Analysis of Gas and Dust Emissions From the Mining and Quarrying Sector in the European Union Countries

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INTRODUCTION

The dynamic socioeconomic development leads to increased demand for electricity and mineral resources which are used in practically all the sectors of the economy worldwide. Unfortunately, in the majority of cases, the exploitation of those resources is associated with an extremely negative impact on the natural environment (Beamish and Vance, 1992; Brodny and Tutak, 2016; Brodny and Tutak, 2018; Brodny and Tutak, 2019; Brodny and Tutak, 2020b, Dubiński, 2013). This concerns air pollution, as well as soil and water contamination (Dubiński, 2013; Salomons, 1995). Despite the changes that have also been taking place for many years in the European Union (EU) countries, mineral and energy resources such as hard coal, brown coal, natural gas, copper ores, zinc ores and many other minerals continue to be extracted (Worldatlas, 2017; World Mining Data, 2018). Each year, the mining and quarrying sector (by NACE Rev. 2 activity) in the EU countries emits thousands of tons of harmful substances into the atmosphere, in the form of greenhouse and air-polluting gases, as well as harmful dusts (Cheng et al., 2011; Tutak and Brodny, 2019a; Tutak and Brodny, 2019b). These substances include, amongst others, carbon dioxide, methane, carbon monoxide, as well as PM2.5 and PM10. The substances emitted into the atmosphere have a very detrimental effect on the life and health of human beings and the surrounding ecosystem.
According to the increasingly promoted ideas of sustainable development and the European Green Deal concept, the exploitation of mineral resources should be carried out in full respect of the principles of their rational and economical acquisition (European Commission, 2019). Therefore, this means the necessity to undertake actions aimed at limiting the emission of greenhouse gases and air pollutants into the atmosphere. One of the first solutions of the European Union in the context of limiting the emission of greenhouse gases and air pollutants into the atmosphere due to anthropogenic activities, including the operations of the mining and quarrying sector, was to implement the Kyoto Protocol on greenhouse gas emissions in 2005 (UNFCCC, 2018). Further actions were undertaken in the subsequent years to prevent negative climate change. Their objective is, amongst others, to limit the emission of greenhouse gases in the

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EU by at least 40% by 2030 compared to the year 1990 (European Commission, 2019). As far as the abatement of air pollutant emissions is concerned, the Directive (Directive, 2016) was approved presenting new emission caps in 2016. These regulations contain the countries' commitments to limit the emissions of sulphur dioxide, nitrogen oxides, non-methane volatile organic compounds, as well as ammonia and fine particulates (with a diameter of less than 2.5 micrometres). The most recent proposal pertaining to the reduction of greenhouse gas and air pollutant emissions is the adoption of the European Green Deal strategy in December 2019.

However, it should be stressed that the EU countries manifest great diversity in terms of the emission of harmful substances. For this reason, it is necessary to carry out a comparative analysis covering the last couple years in order to assess the countries' actions undertaken so far with a view to reducing the emission of these substances. The paper presents the results of such an analysis, which encompassed the emission volumes of the main greenhouse gases and air pollutants from the mining and extraction sector by the EU Member States. The analysis also served as the basis for dividing those countries into groups of similar emission structure and volume. This was achieved using the k-means grouping method. The results obtained unequivocally demonstrate that this emission has been limited in the EU, but there are countries where the emission of certain substances has increased. The primary objective of the analysis in question was to divide the EU countries into groups which, in the long term, may work together on a common climate policy. At the same time, they can jointly apply for EU funds in order to limit the emission of specific substances from the mining and extraction sector. The above-mentioned analysis also demonstrates great differences in the particular countries of the EU, which is visible practically for each of the seven harmful substances under analysis (5 types of gases and 2 types of dusts).

