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Aspects Regarding Renewable Sources in the European Union

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Abstract
The use of renewable energy sources offers opportunities for regional and local development. Thus, it can be appreciated that the use of renewable sources can stimulate the development of local communities. An advantage is also given by an increased security in terms of local energy supply, but also by a reduction in energy transport losses. Recently, there has been some interest in investing in the development of energy generation technologies and especially in renewable sources. For the period 1990-2020, a comparative situation of gross electricity production and electricity production capacities for renewables is presented. Pollution and climate change can affect both the production and consumption of electricity. There has been interest in using more and more diverse sources. Given the interest in reducing energy consumption in transport, important measures are needed to increase the energy efficiency of transport. In the article, an analysis is made of the share of renewable energy in the final gross energy consumption, for the period 2004-2020, with particularization for the transport sector.

Keywords: European Union, renewable sources, energy

1. Introduction

It is unanimously accepted that one of the major sources of carbon emissions is fossil fuels. Even if they are being depleted, their continued use for electricity production will lead to greenhouse gases and climate change (Mogos et al., 2021). Thus, the interest in renewable sources arose, and the way of producing energy was changed (Popescu et al. 2021). It is desirable that natural resources be exploited in the most sustainable way possible. Increasing the share of renewable resources can contribute to a significant impact on the environment, but also in terms of reducing greenhouse gas emissions (Tomaszewska et al., 2021).
The rational use of renewable energy sources favorably affects the environment (Bodislav et al., 2021). Thus, production processes can take place in a framework conducive to improving efficiency (European Commission, 2011). At the level of the European Union, it is desired that, by 2050, some measures be implemented to allow the production of electricity based on renewable sources to reach a share of 80% of total electricity production (EC, 2018).
Economic development is based on electricity (Sarbu et al., 2021). For this reason, the use

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and storage of energy is important. The aim is to increase the benefits of renewable sources by identifying optimal energy storage solutions (AlShafi, & Bicer, 2021).
The desire to increase climate and environmental protection measures puts pressure on the energy requirements of modern society (Profiroiu et al., 2020). One consequence of this is the changes in energy systems in recent years. The transformations aim to increase the share of renewable sources in the total production of electricity (Janota et al., 2022).
Thus, one of the European climate goals is to decarbonise the energy sector (Radulescu et al., 2020). Thus, the importance given to renewable energy sources increases (Bran et al., 2020). The emergence of intelligent energy systems requires fully integrated supply systems (Ramsebner et al., 2021).

2. Literature Review

The way people exploit energy, water and land contribute to climate change. Certain climate change can be avoided, which would improve access to energy and energy security (Bodislav et al., 2020). These issues can also lead to an increase in air quality. Mitigation of these changes, as well as adaptation to them, can be achieved through efficient resource management (Gielen et al., 2019).
Increasing the share of renewable sources in electricity production has an increasing impact on the electricity market (Ortner & Totschnig, 2019).
It is believed that the cost of energy can be influenced by higher energy efficiency, which would also lead to a reduction in energy demand (Adom, 2019).
The management of water as a renewable source must also consider its use in the agricultural sector. Geothermal water is also used as a source of energy, but also as heat. These include the increase in the price of fossil fuels and the pollution of greenhouse gas emissions. Pollution of the environment with greenhouse gas emissions involves the use of fossil fuels. Water shortages are due in part to rising human demand and to pollution and climate change. Global warming has also led to a decrease in freshwater (Tomaszewska et al., 2021).
Regarding the production of electricity based on wind and solar energy, it can be appreciated that it is variable (Angheluta et al., 2019). This is determined by weather conditions and depends on the specifics of the location (Wang et al., 2020).
The reliability and flexibility of an energy system can be increased by interconnecting different technologies based on renewable energy (van Leeuwen et al., 2021).
The production of electricity based on renewable sources is intermittent, being influenced by climatic factors (Negescu Oancea, et al., 2020). This raises the issue of storage and transport of energy. In addition to influencing electricity production, climatic and meteorological conditions also influence electricity demand (Engeland et al., 2017).
Reconsideration of both short-term and long-term storage systems could allow for the expansion of production and transportation capacity (Gonzalez-Romero et al., 2019).
More and more research is trying to identify technical solutions that can change the properties of some materials so that they can perform new functionalities useful, among other things, and storage of electricity. For this purpose, the methodologies used take into account adsorption and uptake processes (Lapponi et al., 2022).
The use of hybrid energy sources, based on renewable energy sources, can change energy

