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CHANGE DYNAMICS OF ELECTRICITY PRICES FOR HOUSEHOLDS IN THE EUROPEAN UNION BETWEEN 2011 AND 2020

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Abstract

The aim of the article: The aim of the article is to evaluate and analyze the dynamics of electricity prices for households in the European Union member states (EU-27) in the period 2011–2020. The study also focuses on the key components of electricity prices in the countries analyzed. The discussed issues are important from the socio-economic point of view. It refers to the issue of sustainable development, where electricity prices are addressed in relation to the problem of energy poverty of households.

Methodology: The study is of a theoretical and analytical character. In addition to the review of available dnational and foreign literature, Eurostat data on electricity prices for households in the EU-27 were analysed. Moreover, the paper presents the application of a selected cluster analysis method, i.e. the *k*-means method, to assess the situation of the EU-27 countries in terms of electricity prices for households in the analysed period of 2011–2020.

Results of the research: The result of the analyses undertaken is a presentation of the share of VAT and other taxes and levies in the price of electricity for households. The analyses showed differences between the countries in the structure of establishing the electricity price for households. Only in three countries (Bulgaria, Hungary, Slovakia) it was found that there was no share of other taxes and levies in the electricity price. In turn, the applied *k*-means method contributed to obtaining the division of countries into four groups reflecting the differentiation in terms of the amount of electricity price for households in the period under study.

Keywords: electricity price, energy sector, sustainable development.

JEL Class: G59, N70, P46, O13, Q01, Q41.

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INTRODUCTION

The energy sector occupies a strategic place in the economic structure. Without electricity it is impossible to imagine both the smooth functioning of economic processes and many aspects of social life. At the same time, the energy sector is indicated as one of the key areas of change aimed at sustainable development (Sulich and Grudziński, 2019; Østergaard et al., 2014). Researchers of the subject stress in their studies that we are dealing with the so-called green transformation of the energy sector (Ansari and Holz, 2020; Crespi, 2016). In this context, the authors of this article note a rather clear division of the undertaken discourse in scientific studies. On the one hand, one can see quite a number of studies that focus on describing new, less carbon-intensive technologies in the energy sector. Here, it is often emphasised that, at the same time, emphasis should be placed on the appropriate technological development of both, the conventional energy and the renewable energy sectors and on creating energy systems that would ensure more efficient energy use (Gasparatos et al., 2017; Omer, 2017). On the other hand, researchers of the subject in their studies analyse numerous indicators describing the energy sector in the context of sustainable development, e.g. greenhouse gas emissions intensity of energy consumption (Sarkodie and Strezov, 2019), final energy consumption (Wang et al., 2019), energy productivity (Li et al., 2020), share of renewable energy in gross final energy consumption (Anton and Nucu, 2020). The conclusions of these studies emphasise that the changes that are taking place in the energy sector are already gradually contributing to the diversification of energy sources. In the opinion of the authors, the two key research topics should be considered classic, as they discuss the issues related to the energy sector from the perspective of greenhouse gas emissions, or energy production from renewable sources.

Along with the conceptual development of the idea of sustainable development, in addition to the classical understanding of the issues related to the energy sector presented above, the social aspects of functioning of the discussed sector of the economy are increasingly discussed, as well as the need to ensure energy security for current and future generations, as an important factor that may affect the quality of life (Pultowicz, 2009; Świerszcz and Grenda, 2018). In this field, the authors note that the issue of electricity pricing is still insufficiently addressed. The importance of this area is evidenced by the fact that consumers (including households) will be shifted part of the costs associated with the green transformation of the energy sector. Consumers will feel this in connection with an increase in their electricity bills (including, above all, in fixed charges independent of the amount of electricity consumed).

The article focuses on the changes in electricity prices between 2011 and 2020 for households in the 27 EU member states (EU-27). The UK was not included in the analysis despite the period covered, as it left the European Union in 2020. The research focused on the price of electricity for households with an annual consumption of 2500–5000 kWh including taxes and charges. The choice of data coverage was deliberate. It resulted from an in-depth analysis of the literature on the subject (Verbič et al., 2017; Benthaus, 2019). Based on the indicated analysis, the authors perceived that the aforementioned data range is presented as appropriate for this type of analysis and, at the same time, allows for the implementation of the set objective, which was to analyse the dynamics that occurred in electricity prices during the selected years.

1. ELECTRICITY PRICE AND ITS COMPONENTS – DESK STUDY

The price of electricity depends on numerous issues, one of which is the structure of electricity generation sources. In this context, in a growing number of studies, researchers refer to the energy transformation aimed at changing the existing energy sector into a more sustainable one. Such a change is characterised by a reduction in the use of non-renewable energy sources such as coal or lignite in the process of electricity generation (with the ultimate goal of complete abandonment of non-renewable energy sources). The result of such actions is the transition from a brown economy (based on coal) to a green economy (based on non-renewable energy sources) (Sulich, 2018). In this article, the authors will discuss the issue of electricity prices taking into account the aforementioned trend, which today is characterised not only by European Union member states, but also by many other countries, e.g. China (Lai and Warner, 2015; Zhang and Lis, 2020).

Electricity prices for EU-27 households are influenced by the electricity price, VAT and other taxes and levies. In this paper the authors will not decompose other taxes and levies into subcategories for analytical reasons. A similar procedure in their analyses is done by other researchers of the subject (Verbič et al., 2017), or Eurostat. The mentioned three components, as indicated in Tables 1, 3, 4 and 5, differentiate individual EU countries.

