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World energy outlook and state of renewable energy: 10-Year evaluation

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ABSTRACT

In this study, the energy situation of the world and the development of renewable energy were evaluated in the 10-year period covering the years 2012–2021. The share of renewable energy in electricity production and primary renewable energy consumption was assessed, and its development over the years was interpreted. The interest in renewable energy has been increasing regularly over the years. By evaluating the world energy data, it has been observed that renewable energy's installed power and consumption have increased significantly in the determined period.

Renewable energy is of great importance for sustainable development. However, even today, fossil fuels have the highest share in primary energy consumption. In addition, the use and consumption of renewable energy worldwide are regularly increasing. While 0.24 Gtoe of the world's primary energy consumption was met from renewable energy sources in 2012, this value increased to 0.95 Gtoe in 2021. Also, approximately 7.4% of the total electricity production in the world was met from renewable energy in 2016; this rate increased to 12.8% in 2021. While the use of renewable energy is more intense in EU countries compared to other parts of the world, it is observed that the use of renewable energy is widespread in other parts of the world.

1. Introduction

With the increase in world energy demand, the use of renewable energy has become widespread. There are studies in the literature about the contribution of renewable energy to sustainable development, the effects of renewable energy on environmental security and economic development, and social and political perspectives on renewable energy, renewable energy, and climate change (Aleixandre-Tudó et al., 2019; Ansari et al., 2021; Becker & Fischer, 2013; Ben Jebli & Ben Youssef, 2015; BILGEN et al., 2004; Carley et al., 2017; Chen et al., 2021; Dey et al., 2022; Dincer, 2000; Ellabban et al., 2014; Feng & Zheng, 2022; Güney, 2019; Inglesi-Lotz, 2016; Johansson, 2013; Jurasz et al., 2020; Khambalkar et al., 2010; Li et al., 2021; Luderer et al., 2014; Nguyen & Kakinaka, 2019; Pacesila et al., 2016; Pata, 2021; Raihan et al., 2023; Sadorsky, 2009; Sasmaz et al., 2020; Shahbaz et al., 2021; Sheikh et al., 2016; Sims, 2004; Soeiro & Ferreira Dias, 2020; Su et al., 2021; Tutak & Brodny, 2022; Vo et al., 2020; White et al., 2013; Çağlar, 2020; Østergaard et al., 2020).

Apart from these studies, Wang et al. evaluated the relationship between income inequality, economic growth, and carbon emissions. Within the scope of the evaluation, data from 56 countries were used. It is stated that the trend of increasing income inequality on carbon emissions has changed (Wang et al., 2023). Fraser et al. evaluated the effects of

renewable energy on social equity. The social equality status of 99 countries between 1990 and 2015 was assessed. The impact of economic development, institutional path dependency, governance capacity, governance quality, and policy design on the social implications of renewable energy are examined (Fraser et al., 2023). Ahmad et al. have studied the effects of natural resources on the environment in China. Within the scope of the study, the environmental impacts of natural resources were evaluated from 1995 through 2017. It has been stated that renewable energy improves environmental quality (Ahmad et al., 2022).

Song et al. evaluated the change in greenhouse gas emissions caused by US household consumption. They stated that changes in household consumption contributed to approximately one-third of the national emission reduction. At the same time, it was noted that greenhouse gas emissions, which peaked in the USA, decreased with the contribution of renewable energy (Song et al., 2022). Destek et al. evaluated the impact of renewable energy consumption on terrorism. A 1% increase in renewable energy consumption is stated to reduce terrorism by 0.315%, according to the CUP-FM estimator, and 0.631%, according to the CUP-BC estimator. It has been evaluated that non-renewable energy consumption has a positive effect on terrorism (Destek et al., 2022). Ponce et al. examined the impact of liberalization of the internal energy market on CO₂ emissions in the European Union. The study evaluating 27 EU countries stated that liberalization of the internal energy market

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effectively reduced CO₂ emissions (Ponce, Oliveira, et al., 2020). Ponce et al. assessed the relationship between renewable and non-renewable consumption, human capital, and non-renewable energy price for the years 1990–2017 for 53 countries with the highest hydroelectric energy consumption globally. Policy implications have been presented to increase renewable energy consumption (Ponce, López-Sánchez, et al., 2020). Ponce et al. investigated the environmental effects of financial development, urbanization, foreign direct investment, and economic growth. The ecological footprint was used as an indicator, and data from 100 countries were used. It has been stated that in the long term, according to the income level of the countries, the private financial system, per capita income, and urbanization have significant positive/negative effects on the ecological footprint (Ponce et al., 2022).