METHODOLOGY OF RESEARCH

The analysis of similarities between the EU countries in terms of the greenhouse gases and air pollutants emitted into the atmosphere from the mining and quarrying sector was carried out on the basis of the 2008 and 2017 data from the Eurostat database (Eurostat, 2008-2017). It encompassed 28 countries, which were the EU Member States in that period, and was based on the *k*-means method. The analysis made use of the data included in Tables 1 and 2. Each of the EU countries was characterised by 7 variables specifying the emission values for greenhouse gases and air pollutants. These data included the emission of carbon dioxide, methane, nitrous oxide, carbon monoxide, nitrogen oxides, PM2.5 and PM10.

The data included in Tables 1 and 2 underwent preliminary statistical processing, which defined their statistical parameters summarised in Tables 3 and 4.

Table 1 Gas and air pollutant emissions into the atmosphere by the EU countries from the mining and quarrying sector in 2008

	Carbon dioxide	Methane	Nitrous oxide	Carbon monoxide	Nitrogen oxides	Particulates < 2.5 μm	Particulates < 10 μm
	thousand tonnes						
Belgium	756.13	2.050	0.02864	0.55832	0.26928	0.1575	0.43801
Bulgaria	249.59	3.407	0.00519	0.57227	1.18517	0.08842	0.09883
Czech Republic	4547.38	222.478	0.05765	3.52695	7.26694	1.05407	4.30821
Denmark	2129.78	7.087	0.24843	1.31952	8.36731	0.35453	1.80119
Germany	7997.90	185.532	0.76401	3.28208	6.65261	2.2117	15.02937
Estonia	121.56	0.006	0.00179	0.73732	0.52168	0.07978	0.18671
Ireland	310.94	1.007	0.00397	1.3095	0.85226	0.44701	3.56882
Greece	746.91	1.845	0.02754	3.33573	0.09108	0.63823	5.00217
Spain	4949.66	28.757	0.0878	3.29734	5.43389	2.88414	20.98669
France	1432.70	5.053	0.08842	2.49475	5.774	2.0026	14.69111
Croatia	915.25	8.511	0.00076	0.29856	0.2015	0.24358	2.22068
Italy	2710.19	26.098	0.3349	4.08604	7.93542	0.55802	0.57402
Cyprus	33.45	0.002	0.00057	0.17808	0.34004	0.09618	0.67384
Latvia	43.30	0.003	0.00505	0.25394	0.24181	0.11126	0.98956
Lithuania	14.59	0.143	0.00079	0.06649	0.03587	0.09608	0.90926
Luxembourg	4.90	0.000	0.00008	0.0052	0.0255	0.0005	0.0006
Hungary	696.53	15.378	0.00232	0.24867	0.42117	0.29744	2.55956
Malta	4.06	0.001	0.00007	0.00322	0.00424	0.0002	0.0002
Netherlands	2212.47	35.707	0.02914	0.93446	4.9692	0.04652	0.07549
Austria	927.41	5.566	0.00517	0.30433	1.86084	0.63561	5.29939
Poland	2286.85	787.251	0.02778	11.01072	8.576	2.79621	11.32001
Portugal	359.20	0.901	0.0057	0.5231	2.4216	0.6789	4.836
Romania	1204.92	315.769	0.00868	0.61727	0.83972	1.77735	5.84341
Slovenia	126.35	12.248	0.005	0.08445	0.24982	0.03493	0.20285
Slovak Republic	82.16	26.751	0.00289	0.34663	0.22874	0.02754	0.16459
Finland	359.78	0.018	0.00785	1.68589	3.08959	1.0134	1.45084
Sweden	771.07	0.678	0.0212	0.5648	4.32061	2.22788	2.79274
United Kingdom	23442.26	161.679	1.27454	38.65487	123.31	5.30408	18.17416

Source: (Own study elaboration on Eurostat)

Table 2 Gas and air pollutant emissions into the atmosphere by the EU countries from the mining and quarrying sector in 2017

