THE CONCEPT OF SUSTAINABLE DEVELOPMENT AND RENEWABLE ENERGIES

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Abstract

The concept of sustainable development is central to the research of several authors in modern times and in the politics of the European Union (EU). One of the main points in the concept is the conservation of the available resources in nature, because of which is the goal of limiting the use of conventional resources and the development of unconventional ones.

The aim of the report is to trace and link the concept of sustainable development with the evolution of photovoltaic technologies as an unconventional source of energy, focusing on their application in the European Union (EU). In conclusion, the negative aspects of the use of photovoltaics are derived.

Keywords: sustainable development, ecology, renewable resources, photovoltaic technologies.

INTRODUCTION

The concept of sustainable development is central to the research of several authors in modern times and in the policy of the European Union (EU). The objectives pursued by the concept are imposed as a mechanism for limiting the harmful impact of people on the environment and slowing down the negative trends of climate change. The main task of the concept is to achieve economic development of society, balancing social and environmental principles, and at a sustainable pace over time, allowing conservation of available resources for present and future generations [1]. This highlights the importance of the concept of sustainable development, which is a prerequisite for its consideration in this paper.

The object of study in the report is the concept of sustainable development of society.

The subject of the study is photovoltaic systems as a source of renewable energy.

The aim of the report is to follow and link the concept of sustainable development with the evolution of photovoltaic technologies, focusing on their application in the European Union (EU). The objective thus defined is achieved by solving the following **tasks:**

- outlining the essence of the concept of sustainable development and defining the role of renewable energy sources in achieving sustainability.
- classification of renewable energy sources.
- tracking the historical development of photovoltaic technologies.
- analysis of the possibilities for using photovoltaic systems in the EU for the period 2010-2022.

A **graphical method** and a **method of comparison** were used to present the results of the study.

THE CONCEPT OF SUSTAINABLE DEVELOPMENT

The concept of sustainable development stems from the 1970 debate "Limits to Grow" looking at the possibility that continued economic growth could lead to environmental and social problems worldwide [2], [3]. Accepting the

consequences of the unforeseen negative impact of human development on the environment, the concept finds a wide resonance through the published World Conservation Strategy [4] and "Brundtland Report" [5].

Later, sustainable development was also the subject of the United Nations Conference on Environment and Development [6], the United Nations Millennium Declaration [7], and the United Nations Sustainable Development Summit [8], which defined the Sustainable Development Goals.

Deepening environmental problems predetermine the growing urgency to achieve sustainability in the development of society by applying the triple approach [9] to human well-being, namely a combination of economic development, environmental sustainability, and social inclusion (see Figure 1).

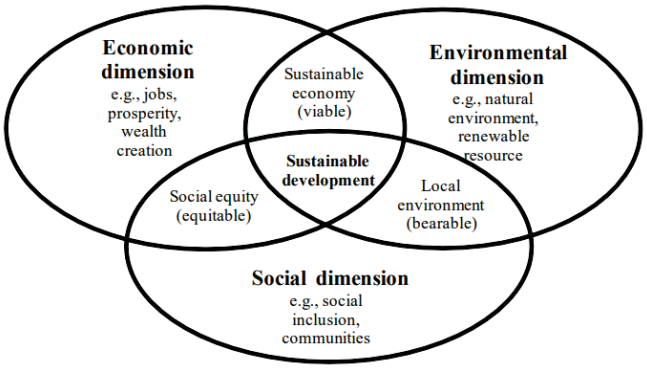

Fig. 1 *Dimensions of sustainable development* [10]

The combination of economic, environmental, and social dimensions in the concept implies consideration of the interests of society with the limitations of conventional resources and the pursuit of economic development. For the purposes of this analysis, priority attention has been given to the environmental dimension and to renewable energy sources.

The development of mankind for centuries has been associated with increased use of limited natural resources as an energy source. An example in this respect is the consumption of fossil fuels, considered one of the most critical factors for increasing greenhouse gas emissions [11]. The proven correlation between greenhouse gases and global climate change [12] requires a rethinking of the use of energy derived from conventional resources and a shift to environmentally friendly renewable energy Renewable energy sources are characterized as inexhaustible sources of energy, the use of which may limit the release of greenhouse gases characteristic of the exploitation of conventional energy resources.