Based on the data presented in Table 1, the electricity price per kWh in euro cents for households was highest in Germany, Denmark and Belgium. On the other hand, France, Romania and Greece had the highest dynamics of electricity price changes between 2011 and 2020 to the obvious disadvantage of households. It should be noted that the electricity price in euro cents per kWh for households in 2020 was lower in six EU-27 countries than in 2011. In 2020, relative to 2019, electricity prices increased most significantly in Luxembourg, Poland and Slovakia. In the case of price increases in Poland, the authors expect further increases also in 2021.

Table 1. Electricity prices for household consumers in the EU-27 in 2011, 2015, 2019, 2020 in euro cents per kWh*

Specification	Household electricity price per kWh in euro cents per year:				Position in 2020 compared to the EU-27	Dynamics [%]				Change D–A
	2011	2015	2019	2020		B/A x 100	C/A x 100	D/A x 100	D/C x 100	
	A	B	C	D	E	F	G	H	I	J
Austria	19,65	19,83	20,74	21,67	6	100,92	105,55	110,28	104,48	2,02
Belgium	21,19	23,52	28,60	27,02	3	111,00	134,97	127,51	94,48	5,83
Bulgaria	8,74	9,57	9,58	9,82	27	109,50	109,61	112,36	102,51	1,08
Croatia	11,46	13,12	13,24	13,07	23	114,49	115,53	114,05	98,72	1,61
Cyprus	24,13	18,38	22,36	16,98	15	76,17	92,66	70,37	75,94	–7,15
Czechia	16,27	14,08	17,70	17,95	11	86,54	108,79	110,33	101,41	1,68
Denmark	29,76	30,42	29,24	28,19	2	102,22	98,25	94,72	96,41	–1,57
Estonia	10,42	12,91	14,11	12,91	25	123,90	135,41	123,90	91,50	2,49
Finland	15,73	15,30	17,83	17,73	12	97,27	113,35	112,71	99,44	2,00
France	14,22	16,82	19,13	19,58	10	118,28	134,53	137,69	102,35	5,36
Germany	25,31	29,46	28,78	30,06	1	116,40	113,71	118,77	104,45	4,75
Greece	12,38	17,71	15,51	16,41	17	143,05	125,28	132,55	105,80	4,03
Hungary	15,53	11,45	10,97	10,09	26	73,73	70,64	64,97	91,98	–5,44
Ireland	20,86	24,54	25,46	26,16	4	117,64	122,05	125,41	102,75	5,30
Italy	20,65	24,28	23,41	21,53	7	117,58	113,37	104,26	91,97	0,88
Latvia	13,42	16,50	16,40	14,32	20	122,95	122,21	106,71	87,32	0,90
Lithuania	12,21	12,43	12,54	13,21	22	101,80	102,7	108,19	105,34	1,00
Luxembourg	16,62	17,67	17,99	19,85	9	106,32	108,24	119,43	110,34	3,23
Malta	16,66	12,69	13,04	12,98	24	76,17	78,27	77,91	99,54	–3,68
Netherlands	18,01	18,46	20,55	13,61	21	102,50	114,1	75,57	66,23	–4,40
Poland	13,51	14,18	13,76	15,10	18	104,96	101,85	111,77	109,74	1,59
Portugal	18,81	22,85	21,81	21,33	8	121,48	115,95	113,40	97,80	2,52
Romania	10,85	13,19	14,21	14,49	19	121,57	130,97	133,55	101,97	3,64
Slovakia	17,10	15,17	15,85	17,24	13	88,71	92,69	100,82	108,77	0,14
Slovenia	14,92	16,31	16,66	16,94	16	109,32	111,66	113,54	101,68	2,02
Spain	20,88	23,70	23,94	22,98	5	113,51	114,66	110,06	95,99	2,10
Sweden	20,44	18,74	20,76	17,18	14	91,68	101,57	84,05	82,76	–3,26

* The data represents the second half of each year for medium residential annual consumption between 2500 and 5000 kWh.

Source: compiled on the basis of data from Eurostat.

Table 2. Share of renewable energy in gross final energy consumption in electricity – comparison between 2011 and 2019

Specification	Share of renewable energy in gross final consumption of energy in electricity [%] in:		Position in 2019 compared to the EU-27	Dynamics [%] B/A x 100	Position in D	Change B–A	Position in F
	2011	2019					
	A	B	C	D	E	F	G
Austria	66,78	75,14	1	112,52	26	8,36	16
Belgium	9,01	20,83	19	231,24	4	11,82	6
Bulgaria	12,62	23,51	15	186,27	10	10,89	9
Croatia	37,59	49,78	6	132,43	18	12,19	5
Cyprus	3,45	9,76	26	283,11	2	6,31	20
Czechia	10,61	14,05	23	132,39	19	3,44	25
Denmark	35,87	65,35	3	182,17	11	29,48	1
Estonia	12,20	22,00	17	180,33	12	9,80	11
Finland	29,39	38,07	9	129,53	20	8,68	14
France	16,18	22,38	16	138,34	16	6,20	21
Germany	20,93	40,82	8	195,02	8	19,89	2
Greece	13,81	31,30	14	226,61	5	17,49	4
Hungary	6,38	9,99	25	156,64	14	3,61	24
Ireland	18,25	36,49	11	199,93	7	18,24	3
Italy	23,55	34,97	12	148,51	15	11,42	8
Latvia	44,69	53,42	5	119,53	21	8,73	13
Lithuania	9,02	18,79	20	208,31	6	9,77	12
Luxembourg	4,08	10,86	24	266,43	3	6,78	19
Malta	0,45	8,04	27	1770,70	1	7,59	18
Netherlands	9,74	18,22	21	187,05	9	8,48	15
Poland	8,16	14,36	22	175,88	13	6,19	22
Portugal	45,78	53,77	4	117,46	23	7,99	17
Romania	31,13	41,71	7	133,98	17	10,58	10
Slovakia	19,31	21,95	18	113,68	25	2,64	26
Slovenia	31,05	32,63	13	105,12	27	1,59	27
Spain	31,56	36,95	10	117,10	24	5,40	23
Sweden	59,62	71,19	2	119,39	22	11,56	7

Source: compiled on the basis of data from Eurostat.