	Carbon dioxide	Methane	Nitrous oxide	Carbon monoxide	Nitrogen oxides	Particulates < 2.5 μm	Particulates < 10 μm
	thousand tonnes						
Belgium	433.86	1.70245	0.01929	0.52068	0.48729	0.14461	0.38206
Bulgaria	210.60	5.92692	0.00513	0.29287	0.89709	0.05681	0.069
Czech Republic	3860.30	137.41673	0.04926	1.12123	3.06532	0.86799	2.96523
Denmark	1651.40	3.21184	0.17583	1.11258	4.77932	0.29877	1.68553
Germany	3828.83	98.80129	0.52648	3.13004	2.88752	2.03717	14.50967
Estonia	96.23	0.0325	0.00742	0.5702	0.266	0.12053	0.23076
Ireland	156.63	1.13988	0.00215	0.85784	0.20658	0.24704	2.02885
Greece	346.18	0.9419	0.00766	0.68582	0.04539	0.39538	3.16146
Spain	1689.84	5.85911	0.04765	2.04747	2.36243	1.00912	4.48435
France	969.31	3.19095	0.07635	1.58147	3.20367	1.46798	11.27517
Croatia	519.03	5.56574	0.00066	0.18365	0.07217	0.13327	1.20405

Italy	4012.71	17.88495	0.4978	6.27296	6.39352	0.37718	0.3846
Cyprus	17.15	0.0009	0.00021	0.04997	0.12202	0.02446	0.1393
Latvia	35.68	0.00202	0.00559	0.15745	0.23427	0.1001	0.87068
Lithuania	9.64	0.06475	0.00071	0.04805	0.02317	0.07415	0.69963
Luxembourg	7.50	0.00011	0.00018	0.0047	0.0168	0.0006	0.0014
Hungary	453.07	13.18871	0.00362	0.20919	0.37074	0.25747	2.33128
Malta	2.62	0.00084	0.00007	0.00206	0.00392	0.00034	0.0005
Netherlands	1920.55	21.15431	0.04394	0.58886	4.1055	0.01885	0.03624
Austria	916.04	5.54236	0.00547	0.23308	1.2924	0.58878	4.97334
Poland	2025.15	781.59979	0.01529	4.72008	6.76426	1.16002	8.60909
Portugal	245.20	0.7954	0.0053	0.2856	1.5008	0.3952	2.7511
Romania	812.21	207.66705	0.00581	0.10835	0.13675	0.5038	4.2229
Slovenia	89.60	9.19343	0.00319	0.04213	0.11959	0.02325	0.14803
Slovak Republic	51.90	19.76734	0.00244	0.09056	0.09231	0.01447	0.10735
Finland	439.15	0.01877	0.00628	1.47706	1.77885	0.65015	1.16175
Sweden	1096.43	0.64845	0.02698	1.07531	5.09598	1.27633	1.54748
United Kingdom	20399.67	72.38884	1.30559	42.6562	108.00964	3.22497	12.84997

Source: (Own elaboration based on Eurostat)

Table 3 Basic statistical parameters of the absolute emission values of studied substances from the mining and quarrying sector in 2008

Variable	Mean	Minimum	Maximum	Standard deviation	Coefficient of variation, %
	thousand tonnes				
Carbon dioxide	2122.760	4.05900	23442.26	4563.901	215.00
Methane	66.212	0.00004	787.25	162.260	245.06
Nitrous oxide	0.109	0.00007	1.27	0.277	254.13
Carbon monoxide	2.868	0.00322	38.65	7.361	256.66
Nitrogen oxides	6.982	0.00424	123.31	22.992	329.30
Particulates < 2.5 μm	0.924	0.00020	5.30	1.242	134.42
Particulates < 10 μm	4.436	0.00020	20.99	5.960	134.36

Source: (Own elaboration)

Table 4 Basic statistical parameters of the absolute emission values of studied substances from the mining and quarrying sector in 2017