In this study, the 10-year energy outlook of the world between the years 2012–2021 was examined, and the development of renewable energy use was evaluated. Values are taken from the “Statistical Review of World Energy” reports published by BP (BP, 2022, 2021, 2020, 2019, 2018, 2017, 2016, 2015, 2014, 2013) and “Renewables, Global Status Report” reports published by REN21 (REN21, 2022, 2021, 2020, 2019, 2018, 2017, 2016, 2015, 2014, 2013). The data examined in the study shows that the interest in renewable energy and the consumption of renewable energy is regularly increasing. Therefore, it increases the positive effects of the contribution of renewable energy to sustainable development, renewable energy on environmental security and economic development, and renewable energy and climate change, which are the topics discussed in the literature. While the contributions mentioned above of renewable energy are obvious, in this study, the energy situation of the world and the development of renewable energy were evaluated in a 10-year period.

2. Primary consumption

The primary energy consumption values of the world and OECD, Non-OECD, and European Union (EU) countries are shown in Table 1 (BP, 2022, 2021, 2020, 2019, 2018, 2017, 2016, 2015, 2014, 2013). Values are shared in gigatonne of oil equivalent (Gtoe).

When the values are analyzed, a sharp decrease is observed in the primary energy consumption values in 2020 due to the global Covid-19 pandemic. While world primary energy consumption reached 14.21 Gtoe from 12.62 Gtoe in 10 years, primary energy consumption in EU countries decreased from 1.51 Gtoe to 1.44 Gtoe in the same period.

Primary energy consumption amounts according to fuels are shown in Table 2 (BP, 2022, 2021, 2020, 2019, 2018, 2017, 2016, 2015, 2014, 2013). Fossil fuels have the highest share in primary energy consumption in the examined date range. However, the share of renewable energy sources in primary energy consumption has increased. While 0.24 Gtoe of the world's primary energy consumption was met from renewable energy sources in 2012, this value increased to 0.95 Gtoe in 2021. When analyzed proportionally, while renewable energy was approximately 2% in 2012, this rate rose to 6.7% in 2021.

3. Analysis of primary energy consumption according to energy resources

3.1. Non-renewable energy

While evaluating the place of non-renewable energy sources in primary energy consumption, the United States (US) and China, the two

largest economies in the world (International Monetary Fund, 2023), were evaluated separately, in addition to the regions discussed in the previous sections. The values of non-renewable energy sources in primary energy consumption are shown in Table 3 (BP, 2022, 2021, 2020, 2019, 2018, 2017, 2016, 2015, 2014, 2013). Accordingly, while China alone provides about half of the world's primary coal consumption, the US is responsible for about one-third of the world's primary nuclear energy consumption. Oil has the highest consumption rate of non-renewable primary energy sources, followed by coal and natural gas, respectively.

3.2. Renewable energy

As can be seen from Table 2, the amount of renewable energy in primary energy consumption has increased significantly. In the ten years, renewable primary energy consumption has increased by a factor of one in EU countries, by two times in OECD countries, by three times in the world total, and by approximately five times in Non-OECD countries.

World renewable capacities are shown in Table 4 (REN21, 2022, 2021, 2020, 2019, 2018, 2017, 2016, 2015, 2014, 2013). Bio-power (Bio.), concentrated solar power (CSP), geothermal (Geo.), photovoltaics (PV), and wind sources were examined, and hydroelectricity was not included in the table. When the values are analyzed, it is seen that the world renewable capacity, which was 480 GW at the end of 2012, reached 1945 GW by the end of 2021. In particular, PV capacity has reached 942 GW, with an increase of 842% in the 10-year period.