This increase is due to additional charges in electricity bills, which pass on to households part of the costs aimed at changing the existing energy sector into a more sustainable one. As Table 2 indicates, Poland was only ranked 22nd among the EU-27 countries in 2019 (data availability) in terms of the share of renewable energy sources in electricity in gross final energy consumption. Despite the observed average dynamics of changes against the background of the EU-27 countries that have taken place since 2011 in terms of increasing the share of renewable energy sources in electricity, it should be stated that the actions taken in the transformation of the energy sector in Poland are insufficient.

The essential component of the kWh price for households is the electricity price excluding taxes. In 2020, citizens of Ireland, Belgium and Luxembourg paid the most for this component of the electricity price. The analysis carried out in Table 3 allows us to conclude that in as many as 13 cases in 2020, compared to 2011, there was a decrease in the price of this component affecting household electricity charges. However, as shown in Table 1, only some of the EU-27 countries saw a decrease in electricity prices per kWh in the period in question. Therefore, it becomes necessary to analyse VAT (Table 4) and other taxes and levies (Table 5) to indicate whether they contributed to the increase in electricity prices for households.

Table 4 shows the value of VAT per kWh of electricity for households in individual EU-27 countries. The analysis of the presented data allows us to conclude that in 2020, VAT paid per kWh was highest in Slovakia, Denmark and Belgium. Moreover, it should be pointed out that in most EU Member States there was an increase in VAT payments per kWh compared to 2011. The highest growth dynamics in 2020 compared to 2011 was observed in Slovakia, Portugal and Luxembourg. In 2020, Poland was characterised by an average level of VAT compared to the EU-27.

The analysis of other taxes and levies, which is carried out in Table 5, shows that in 2020 in three countries such levies were not present in the retail price for household electricity. The Netherlands provide a refund (allowance), and thus reported a negative share of other taxes and levies. In contrast, Denmark, Germany and Spain had the highest other taxes and levies in 2020. What should also be noted is the very high dynamics of changes in other taxes and levies between 2011 and 2020. This dynamics is understandable given that other taxes and levies include, inter alia, charges related to renewable taxes, capacity taxes or environmental taxes. Many of these levies and taxes have increased in recent years as a result of the need to carry out a green transformation of the energy sector. This increase in levies is noticeable, among others, in Poland that was already mentioned.

Table 3. Electricity prices excluding taxes and charges for households in the EU-27 in 2011, 2015, 2019, 2020 in euro cents per kWh*

Specification	Electricity price excluding taxes and charges to households per kWh in euro cents per year:				Position in 2020 compared to the EU-27	Dynamics [%]				Change D–A
	2011	2015	2019	2020		B/A x 100	C/A x 100	D/A x 100	D/C x 100	
	A	B	C	D	E	F	G	H	I	J
Austria	14,44	12,39	13,49	13,84	5	85,80	93,42	95,84	102,59	–0,60
Belgium	15,95	18,42	19,54	17,98	2	115,49	122,51	112,72	92,02	2,03
Bulgaria	7,27	7,98	7,98	8,18	26	109,77	109,77	112,52	102,51	0,91
Croatia	9,25	10,03	10,3	10,17	20	108,43	111,35	109,95	98,74	0,92
Cyprus	20,35	14,63	15,76	11,84	14	71,89	77,44	58,18	75,13	–8,51
Czechia	13,45	11,53	12,55	12,83	9	85,72	93,31	95,39	102,23	–0,62
Denmark	12,01	8,83	10,42	9,08	25	73,52	86,76	75,60	87,14	–2,93
Estonia	7,63	9,51	10,27	9,53	23	124,64	134,6	124,90	92,79	1,90
Finland	11,08	10,09	12,01	12,05	13	91,06	108,39	108,75	100,33	0,97
France	10,17	11,13	12,6	12,92	8	109,44	123,89	127,04	102,54	2,75
Germany	13,95	14,27	13,21	14,51	4	102,29	94,70	104,01	109,84	0,56
Greece	10,03	12,27	11,89	12,78	10	122,33	118,54	127,42	107,49	2,75
Hungary	11,92	9,02	8,64	7,94	27	75,67	72,48	66,61	91,90	–3,98
Ireland	17,55	19,91	21,3	21,79	1	113,45	121,37	124,16	102,30	4,24
Italy	14,12	14,79	14,27	13,31	7	104,75	101,06	94,26	93,27	–0,81
Latvia	11,00	10,96	11,44	10,05	21	99,64	104,00	91,36	87,85	–0,95
Lithuania	10,09	8,63	9,47	9,72	22	85,53	93,86	96,33	102,64	–0,37
Luxembourg	14,36	13,31	13,25	14,65	3	92,69	92,27	102,02	110,57	0,29
Malta	15,86	12,09	12,27	12,21	12	76,23	77,36	76,99	99,51	–3,65
Netherlands	13,05	12,38	13,59	13,65	6	94,87	104,14	104,60	100,44	0,60
Poland	10,52	11,05	8,67	9,53	24	105,04	82,41	90,59	109,92	–0,99
Portugal	10,68	11,53	12,04	11,38	16	107,96	112,73	106,55	94,52	0,70
Romania	8,23	9,38	10,25	10,40	18	113,97	124,54	126,37	101,46	2,17
Slovakia	13,95	12,32	9,69	11,06	17	88,32	69,46	79,28	114,14	–2,89
Slovenia	11,49	11,26	11,46	11,80	15	98,00	99,74	102,70	102,97	0,31
Spain	16,84	18,64	12,87	12,60	11	110,69	76,43	74,82	97,90	–4,24
Sweden	13,40	12,02	13,16	10,32	19	89,70	98,21	77,01	78,42	–3,08

* The data represents the second half of each year for medium residential annual consumption between 2500 and 5000 kWh.

