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The Renewable Energy Production Capability of Settlements to Meet Local Electricity and Transport Energy Demands

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Abstract: In addition to the examination of electric power from local renewables, this study has sought the answer to the question of what proportion of vehicles are fueled by environmentally friendly energy saving technologies in the vehicle fleets of Hungarian settlements. Further, the study attempts to shed light on the self-sufficiency of Hungarian settlements with respect to the electricity and transport segments. In our assessments, the performance of small-scale household power plants (SSHPPs) utilizing local renewable energy sources, and small-scale power plants with installed capacities under 0.5 MW, was taken into account, as were the proportions of vehicles operating with partly or completely clean energy sources in the vehicle fleets of the individual settlements. Finally, the composition of the vehicle fleet has been examined in the light of the quantities of renewable electricity generated in the individual settlements, in order to consider whether these settlements are capable of covering the energy needs of their vehicle stocks from local sources. In the light of the results, the changes generated by the incentives and investments introduced over the past ten years can be established and subsequently, the energy policy needs in the future can be assessed. Our study has incorporated energy geography and settlement geography aspects.

Keywords: sustainability; self-sufficient settlements; electromobility; motor vehicle stock; renewable energy; energy geography; Hungary

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1. Introduction

Alongside meeting the ever-increasing energy needs of humanity, the energy industry is facing significant challenges in counteracting global warming. Energy transition, i.e., the shift to renewable energy carriers with the elimination of the use of fossil fuels, would be impossible to achieve from one moment to another, but the increasingly pessimistic climate change forecasts operate as drivers of faster action. Energy transition needs to be implemented in all three consumer-related sectors: electricity, heating/cooling, and transport. A significant part of these energy needs together with the associated detrimental effects can be attributed to settlements, and therefore it is evident that efforts have to be taken to produce energy locally, too.

Fossil energy sources still dominate the Hungarian energy balance, and furthermore, the majority is imported. Consequently, a priority should be to increase the share of locally produced renewable energy sources in the Hungarian energy mix. In Hungary, the energy transition process was initiated relatively late; despite this, significant achievements have been made in the past 10 years, principally by making electricity production carbon-neutral [1]. At the European level, however, there is a wide negative gap [2].

The technology offers various alternatives for placing the transport sector on a renewable basis. However, the tendencies witnessed so far reflect the expanding use of electric and hybrid-powered vehicles, and as a result their market share has been rising steadily. While global sales stood at a few thousand units in 2010, this figure climbed to 2 million units in 2018, and forecasts suggest further increases [3].

The target to cover 100% of energy demands from renewable resources at the national level was first formulated as early as 1975, in Denmark [4], to be followed by further theories [5] and software models worldwide [6]. Beyond scientific theories, the first concrete steps were taken by Iceland in 1998, where a government decision was adopted on power transition. The earliest aspirations to develop self-sufficient systems for settlements can be traced back to the passing of the German Renewable Energy Act in 1997, which allowed for predictable returns [7]. The Stern Review of 2006 brought about another breakthrough in the assessment of renewables, as, in addition to environmental and technological arguments, it also credibly underpinned the compelling and reasonable necessity of energy transition in the economic field, too [8]. In Hungary, the first computer modeling of energy transition was performed at the Department of Environmental and Landscape Geography of Eötvös Loránd University (ELTE) [9].

In the field of conversion to zero emission transport, Norway has been the most successful nation so far. In 2019, the proportion of the vehicle park which is environment-friendly reached 17.4% (all-electric 9.3%, plug-in hybrid 4.1%, hybrid 4.0%). The number of purely electric vehicles was 260,692, while the proportion of newly sold electric vehicles reached 46% in a country where the population is just over 5 million [10]. By 2019, the sales value of electric and plug-in hybrid vehicles increased to a 50% market share. Over the past 25 years, Norwegian governments have introduced a series of measures to encourage the transition, which have so far produced outstanding results, and have now made full-scaling transition an achievable goal. From 2025, all new car sales must be zero-emission, electric or hydrogen-powered vehicles [11]. With respect to electric vehicles, an important factor is that sustainable operation can only be realized if the electricity utilized comes from renewable energy resources. In Norway, more than 100% of electricity consumption is provided from renewables with the vast majority generated by hydropower, which has proved to be a good basis for Norwegian success. [12].

Kadurek et al. [13] were the first to focus on the connection of the consumer sectors to the energy self-sufficient systems of settlements; they suggest that the electric vehicle fleet of a settlement can be effectively used to compensate for fluctuations in the outputs of renewable energy generation systems, as well as to support electricity consumption in the settlement and implement a zero-emission transport system. Dallinger and Wietschel's study has addressed the system balancing potentials that are inherent in electric vehicles by allowing the storage, use, and feeding of the electric power that is rapidly generated by renewable electricity systems, through smart grids [14].

On the settlement level, one of the earliest examples was the Bavarian settlement of Wildpoldsried, where—following the German Renewable Energy Act (EEG, 2000–2017)—the municipality wanted to base its entire supply of electricity, heat energy and transport energy on renewables, with reliance on locally available resources [15]. After the first success, it has mainly been German (Aller-Leine-Tal, Effelter, Alzey-Land region, Bruchsmühlbach-Miesau, Dardesheim, Groβbardorf), Danish (Samsø Island, Frederikshavn) and Austrian (Güssing) settlements that have played a model role. Li Wen Li et al. 2013 dealt with the social and sociological success factors in the implementation of community-owned renewable energy projects through case studies in Germany [16]. The first good practices were followed by other settlements, ranging from villages to large cities [17–26].

2. Aim of the Study

The aim of the study was to determine the proportion of vehicles partly or fully operated with clean energy sources in the vehicle fleets of Hungarian settlements, as well as understanding the progress made by Hungarian settlements towards the implementation of self-sufficiency in the light of their vehicle stocks. The study attempts to establish which settlements have the largest numbers of alternative-powered vehicles, and within the vehicle fleets of the settlements, where these vehicles represent the most significant proportions. The focal point of the studies has fallen on the spatial distribution of electric and hybrid vehicles, as well as vehicles powered with various biofuels. The composition of the vehicle fleet has been examined in the light of the quantities of renewable energies generated in the individual settlements in order to see whether there are settlements in Hungary that are capable of covering the energy needs of their vehicle stocks from local sources. The novelty and added value of the paper are that it examines the energy transition not on global, regional, or national levels, but on the settlement level. We do not perform case studies but analyze the complete settlement stock of a country, using more than 300,000 data items from of 3155 settlements.

3. Materials and Methods

- Source of the vehicle fleet data and its connection to the settlement.
- Power plant categories examined.
- Classification of vehicle fleet from fuel.
- Ratio of the renewable energy sources in the fuels.
- The change in the number of alternative drive vehicles between 2008 and 2017.

For these studies, we used the structured database of the Hungarian Central Statistical Office (HCSO) [27], which was compiled by the office at our request, according to the following parameters. The database includes the details of the Hungarian motor vehicle stock for the years 2008–2017. The stock is differentiated by fuel types or combinations of fuels as the sources of power, and distinguishes passenger cars from freight vehicles, buses, tractors, slow vehicles, and motorcycles with all these data broken down for the individual settlements. In 2017, there were 3155 local authorities operating in Hungary [28], and their powers included the registration of motor vehicles. Therefore, each of these vehicles belonged to a specific Hungarian settlement. Despite the necessary movement of the vehicle stock, this method is the most accurate way to link the vehicles to a given settlement, and in this context their composition with respect to the individual settlements can be examined. The reason for our taking the period from 2008 to 2017 into account is that this time interval offers the most recent information available among the data types used in our comparative analysis. The parallel data used include the number of local authorities registered in the territorial database of the HCSO, their respective populations, and the above-mentioned figures in relation to vehicles in the respective settlements [27]. The Hungarian Energy and Public Utility Regulatory Authority (MEKH) and the universal public utility suppliers are the source of data for the number and capacity of small-scale household power plants (SSHPP) and small-scale power plants with installed capacities under 0.5 MW (not subject to authorization or not belonging to the SSHPP category). The settlement's electricity production capacity can be calculated from the data of small-scale power plants that utilize local renewable energy sources and which can be regarded as the most decentralized form of power generation.

3.1. Methods for the Calculation of the Electricity Production Capacity

The MAVIR Hungarian Transmission System Operator Company (Magyar Villamosenergia-ipari Átviteli Rendszerirányító Zrt., Budapest, Hungary) distinguishes the following power plant categories according to the capacity of the power plants in the Hungarian power system. Basically, power plants under 50 MW are categorized as small-scale power plants and power plants of 50 MW and above are large-scale power plants. Small-scale power plants with capacities between 50 and 0.5 MW, between 0.5 MW and 50 kW, and below 50 kW are distinguished within the below-50 MW category [29,30]. Our studies have considered the capacities of small household-scale power plants at and under 50 kVA (50 kW) not subject to authorization (SSHPP), as well as small-scale power plants with installed electric capacities under 0.5 MW that are not subject to authorization, and do not belong to the SSHPP category (small-scale power plants), the establishment of which has been allowed by the Hungarian Electric Energy Act since 1 January 2008.