Information on the more commonly used types of renewable energy sources can be obtained from Figure 2.

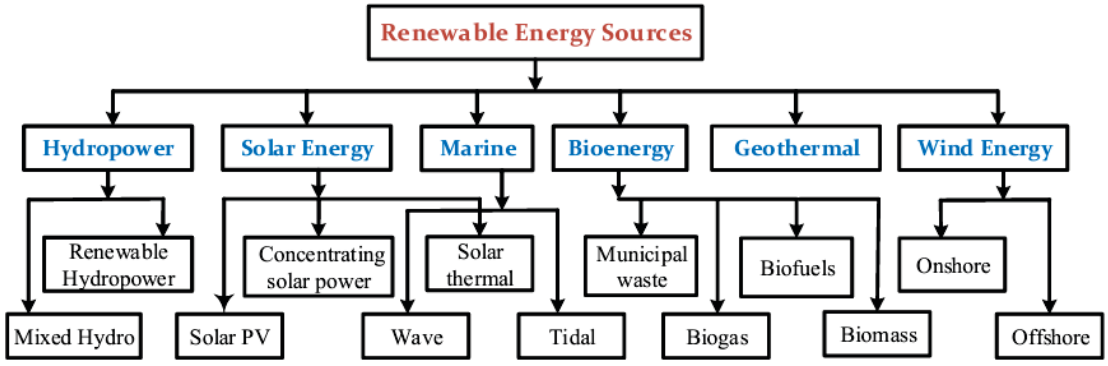

Fig. 2 *A summary of the most common renewable energy sources* [13]

The classification of unconventional energy sources stems from the natural forces used to generate energy. Priority in the research is given to solar energy as a renewable energy source and the photovoltaic (PV) systems developed for its operation, as for the period up to the beginning of the COVID-19 pandemic the production of photovoltaic energy is growing at the fastest pace [13].

PV SYSTEMS DEVELOPMENT

Photovoltaic systems are based on the photovoltaic effect first observed in 1839 by the French physicist Alexandre Edmond Becquerel. Years later, in 1877, Adams and Richard Day developed the first solar cell using selenium, and in 1878 Charles Fritts was able to double its efficiency by applying a different approach to using selenium [14].

Since then, photovoltaic technologies have been constantly evolving (see Figure 3), with a clear desire to increase the efficiency of photovoltaics in reducing the harmful impact on the environment.

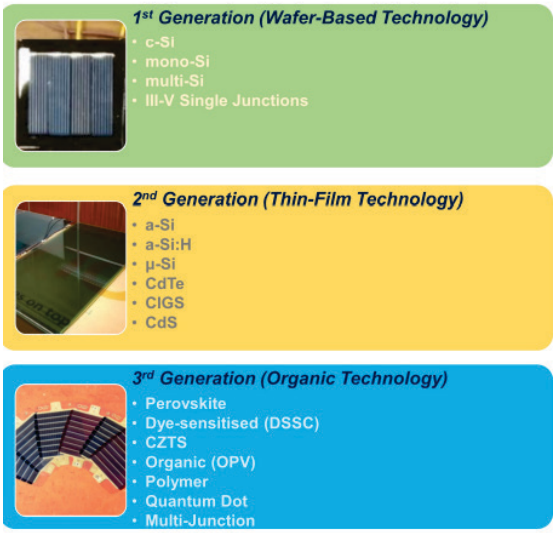

Fig. 3 *Categorisation of photovoltaic generations* [14]

Differences in photovoltaic generations (see Figure 3) stem from the techniques and materials used in their manufacture.

The first generation of photocells are among the most used today [15]. They were developed on wafer-based technology, using silicon, which is widely used in the production of semiconductors for microchips.

The second generation of cells aims to limit the production costs that are calculated in the previous generation of photocells and are based on thin film technology. It in turn cannot achieve the same efficiency as the first generation of photocells, but it does give rise to the possibility of innovative applications of photovoltaic cells in portable devices [16].

The third generation of photovoltaic cells are again based on thin film technology, but it is applied in combination with innovative materials such as organic compounds [14].