Source: compiled on the basis of data from Eurostat.

Table 4. Value of VAT on electricity for household customers in the EU-27 in 2011, 2015, 2019, 2020 in euro cents per kWh*

Specification	VAT rate for households per kWh in euro cents per year:				Position in 2020 compared to the EU-27	Dynamics [%]				Change D–A
	2011	2015	2019	2020		B/A x 100	C/A x 100	D/A x 100	D/C x 100	
	A	B	C	D	E	F	G	H	I	J
Austria	3,27	3,31	3,46	3,61	7	101,22	105,81	110,398	104,34	0,34
Belgium	3,59	2,92	4,90	4,60	3	81,34	136,49	128,13	93,88	1,01
Bulgaria	1,47	1,59	1,60	1,64	23	108,16	108,84	111,56	102,50	0,17
Croatia	2,14	2,62	1,52	1,50	24	122,43	71,03	70,09	98,68	–0,64
Cyprus	3,09	2,84	3,41	2,63	15	91,91	110,36	85,11	77,13	–0,46
Czechia	2,70	2,44	3,08	3,12	10	90,37	114,07	115,56	101,30	0,42
Denmark	5,95	6,09	5,85	5,64	2	102,35	98,32	94,79	96,41	–0,31
Estonia	1,73	2,06	2,35	2,15	21	119,08	135,84	124,28	91,49	0,42
Finland	2,94	2,96	3,45	3,43	9	100,68	117,35	116,67	99,42	0,49
France	2,02	2,48	2,75	2,83	13	122,77	136,14	140,10	102,91	0,81
Germany	4,04	4,70	4,60	4,15	4	116,34	113,86	102,72	90,22	0,11
Greece	1,42	2,04	0,88	0,92	26	143,66	61,97	64,79	104,55	–0,50
Hungary	3,10	2,43	2,33	2,15	20	78,39	75,16	69,35	92,27	–0,95
Ireland	2,49	2,92	3,02	3,11	11	117,27	121,29	124,9	102,98	0,62
Italy	1,83	2,21	2,14	1,97	22	120,77	116,94	107,65	92,06	0,14
Latvia	2,42	2,86	2,85	2,49	16	118,18	117,77	102,89	87,37	0,07
Lithuania	2,12	2,16	2,17	2,29	19	101,89	102,36	108,02	105,53	0,17
Luxembourg	0,94	1,31	1,34	1,47	25	139,36	142,55	156,38	109,70	0,53
Malta	0,80	0,60	0,62	0,62	27	75,00	77,50	77,50	100,00	–0,18
Netherlands	2,87	3,21	3,57	2,37	17	111,85	124,39	82,58	66,39	–0,50
Poland	2,52	2,65	2,57	2,82	14	105,16	101,98	111,90	109,73	0,30
Portugal	2,45	4,25	4,03	3,89	6	173,47	164,49	158,78	96,53	1,44
Romania	2,62	2,56	2,27	2,31	18	97,71	86,64	88,17	101,76	–0,31
Slovakia	2,85	2,53	2,64	6,18	1	88,77	92,63	216,84	234,09	3,33
Slovenia	2,49	2,94	3,01	3,05	12	118,07	120,88	122,49	101,33	0,56
Spain	3,18	4,11	4,16	3,99	5	129,25	130,82	125,47	95,91	0,81
Sweden	4,08	3,75	4,15	3,44	8	91,91	101,72	84,31	82,89	–0,64

* The data represents the second half of each year for medium residential annual consumption between 2500 and 5000 kWh.

Source: compiled on the basis of data from Eurostat.

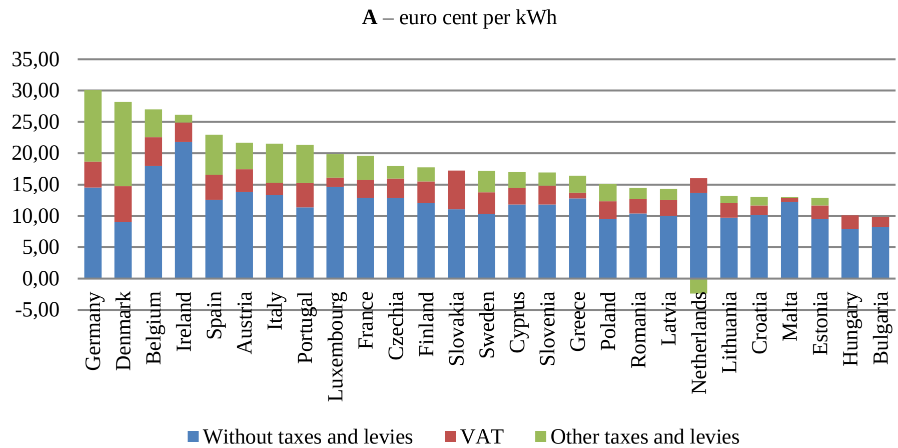
Table 5. Value of other taxes and levies in electricity prices for household consumers in the EU-27 in 2011, 2015, 2019, 2020 in euro cents per kWh*