SSHPP units are basically installed by the institutional, corporate, and household segment to cover their own electricity needs in full or part. Electricity input and consumption is measured with the use of electronic, single phase meters. The generated energy is used locally, and any superfluous volume is fed into the grid. When production is suspended, the necessary electric power is available from the grid. The service providers make payments based on the balance calculated from the total quantities of consumed and input energy as recorded by the consumption meters, as well as the currently valid unit prices. Since 2008, the number of HSPP units has been growing dynamically; they numbered 29,685 at the end of 2017 with a total installed capacity of 241.4 MW. A total of 99.41% of the power plants use the power of the sun, while the remaining 0.59% rely on thermal methane gas, diesel, natural gas, biomass, biogas, water, and wind energy sources. The volume of electricity fed by SSHPP units into the grid in 2017 was 105,086 MWh [31] (Table 1).

Table 1. Summary data of small-scale household power plants at the end of 2017 [31].

Nominal Capacities of Household-Scale Small Power Plants Per Energy Source (kW)										
year	other	diesel	natural gas	biomass	thermal methane	biogas	hydro power	wind power	solar energy	total
2017	36	11	291	20	206	115	112	619	239,960	241,370
Quantity of Household-Scale Small Power Plants Per Energy Source (Units)										
year	other	diesel	natural gas	biomass	thermal methane	biogas	hydro power	wind power	solar energy	total
2017	1	1	20	1	26	28	14	84	29,510	29,685
Volume of Energy Supplied to the Network by Household-Scale Small Power Plants Per Energy Source (MWh)										
year	other	diesel	natural gas	biomass	thermal methane	biogas	hydro power	wind power	solar energy	total
2017	125	0	258	0	553	32	387	105	103,626	105,086

The number of small-scale power plants under 0.5 MW stood at 238 as of 31 December 2017 with an aggregate installed capacity of 78.2 MW. The energy carriers concerned embrace a broad spectrum, including both renewable and fossil energy sources. In this category, electricity is generated mostly from renewables, such as solar power, wind and water, biogas, landfill gas, and sewage gas. Although, to a small extent, fossil energy carriers are also among the energy sources of these small-scale power plants, primarily with production from natural gas, thermal methane gas, other gases, and petrol [31]. A total of 71% of the power plants are solar power facilities, followed by biogas and hydropower plants, with 14% and 10%, respectively. With respect to capacities, solar power plants made up the greatest proportion with 78% of the installed capacity, followed by the 14% share of aggregate capacity deriving from biogas power plants. Hydropower (4%) and natural gas (3%) also have considerable shares in the energy mix.

Unlike SSHPP units, these power plants are mostly constructed by business operators. The establishment of these power plants is mostly driven by the goal of realizing business profits, with connection to the Mandatory Take-Off System (KÁT) effectively operated until 31 December 2016 [29,32,33] by the Ministry of National Development), and thereafter, from 1 January 2017 to the Renewable Energy Support Scheme (METÁR) [32–37].

The settlement-level SSHPP unit and capacity data were made available to us by E.ON Energiaszolgáltató Kft., ELMÜ-ÉMÁSZ Energiaszolgáltató Zrt. and Dél-magyarországi Áramszolgáltató Zrt. (Budapest, Hungary) (DÉMÁSZ) as universal suppliers operating in the territory of Hungary, whereas information relating to the number and capacities of small-scale power plants under 0.5 MW was disclosed by the Hungarian Energy and Public Utility Regulatory Authority (MEKH). The detailed, settlement-level electricity production data are handled by MEKH and MAVIR and treated as a business secret, and are therefore not available for study; furthermore, the production data measured by universal suppliers do not reflect the real electric power generation in the SSHPP units. The underlying reason for this is that in the course of production the energy used by consumers before reaching the meter does not enter the grid, and therefore is not metered. Universal suppliers are only in possession of data relating to the electricity volumes delivered by the production equipment. As a result, the available data are not suitable for determining the volumes of electric power generated in the settlements from renewable energy sources.

Therefore, information in relation to the electricity generated locally from renewables and settlement-level data were generated by calculations based on the following principles.

To determine the level of self-sufficiency in settlements that accommodate power plants from the two categories, the annual volume of electricity that can be theoretically generated by the power plants (for solar power), and that can be determined based on the average level of utilization annually (for other renewable energy sources) were compared with the annual electricity consumption of the respective settlements in 2017 (Hungarian Regional-development and Spatial-planning Information System (HRSIS) 2017). Our calculations were made in order to understand in what proportions the studied power plant categories, and notably the power plants utilizing local energy resources were able to satisfy the electricity demands of the individual settlements.

For solar panel systems, the settlement-level data for total capacities in 2017 were considered to determine the theoretical quantity of electricity produced annually. The calculations were performed using the Photovoltaic Geographical Information System (PVGIS) operated by the European Commission Joint Research Centre [38]. With reliance on the software, the calculations were performed for all Hungarian settlements where SSHPP and/or small-scale photovoltaic power plants under 0.5 MW capacity were operated.

In the case of the other renewable energy sources, their average national utilization data for 2017 were used to determine the volume of electricity that could theoretically be generated in the settlements during 2017, for which purpose average utilization figures were provided by MEKH (Table 2). Annual utilization data were also available for solar power, but in the case of this source of energy PVGIS allowed more accurate calculations.

Table 2. The average utilization rates of small-scale household power plant (SSHPP) units using renewable energy resources and small-scale power plants with installed capacities under 0.5 MW in 2017 [1].

Energy Source	Wind Power	Hydropower	Biomass	Biogas	Landfill Gas	Sewage Gas	Solar Energy
Average utilization (%)	25.9	40.9	60.1	46.5	57.1	50.9	15.2

From among other energy carriers, wherever petrol, diesel, natural gas, gas, and thermal methane gas were used in the small-scale power plants, these fossil energy sources—being those which were not relevant to our studies—were not taken into consideration. The studies were conducted in relation to the areas of 3155 local authorities in Hungary [28].

This allowed the determination of the level of self-sufficiency of the settlements with respect to electricity generation. Similarly, the roles of these settlements generating electric power in excess of their actual demands could be defined in regional electricity supply, i.e., the satisfaction of the needs of the neighboring settlements by means of exporting their overproduction. In this context, the local renewable energy generation capacity of the settlements is known.

3.2. Fuel Types Taken into Consideration in the Studies

In 2017, Hungary's vehicle stock numbered 4,342,447 vehicles, resulting from a steady increase since the three-year decline following the 2008 economic crisis. A total of 80% of the vehicles are passenger cars, 11% are freight vehicles, the proportion of buses is 0.5%, tractors 1.5%, slow vehicles 3%, and nearly 4% are motorcycles.

Half of the fuel types listed in the database come from purely fossil energy sources (10 fuel categories), mainly hydrocarbon derivatives and their combinations, such as petrol, diesel, mixed, liquefied petroleum gas (LPG) and compressed natural gas (CNG), LPG/petrol, CNG/diesel, CNG/petrol, diesel, and LPG/diesel. Purely renewable energies and the combinations of renewable and fossil energies make up the other half of fuel types (11 fuel categories), including hybrid, electric, gas/vegetable oil, methanol, vegetable oil, biogas, petrol/ethanol (bioethanol—E85), and various hybrid combinations (Table 3):

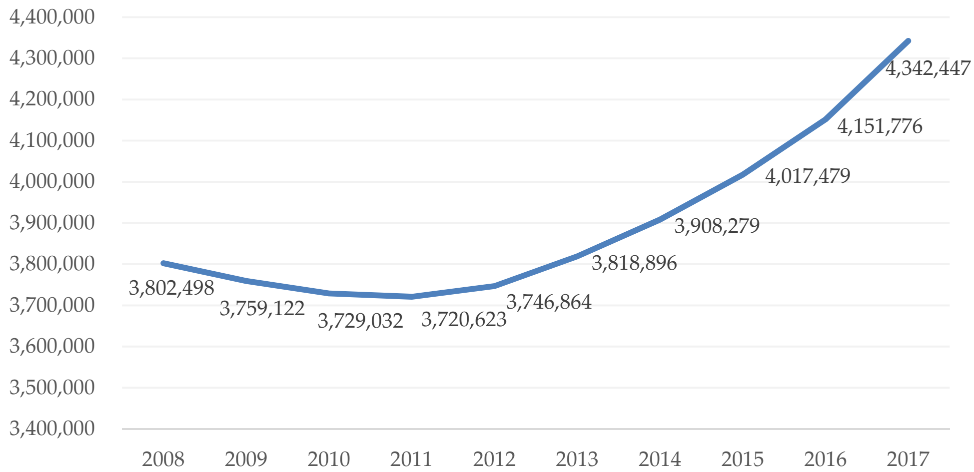
- HYB/E/P = hybrid/electric/petrol.
- HYB/E/P/LPG = hybrid/electric/petrol/LPG.

- HYB/E/G = hybrid/electric/gas.
- HYB/E/G/CNG = hybrid/electric/gas/CNG.

Table 3. Changes in the number of vehicles in the period 2008–2017, in Hungary.