demands, respectively can change regional and global trends (Jurasz et al., 2019).
Sustainable energy systems can be implemented at the community level (Profiroiu et al., 2020). Considering the efficient use of renewable sources, microgrids can be such an example (Bodislav et al., 2019). Easier management of energy supply, as well as energy demand, can help improve the efficiency of these microgrids (Takano et al., 2020).
Analyzes are needed to lead to the development of strategies resistant to uncertainties that may arise in different systems, as is the case of the European Union's energy innovation system (Kim & Wilson, 2019).

3. Methodology of Research

Recently, there has been some interest in investing in the development of energy-generating technologies and especially in renewable sources. For the period 1990-2020, a comparative situation of gross electricity production and electricity production capacities for renewables is presented. Pollution and climate change can affect both the production and consumption of electricity.
There has been interest in using more and more diverse sources. Given the interest in reducing energy consumption in transport, important measures are needed to increase the energy efficiency of transport. In the article, an analysis is made of the share of renewable energy in the final gross energy consumption, for the period 2004-2020, with particularization for the transport sector.

4. Results and Discussions

An important indicator in terms of energy production is given by gross electricity production. Thus, the Table 1 presents the comparative situation for gross electricity production, for the period 1990-2020 (gigawatt-hour).
From the data presented in the Table 1, it is observed that, at the level of the European Union, compared to 1990, in 2020, gross electricity production increased by 506382.1 gigawatt-hours. The largest increases were recorded in: Spain (+111290 gigawatt-hours), France (+110448.8 gigawatt-hours), Italy (+63429.5 gigawatt-hours), Netherlands (+51247.3 gigawatt-hours), Austria (+22261.8 gigawatt-hours), Portugal (+24577.4 gigawatt-hours), Poland (+21638 gigawatt-hours), Germany (+21074 gigawatt-hours). In some countries gross electricity production has fallen. These countries are: Lithuania (-23056.1 gigawatt-hours), Estonia (-11225.1 gigawatt-hours), Romania (-8374.1 gigawatt-hours), Bulgaria (-1409.9 gigawatt-hours), Latvia (-923.1 gigawatt-hours).
Also, in 2020, the highest values of gross electricity production were in: Germany (571089 gigawatt-hours), France (531201 gigawatt-hours), Italy (280029.5 gigawatt-hours), Spain (263213 gigawatt-hours), Sweden (163833 gigawatt-hours), Poland (157949 gigawatt-hours), Netherlands (123041.4 gigawatt-hours). The lowest values of gross electricity production were recorded in: Malta (2143.1 gigawatt-hours), Luxembourg (2233.9 gigawatt-hours), Cyprus (4849.2 gigawatt-hours), Lithuania (5310.9 gigawatt-hours), Latvia (5724.8 gigawatt-hours), Estonia (5955.9 gigawatt-hours).

Table 1: Comparative situation for gross electricity production, for the period 1990-2020 (gigawatt-hour).