4. Electricity generation

World electricity production values are shown in Table 5 (BP, 2022, 2021, 2020, 2019, 2018, 2017, 2016, 2015, 2014, 2013). World electrical energy production, which has shown a regular increase over the years, decreased in 2020 due to the Covid-19 pandemic. The electricity production was 22.8 PWh in 2012 and was realized as 28.5 PWh in 2021.

The amounts of world electricity production according to the sources are given in Table 6. (BP, 2022, 2021, 2020, 2019, 2018, 2017). In 2021, while the largest share in electricity generation in OECD countries and Non-OECD countries, and therefore in the world, belongs to coal, the largest share in electricity generation in EU countries belongs to nuclear energy and renewables.

When examined with all energy sources, the share of renewable energy in electricity generation has increased regularly. While approximately 7.4% of the total electricity production in the world was met from renewable energy in 2016, this rate increased to 12.8% in 2021.

Table 7 shows the electricity generation values from wind, solar, and other (geothermal, biomass, and other sources of renewable energy) renewable energy sources (BP, 2022, 2021, 2020, 2019). In the 4-year period, it is observed that electricity production from solar energy has increased significantly. Electricity generation from solar energy in non-OECD countries has doubled in 4 years and has grown from 582.8 TWh to 1032.5 TWh worldwide.

Table 8 shows the wind + solar energy ratios in total electricity generation (BP, 2022, 2021, 2020, 2019). In the 4-year period, this rate has increased from 9.5% to 13.4% in OECD countries, from 5.1% to 8.1% in non-OECD countries, from 17.2% to 19% in EU countries, and from 6.9% to 10.2% in the world. World renewable energy investment is shown in Fig. 1 (IEA, 2022). World renewable energy investment, which was \$326 billion in 2017, increased to \$446 billion in 2021.

Table 1
Primary energy consumption for 2012–2021 (Gtoe).

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
OECD	5.54	5.59	5.54	5.56	5.59	5.63	5.72	5.67	5.26	5.49
Non-OECD	7.08	7.25	7.44	7.53	7.69	7.90	8.19	8.36	8.21	8.72
EU	1.51	1.50	1.44	1.46	1.48	1.49	1.50	1.48	1.36	1.44
World	12.62	12.84	12.98	13.09	13.28	13.53	13.91	14.03	13.47	14.21

Table 2

Primary energy consumption by fuel for 2012–2021 (Gtoe).

		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
OECD	Oil	2.07	2.06	2.03	2.06	2.09	2.20	2.20	2.15	1.88	2.00
	NG	1.43	1.46	1.43	1.46	1.50	1.44	1.51	1.55	1.51	1.54
	Coal	1.05	1.07	1.05	0.97	0.91	0.89	0.86	0.77	0.66	0.71
	NE	0.44	0.45	0.45	0.45	0.45	0.44	0.45	0.42	0.40	0.41
	HE	0.32	0.32	0.32	0.31	0.32	0.31	0.32	0.31	0.31	0.32
Non-OECD	Ren.	0.17	0.20	0.22	0.25	0.27	0.30	0.33	0.40	0.43	0.50
	Oil	2.06	2.12	2.18	2.28	2.33	2.41	2.46	2.43	2.29	2.40
	NG	1.55	1.59	1.63	1.68	1.71	1.71	1.80	1.81	1.78	1.93
	Coal	2.68	2.80	2.83	2.81	2.82	2.83	2.91	2.99	2.96	3.11
	NE	0.12	0.12	0.12	0.14	0.15	0.15	0.17	0.17	0.17	0.19
EU	HE	0.52	0.54	0.56	0.57	0.59	0.61	0.63	0.59	0.60	0.64
	Ren.	0.07	0.09	0.10	0.12	0.15	0.19	0.23	0.29	0.33	0.45
	Oil	0.61	0.60	0.59	0.60	0.61	0.65	0.65	0.55	0.48	0.51
	NG	0.40	0.39	0.35	0.36	0.39	0.40	0.39	0.34	0.33	0.34
	Coal	0.29	0.29	0.27	0.26	0.24	0.23	0.22	0.17	0.14	0.16
World	NE	0.20	0.20	0.20	0.19	0.19	0.19	0.19	0.16	0.15	0.16
	HE	0.07	0.08	0.08	0.08	0.08	0.07	0.08	0.07	0.07	0.08
	Ren.	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.16	0.17	0.19
	Oil	4.13	4.18	4.21	4.34	4.42	4.61	4.66	4.58	4.16	4.40
	NG	2.99	3.05	3.07	3.15	3.20	3.14	3.31	3.36	3.29	3.47
	Coal	3.73	3.87	3.88	3.78	3.73	3.72	3.77	3.77	3.62	3.82
	NE	0.56	0.56	0.57	0.58	0.59	0.60	0.61	0.60	0.57	0.60
	HE	0.83	0.86	0.88	0.88	0.91	0.92	0.95	0.90	0.91	0.96
	Ren	0.24	0.28	0.32	0.37	0.42	0.49	0.56	0.69	0.76	0.95