Vehicle Units	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Petrol	2,644,209	2,584,932	2,533,936	2,491,458	2,461,538	2,458,558	2,454,682	2,459,602	2,484,902	2,553,338
Diesel	1,152,864	1,168,384	1,186,254	1,213,894	1,260,322	1,330,166	1,419,469	1,520,028	1,582,956	1,490,665
Hybrid	2595	2941	3267	3841	4447	5220	6446	8388	10,669	10,364
Electric	261	271	280	316	344	369	459	691	1225	2646
Mixed	2569	2594	1220	940	761	647	490	332	206	156
Natural gas/Vegetable oil	0	0	84	140	198	207	211	209	275	269
LPG	0	0	8	10	21	20	26	32	33	33
CNG	0	0	27	72	297	573	967	1178	1381	1570
LPG/petrol	0	0	3708	9507	17,792	21,665	23,805	25,014	26,029	26,938
CNG/gas oil	0	0	138	176	219	250	247	230	237	219
Methanol	0	0	3	10	12	17	26	43	56	47
Vegetable oil	0	0	2	3	4	6	8	11	11	6
Biogas	0	0	1	1	2	1	0	2	3	3
Petrol/ethanol	0	0	61	109	362	397	417	437	463	477
CNG/petrol	0	0	43	146	545	800	1025	1155	1233	1364
Gas oil	0	0	0	0	0	0	0	0	40,263	244,650
HIB/E/B	0	0	0	0	0	0	0	119	1775	9473
HIB/E/B/LPG	0	0	0	0	0	0	0	3	7	14
HIB/E/G	0	0	0	0	0	0	0	5	46	184
HIB/E/G/CNG	0	0	0	0	0	0	0	0	1	1
LPG/gas oil	0	0	0	0	0	0	0	0	5	30

ALL VEHICLE



No data were available for vehicles powered with hydrogen (H2) and liquefied natural gas (LNG).

For the purpose of the studies, the first group consisted of purely electric vehicles, the second group—by aggregating various hybrid combinations—included hybrids, and finally the third group—by aggregating gas/vegetable oil, methanol, vegetable oil, biogas and petrol/ethanol fuels—was made up of biofuel-powered vehicles.

3.3. *Proportion of Renewable Energy Sources in Fuels (Vehicle Units)*

Based on the statutory biofuel blending ratio prescribed in Act CXVII of 2010, fossil fuels are required to have some renewable energy content [30,31]. The given quantity of biofuels needs to be marketed by distributors in pure form or as blended into petrol or diesel fuel. Determined in the act and its implementation decree, the maximum 5% ratio by volume was applied until 1 January 2020, after which—pursuant to the amendment of Directive 98/70/EC and Directive 2009/28/EC—the European Union's Directive 2015/1513 (9 September 2015) increased it to 10% by volume [32,33].

Since the effective dates of these legal regulations, the bioethanol content of 95 octane petrol was first set at 4.9%, and then increased to at least 6.1% on 1 January 2020, whereas the share of biodiesel blended with diesel fuel rose from 6.4% to 8.2%.

In Hungary, the E85 fuel containing 85% bioethanol and 15% petrol has been marketed since 2007. As a proportion of all fuels, it has been steadily declining since the reduction of the excise tax rate in 2012, similarly to the number of fueling stations offering this type of fuel (Figure 1).

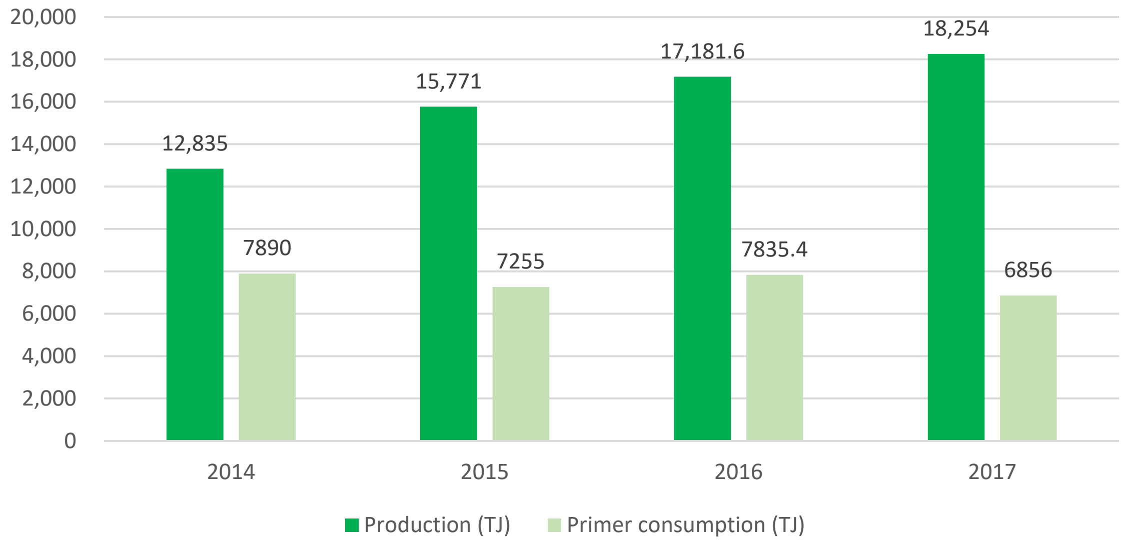


Figure 1. Production and primary use of biofuels in Hungary, 2014–2017.

A certain proportion of the electricity consumed by electric road vehicles has to be electric power produced from renewable energy sources, and is calculated using the method determined in the ILUC Directive [35]. In this context, according to the latest data from 2016, in Hungary this proportion was 27.46%, which is due to the electricity consumption of trolleybuses, while the associated statistics still have not been extended to cover electric motor vehicles.

The use of biogas in the transport sector cannot, in fact, be measured, as a part of the biogas capacities operated in Hungary for this purpose is not serviceable. Others use biogas generated for electric power production, or feed biogas in the form of purified biomethane into the natural gas network. Due to the biomethane sold abroad, the volume of renewable energies fed into the network can no longer be recognized as domestic renewable energy use.

The volume of energy produced from renewable energy resources and used in transport was 8.3 PJ in 2015. It then increased to 8.9 PJ in 2016, mainly due to the increasing use of electricity from renewable energy sources, as well as bioethanol and biodiesel [36] (Figures 1 and 2).

By breaking down the data at the settlement level, the numbers of vehicles in the individual settlements become available by fuel type, alongside their proportion among all the vehicles registered in the same settlements. Consequently, the level that a settlement concerned has achieved in the shift to environmentally friendly vehicles within the transport sector, i.e., its progress in energy transition, can be determined. These data, however, reflect only conditional self-sufficiency, because some fuels and electricity for transport purposes are not necessary produced locally, but are brought to the consumers of the settlement by various means of transport. Nevertheless, the results suggest which settlements would be able to supply their vehicle fleet with energy from local renewable sources.

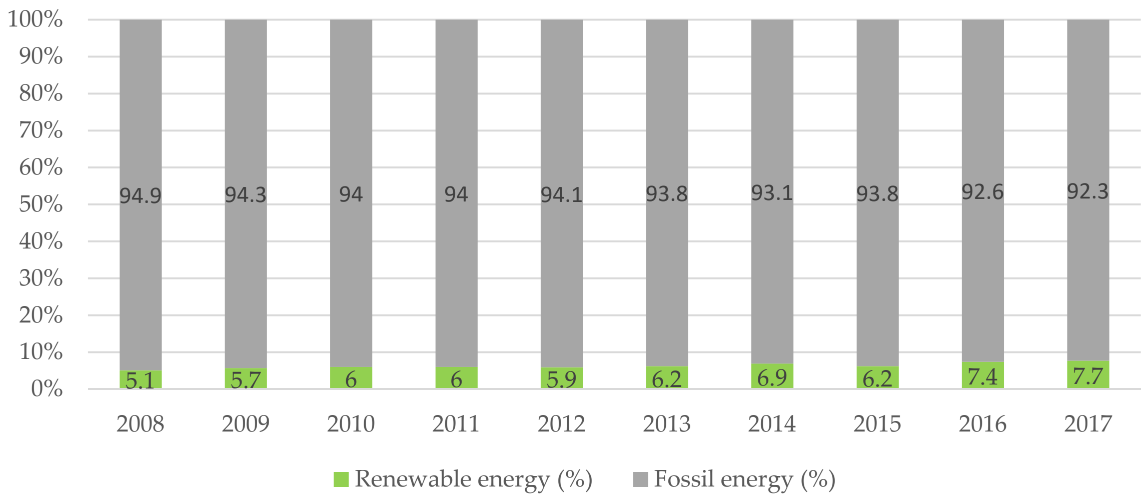


Figure 2. Share of the use of energy produced from renewable energy resources in transport in Hungary, 2008–2017.

3.4. Changes in the Number of Alternative-Powered Vehicles from 2008 until 2017

The number of hybrid vehicles increased at a moderate pace from 2008 until 2015, followed by a dynamic growth thereafter. From 2016 to 2017, their number nearly doubled. The stock of purely electric vehicles was almost negligible until 2015, but in the following two years their number doubled, and the trend continued, both in 2018 (4272 vehicles) and 2019 (7432 vehicles). The reason for the stronger popularity of hybrid vehicles is the longer and more reliable range owing to the internal combustion engine installed in addition to the electric motor, as well as the more moderate purchase prices compared to those of purely electric vehicles. However, this price level can still be considered high in Hungarian circumstances. Arguments in favor of electric vehicles include low operating costs, favorable charging, and, parking fees, and tax rebates—provided that the vehicle is a purely electric car carrying a green number plate or a hybrid capable of covering 25 km by purely electric means—and a subsidization scheme made available from the end of 2018 to support the purchasing of electric cars. Despite the advantages, the small volume of this vehicle stock is due to the consistently high prices of the vehicles, their short range and the insufficient charging capacities that were available at that time. The increased amount of the subsidy from June 2020, as well as the option to use the subsidy for purchasing lower priced models can be helpful in this situation. Furthermore, the country became fully traversable in the middle of 2019 with the commissioning of approximately 330 charging stations [37] (Figure 3).