Specifica-tion	Amount of other taxes and levies in household electricity price per kWh in euro cents per year:				Position in 2020 compared to the EU-27	Dynamics [%]				Change D–A
	2011	2015	2019	2020		B/A x 100	C/A x 100	D/A x 100	D/C x 100	
	A	B	C	D	E	F	G	H	I	J
Austria	1,94	4,13	3,79	4,22	7	212,89	195,36	217,53	111,35	2,28
Belgium	1,65	2,18	4,16	4,44	6	132,12	252,12	269,09	106,73	2,79
Bulgaria	0	0	0	0	25	–	–	–	–	0
Croatia	0,07	0,47	1,42	1,40	19	671,43	2028,57	2000,00	98,59	1,33
Cyprus	0,69	0,91	3,19	2,51	13	131,88	462,32	363,77	78,68	1,82
Czechia	0,12	0,11	2,07	2,00	16	91,67	1725,00	1666,67	96,62	1,88
Denmark	11,8	15,50	12,97	13,47	1	131,36	109,92	114,15	103,86	1,67
Estonia	1,06	1,34	1,49	1,23	21	126,42	140,57	116,04	82,55	0,17
Finland	1,71	2,25	2,37	2,25	14	131,58	138,60	131,58	94,94	0,54
France	2,03	3,21	3,78	3,83	8	158,13	186,21	188,67	101,32	1,80
Germany	7,32	10,49	10,97	11,40	2	143,31	149,86	155,74	103,92	4,08
Greece	0,93	3,40	2,74	2,71	12	365,59	294,62	291,40	98,91	1,78
Hungary	0,51	0	0	0	25	–	–	–	–	–0,51
Ireland	0,82	1,71	1,14	1,26	20	208,54	139,02	153,66	110,53	0,44
Italy	4,70	7,28	7,00	6,25	4	154,89	148,94	132,98	89,29	1,55
Latvia	0	2,68	2,11	1,78	17,5	–	–	–	84,36	1,78
Lithuania	0	1,64	0,9	1,20	22	–	–	–	133,33	1,20
Luxem-bourg	1,32	3,05	3,4	3,73	9	231,06	257,58	282,58	109,71	2,41
Malta	0	0	0,15	0,15	23	–	–	–	100,00	0,15
Netherlands	2,09	2,87	3,39	-2,41	27	137,32	162,20	–115,31	–71,09	–4,50
Poland	0,47	0,48	2,52	2,75	11	102,13	536,17	585,11	109,13	2,28
Portugal	5,68	7,07	5,74	6,06	5	124,47	101,06	106,69	105,57	0,38
Romania	0	1,25	1,69	1,78	17,5	–	–	–	105,33	1,78
Slovakia	0,30	0,32	3,52	0	25	106,67	1173,33	–	–	–0,30
Slovenia	0,94	2,11	2,19	2,09	15	224,47	232,98	222,34	95,43	1,15
Spain	0,86	0,95	6,91	6,39	3	110,47	803,49	743,02	92,47	5,53
Sweden	2,96	2,97	3,45	3,42	10	100,34	116,55	115,54	99,13	0,46

* The data represents the second half of each year for medium residential annual consumption between 2500 and 5000 kWh.

Source: compiled on the basis of data from Eurostat.

The analyses carried out above allow for a graphical depiction of the price of kWh of electricity and its components. Figure 1 compares a graphic based on previous analyses with data on electricity prices based on the purchasing power standard (PPS). In the opinion of the authors, such a juxtaposition allows us to deepen the analyses of the existing data by taking into account the differences in purchasing power between the EU-27 countries (including the Euro area member states).



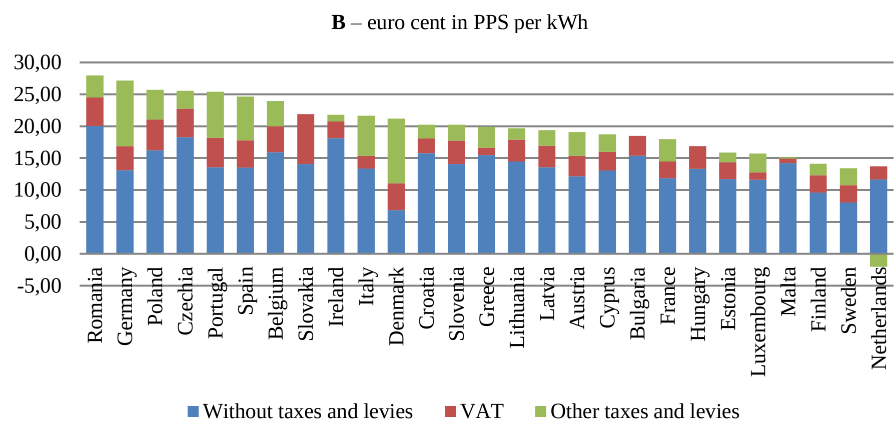


Figure 1. Electricity prices for household consumers, second half of 2020 (A – euro cents per kWh, B – euro cents in PPS per kWh)

* For medium residential annual consumption between 2500 and 5000 kWh

Source: compiled on the basis of data from Eurostat.

The overview shown in Figure 1 illustrates that kWh calculated in euro cents for households is the most expensive in Germany, Denmark and Belgium. However, in terms of PPS, the price of kWh is the most expensive for residents of Romania, Germany and Poland. When discussing electricity prices, it is also important to point to the share of taxes and levies paid by household consumers for electricity (Figure 2).