Table 3

Status of non-renewable energy sources in primary energy consumption (Gtoe).

		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
China	Oil	0.49	0.51	0.53	0.56	0.59	0.61	0.63	0.67	0.69	0.73
	NG	0.13	0.15	0.17	0.18	0.18	0.21	0.24	0.26	0.29	0.33
	Coal	1.86	1.93	1.95	1.92	1.89	1.89	1.91	1.95	1.97	2.06
	NE	0.02	0.03	0.03	0.04	0.05	0.06	0.06	0.07	0.08	0.09
US	Oil	0.82	0.83	0.84	0.85	0.91	0.91	0.89	0.88	0.78	0.84
	NG	0.66	0.67	0.69	0.71	0.65	0.64	0.71	0.73	0.72	0.71
	Coal	0.44	0.46	0.45	0.40	0.34	0.33	0.32	0.27	0.22	0.25
	NE	0.18	0.19	0.19	0.19	0.19	0.19	0.18	0.18	0.18	0.18
OECD	Oil	2.07	2.06	2.03	2.06	2.09	2.20	2.20	2.15	1.88	2.00
	NG	1.43	1.46	1.43	1.46	1.50	1.44	1.51	1.55	1.51	1.54
	Coal	1.05	1.07	1.05	0.97	0.91	0.89	0.86	0.77	0.66	0.71
	NE	0.44	0.45	0.45	0.45	0.45	0.44	0.45	0.42	0.40	0.41
Non-OECD	Oil	2.06	2.12	2.18	2.28	2.33	2.41	2.46	2.43	2.29	2.40
	NG	1.55	1.59	1.63	1.68	1.71	1.71	1.80	1.81	1.78	1.93
	Coal	2.68	2.80	2.83	2.81	2.82	2.83	2.91	2.99	2.96	3.11
	NE	0.12	0.12	0.12	0.14	0.15	0.15	0.17	0.17	0.17	0.19
EU	Oil	0.61	0.60	0.59	0.60	0.61	0.65	0.65	0.55	0.48	0.51
	NG	0.40	0.39	0.35	0.36	0.39	0.40	0.39	0.34	0.33	0.34
	Coal	0.29	0.29	0.27	0.26	0.24	0.23	0.22	0.17	0.14	0.16
	NE	0.20	0.20	0.20	0.19	0.19	0.19	0.19	0.16	0.15	0.16
World	Oil	4.13	4.18	4.21	4.34	4.42	4.61	4.66	4.58	4.16	4.40
	NG	2.99	3.05	3.07	3.15	3.20	3.14	3.31	3.36	3.29	3.47
	Coal	3.73	3.87	3.88	3.78	3.73	3.72	3.77	3.77	3.62	3.82
	NE	0.56	0.56	0.57	0.58	0.59	0.60	0.61	0.60	0.57	0.60

Table 4

World renewable energy capacities (GW).