The number of vehicles running on gas/vegetable oil, methanol, vegetable oil, biogas and petrol/ethanol fuels is negligible within the Hungarian vehicle stock with their number reaching only 802 by 2017. The great majority of vehicles running on methanol are passenger cars, and are fundamentally vehicles used for competitive sports, while those running on vegetable oil and biogas are so-called experimental vehicles. Concerning the five fuel combinations, significant numbers of vehicles belong to the gas/vegetable oil and petrol/ethanol fuels categories (Figure 4). In general, the combined biofuel category does not and is unlikely to, constitute a perceivable vehicle fleet in the future.

For any settlement, energy self-sufficiency in the transport sector can be realized if the settlement is able to supply the energy that is necessary for its vehicle stock from local renewable energy resources. In broader circles, this goal can be accomplished by serving the electric power demands of electric and hybrid vehicles.

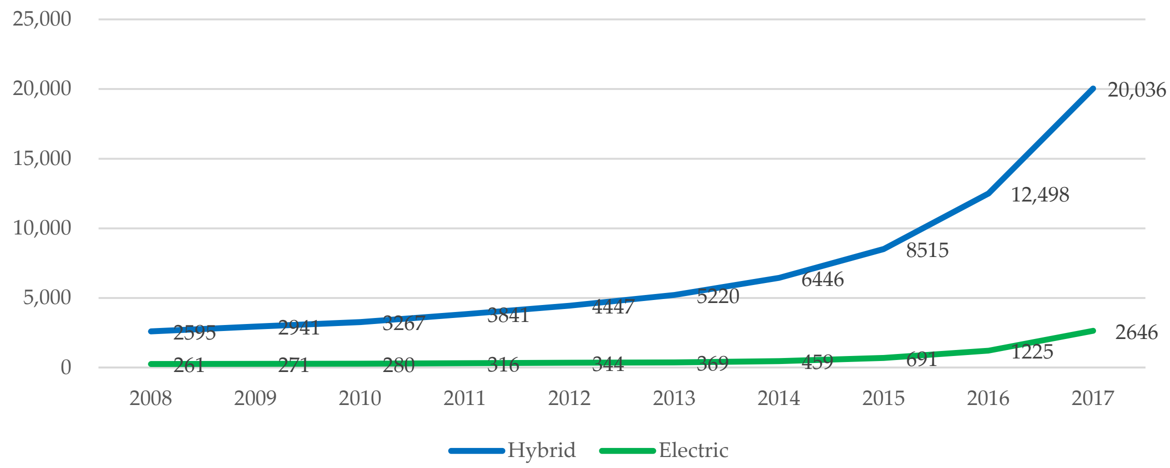


Figure 3. Changes in the number of electric and hybrid vehicles between 2008 and 2017 in Hungary (vehicle units).

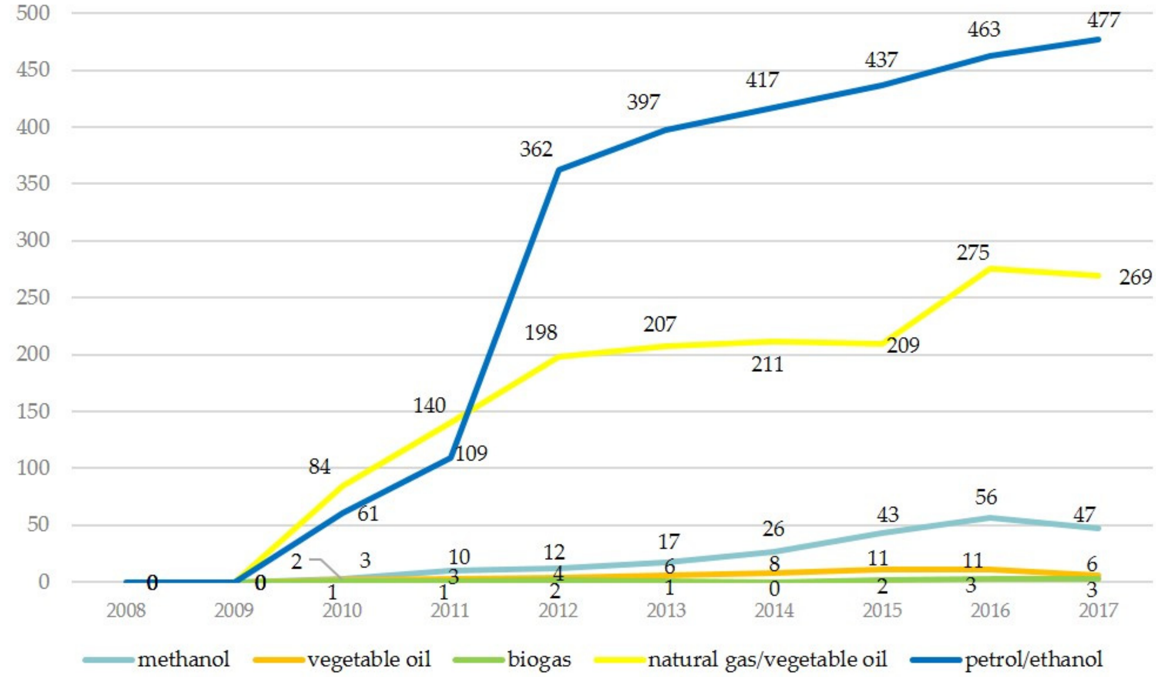


Figure 4. Changes in the number of vehicles powered by purely or partially renewable fuels in the period 2008–2017 in Hungary—gas with vegetable oil, methanol, vegetable oil, biogas, and petrol/ethanol (vehicle units).

4. Results

During the evaluation of the results, corresponding to the three environmentally friendly groups of fuels, separate ranks were established based on the numbers of the purely electric, hybrid and biofuel-powered vehicles in the individual settlements and their proportions within the respective vehicle fleets.

4.1. Number and Proportion of Electric Vehicles

In Hungary, only 2646 purely electric vehicles were operated in 2017. Most of them, i.e., some 1273 vehicles, were to be found in Budapest with other larger fleets used in the county towns and the smaller towns of the Budapest metropolitan area. The number of these vehicles in the individual settlements ranged between 10 and 40. There were two settlements that challenged the dominance of large cities; one of them was Balatonalmádi, where 180 electric vehicles had been registered by the end of 2017. On the whole, purely electric vehicles make up 3.47% of the vehicle stock of this small-sized town. However, these cars belong to a corporate fleet registered in the settlement. Lying in the middle of the Transdanubian region, with just over 500 inhabitants, the village of Tüskevár is in a similar situation, as it has a fleet of 21 electric vehicles (Table 4).

Table 4. Number and proportion of electric vehicles in the vehicle fleets of Hungarian settlements, together with the proportions of electricity produced by SSHPPs and small-scale power plants under 0.5 MW in the consumption of the settlements (2017).

Number and Proportion of Electric Vehicles in Settlements with the Largest Number of Electric Vehicles					Number and Proportion of Electric Vehicles in Settlements with the Highest Proportion of Electric Vehicles (Settlement Rank)				
	SETTLEMENT	Number of Electric Vehicles in Total (Vehicle Units)	Proportion of Electric Vehicles (%)	Proportion of the Annual Electricity Demand of the Settlement Covered from Renewable Energy Sources (%)		SETTLEMENT	Number of Electric Vehicles in Total (Vehicle Units)	Proportion of Electric Vehicles (%)	Proportion of the Annual Electricity Demand of the Settlement Covered from Renewable Energy Sources (%)
1	Budapest	1 273	0.16	0.73	1	Balatonalmádi	180	3.47	2.63
2	Balatonalmádi	180	3.47	2.63	2	Hernyék	1	3.44	0
3	Székesfehérvár	41	0.08	0.36	3	Nagyút	3	1.64	0
4	Kecskemét	37	0.06	1.03	4	Újszalonta	1	1.63	0
5	Győr	36	0.05	1.31	5	Borgáta	1	1.61	0
6	Debrecen	35	0.04	1.65	6	Hevesaranyos	2	1.41	0
7	Érd	33	0.09	3.00	7	Bakonykúti	1	1.36	0
8	Vecsés	31	0.25	2.87	8	Hosszúvölgy	1	1.26	0
9	Miskolc	25	0.04	1.68	9	Tésa	5	1.07	0
10	Budaörs	24	0.13	2.07	10	Patca	2	1.00	70.55
11	Szeged	22	0.03	1.67	11	Nadap	7	0.83	7.28
12	Pécs	21	0.03	1.44	12	Zalaszentlőrinc	1	0.82	0
13	Tüskevár	21	0.70	0	13	Tüskevár	21	0.70	0
14	Szombathely	20	0.05	1.49	14	Pilisszentlászló	4	0.66	6.59
15	Dunakeszi	18	0.08	2.78	15	Gic	1	0.62	0.97
16	Szentendre	16	0.11	3.18	16	Vanyola	1	0.53	1.36
17	Szigetszentmiklós	16	0.08	2.09	17	Csénye	2	0.52	1.70
18	Nyíregyháza	15	0.02	1.01	18	Kővágóörs	2	0.51	41.60
19	Zalaegerszeg	14	0.04	1.73	19	Fertőrákos	6	0.51	0.46
20	Siófok	13	0.09	2.11	20	Balatonszepezd	1	0.46	3.46

When the number of electric vehicles belonging to the individual settlements is related to the number of vehicles registered in the same settlements, then Balatonalmádi, with a population of 8640 inhabitants, is again the highest ranked, with 3.47%, which represents the highest proportion of electric vehicles in a single settlement across the country. The vast majority of the top 20 settlements in the ranking are villages with small populations and fleets consisting of just a few vehicles, and therefore one or two electric vehicles represent perceivable proportions, as is the case in Hernyék in Zala County (Table 4, Figure 5).