Countries	1990	2000	2010	2020
European Union	2.275.046,4	2.656.927,1	2.979.660,5	2.781.428,5
Belgium	70.923,0	84.012,0	94.315,7	88.890,8
Bulgaria	42.141,0	40.924,0	46.638,6	40.731,1
Czechia	62.559,0	73.464,9	85.819,4	81.398,9
Denmark	25.982,0	36.014,0	38.862,1	28.733,5
Germany	550.015,0	576.543,0	631.038,0	571.089,0
Estonia	17.181,0	8.513,3	12.963,9	5.955,9
Ireland	14.515,0	23.978,0	28.353,3	32.290,5
Greece	35.003,0	53.843,0	57.404,9	48.251,9
Spain	151.923,0	224.468,0	301.368,2	263.213,0
France	420.752,3	539.954,9	569.153,1	531.201,0
Croatia	8.873,2	11.281,2	14.902,6	13.385,3
Italy	216.600,0	275.855,2	301.284,9	280.029,5
Cyprus	1.974,0	3.370,0	5.322,2	4.849,2
Latvia	6.647,9	4.136,6	6.626,9	5.724,8
Lithuania	28.367,0	11.334,0	5.499,0	5.310,9
Luxembourg	1.377,0	1.166,3	4.591,3	2.233,9
Hungary	28.436,0	35.190,8	37.370,1	34.787,0
Malta	1.100,0	1.917,0	2.113,7	2.143,1
Netherlands	71.794,1	89.383,0	119.115,3	123.041,4
Austria	50.294,5	61.235,5	71.110,1	72.556,2
Poland	136.311,0	145.184,6	157.575,2	157.949,0
Portugal	28.501,0	43.764,0	54.085,7	53.078,4
Romania	64.309,0	51.560,0	60.978,9	55.934,9
Slovenia	12.444,0	13.624,5	16.438,3	17.190,7
Slovakia	26.132,0	31.158,0	27.817,9	28.903,0
Finland	54.377,5	69.784,9	80.364,8	68.722,5
Sweden	146.514,0	145.266,4	148.546,5	163.833,0

Source: processing according to data published by EUROSTAT, 2022

The following figure shows the evolution of gross electricity production in the European Union, for the period 1990-2020 (gigawatt-hour).

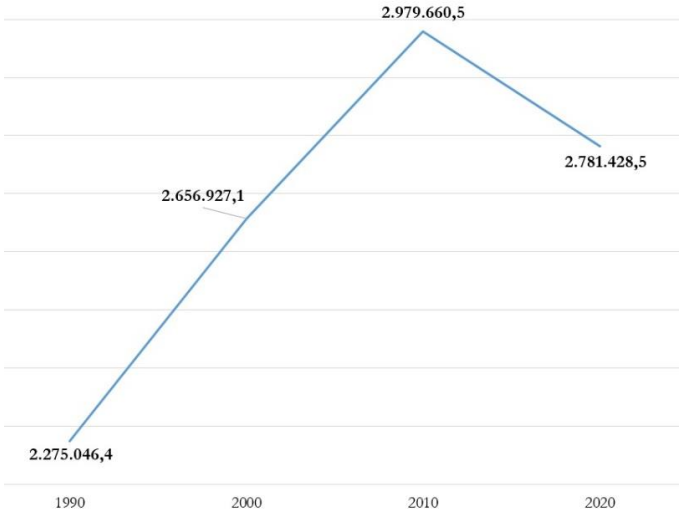

Figure 1: The evolution of gross electricity production in the European Union, for the period 1990-2020 (gigawatt-hour)
Source: processing according to data published by EUROSTAT, 2022

It is observed that the values increased for the period 1990-2010, up to 2979660.5 gigawatt-hours. In the next period (2010-2020), gross electricity production decreased to 2781428.5 gigawatt-hours (in 2020).
In the current context, the role of renewables has grown. The comparative situation of electricity generation capacities for the main renewable sources (hydro, geothermal, wind, solar, tide, wave, ocean), for the period 1990-2020, is presented in the following table (megawatt).

Table 2: Comparative situation of electricity generation capacities for the main renewable sources (hydro, geothermal, wind, solar, tide, wave, ocean), for the period 1990-2020.

Countries	1990	2000	2010	2020
European Union	122.624	148.020	253.528	467.286
Belgium	1.406	1.427	3.344	11.672
Bulgaria	1.975	1.880	3.561	5.177
Czechia	1.410	2.099	4.136	4.728
Denmark	336	2.401	3.818	7.571
Germany	8.232	15.694	56.134	126.741
Estonia	0	2	114	533
Ireland	513	645	1.628	4.928
Greece	2.411	3.298	4.715	10.824
Spain	15.662	20.176	43.833	59.530
France	24.913	25.412	32.597	55.447
Croatia	2.046	2.067	2.208	3.119
Italy	19.273	21.318	31.634	55.987
Cyprus	0	0	89	387
Latvia	1.487	1.515	1.606	1.669
Lithuania	95	863	1.009	1.581