Variable	Mean	Minimum	Maximum	Standard deviation	Coefficient of variation, %
	thousand tonnes				
Carbon dioxide	1653.445	2.61700	20399.67	3865.329	233.77
Methane	50.490	0.00011	781.60	151.304	299.67
Nitrous oxide	0.102	0.00007	1.31	0.271	265.69
Carbon monoxide	2.504	0.00206	42.66	8.005	319.69
Nitrogen oxides	5.512	0.00392	108.01	20.193	366.35
Particulates < 2.5 μm	0.552	0.00034	3.22	0.737	133.51
Particulates < 10 μm	2.958	0.00050	14.51	4.037	136.48

Source: (Own elaboration)

The data presented in Tables 1 and 2 meet the condition of diagnostic variables that demonstrate significant value spread of the coefficient of variation (Tables 3 and 4).

The analysis of similarities between the EU countries in terms of the emission volumes of greenhouse gases and air pollutants from the mining and quarrying sector was carried out using the *k*-means method, which is the algorithm of cluster analysis. The primary assumption behind this method is such a division of objects (the EU countries) that would minimise the variability within the clusters formed, while maximising the variability between the remaining clusters. This method involves searching for and identification of groups of similar objects. The similarity within a cluster between the particular objects should be as great as possible, whereas separate clusters should exhibit maximum differences from one another.

The algorithm of the *k*-means method consists of the following stages (Everitt et al., 2011; Mardia, 1979):

1. Determining the number of clusters (*k*).
2. Determining the preliminary centres for each cluster.
3. Identifying the distance of the objects (EU countries) from the centres of the clusters. This stage was performed using the Euclidean distance.

$$D(x, y) = \sqrt{\sum_{i=1}^{k}\left(x_{ij} - y_{ij}\right)^2} \quad (1)$$

where:

y_{ij} is distance from the center of cluster.

4. Assigning the objects (EU countries) to the clusters. For a given object, it is necessary to compare the distances to all the centres of the clusters (determined in point 3).
5. Assigning objects to such a cluster to whose centre they have the shortest distance, as determined by the equation (1).
6. Determining new centres of the clusters – It is usually assumed that this is a point whose coordinates are the arithmetic means of the coordinates of the objects which belong to a given cluster at a given operational stage of the algorithm.
7. If the centres of clusters were shifted in point 6, it is necessary to repeat steps 3, 4 and 5. If not, the algorithm stops and the current division is deemed to be the final segmentation.

RESULTS AND DISCUSSION

The first stage of the research involved grouping the EU countries according to the structure and volume of greenhouse gas and air pollutant emissions into the atmosphere from the mining and quarrying sector, based on the Eurostat data.
The calculations were performed on the assumption that the EU countries would be divided into four clusters. The number of clusters was determined according to the assumptions set out in the work (Mardia, 1979; Brodny and Tutak, 2020a). The composition of the particular clusters and their distances from the centres (in brackets) are presented in Table 5.

Table 5 Elements of clusters with distances form centres in 2008

Cluster 1 and distance from centre of cluster 1	Cluster 2 and distance from centre of cluster 2	Cluster 3 and distance from centre of cluster 3	Cluster 4 and distance from centre of cluster 4
United Kingdom (0.00)	Czech Republic (486.29)	Denmark (63.14)	Belgium (132.25)
	Germany (818.91)	France (280.02)	Bulgaria (59,76)
	Spain (336.28)	Italy (217.22)	Estonia (108.08)
		Netherlands (56.14)	Ireland (36.98)
		Poland (237.81)	Greece (128.78)
			Croatia (192.25)
			Cyprus (141.31)
			Latvia (137.59)
			Lithuania (148.43)
			Luxembourg (152.09)
			Hungary (109.55)
			Malta (152.40)
			Austria (196.88)
			Portugal (19.51)
			Romania (321.63)
			Slovenia (106.30)
			Slovakia (122.70)
			Finland (19.43)
			Sweden (137.92)

Source: (Own elaboration)

The countries inside the particular clusters are characterised by great similarity in terms of the pollutants in question. Moreover, the smaller the values of the countries' distance from the centre of the cluster they belong to, the more similar the countries are in terms of the emission structure and volume of these substances.

