs)	0.147/0.078	0.495/0.000	0.555/0.000	−0.259/0.002	0.223/0.007	0.174/0.036	0.192/0.021	0.147/0.078
Total amount of electricity supplied per 1000 population (1000 kWh)	0.236/0.000	0.542/0.000	0.600/0.000		0.237/0.004	0.172/0.038	0.195/0.019	0.212/0.010
Length of low-voltage electricity distribution network per 1000 population (km)	0.260/0.002	0.482/0.000	0.546/0.000	−0.211/0.011		0.144/0.085	0.161/0.054	0.079/0.343
Number of registered enterprises per 1000 population (pcs)	0.209/0.012	0.497/0.000	0.545/0.000	−0.205/0.013	0.213/0.010		0.240/0.004	0.154/0.064
Number of registered economic organizations per 1000 population (pcs)	0.228/0.006	0.491/0.000	0.540/0.000	−0.205/0.014	0.204/0.014	0.221/0.007		0.142/0.089
Number of operating commercial accommoda-tion units per 1000 population (pcs)	0.206/0.012	0.482/0.000	0.539/0.0000	−0.241/0.003	0.179/0.031	0.157/0.059	0.173/0.038	

Table A4. The strength of the relationship between the total power of business-owned HMKEs per 1000 population and district indicators (Pearson's correlation coefficient/p value; if $p <$ 0.05, then there is a significantly confirmed relationship between the two variables). In the table, for the correlation coefficient, a white background refers to a non-significant relationship, a gray background to a weak relationship, and a yellow background to a weak–moderate relationship. For the partial correlation, a white background refers to a non-significant relationship, a red background refers to a partially distorted relationship, a blue background refers to a partial explanation (the controlled variable only partially explains the relationship between variables i and j), and a black background refers to an irrelevant comparison.

Description	Correlation Coefficient	Partial Correlation Coefficient				
	Total Power of Business-Owned HMKEs Per 1000 Population (kW) ELMŰ-ÉMÁSZ, EON	Total Budget Revenue of Local Governments Per 1000 Population HUF 1000)	Total Budget Expenditures of Local Governments Per 1000 Population HUF 1000)	Length of Low-Voltage Electricity Distribution Network Per 1000 Population (Km)	Number of Registered Enterprises Per 1000 Population (Pcs)	Number of Registered Economic Organizations Per 1000 Population (Pcs)
Total budget revenue of local governments per 1000 population (HUF 1000)	0.429/0.000		0.200/0.016	0.135/0.105	0.346/0.000	0.346/0.000
Total budget expenditure of local governments per 1000 population (HUF 1000)	0.462/0.000	0.064/0.444		0.155/0.063	0.324/0.000	0.327/0.000
Number of household electricity consumers per 1000 population (pcs)	0.143/0.086	0.413/0.000	0.455/0.000	0.156/0.061	0.344/0.000	0.358/0.000
Total amount of electricity supplied to households per 1000 population (1000 kWh)	−0.079/0.343	0.423/0.000	0.458/0.000	0.272/0.001	0.403/0.000	0.420/0.000
Number of electricity consumers per 1000 population (pcs)	0.163/0.049	0.409/0.000	0.452/0.000	0.136/0.103	0.338/0.000	0.352/0.000
Total amount of electricity supplied per 1000 population (1000 kWh)	0.197/0.017	0.452/0.000	0.489/0.000	0.189/0.023	0.343/0.000	0.360/0.000
Length of low-voltage electricity distribution network per 1000 population (km)	0.210/0.011	0.402/0.000	0.444/0.000		0.327/0.0000	0.341/0.000
Number of registered enterprises per 1000 population (pcs)	0.367/0.000	0.412/0.000	0.432/0.000	0.115/0.167		0.196/0.018
Number of registered economic organizations per 1000 population (pcs)	0.382/0.000	0.399/0.000	0.421/0.000	0.104/0.214	0.162/0.051	
Number of operating commercial accommoda-tion units per 1000 population (pcs)	0.189/0.022	0.399/0.000	0.436/0.000	0.130/0.120	0.332/0.000	0.345/0.000

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