Countries	1990	2000	2010	2020
Luxembourg	1.133	1.147	1.207	1.670
Hungary	48	48	348	2.513
Malta	0	0	1	188
Netherlands	88	497	2.364	17.605
Austria	10.947	11.668	14.000	19.874
Poland	1.888	2.187	3.450	12.653
Portugal	3.358	4.633	9.061	13.492
Romania	5.687	6.120	6.863	11.048
Slovenia	755	844	1.266	1.725
Slovakia	0	2.420	2.538	3.067
Finland	2.622	2.922	3.243	6.068
Sweden	16.339	16.737	18.760	27.489

Source: processing according to data published by EUROSTAT, 2022

Given the main renewable sources (hydro, geothermal, wind, solar, tide, wave, ocean), it is observed that in 1990, some countries did not have electricity generation capacity based on them (Estonia, Cyprus, Malta, Slovakia). In 1990, at the level of the European Union, the capacity to produce electricity based on the main renewable sources was 122624 megawatts. In 2020, the values increased by +344662 megawatts, to 467286 megawatts. Significant increases compared to 1990 had: Germany (+118509 megawatts), Spain (+43868 megawatts), Italy (+36714 megawatts), France (+30534 megawatts), Netherlands (+17517 megawatts), Sweden (+11150 megawatts).

In 2020, the highest values were recorded in: Germany (126741 megawatts), Spain (59530 megawatts), Italy (55987 megawatts), France (55447 megawatts), Sweden (27489 megawatts). The lowest electricity generation capacities based on the main renewable sources were in: Malta (188 megawatts), Cyprus (387 megawatts), Estonia (533 megawatts), Lithuania (1581 megawatts), Latvia (1669 megawatts), Luxembourg (1670 megawatts), Slovenia (1725 megawatts).

The Table 3 presents the comparative situation of electricity production capacities for the main renewable sources for 1990 and 2020, respectively, for each of the main renewable sources (hydro, geothermal, wind, solar, tide, wave, ocean).

The data in the table give us an idea of the interest that the countries of the European Union give to the production of electricity based on renewable sources. Thus, it is observed that, compared to 1990, when only Italy (with 496 megawatts), Greece (with 2 megawatts) and Portugal (with 1 megawatt) had capacities to produce electricity based on geothermal sources, in 2020 it increased the number of countries that have the capacity to produce electricity based on these sources. In 2020, the situation of geothermal power generation capacities is as follows: Italy (772 megawatts), Germany (40 megawatts), Portugal (29 megawatts), France (16 megawatts), Croatia (10 megawatts), Hungary (3 megawatts), Austria (1 megawatt), Romania (0.05 megawatts).

Table 3: Comparative situation of electricity generation capacities for the main renewable sources for 1990 and 2020.

Countries	1990					2020				
	hydro	geothermal	wind	solar	tide, wave, ocean	hydro	geothermal	wind	solar	tide, wave, ocean
European Union	121.430	499	444	11	240	150.771	871	176.984	138.443	217
Belgium	1.401	0	5	0	0	1.416	0	4.681	5.575	0
Bulgaria	1.975	0	0	0	0	3.376	0	703	1.097	0
Czechia	1.410	0	0	0	0	2.265	0	339	2.123	0
Denmark	10	0	326	0	0	7	0	6.259	1.304	0
Germany	8.182	0	48	2	0	10.792	40	62.188	53.721	0
Estonia	0	0	0	0	0	8	0	317	208	0
Ireland	513	0	0	0	0	529	0	4.307	93	0
Greece	2.408	2	1	0	0	3.417	0	4.119	3.288	0
Spain	15.657	0	2	3	0	20.117	0	26.819	12.589	5
France	24.673	0	0	0	240	25.712	16	17.484	12.022	212
Croatia	2.046	0	0	0	0	2.200	10	801	109	0
Italy	18.770	496	3	4	0	22.695	772	10.871	21.650	0
Cyprus	0	0	0	0	0	0	0	158	229	0
Latvia	1.487	0	0	0	0	1.586	0	78	5	0
Lithuania	95	0	0	0	0	877	0	540	164	0
Luxembourg	1.133	0	0	0	0	1.331	0	153	187	0
Hungary	48	0	0	0	0	58	3	321	2.131	0
Malta	0	0	0	0	0	0	0	0	188	0
Netherlands	37	0	50	1	0	37	0	6.619	10.950	0
Austria	10.947	0	0	0	0	14.605	1	3.226	2.043	0
Poland	1.888	0	0	0	0	2.400	0	6.298	3.955	0
Portugal	3.356	1	1	0	0	7.241	29	5.122	1.100	0
Romania	5.687	0	0	0	0	6.652	0	3.013	1.383	0
Slovenia	755	0	0	0	0	1.352	0	3	370	0
Slovakia	0	0	0	0	0	2.529	0	3	535	0
Finland	2.621	0	0	1	0	3.164	0	2.586	318	0
Sweden	16.331	0	8	0	0	16.406	0	9.976	1.107	0