The number of countries in the particular clusters is highly diversified, ranging from 1 country (cluster 1) to 19 countries (cluster 4). The results obtained demonstrate that, in terms of emissions in 2008, there was homogeneity of one of the EU countries, namely the United Kingdom. This means that no other EU country was similar enough to the UK in terms of the emission structure and volume to belong to the same cluster.

Based on the results obtained, it can be concluded that the countries with the highest average emission level for the substances under analysis were classified under cluster 1, whereas the countries with the lowest emission level for the substances under analysis – under cluster 4. The basic descriptive statistics for each cluster are presented in Table 6.

Table 6 Descriptive statistics of clusters on the basis data

Cluster 1 – 1 object	Mean	Standard deviation	Variance	Sum
Carbon dioxide	23442.26	0.00	0.00	23442.26
Methane	161.68	0.00	0.00	161.68
Nitrous oxide	1.27	0.00	0.00	1.27
Carbon monoxide	38.65	0.00	0.00	38.65
Nitrogen oxides	123.31	0.00	0.00	123.31
Particulates < 2.5μm	5.30	0.00	0.00	5.30
Particulates < 10μm	18.17	0.00	0.00	18.17
Cluster 2 – 3 objects				
Carbon dioxide	5831.65	1886.78	3559953	17494.94

Methane	145.59	102.85	10579	436.77
Nitrous oxide	0.303	0.399	0	0.91
Carbon monoxide	3.369	0.137	0	10.11
Nitrogen oxides	6.451	0.933	1	19.35
Particulates < 2.5μm	2.050	0.926	1	6.15
Particulates < 10μm	13.441	8.452	71	40.32
Cluster 3 – 5 objects				
Carbon dioxide	2154.40	461.32	212820.4	10771.99
Methane	172.24	344.04	118366.1	861.20
Nitrous oxide	0.15	0.14	0.0	0.73
Carbon monoxide	3.97	4.12	17.0	19.85
Nitrogen oxides	7.12	1.64	2.7	35.62
Particulates < 2.5μm	1.152	1.19	1.4	5.76
Particulates < 10μm	5.6	6.81	46.4	28.46
Cluster 4 – 19 objects				
Carbon dioxide	406.74	385.41	148542.7	7728.10
Methane	20.76	71.79	5153.1	394.28
Nitrous oxide	0.01	0.01	0.0	0.13
Carbon monoxide	0.62	0.79	0.6	11.69
Nitrogen oxides	0.91	1.19	1.4	17.20
Particulates < 2.5μm	0.46	0.62	0.4	8.65
Particulates < 10μm	1.96	2.03	4.1	37.24

Source: (Own study)

The next stage involved grouping the EU countries according to the structure and volume of greenhouse gas and air pollutant emissions into the atmosphere from the mining and extraction sector, based on the 2017 data (Table 7).

Table 7 Elements of clusters with distances form centres in 2017

Cluster 1 and distance from centre of cluster 1	Cluster 2 and distance from centre of cluster 2	Cluster 3 and distance from centre of cluster 3	Cluster 4 and distance from centre of cluster 4
United Kingdom (0.00)	Czech Republic (25.13)	Denmark (111.25)	Belgium (90.43)
	Germany (27.84)	Spain (124.17)	Bulgaria (6.11)
	Italy (49.39)	France (164.17)	Estonia (37.22)
		Netherlands (206.42)	Ireland (14.40)
		Austria (183.30)	Greece (57.30)
		Poland (345.60)	Croatia (122.61)
		Romania (218.59)	Cyprus (67.10)
		Sweden (119.36)	Latvia (60.09)
			Lithuania (69.93)
			Luxembourg (70.74)
			Hungary (97.75)
			Malta (72.59)
			Portugal (19.16)
			Slovenia (39.75)
			Slovakia (54.29)
			Finland (92.43)

Source: (Own study)

The size of the resultant clusters and their composition in terms of emissions of the substances under analysis in 2017 differ slightly from the clusters created for the data concerning these emissions from 2008.