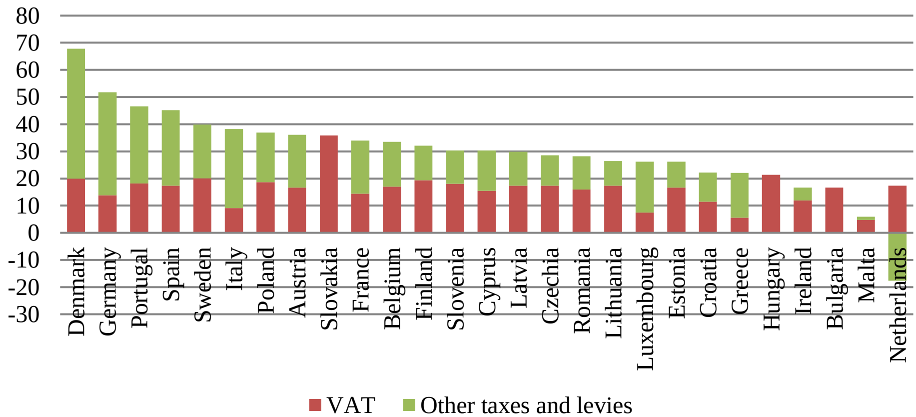


Figure 2. Share of taxes and levies paid by household consumers for electricity, second half of 2020*

* For medium residential annual consumption between 2500 and 5000 kWh

Source: compiled on the basis of data from Eurostat.

Based on Figure 2, it can be noted that in 2020 in two EU-27 countries VAT and other taxes and levies exceed 50% of the electricity kWh price (Denmark, Germany). The share of taxes in the second half of 2020 was the smallest in the Netherlands, where it was even negative (–0.3%). Poland in this comparison ranks quite high at 7th place and is at the same time among the 14 EU-27 countries where the share of VAT and other taxes and levies exceeds 30% of the electricity kWh price.

2. RESEARCH METHOD

One method of cluster analysis, namely the *k*-means clustering method, has been used to further deepen the analysis of the found data and to show the variation within the EU countries in terms of household electricity prices. Cluster analysis means the segmentation or clustering of data. It is also called object clustering.

The *k*-means clustering method is one of the most well-known data mining methods (Gatnar and Walesiak, 2004). It is one of the most widely used unsupervised machine learning algorithms for partitioning a given data set into a set of *k* groups (*k*-clusters), where *k* represents the number of groups predefined by the analyst (MacQueen, 1967). This method makes it possible to classify objects into multiple groups (clusters) so that objects in the same cluster are as similar as possible (high intra-class similarity), while objects from different clusters are as dissimilar as possible (low inter-class similarity) (Heffner Gibas, 2007).

In *k*-means clustering, each cluster is represented by its centre (centroid), which corresponds to the mean of the scores assigned to the cluster. In general, a model built using the *k*-means algorithm represents clusters as a set (vector) of *k*-means. Observations in the dataset are associated with their closest mean (centroid) and are thus divided into *k* clusters (Panek, 2009). Grouping by the *k*-means method belongs to non-hierarchical grouping methods. Unlike hierarchical methods, in this type of methods we end up with a breakdown in which no cluster is a subset of another.

The basic idea of *k*-means clustering is to define clusters in such a way that the total intra-cluster variability is minimised. The Hartigan-Wong algorithm (Hartigan and Wong, 1979) defines the total intra-cluster variability as the sum of the squares of the Euclidean distances between objects and the corresponding centre of gravity:

$$W(C_k) = \sum_{x \in C_k} (x_i - \mu_k)^2$$

where:
x_i – is the data point belonging to cluster C_k;
μ_k – is the mean value of the points assigned to cluster C_k.

Each observation (x_i) is assigned to a given cluster such that the sum of squares of the distances of the observations to their assigned cluster means (μ_k) is minimised (Hartigan and Wong, 1979).

In the analyses conducted, the total intra-cluster variability was defined as follows:

$$\text{total variation} = \sum_{k=1}^{k} W(C_k) = \sum_{k=1}^{k} \sum_{x \in C_k} (x_i - \mu_k)^2$$

The operation of the algorithm (individual steps) is presented in Figure 3. In the first step, the number of clusters (*k*) to be separated is determined.