Source: processing according to data published by EUROSTAT, 2022

Also, in 2020, the tide, wave, ocean-based electricity generation capacities were: France (212 megawatts), Spain (5 megawatts).

Interest has also increased in the production of energy based on wind or sunlight. Thus, in 2020, the highest values of wind-based electricity generation capacity were in: Germany (62188 megawatts), Spain (26819 megawatts), France (17484 megawatts), Italy (10871 megawatts), Netherlands (6619 megawatts), Poland (6298 megawatts), Denmark (6259 megawatts), Portugal (5122 megawatts). At the same time, for some countries the capacity to produce electricity based on solar rays reached high values in 2020: Germany (53721 megawatts), Italy (21650 megawatts), Spain (12589 megawatts), France (12022 megawatts), Netherlands (10950 megawatts), Belgium (5575 megawatts), Poland (3955 megawatts), Greece (3288 megawatts).

Countries that have the ability to use water for electricity production have increased their capacity. Thus, in 2020, the highest values were recorded in: France (25712 megawatts), Italy (22695 megawatts), Spain (20117 megawatts), Sweden (16406 megawatts), Austria (14605 megawatts), Germany (10792 megawatts).
An important indicator is the share of renewable energy in gross final energy consumption. The Table 4 shows the comparative situation for the period 2004-2020 (%).
There is an increase in the share of renewable energy in gross final energy consumption in all European Union countries. The largest increases were recorded in: Sweden (+21.7%), Denmark (+16.81%), Portugal (+14.78%), Greece (+14.59%), Finland (+14.57%).
At the level of the European Union, in 2020, the share of renewable energy in gross final energy consumption was 22.09%. The highest values were in: Sweden (60.12%), Finland (43.8%), Latvia (42.13%), Austria (36.55%), Portugal (33.98%). The lowest values were recorded in: Malta (10.71%), Luxembourg (11.7%), Belgium (13%), Hungary (16.85%), Netherlands (14%).

Table 4: Comparative situation of share of renewable energy in gross final energy consumption 2004-2020 (%).

Countries	2004	2010	2020
European Union	9,61	14,41	22,09
Belgium	1,92	6,00	13,00
Bulgaria	9,23	13,93	23,32
Czechia	6,77	10,51	17,30
Denmark	14,84	21,89	31,65
Germany	6,21	11,67	19,31
Estonia	18,42	24,58	30,07
Ireland	2,38	5,76	16,16
Greece	7,16	10,08	21,75
Spain	8,35	13,78	21,22
France	9,32	12,67	19,11
Croatia	23,40	25,10	31,02
Italy	6,32	13,02	20,36
Cyprus	3,07	6,16	16,88
Latvia	32,79	30,38	42,13
Lithuania	17,22	19,64	26,77
Luxembourg	0,90	2,85	11,70
Hungary	4,36	12,74	13,85
Malta	0,10	0,98	10,71
Netherlands	2,03	3,92	14,00
Austria	22,55	31,21	36,55
Poland	6,88	9,28	16,10
Portugal	19,21	24,15	33,98
Romania	16,81	22,83	24,48
Slovenia	18,40	21,08	25,00
Slovakia	6,39	9,10	17,35
Finland	29,23	32,17	43,80
Sweden	38,43	46,10	60,12