PV SYSTEMS IN THE EU-27

As one of the leaders in the transition to a "green economy", the EU is working to accelerate the transformation of reducing harmful carbon emissions and increasing the share of renewables [17]. One of the main strategic objectives of the EU in this direction is the process of switching from energy obtained from conventional resources to environmentally friendly renewable energy. This problem has been the subject of study by several authors [18], [19], [20], [21], which discuss both the economic and industrial side and the social side of this transformation.

The economic side of the transformation is associated with the export of low-carbon technologies and the creation of new jobs, along with attracting new investments. The industrial side refers to the modernization of the economy, which leads to the limitation of environmental pollution. The social aspect is a consequence of the economic and industrial aspect and includes environmental and climate protection activities, which also has an impact on public health [17].

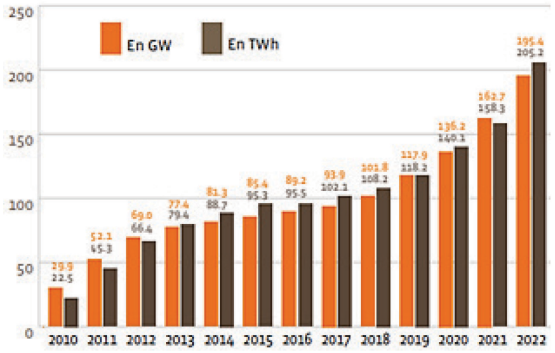

Fig. 4 *Development of PV systems in the EU-27 for the period 2010-2022* [22]

The EU's efforts focused on green transformation are part of the climate policies implemented and it is the duty of each Member State to increase the share of renewables [18], [23], [24], [25]. The consistency in the implemented energy transformation policies can be established from the data on the development of PV systems in the EU-27 for the period 2010-2022 (see Figure 4).

Data on PV system capacity for each of the EU-27 Member States are tabulated (see Table 1).

Table 1. Photovoltaic capacity in European Union countries in years 2010–2022 (MW)

Държави	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Austria	2	2.9	49	1022	770	937	1077	1269	1437	1660	2042.9	2809.4	3791.7
Belgium	97	118	321	739	3105	3252	3425	3610	3986	7530	5574.8	6300	6490
Bulgaria	2	1.8	3.4	4.2	1020	1029	2032	1035	1032	1065	1097.4	1186	1726
Croatia	0.1	0.1	6.1	68	34	45	50	60	67	69	108.5	108.5	182
Cyprus	10	11	11	11	51	51	55	110	118	128	229.1	316	464
Czech Republic	1953	1959	2022	2064	2047	2047	2075	2069	2075	2100	2122.7	2119	2535
Denmark	7	16	391	572	601	786	858	906	995	1080	1340	1597	3070
Estonia	16	16	20	20	0.2	7	10	10	31	107	207.7	414	506
Finland	6	10	17	35	10	15	20	74	140	215	318	404	591
France	1054	2831	4027	4625	5600	6605	7164	8610	9617	10575	12022	14780	17169
Germany	17370	24875	32698	36402	38301	39864	41340	42339	45181	49016	53721	58728	67399
Greece	787	1812	2649	3040	2602	2603	2603	2605	2645	2793	3287.7	3961.9	5270
Hungary	17	132	933	1019	38	175	288	355	726	1277	2131	2131	4056
Ireland	0.6	0.7	0.7	1	1.1	2.1	5	16	24	36	92.8	136	169.5
Italy	3478	12764	16361	18065	18450	18905	19274	19682	20107	20864	21650	22600	25060
Latvia	<0.1	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2	3	5.1	8	56
Lithuania	<0.1	0.2	0.2	0.2	68	73	73	74	82	83	164	255	572
Luxembourg	27	30	76	95	110	116	122	132	130	140	186.6	276.3	317
Malta	2	11	18	28	54	74	82	112	131	150	187.9	204.9	205.7
Netherlands	205	631	1543	2585	1100	1515	2040	2903	4522	6924	10949.7	14249	18849
Poland	144	488	517	588	24	111	195	287	562	1317	3955	7670	12189.1
Portugal	2	4.1	3.7	35	419	465	470	585	667	907	1071	1648	2563
Romania	103	173	421	631	1292	1302	1371	1374	1385	1385	1382.5	1398	1414
Slovakia	131	143	228	303	540	540	545	545	472	472	535	535	537
Slovenia	36	90	217	248	210	239	259	246	221	221	369.8	367	632
Spain	3421	3438	3808	4214	4787	4773	4801	4725	5239	9232	10285.5	13104.9	17195
Sweden	10	18	23	43	79	126	153	244	428	698	1107	1604.5	2404.5

Source: compiled from data from EurObserv'ER [26]

Analysing the information set out in Table 1, the leading role of individual countries (see Figure 5) in renewable energy production is noteworthy. These data testify to the EU's measures taken to achieve carbon neutrality and ensure the future of generations.