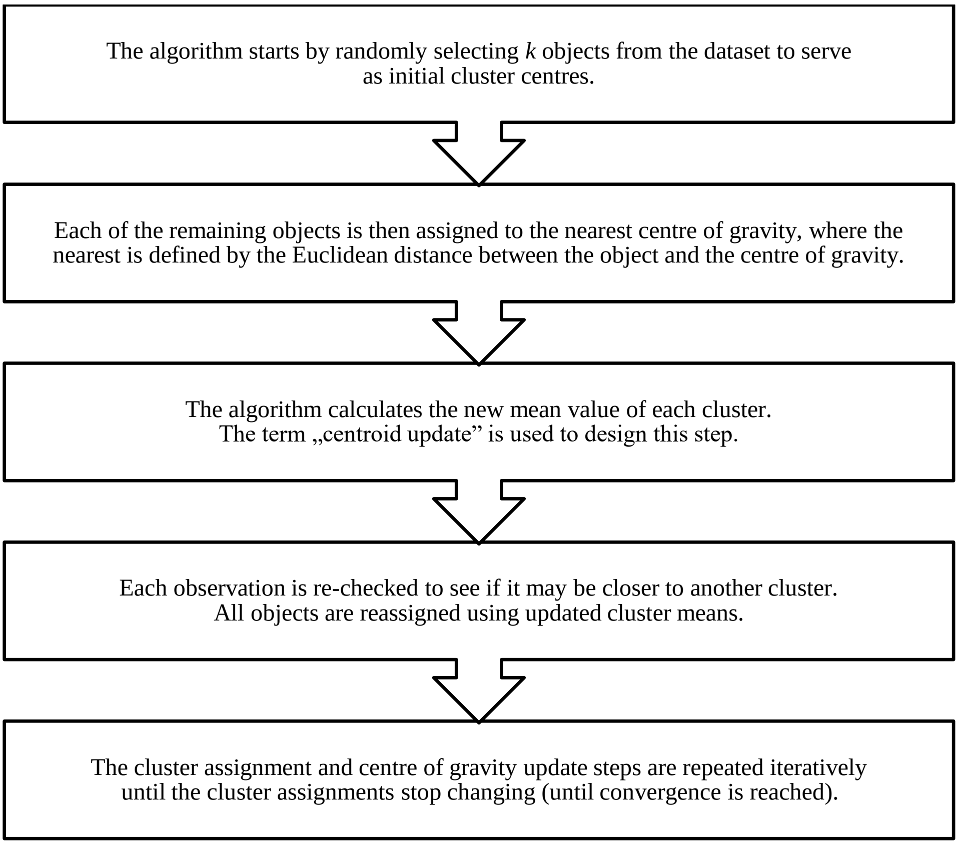


Figure 3. Schematic individual steps of the *k*-means algorithm

Source: own elaboration based on: Gatnar and Walesiak, 2004; Panek, 2009; Heffner and Gibas, 2007; Hartigan and Wong, 1979.

One method to determine the number of clusters is the so-called elbow method. Its use illustrates on one axis the number of groups and on the other axis the sum of squares of distances of individual observations from centroids. One should choose the number of groups at which a significant slump in the sum of squares is visible. Then adding another group does not bring as much benefit. The smaller the variance, the more similar the observations will be in the separated groups:

$$min\left(\sum_{k=1}^{k} W(C_k)\right)$$

where:
C_k is the k-th cluster,
$W(C_k)$ is the variation within a cluster.

The *k*-means algorithm aims to obtain coherent clusters based on a given number of clusters, i.e. *k*. It creates coherent compact clusters by minimising the total intra-cluster variation, defined as the sum of the intra-cluster squares. The algorithm starts with randomly selected centroids for a given number of clusters (Hartigan and Wong, 1979). The next steps of the *k*-means algorithm are shown in Figure 3.

The choice of the number of clusters has a great influence on the quality of the segmentation obtained. A large number of clusters makes the clusters internally homogeneous, but makes it difficult to interpret the results and apply them in practice. On the other hand, a small number of clusters leads to a much lower internal homogeneity of the cluster. To a large extent the quality of the obtained results is determined by the number of clusters, the initial determination of cluster means and how the distance between objects will be calculated.

As far as the distance between objects of the analysed quantitative variable is concerned, the Euclidean distance was used. On the other hand, when it comes to calculating the distance between the objects of the quantitative variable under analysis, the Euclidean distance was used, i.e. the geometric distance in multidimensional space calculated as the root of the sum of squares of the difference between the values of the *i*-th characteristic for the two objects under study *x* and *y* (Zalewska, 2017):

$$d(x,y) = \sqrt{\sum\nolimits_{i=1}^{n} (x_i - y_i)^2}$$

where:
x and *y* are two vectors of length *n*.

The more similar an object (x_i) is to the pattern (y_i), the higher is the level of complex phenomena for that object.

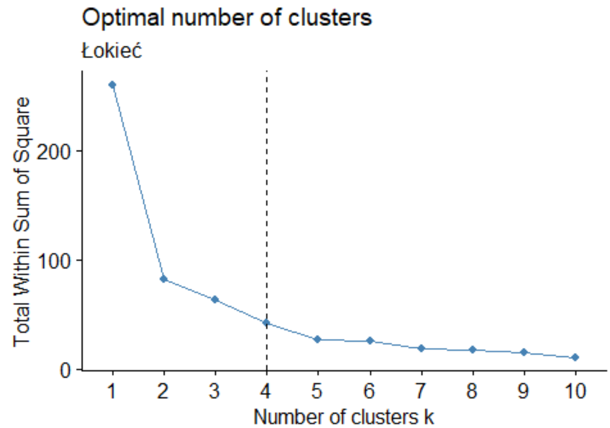


Figure 4. Determination of optimal number of clusters using the elbow method

Source: own elaboration using R Cran package based on data from Eurostat.

Data from Eurostat was used for the above analysis. The time span of the study covered the period from 2011 to 2020. Before starting the grouping, the development of average electricity prices for households in individual European countries was analysed. This is presented in Figure 5.

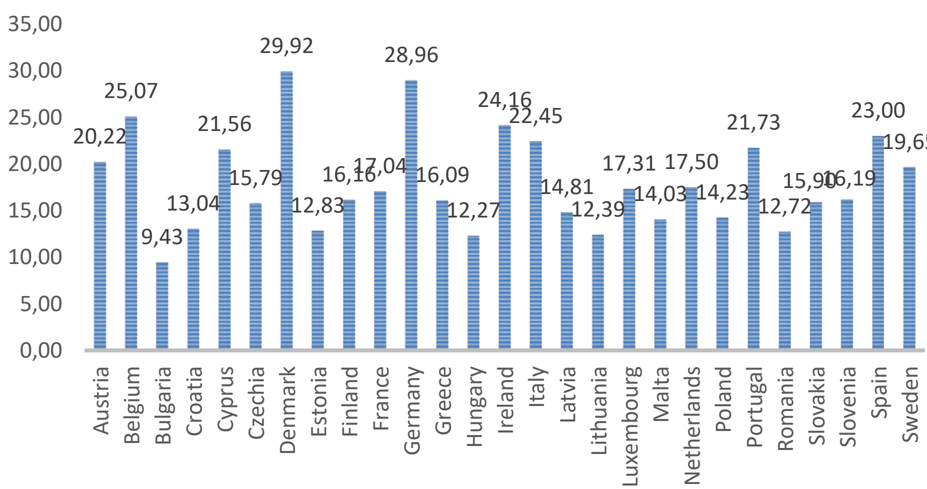


Figure 5. Average electricity prices 2011–2020 [in euro cents per kWh] by EU-27

Source: own elaboration based on data from Eurostat.