The composition of cluster 1 remained unchanged – it is still made up of the United Kingdom. A slight change was observed in the composition of cluster 2,

which is still made up of the Czech Republic and Germany, yet with Spain having been replaced by Italy. A slightly greater change was noted in the composition of cluster 3 – in 2008, similarity was demonstrated by 5 countries, while in 2017 – 8 countries. In 2008, those countries included Denmark, France, Italy, Poland and the Netherlands, while in 2017 – Denmark, Spain, France, Austria, Poland, Romania, Sweden and the Netherlands. This means that only 4 countries retained the same similarity against one another. A change was also observed in the composition of cluster 4 – in 2017, it was made up of 16 countries, while in 2008 – by 19. This is due to the fact that Sweden, Romania and Austria were grouped into cluster 3.
Based on the results obtained, it can be concluded that the countries with the highest average emission level for the substances under analysis were classified under cluster 1, whereas the countries with the lowest emission level for the substances under analysis – under cluster 4. The basic descriptive statistics for each cluster are presented in Table 8.

Table 8 Descriptive statistics of clusters on the basis data

	Mean	Standard deviation	Variance	Sum
Cluster 1 – 1 object				
Carbon dioxide	20399.67	0.00	0.00	20399.67
Methane	72.39	0.00	0.00	72.39
Nitrous oxide	1.31	0.00	0.00	1.31
Carbon monoxide	42.66	0.00	0.00	42.66
Nitrogen oxides	108.01	0.00	0.00	108.01
Particulates < 2.5μm	3.22	0.00	0.00	3.22
Particulates < 10μm	12.85	0.00	0.00	12.85
Cluster 2 – 3 objects				
Carbon dioxide	3900.61	98.34	9671.349	11701.84
Methane	84.70	61.00	3721.075	254.103
Nitrous oxide	0.36	0.268	0.072	1.07354
Carbon monoxide	3.51	2.60	6.742	10.52
Nitrogen oxides	4.12	1.97	3.900	12.35
Particulates < 2.5μm	1.09	0.85	0.727	3.28
Particulates < 10μm	5.95	7.52	56.575	17.86
Cluster 3 – 8 objects				
Carbon dioxide	1385.12	487.65	237797.9	11080.93
Methane	128.61	273.14	74605.0	1028.87
Nitrous oxide	0.05	0.0564	0.0	0.40
Carbon monoxide	1.43	1.4805	2.2	11.47
Nitrogen oxides	3.47	2.1635	4.7	27.74
Particulates < 2.5μm	0.79	0.5126	0.3	6.32
Particulates < 10μm	4.60	3.7714	14.2	36.83
Cluster 4 – 16 objects				
Carbon dioxide	194.63	186.23	34681.95	3114.02
Methane	3.65	5.82	33.89	58.34
Nitrous oxide	0.004	0.004	0.00	0.07
Carbon monoxide	0.34	0.40	0.16	5.48
Nitrogen oxides	0.39	0.54	0.29	6.24
Particulates < 2.5μm	0.16	0.18	0.03	2.64
Particulates < 10μm	0.96	1.05	1.12	15.29

Source: (Own study)

Table 9 presents a comparison of the absolute values of gas and dust emissions for all the countries, in the years 2017 and 2008. The rows of the table specify the ratio of atmospheric emission volumes of the gases and dusts under analysis from the mining and extraction sector in the EU countries from 2017 and 2008. Values above 1 indicate increased emissions of a given substance in a given country, whereas values below 1 – decreased emissions. Analysing the results obtained, it can be concluded that values higher than 1 were obtained for as many as 31 cases out of the total 196 possibilities, with a single case where the value was equal to one. The highest number of increases in the emission of the substances under analysis occurred in Luxembourg (5), Estonia (4), Malta (4) and Sweden (4). On the other hand, the value obtained for the entire EU for the emissions of each substance under analysis was below 1 (the last row in Tab. 9).