Source: processing according to data published by EUROSTAT, 2022

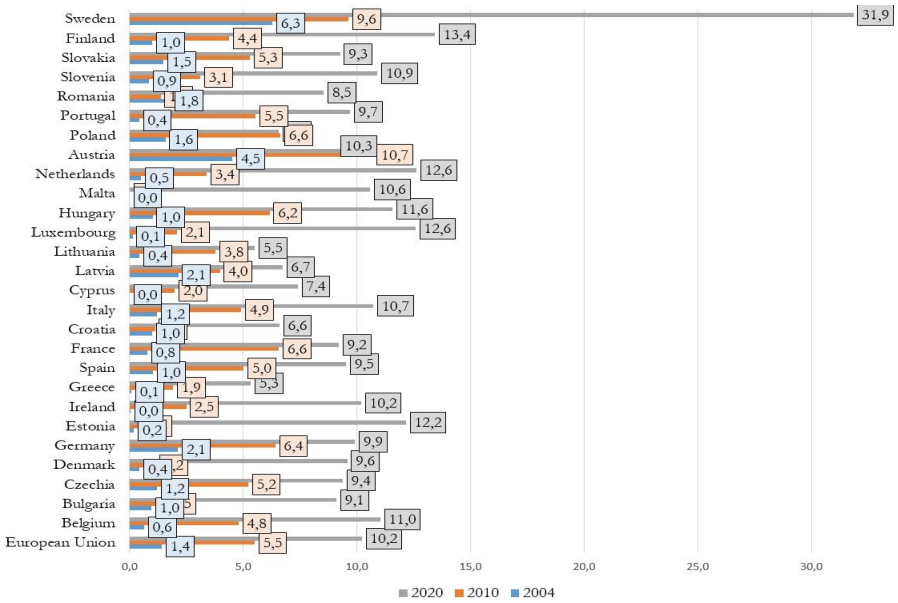

Figure 2: The share of renewable energy in gross final energy consumption, for the transport sector, for the period 2004-2020
Source: processing according to data published by EUROSTAT, 2022

The share of renewable energy in the final gross energy consumption, for the transport sector, for the period 2004-2020, is presented in the Figure 2 (%).
It is observed that, at the level of the European Union, for the transport sector, the share of renewable energy in the gross final energy consumption has increased (from 1.4% in 2004 to 10.2% in 2020). Sweden (+25.6%), Finland (+12.4%), Luxembourg (+12.4%), the Netherlands (+12.1%), Estonia (+12%) also had significant increases. In 2020, high values were in: Sweden (31.9%), Finland (13.4%), Netherlands (12.6%), Luxembourg (12.6%), Estonia (12.2%).
The lowest values of the share of renewable energy in gross final energy consumption for the transport sector were recorded in: Greece (5.3%), Lithuania (5.5%), Croatia (6.6%), Poland (6.6 %), Latvia (6.7%), Cyprus (7.4%).

5. Conclusions

At the level of the European Union, compared to 1990, in 2020, gross electricity production increased by 506382.1 gigawatt-hours. The largest increases were recorded in: Spain, France, Italy, Netherlands, Austria, Portugal, Poland, Germany.
In 2020, the highest values of gross electricity production were in: Germany, France, Italy, Spain, Sweden, Poland, Netherlands.
In 1990, at the level of the European Union, the capacity to produce electricity based on the main renewable sources was 122624 megawatts.
In 2020, the highest values were recorded in: Germany, Spain, Italy, France, Sweden.
Compared to 1990, in 2020, the interest that the countries of the European Union give to

the production of electricity based on renewable sources has increased.
At the level of the European Union, in 2020, the share of renewable energy in gross final energy consumption was 22.09%. The highest values were in: Sweden, Finland, Latvia, Austria, Portugal.
At the level of the European Union, for the transport sector, the share of renewable energy in the final gross energy consumption increased (from 1.4% in 2004 to 10.2% in 2020). In 2020, high values were in: Sweden, Finland, Netherlands, Luxembourg, Estonia.
It is found that increasing the capacity of renewable energy installations allows to reduce the costs of producing electricity from renewable sources compared to the production of electricity based on fossil fuels (Susskind et al., 2022).

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