Table 4 shows the number and proportion of electric vehicles. Next to these figures is the proportion of electricity produced in the settlement in local small-scale power plants from renewable energy sources. It can be seen that the cities and towns on the left-hand side of the table are in possession of the largest numbers of electric vehicles countrywide, but in terms of the proportions the given numbers of vehicles are still not sufficient to bring about noticeable changes in self-sufficiency in terms of transport in the settlements. Balatonalmádi boasts the highest proportion, with 2.63% of electricity consumption coming from renewable sources, in addition to the 3.47% share of electric vehicles. From among the settlements with the largest vehicle ratios in the country as shown on the right-hand side, beside Balatonalmádi, Patca can boast a 70.55% level of electric power self-sufficiency with a 1% share of electric vehicles. Kővágóörs is similarly outstanding with a 0.5% ratio of electric vehicles accompanied by 41.6% renewable electricity.

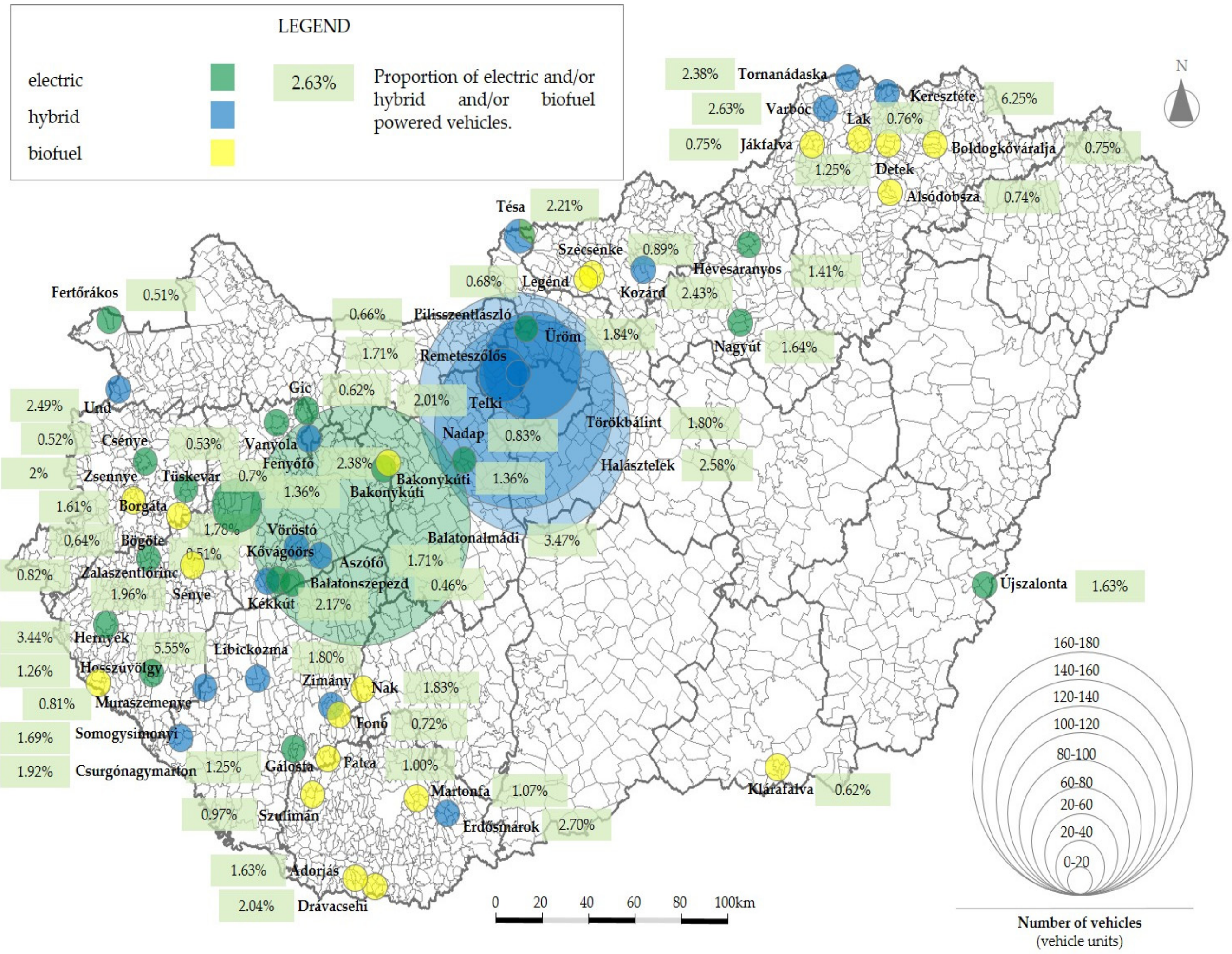


Figure 5. Settlements with the largest proportions of electric and/or hybrid and/or biofuel powered vehicles in their vehicle stocks, in Hungary, 2017 (settlement rank).

Consequently, in 2017 none of the settlements with the largest numbers and highest proportions of electric vehicles were able to become energy self-sufficient in transport or electricity generation. Patca has come the closest to generating the electric power needed for charging electric vehicles from renewable sources. In this settlement, after the installation of electric power generation capacities to cover a further 30% proportion of electricity consumption from renewable sources, excess electric power could be used to charge the electric vehicles of the settlement.

4.2. Number and Proportion of Hybrid Vehicles

As shown in Table 5, hybrid vehicles numbered approximately 20,000 vehicle units in 2017. Almost half of these vehicles running on Hungarian roads are registered in Budapest. In each of the county towns, there are 100–500 vehicles. Large cities listed in the left-hand column are again interspersed with the settlements of the Budapest metropolitan area. The underlying reason is the more favorable investment positions of the wealthier population living there, as they can more easily exploit the benefits offered by alternative-powered vehicles, and make use of the economical operating characteristics for commuting within a 50-km range. Of the 20 settlements with the highest proportions of hybrid vehicles, Keresztéte in Borsod County tops the ranking with 6.25%, followed by Libickozma with 5.55%. These high proportions are given by one and two vehicles, respectively. The situation is similar in most of the settlements included in the ranking, as one or two cars represent significant proportions due to the small populations. Six settlements stand out in this list; Halásztelek and Törökbálint boast 141 and 143 hybrid cars, which make up 2.58% and 2.8% of the local vehicle fleets, respectively. The settlements of Telki and Üröm are also to be specifically mentioned with their fleets of 37 and 65 hybrid cars, respectively, which account for proportions of around 2% (Table 5, Figure 5).

Table 5. Number and proportion of hybrid vehicles in the vehicle fleets of Hungarian settlements, as well as the proportions of electricity produced by SSHPPs and small-scale power plants under 0.5 MW in the consumption of the settlements (2017).

Number and Proportion of Hybrid Vehicles in Settlements with the Largest Number of Hybrid Vehicles					Number And Proportion Of Hybrid Vehicles In Settlements With The Highest Proportion Of Hybrid Vehicles (Settlement Rank)				
	SETTLEMENT	**Number of Hybrid Vehicles in Total (Vehicle Units)**	**Proportion of Hybrid Vehicles (%)**	**Proportion of the Annual Electricity Demand of the Settlement Covered from Renewable Energy Sources (%)**		**SETTLEMENT**	**Total Number of Hybrid Vehicles (Vehicle Units)**	**Proportion of Hybrid Vehicles (%)**	**Proportion of the Annual Electricity Demand of the Settlement Covered from Renewable Energy Sources (%)**
1	Budapest	8 246	1.09	0.73	1	Keresztéte	2	6.25	0
2	Debrecen	471	0.55	1.65	2	Libickozma	1	5.55	0
3	Szeged	352	0.54	1.67	3	Erdősmárok	1	2.70	15
4	Győr	273	0.45	1.31	4	Varbóc	1	2.63	0
5	Pécs	253	0.41	1.44	5	Halásztelek	141	2.58	3.31
6	Érd	246	0.73	3.00	6	Und	7	2.49	0
7	Székesfehérvár	243	0.48	0.36	7	Kozárd	2	2.43	8.08
8	Miskolc	227	0.38	1.68	8	Fenyőfő	1	2.38	2.56
9	Kecskemét	226	0.41	1.03	9	Tornanádaska	1	2.38	0
10	Nyíregyháza	103	0.38	1.01	10	Kékkút	1	2.17	0.06
11	Budaörs	200	1.15	2.07	11	Tésa	10	2.14	0
12	Dunakeszi	198	0.94	2.78	12	Telki	37	2.01	17.28
13	Csomád	183	0.93	148.51	13	Csurgónagyma	1	1.92	26.42
14	Szentendre	181	1.32	3.18	14	Üröm	65	1.84	8.63
15	Szombathely	171	0.45	1.49	15	Zimány	3	1.80	0
16	Veszprém	157	0.57	0.96	16	Törökbálint	143	1.80	2.46
17	Gödöllő	146	0.89	2.74	17	Vöröstó	1	1.78	3.9
18	Szigetszentmiklós	143	0.74	2.09	18	Aszófő	5	1.71	0.15
19	Törökbálint	143	1.80	2.46	19	Remeteszőlős	8	1.71	10.55
20	Halásztelek	141	2.58	3.31	20	Somogysimonyi	1	1.69	0