Table 9 The ratio of atmospheric emission volumes of the gases and dusts under analysis from the mining and quarrying sector in the EU countries from 2008 and 2017

	Carbon dioxide	Methane	Nitrous oxide	Carbon monoxide	Nitrogen oxides	Particulates < 2.5 µm	Particulates < 10 µm
	thousand tonnes						
Belgium	0.57	0.83	0.67	0.93	**1.81**	0.92	0.87
Bulgaria	0.84	**1.74**	0.99	0.51	0.76	0.64	0.70
Czech Republic	0.85	0.62	0.85	0.32	0.42	0.82	0.69
Denmark	0.78	0.45	0.71	0.84	0.57	0.84	0.94
Germany	0.48	0.53	0.69	0.95	0.43	0.92	0.97
Estonia	0.79	**5.37**	**4.15**	0.77	0.51	**1.51**	**1.24**
Ireland	0.50	**1.13**	0.54	0.66	0.24	0.55	0.57
Greece	0.46	0.51	0.28	0.21	0.50	0.62	0.63
Spain	0.34	0.20	0.54	0.62	0.43	0.35	0.21
France	0.68	0.63	0.86	0.63	0.55	0.73	0.77
Croatia	0.57	0.65	0.87	0.62	0.36	0.55	0.54
Italy	**1.48**	0.69	**1.49**	**1.54**	0.81	0.68	0.67
Cyprus	0.51	0.41	0.37	0.28	0.36	0.25	0.21
Latvia	0.82	0.67	1.11	0.62	0.97	0.90	0.88
Lithuania	0.66	0.45	0.90	0.72	0.65	0.77	0.77
Luxembourg	**1.53**	**2.75**	**2.25**	0.90	0.66	**1.20**	**2.33**
Hungary	0.65	0.86	**1.56**	0.84	0.88	0.87	0.91
Malta	0.64	**1.45**	**1.00**	0.64	0.92	**1.70**	**2.50**
Netherlands	0.87	0.59	**1.51**	0.63	0.83	0.41	0.48
Austria	0.99	**1.00**	**1.06**	0.77	0.69	0.93	0.94
Poland	0.89	0.99	0.55	0.43	0.79	0.41	0.76
Portugal	0.68	0.88	0.93	0.55	0.62	0.58	0.57
Romania	0.67	0.66	0.67	0.18	0.16	0.28	0.72
Slovenia	0.71	0.75	0.64	0.50	0.48	0.67	0.73
Slovak Republic	0.63	0.74	0.84	0.26	0.40	0.53	0.65
Finland	**1.22**	**1.06**	0.80	0.88	0.58	0.64	0.80
Sweden	**1.42**	0.96	**1.27**	**1.90**	**1.18**	0.57	0.55
United Kingdom	0.87	0.45	**1.02**	**1.10**	0.88	0.61	0.71
UE	0.78	0.76	0.93	0.87	0.79	0.60	0.67

Source: (Own study)

This demonstrates the general improvement with respect to the emission of harmful gases and dusts in the EU. Considerably greater decreases in the emission were recorded for PM2.5 (a decrease by 40% compared with the 2008 emissions) and PM10 (a decrease by 33%).

CONCLUSION

The analysis conducted demonstrates that, despite the changes implemented (especially in the energy sector), the extraction industry in the EU countries continues to be a significant sector of the economy. Despite the considerable import of mineral resources by the EU countries, the mining activities have not been abandoned in those countries. Unfortunately, despite the measures taken to limit harmful emissions, it is associated with an extremely negative environmental impact.