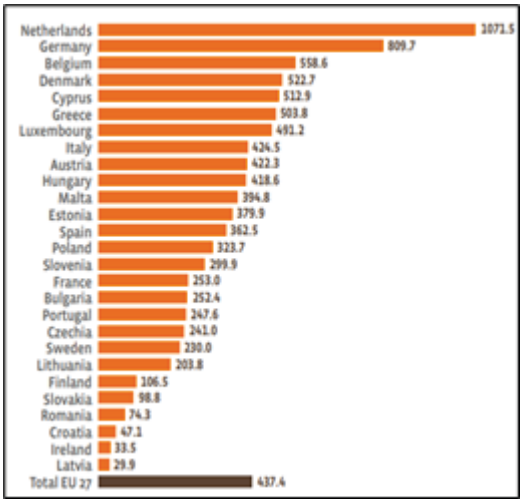

***Fig. 5**. Photovoltaic capacity per inhabitant (W/inhab.) for each EU-27 country in 2022* [22]

By 2022, 82% of the energy mix is still due to the use of fossil fuels and only 18% is allocated to renewable energy. [28]. Renewable energy sources are expected to reach 32% by 2035 and 50% of the total energy mix by 2050 (see Figure 6), which will reduce Europe's energy dependence on conventional energy sources.

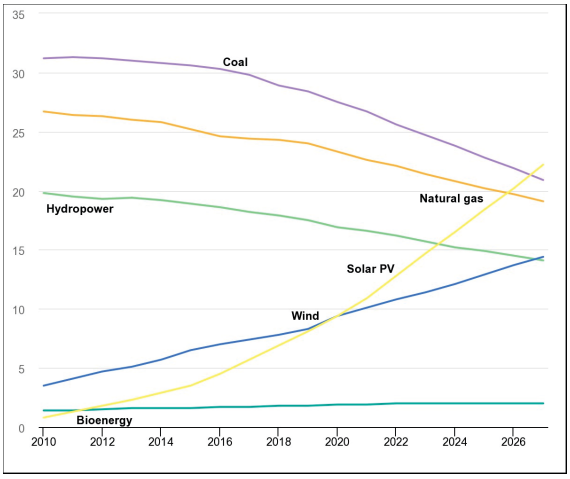

***Fig. 6**. Fossil fuel capacity* [27]

CONCLUSION

In summary of the information reviewed so far on the concept of sustainable development and the role of photovoltaic systems as a source of renewable energy contributing to the reduction of harmful greenhouse gas emissions into the environment, attention should also be paid to the negative consequences associated with the use of photovoltaics, namely:

- The production of solar photovoltaic energy also emits greenhouse gases (Figure 7) arising from solar energy systems [30].

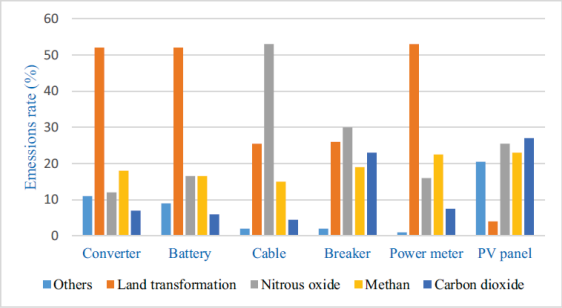

***Fig. 7**. Emissions of greenhouse gases from solar PV power over a 100-year period*

- Use of land area for photovoltaic parks, which does not allow its cultivation for agricultural purposes, leads to deforestation, and displaces the habitats of animal species [13].
- Soil and water are polluted, human health is threatened by toxic chemicals used in the production of solar panels.

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