In cities with the largest numbers of hybrid vehicles, the proportion of electric power from renewable sources tends to be small. In Budaörs, Szentendre and Halásztelek, the 1–3% hybrid proportion of hybrid cars are coupled with 2–3% proportions of electricity, but these figures are far from indicating self-sufficiency. From among settlements with higher green electricity production, Telki has a 2% proportion of hybrid cars and 17% renewable electricity generation. In Csurgónagymarton, the proportion of hybrid vehicles is 2%, and 26% of electricity comes from renewables. These settlements do produce considerable volumes of green electricity, but still cannot reach the benchmark of self-sufficiency in spite of the fact that in their own areas they generate renewable electric power on the highest level as a proportion of local consumption. As a result, none of the settlements are capable of supplying their hybrid vehicle stocks with local renewable energy sources (Table 5).

4.3. Number and Proportion of Biofuel-Powered Vehicles

In 2017, the total number of vehicles running on biofuels in Hungary remained under 1000. Most of these vehicles, some 133 cars in total, can be found in Budapest, but they represent an invisible number in the city's total fleet, which number more than 750,000 vehicles. Even in cities where the largest numbers of cars powered by bioenergy are used, the number of cars fueled with methanol, biogas, vegetable oil, and petrol/ethanol ranges between 6 and 14. All the first 20 top-ranking settlements with the largest rates of biofuel-powered vehicles are villages with small populations, and therefore the one or two registered vehicles account for 0.5–2% (Table 6, Figure 5).

Table 6. Number and proportion of biofuel-powered vehicles in the vehicle fleets of Hungarian settlements, as well as the proportions of electricity produced by SSHPPs and small-scale power plants under 0.5 MW in the consumption of the settlements (2017).

Number and Proportion of Biofuel-Powered Vehicles in Settlements with the Largest Biofuel-Powered Vehicles					Number and Proportion of Biofuel-Powered Vehicles in Settlements with the Highest Proportion of Biofuel-Powered Vehicles (Settlement Rank)				
	SETTLEMENT	Number of Biofuel-Powered Vehicles in Total (Vehicle Units)	Proportion of Biofuel-Powered Vehicles (%)	Proportion of the Annual Electricity Demand of the Settlement Covered from Renewable Energy Sources (%)		SETTLEMENT	Number of Biofuel-Powered Vehicles in Total (Vehicle Units)	Proportion of Biofuel-Powered Vehicles (%)	Proportion of the annual Electricity Demand of the Settlement Covered from Renewable Energy Sources (%)
1	Budapest	133	0.01	0.73	1	Drávacsehi	1	2.04	0
2	Kecskemét	14	0.02	1.03	2	Zsennye	1	2	0
3	Szeged	14	0.02	1.67	3	Sénye	1	1.96	17.77
4	Győr	13	0.02	1.31	4	Nak	4	1.83	0
5	Miskolc	13	0.02	1.68	5	Adorjás	1	1.63	0
6	Debrecen	11	0.01	1.65	6	Bakonykúti	1	1.36	0
7	Nyíregyháza	11	0.02	1.01	7	Detek	1	1.25	5.10
8	Eger	9	0.03	1.29	8	Gálosfa	1	1.25	1.53
9	Dunaharaszti	8	0.06	2.07	9	Martonfa	1	1.07	7.13
10	Gödöllő	8	0.04	2.74	10	Szulimán	1	0.97	0
11	Hódmezővásárhe	8	0.04	4.87	11	Szécsénke	1	0.89	0
12	Pécs	8	0.01	1.44	12	Muraszemenye	2	0.81	0.24
13	Veszprém	8	0.02	0.96	13	Lak	1	0.76	0
14	Cegléd	7	0.04	0.28	14	Boldogkőújfalu	1	0.75	10.38
15	Érd	7	0.02	3.00	15	Jákfalva	1	0.75	2.14
16	Székesfehérvár	7	0.01	0.36	16	Alsódobsza	1	0.74	2.58
17	Vác	7	0.04	0.51	17	Fonó	1	0.72	0
18	Kőszeg	6	0.11	0.96	18	Legénd	1	0.68	0
19	Sopron	6	0.02	1.75	19	Bögöte	1	0.64	0.95
20	Zalaegerszeg	6	0.02	1.73	20	Klárafalva	1	0.62	0

Beyond covering the annual electricity demands of the settlements, the electric power generated from local renewables has no relevance to the operation of vehicles running on biofuel. Still, in a significant proportion of these settlements, the source of electricity originating from renewable sources is biogas, landfill gas, and sewage gas, which can potentially serve as local options for the fuel supply of partially or fully gas-powered vehicles. The ranking includes settlements such as Győr, Miskolc, Debrecen, Szeged, or Hódmezővásárhely, of which the latter has the largest share of renewable electricity (Table 6). In Debrecen, for instance, buses serving urban transport run on biomethane produced from landfill gas and sewage gas generated in the city's landfill site and wastewater treatment plant by way of purification. Around half of the settlements with the highest proportions of biofuel-powered vehicles are capable of generating renewable electricity in their own areas, but none of them from energy sources that can be used for the vehicles in question. That is the result of the fact that without exception, the power plants of the 20 top-ranking settlements are solar power plants.

4.4. Number and Proportion of Environmentally Friendly, Alternative-Powered Vehicles

If electric, hybrid, and biofuel-powered vehicles are combined into a single category of environmentally friendly, alternative-powered vehicles, then Budapest can boast the largest number of such vehicles with the stock numbering nearly 10,000. They represent only 1.27% of the city's cars. The capital city is followed by Debrecen with 517 vehicles, which make up only 0.61% of the vehicle stock of the second most populous settlement. Again, the combined category lists large cities and small towns in the metropolitan area of the capital city. Of the 20 settlements with the largest number of alternative-powered vehicles, Balatonalmádi on the shores of Lake Balaton stands out, with a nearly 5% proportion of alternative-powered vehicles. With the focus shifted to the percentage ratio among all the vehicles registered in the given settlement, then the highest proportion, 6.25% is found in Keresztéte. This is followed by Libickozma with 5.55% and Balatonalmádi with 4.98%. While in the first two settlements the given proportions are made up of one or two vehicles, Balatonalmádi needed 258 vehicles to achieve its ranking (Table 7, Figure 6).

Table 7. Number and proportion of alternative-powered vehicles in the vehicle fleets of Hungarian settlements, as well as the proportions of electricity produced by SSHPPs and small-scale power plants under 0.5 MW in the consumption of the settlements (2017).

Number and Proportion of Alternative-Powered Vehicles in Settlements with the Largest Number of Alternative-Powered Vehicles					Number and Proportion of Alternative-Powered Vehicles in Settlements with the Highest Proportion of Alternative-Powered Vehicles (Settlement Rank)				
	SETTLEMENT	**Number of Alternative-Powered Vehicles (Vehicle Units)**	**Proportion of Alternative-Powered Vehicles (%)**	**Proportion of the Annual Electricity Demand of the Settlement Covered from Renewable Energy Sources (%)**		**SETTLEMENT**	**Number of Alternative-Powered Vehicles (Vehicle Units)**	**Proportion of Alternative-Powered Vehicles (%)**	**Proportion of the Annual Electricity Demand of the Settlement Covered from Renewable Energy Sources (%)**
1	Budapest	9652	1.27	0.73	1	Keresztéte	2	6.25	0
2	Debrecen	517	0.61	1.65	2	Libickozma	1	5.55	0
3	Szeged	388	0.60	1.67	3	Balatonalmádi	258	4.98	2.63
4	Győr	322	0.53	1.31	4	Hernyék	1	3.44	0
5	Székesfehérvár	291	0.58	0.36	5	Tésa	15	3.21	0
6	Érd	286	0.85	3.00	6	Halásztelek	154	2.81	3.31
7	Pécs	282	0.46	1.44	7	Bakonykúti	2	2.73	0
8	Kecskemét	277	0.50	1.03	8	Erdősmárok	1	2.70	15
9	Miskolc	265	0.44	1.68	9	Varbóc	1	2.63	0
10	Balatonalmádi	258	4.98	2.63	10	Gálosfa	2	2.5	1.53
11	Nyíregyháza	236	0.43	1.01	11	Und	7	2.49	0
12	Budaörs	229	1.32	2.07	12	Kozárd	2	2.43	8.08
13	Dunakeszi	217	1.04	2.78	13	Fenyőfő	1	2.38	2.56
14	Csomád	198	1.01	148.64	14	Tornanádaska	1	2.38	0
15	Szentendre	197	1.43	3.18	15	Tüskevár	69	2.33	0
16	Szombathely	195	0.51	1.49	16	Telki	41	2.23	17.28
17	Veszprém	169	0.61	0.96	17	Kékkút	1	2.17	0.06
18	Gödöllő	166	1.01	2.74	18	Martonfa	2	2.15	7.13
19	Szigetszentmiklós	163	0.84	2.09	19	Remeteszőlős	10	2.14	10.55
20	Halásztelek	154	2.81	3.31	20	Drávacsehi	1	2.04	0