In order to carry out the data clustering procedure, the authors first subjected the diagnostic variable to a standardisation procedure. Standardisation involves the quotient transformation of the value of a normalised variable or the value of this variable minus its mean with respect to its standard deviation[1]. Classification analysis was performed using individual procedures of the *k*-means algorithm (Figure 3).

3. TEST RESULTS AND THEIR INTERPRETATION

The aim of the research conducted using the *k*-means clustering method was to organise the analysed entities into groups with relatively high internal similarity (due to the price of electricity for households expressed in euro cents per kWh), with relatively high differences between the clusters. The results obtained are presented in Table 6.

Table 6. Degree of similarity of the given countries in terms of the price of electricity for households in European countries between 2011 and 2020

Cluster/group	Countries	Group average electricity price 2011–2020 [in euro cents per kWh]
I	Bulgaria, Estonia, Romania, Croatia, Lithuania, Hungary, Malta, Poland	12,62
II	Denmark, Germany	29,44
III	Czech Republic, Greece, Slovakia, Latvia, France, Luxembourg, Netherlands, Slovenia, Slovakia, Finland	16,31
IV	Belgium, Ireland, Spain, Italy, Cyprus, Portugal, Austria, Sweden	22,23

Source: own elaboration using R Cran package based on data from Eurostat.

The result of grouping the European countries by the *k*-means method showed that eight countries were placed in the 1st group, including seven countries from Central and Eastern Europe (Bulgaria, Estonia, Romania, Croatia, Lithuania, Hungary, Poland) and Malta. These countries showed the lowest average electricity price for the period 2011–2020. The average energy price in this group of countries was 12.62 euro cents/kWh and represented about 72% of the average price calculated for all European countries analysed.

[1] It is one of the measures of the procedure of normalisation of variables, which ensures the elimination of formal restrictions and interpretation difficulties. After standardisation, the variances of a characteristic are equal to 1 and the arithmetic means are equal to 0.

Two countries (Germany and Denmark) were in cluster II. In the analysed period, the average electricity price in these countries was the highest among all European countries. The average energy price was almost 68% higher than the average for all EU countries.

Group III was formed by four Central and Eastern Europe countries (Czech Republic, Slovakia, Latvia and Slovenia), as well as Greece, France, Luxembourg, the Netherlands and Finland. This was the most numerous group, with average electricity price rates between 15.79 (Czech Republic) and 16.16 (Finland) per kWh. Price rates in this group, as in group 1, were below the calculated EU average (a difference of only 8 percentage points below average).

The last cluster indicated in Table 6 included Southern European countries such as: Spain, Italy, Portugal, as well as Belgium, Cyprus, Ireland, Austria and Sweden. The average electricity rate was 22.23 euro cents per kWh. These were rather high rates when compared with the other European countries (higher results were only found in Group II).

SUMMARY

The cost and availability of electricity is an important factor influencing the dynamics of the development of economies and, consequently, the improvement of living conditions in societies. In the article, the authors analyzed the dynamics of electricity prices for households in European Union countries. The issue discussed is very important from a socio-economic perspective and relates directly to the issue of sustainable development, where the issue of household energy poverty is often raised (Llera-Sastresa et al., 2017; Herrero, 2017; Primc and Slabe-Erker, 2020). Due to a number of actions in the socio-economic policies of EU countries leading to climate protection and also the growing demand for energy, we are facing rising energy prices, which translates into an increased burden for end users. Nevertheless, in the opinion of the authors, the green transformation of the energy sector cannot be blamed for the increase in electricity prices. It is often the result of many years of neglect in the energy sector (outdated infrastructure, lack of decisive action by decision makers focused on renewable energy sources).

The aim of this article was to show and analyze the dynamics of electricity prices between 2011 and 2020 in the EU-27. The results showed that the electricity price per kWh in euro cents for households was highest in Germany, Denmark and Belgium. On the other hand, France, Romania and Greece had the highest dynamics of electricity price changes between 2011 and 2020, to the detriment of households. However, when taking into account the PPS, the price of kWh will be most affected in Romania, Germany and Poland. Eurostat data shows that the main component of the kWh price for households is the price of electricity without taxes. In addition, it should be pointed out that most EU Member States saw an increase in VAT-related charges per kWh relative to 2011. This dynamics is understandable given that other taxes and levies include i.a. renewable taxes, capacity taxes or environmental taxes.

In the case of Poland, electricity prices increased most significantly in 2020 relative to 2019 (a similar situation was observed in Luxembourg and Slovakia). In the case of price increases in Poland, the authors expect further increases also in 2021. This increase is due to additional charges in electricity bills, which pass on to households part of the costs aimed at changing the existing energy sector into a more sustainable one.

The *k*-means method divided European countries into four groups reflecting differences in electricity prices for households in 2011–2020. Poland was placed in the group characterised by the lowest average electricity price in the analysed period. Despite this fact, it must be taken into account that prices per kWh were expressed in euro cents and not in purchasing parity. Thus, despite relatively low electricity prices expressed in euro cents per kWh against the background of the EU-27, it should be remembered that taking into account the PPS, electricity prices in Poland are among the highest among the EU-27 countries for consumers.

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