The results obtained clearly demonstrate that the last 10 years have brought a decrease in the emission of greenhouse gases and air pollutants into the atmosphere by EU countries from the mining and quarrying sector. This is obviously the result of the legal regulations adopted in terms of reducing the atmospheric emission of these substances by the EU Member States and the growing concern for the environment. An essential factor is also the development of innovative technological solutions implemented into the area of environmental protection. These good results are also driven by the closure of or significant reduction in the production by the greatest gas- and dust-producing enterprises involved in the extraction of mineral resources. A very important role for the climate policy of the EU countries is its relevant direction. The division of the EU countries into similar groups in terms of the emission of selected substances, as presented in the paper, may be helpful in this regard.

The results obtained show a great similarity of a series of countries over the past 10 years. In a number of cases, there were significant shifts, but still the division presented indicates the need to dedicate climate actions to the particular groups rather than all the countries in general. The results presented also indicate the great differences between the particular groups, which confirm the diversity of the EU countries.

In the analysis period, only one cluster retained exactly the same composition, namely the homogeneous cluster 1 with the United Kingdom. The composition of cluster 2 underwent a minor change, and some changes in terms of the similarities between the countries also took place in clusters 3 and 4 between the years 2008 and 2017. Sweden, Romania and Austria – which belonged to cluster 4 in 2008 and manifested the lowest emission values for the substances under analysis – were grouped into cluster 3 in 2017 along with other countries of moderate emission levels. In 2017, Sweden and Austria increased the emissions of certain substances, and hence ceased to demonstrate sufficient similarity to the remaining countries from cluster 4. On the other hand, in 2008 Romania quite considerably differed in terms of emission volumes from the other countries in cluster 4 (well above the average emission value for the cluster), while still demonstrated too little similarity to the countries from cluster 3. Due to the decreased emissions of gases and dusts in the remaining countries from cluster 4 in 2017, this disproportion was even greater, and hence Romania was eventually grouped into cluster 3. The results obtained represent a valuable analytical material. They can serve as the basis for drawing conclusions about both the effectiveness of the climate policy in force and future possibilities. Overall, it should be concluded that the results of the EU climate policy will, to a considerable extent, depend on the effectiveness of economic actions. And this should be targeted for the groups of countries and for the particular sectors. The mining and quarrying sector is, undoubtedly, one of the first that should be covered by this policy.

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Abstract: Despite the ongoing changes in the energy and economic structure of the European Union countries, mineral and energy resources such as hard coal, brown coal, natural gas, copper ores, zinc ores and many other minerals continue to be extracted. Each year, the mining and extraction sector emits thousands of tons of harmful substances into the atmosphere, in the form of greenhouse and other air-polluting gases, as well as harmful dusts. These substances include, amongst others, carbon dioxide, methane, carbon monoxide, as well as PM2.5 and PM10. The European Union climate policy clearly recommends that the exploitation of mineral resources be carried out in full respect of the principles of their rational, economical and environmentally neutral acquisition, which is confirmed by the promoted strategy of sustainable development economy. Therefore, this means the necessity to undertake actions aimed at limiting the emission of greenhouse gases and air pollutants into the atmosphere. To assess the actions taken by the European Union countries to date with respect to limiting those emissions, a comparative analysis was carried out for the particular countries. This analysis encompassed the emission of harmful substances from the mining and quarrying sector by the European Union countries in the years 2008 and 2017. The purpose of the analysis was to show the diversity of those countries in terms of the emission of harmful gases and dusts, as well as to divide them into similar groups. Such a division paves the way for developing a common climate policy and exchanging experiences between the countries from the particular groups. The European Union countries were divided into similar groups using the k-means grouping method. Comparison was also made for the emissions of the substances under analysis for the particular countries over the research years. The results obtained unequivocally demonstrate that this emission has been limited in the European Union, but there are countries where the emission of certain substances has increased.

Keywords: mining and quarrying, gas and dust emissions, analysis of similarity, the European Union countries