Of the 20 settlements with the largest number of environmentally friendly, alternative-powered vehicles, there is only one settlement that produces electric power from local renewable resources beyond its own needs. This settlement is the village of Csomád, situated in the Budapest metropolitan area, which has a stock of nearly 20,000 vehicles despite having a population of only 1650. This is due to the fact that the fleets of several business operators are registered in the settlement as a result of the favorable conditions of taxation offered by the local authority. A total of 1% of its vehicle stock is made up of cars operating with alternative, environmentally friendly, mostly hybrid and electric technologies. The renewable electricity generated in the area of the settlement exceeds the needs of the settlement by almost 50%, and this energy can be utilized to supply its hybrid and electric vehicles. This electric power is sufficient for the annual electricity demand of the vehicles belonging to the village, but if all the vehicles in the settlement were electric or hybrid, it would prove to be inadequate.

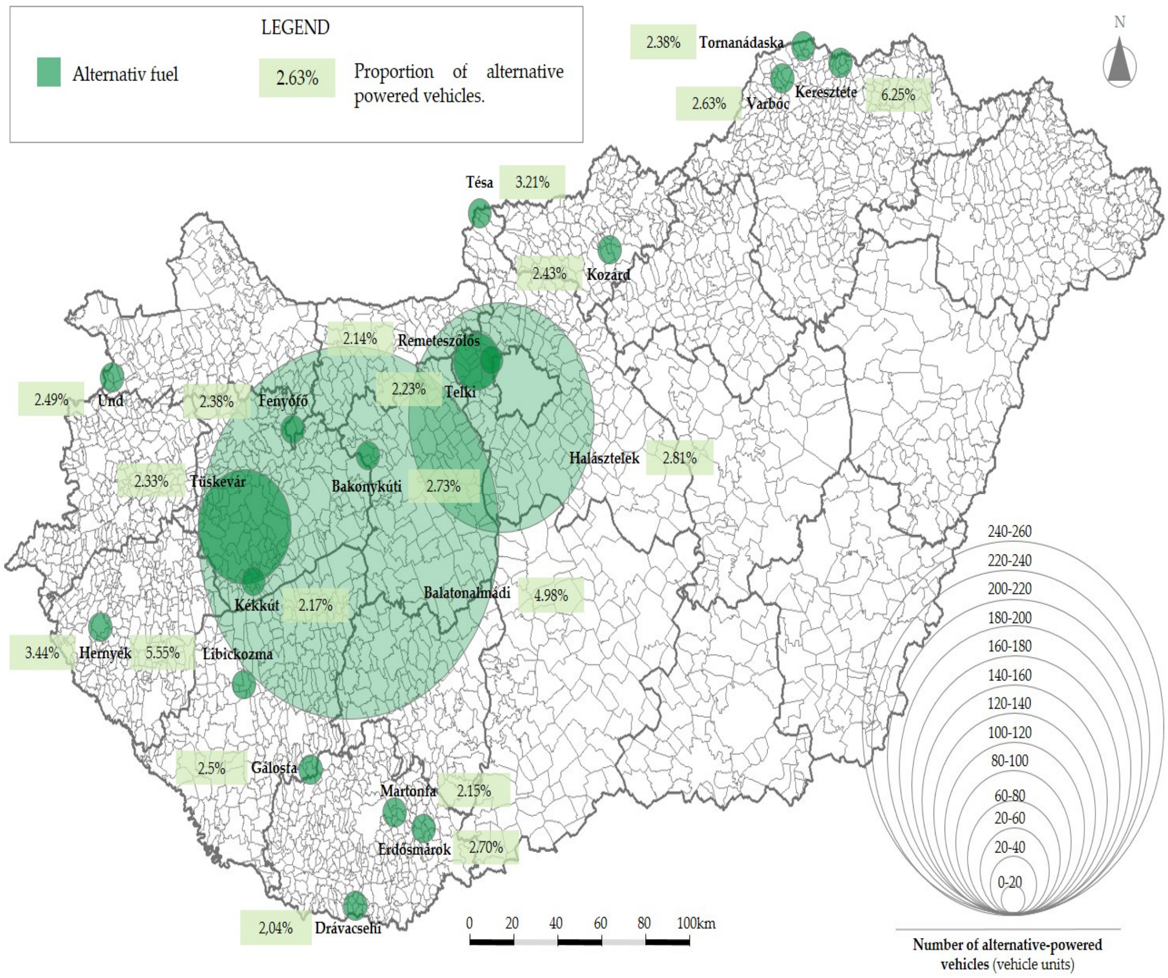


Figure 6. Numbers and proportions of environmentally friendly, alternative powered vehicles in the settlements with the largest ratio of alternative powered vehicles, in Hungary, 2017 (settlement rank).

4.5. The Link between Renewable Electricity Generation and the Environmentally Friendly Vehicle Stock

With respect to the settlements that generate the most local, renewable electric power in comparison to their respective annual consumption, there are 30 Hungarian settlements that would be capable of ensuring the potential supply of their alternative-fueled motor vehicle stocks with fuel. In their own areas, these settlements annually produce electricity in excess of their own needs with the use of small-scale power plants utilizing renewable energy. Local overproduction is of such an extent that these settlements would be able to satisfy the annual electricity demands of 29 other, neighboring settlements by transferring their unused electric power. This means that the energy from overproduction could be used for charging electric vehicles; however, only three of these settlements have hybrid and/or electric vehicles (Table 8, Figure 7). In addition to the already mentioned Csomád, they are Ganna and Bodrogkeresztúr.

Owing to their settlement geographic characteristics, these small settlements are in more favorable positions in terms of energy self-sufficiency, and therefore the associated objectives can be accomplished more easily. They are on the top of the absolute ranking. To assess the situation of larger settlements, studies have been conducted in relation to settlements with populations between 10,000 and 100,000 inhabitants, as well those with over 100,000 inhabitants. These two categories have been created arbitrarily, in consideration of the typical sizes of Hungarian settlements.

Among the small towns and cities with populations between 10,000 and 100,000 inhabitants, Kerepes has the highest electricity self-sufficiency rate, which reaches 47%, followed by Nagykőrös with 27%. In the ranking that lists 20 settlements, none of them have an electric or hybrid car proportion above 1%. From among the cities with populations over 100,000 inhabitants, Miskolc has the highest proportion of renewable electricity generation, accounting for 1.68%. Compared to their vehicle stocks, in these large cities the proportions of alternative-powered vehicles using electricity are also under 1% (Table 9, Figure 7).

Table 8. Proportion of hybrid and electric vehicles in the vehicle stocks of settlements that are self-sufficient in the field of electric power generation from local renewable energy sources. (Renewable electricity production only as based on the combined electricity production capacity of the categories of small-scale household power plants (SSHPP) and small-scale power plants with installed capacities under 0.5 MW that are not subject to authorization or do not belong to the SSHPP category (2017)).

	SETTLEMENT among all Settlements in Hungary	Proportion of the Annual Electricity Demand of the Settlement Covered from Renewable Energy Sources (%)	Population (Person)	Total Vehicles	Number of Hybrid Vehicles (Vehicle Units)	Proportion of Hybrid Vehicles %	Number of Electric Vehicles (Vehicle Units)	Proportion of Electric Vehicles %
1	Sóstófalva	558	262	84	0	0	0	0
2	Ipacsfa	534	200	85	0	0	0	0
3	Gibárt	493	335	142	0	0	0	0
4	Galvács	391	87	91	0	0	0	0
5	Vekerd	346	119	101	0	0	0	0
6	Csanádalberti	280	468	120	0	0	0	0
7	Barnag	272	142	82	0	0	0	0
8	Illocska	252	268	69	0	0	0	0
9	Tiszadorogma	234	377	173	0	0	0	0
10	Ganna	232	269	154	1	0.64	0	0
11	Alsótelekes	224	140	35	0	0	0	0
12	Kupa	204	186	47	0	0	0	0
13	Bodrogkeresztúr	197	1102	599	1	0.16	0	0
14	Egyházasharaszti	168	334	107	0	0	0	0
15	Somogyhatvan	167	372	109	0	0	0	0
16	Peterd	165	223	88	0	0	0	0
17	Csörötnek	165	862	360	0	0	0	0
18	Kémes	156	475	211	0	0	0	0
19	Csomád	149	1631	19,533	87	0.44	11	0.05
20	Csonkamindszent	143	176	62	0	0	0	0
21	Nógrádkövesd	142	660	289	0	0	0	0
22	Hejce	132	223	184	0	0	0	0
23	Buzsák	127	1525	603	0	0	0	0
24	Pornóapáti	125	384	213	0	0	0	0
25	Hejőpapi	125	1175	345	0	0	0	0
26	Zalaszentmihály	116	1005	428	0	0	0	0
27	Csörög	112	2148	780	0	0	0	0
28	Bojt	106	598	143	0	0	0	0
29	Nagyhuta	102	64	28	0	0	0	0
30	Demjén	101	613	300	0	0	0	0

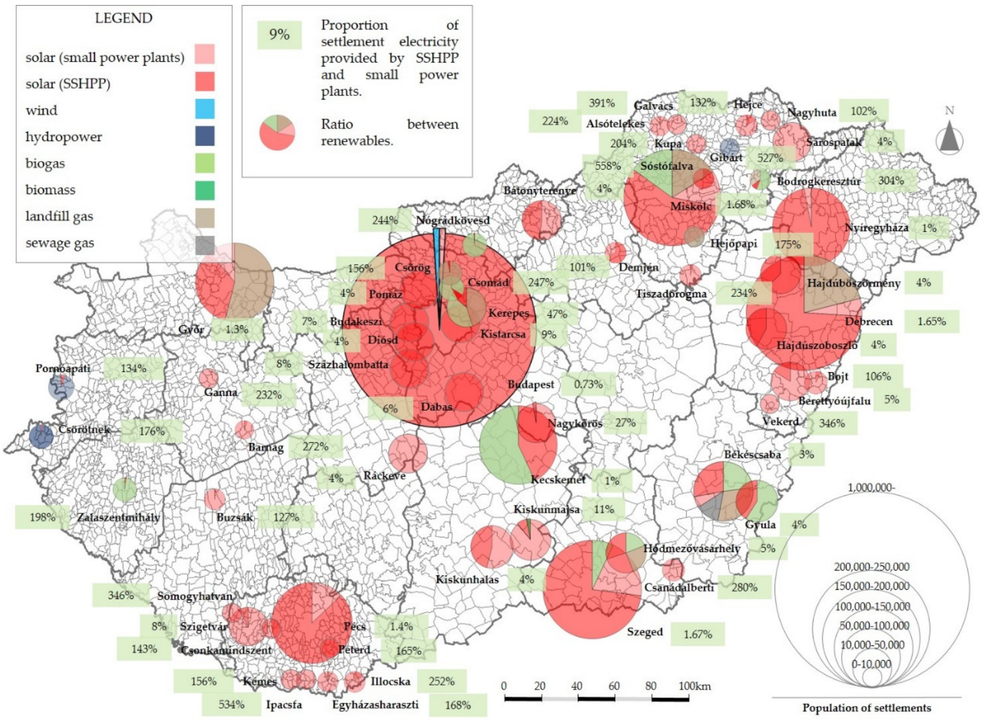


Figure 7. Self-sufficient settlements in Hungary: the combined share of electricity produced in the categories of small household-scale power plants (SSHPP) and small-scale power plants with installed capacities under 0.5 MW—not subject to authorization or belonging to the SSHPP category—from local renewable energy sources in the electricity consumption of the settlements (2017).

Table 9. Proportions of hybrid and electric vehicles in the vehicle stocks of settlements with populations of 10,000–100,000 and over 100,000 inhabitants, accompanied by the largest proportions of electric power generation from local renewable energy resources. (Renewable electricity production only as based on the combined electricity production capacity of the categories of small-scale household power plants (SSHPP) and small-scale power plants with installed capacities under 0.5 MW that are not subject to authorization or do not belong to the SSHPP category (2017)).

	SETTLEMENTS between 10,000 and 100,000 Inhabitants	Proportion of the Annual Electricity Demand of the Settlement Covered from Renewable Energy Sources (%)	Population (Person)	Total Vehicles	Number of Hybrid Vehicles (Vehicle Units)	Proportion of Hybrid Vehicles %	Number of Electric Vehicles (Vehicle Units)	Proportion of Electric Vehicles %
1	Kerepes	47	10,473	5025	15	0.29	5	0.09
2	Nagykőrös	27	23,935	10,115	8	0.07	0	0
3	Kiskunmajsa	11	11,534	5904	3	0.05	0	0
4	Kistarcsa	9	12,990	5807	28	0.48	3	0.05
5	Szigetvár	8	10,558	4346	8	0.18	2	0.04
6	Százhalombatta	8	19,228	9486	14	0.14	2	0.02
7	Budakeszi	7	14,887	6721	50	0.74	7	0.10
8	Dabas	6	17,014	9531	16	0.16	3	0.03
9	Berettyóújfalu	5	14,989	6383	14	0.21	0	0
10	Hódmezővásárhely	5	45,159	18,094	26	0.14	4	0.02
11	Hajdúböszörmény	4	31,026	12,245	13	0.10	0	0
12	Sárospatak	4	12,375	5474	6	0.10	4	0.07
13	Gyula	4	30,656	12,709	16	0.12	4	0.03
14	Diósd	4	10,354	5249	32	0.60	1	0.01
15	Pomáz	4	17,889	7912	38	0.48	7	0.08
16	Hajdúszoboszló	4	23,987	10,379	16	0.15	3	0.02
17	Bátonyterenye	4	12,525	4409	4	0.09	1	0.02
18	Kiskunhalas	4	28,532	13,137	25	0.19	5	0.03
19	Ráckeve	4	10,392	4760	14	0.29	1	0.02
20	Békéscsaba	3	60,137	27,586	60	0.21	12	0.04

Table 9. *Cont.*

	SETTLEMENTS between 10,000 and 100,000 Inhabitants	Proportion of the Annual Electricity Demand of the Settlement Covered from Renewable Energy Sources (%)	Population (Person)	Total Vehicles	Number of Hybrid Vehicles (Vehicle Units)	Proportion of Hybrid Vehicles %	Number of Electric Vehicles (Vehicle Units)	Proportion of Electric Vehicles %
SETTLEMENTS over 100,000 Inhabitants								
1	Miskolc	1.68	160,325	59,256	106	0.17	25	0.04
2	Szeged	1.67	163,763	64,436	177	0.27	22	0.03
3	Debrecen	1.65	203,493	84,496	262	0.31	35	0.04
4	Pécs	1.4	149,030	60,725	122	0.20	21	0.03
5	Győr	1.3	124,743	60,189	140	0.23	36	0.05
6	Nyíregyháza	1	120,086	53,948	103	0.19	15	0.02
7	Kecskemét	1	110,974	54,597	122	0.22	37	0.06
8	Budapest	0.73	1,693,051	754,524	4347	0.57	1273	0.16

5. Conclusions, Summary

According to the requirements that we have set, a settlement must be capable of producing the electricity it needs within its own area in order to be self-sufficient, as well as all vehicle of the settlement must be alternative drive.

Among the Hungarian settlements, there are 30 settlements that are able to generate more green electricity than their annual electric power demands. One of the potential ways to utilize the electricity from overproduction is to charge the electric and hybrid vehicles belonging to the settlement, which can be used to supply energy to local transport, as well.

However, the settlements that have achieved self-sufficiency still have not acquired an electric vehicle fleet that would consume the overproduced energy locally. On the other hand, settlements that are in possession of significant quantities of electric, hybrid, and biofuel-powered vehicles are not able to satisfy the energy demanded for the operation of these vehicles with renewable energy produced in their own areas. In addition, these vehicle fleets account for only a fraction of all the vehicles registered in the settlements concerned.

The above results serve as useful feedback in relation to the outcomes of the governmental or municipal measures taken, and the allowances and subsidies provided for spreading environmentally friendly technologies until the end of 2017, in the energy transition process of Hungary's system of transportation. They indicate that there is still a long way to go until the realization of the self-sufficiency of settlements in the fields of electricity supply and transport. If energy transition is to be implemented in the foreseeable future, in the electricity supply and transport of settlements, the incentives provided so far are not sufficient.

The results of the study answer the political and social question marks that locally available renewable energy sources are not able to meet the electricity needs of a settlement.

The proportion of the 2017 electricity production capacities and alternative drive vehicles still has not proved empirically, that settlement are capable of meeting the energy demands of their vehicle fleet. However, it is apparent already that there is no technological barrier. In order to achieve the goal more quickly, energy policy measures are needed:

- We suggest support for small-scale household power plants. The energy conservation and cost reduction have inspired the dynamic increase in household power plants in favor of balanced energy supply in settlements. The calculation of remodeling designs (gross calculation) will set back any positive attitude to investment. The support for investment, the opportunity to build bigger capacity, the supported purchase price, the support for household and municipal accumulator systems can increase capacity.
- The expansion of alternative – primarily electric drive – vehicles is multifactorial: range, charge time, charge stations density, the maturity of the technology, and the price of the vehicles. In Hungary, the price of the vehicles is an important question.
- The expansion of market-based small power plants under 0.5 MWs capacity is dynamic, due to the Renewable Energy Support Scheme (METÁR). There are few examples of municipal power plant projects and storage capacity building before the

end of 2017. One of the reasons for this is the limited financial room for maneuver of local authorities. We suggest supporting the building of municipal power plants and storage capacities, which will provide better energy security, decentralized energy generation, an increasing level of self-sufficiency, and the better functioning of complex settlement energy systems.

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