		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Bio.	83	88	101	106	114	122	131	139	133	143	
CSP	2.5	3.4	4.3	4.8	4.8	4.9	5.6	6.2	6.2	6.0	
Geo.	11.5	12	12.9	13.2	12.1	12.8	13.2	13.9	14.2	14.5	
PV	100	139	177	227	303	402	512	627	767	942	
Wind	283	318	370	433	487	539	591	651	745	845	
Total	480	560	665	785	922	1081	1252	1437	1672	1945	

5. Conclusion

In this study, the energy status of the world was evaluated in the ten years between 2012 and 2021. While assessing the energy situation, the

world's renewable energy situation was emphasized. The share of renewable energy sources in primary energy consumption has increased. While 0.24 Gtoe of the world's primary energy consumption was met from renewable energy sources in 2012, this value increased to 0.95 Gtoe

Table 5

World electricity generation (PWh).

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
OECD	11.023	11.015	10.955	11.004	11.082	11.124	11.311	11.191	10.901	11.210
Non-OECD	11.795	12.438	13.095	13.288	13.842	14.523	15.366	15.845	15.989	17.256
EU	2.931	2.912	2.849	2.898	2.919	2.951	2.935	2.894	2.779	2.895
World	22.818	23.452	24.050	24.292	24.924	25.648	26.677	27.037	26.889	28.466

Table 6

Electricity generation by fuel for 2016–2021 (TWh).

		2016	2017	2018	2019	2020	2021
OECD	Oil	226.6	196.1	196.4	164.9	145.6	142.5
	NG	3056.4	3016.2	3201.2	3347.5	3399.6	3372.4
	Coal	3007.2	2992.0	2829.6	2471.0	2065.6	2253.0
	NE	1970.4	1956.1	1969.8	1993.0	1872.3	1911.0
	HE	1406.8	1391.1	1423.0	1380.2	1483.3	1440.3
	Ren.	1193.7	1347.7	1442.4	1616.8	1766.1	1910.1
Non-OECD	Other	114.2	114.2	183.9	162.6	168.2	181.0
	Oil	731.8	686.9	694.0	660.4	516.0	577.8
	NG	2793.3	2899.1	2881.3	2950.4	2972.0	3146.1
	Coal	6443.8	6731.5	7261.7	7353.1	7373.7	7991.0
	NE	642.4	679.5	730.6	803.0	821.7	889.2
	HE	2629.2	2668.8	2748.4	2842.1	2862.7	2833.6
EU	Ren.	651.0	803.9	1025.6	1188.8	1380.5	1747.2
	Other	63.3	68.4	65.0	71.0	61.8	71.2
	Oil	59.3	57.2	52.6	49.1	45.5	43.0
	NG	607.2	658.5	621.2	692.2	561.4	548.0
	Coal	719.4	693.8	643.6	488.4	369.1	439.2
	NE	839.9	830.5	827.0	822.4	683.8	732.2
World	HE	350.0	299.7	346.9	327.9	343.2	344.4
	Ren.	602.5	673.3	700.9	768.2	710.6	730.2
	Other	76.2	73.6	77.9	67.2	65.4	58.4
	Oil	958.4	883.0	290.4	825.3	661.7	720.3
	NG	5849.7	5915.3	6082.5	6297.9	6371.7	6518.5
	Coal	9451.0	9723.4	10,091.3	9824.1	9439.3	10,244.0
	NE	2612.8	2635.6	2700.4	2796.0	2694.0	2800.3
	HE	4036.1	4059.9	4171.4	4222.2	4346.0	4273.8
	Ren.	1844.6	2151.5	2468.0	2805.5	3146.6	3657.2
	Other	177.5	182.6	248.9	233.6	230.0	252.2

Table 7

Electricity generation by renewables for 2018–2021 (TWh).

		2018	2019	2020	2021
OECD	Wind	745.4	841.8	935.4	976.7
	Solar	329.9	387.2	442.5	523.3
	Other	367	387.8	388.2	410.1
Non-OECD	Wind	524.7	587.9	661.1	885.2
	Solar	252.8	336.9	403.8	509.2
	Other	248	264	315.7	352.7
EU	Wind	376.9	430.7	397.3	389.5
	Solar	127.5	138.4	143.3	160.6
	Other	196.4	199.1	170	180.1
World	Wind	1270.2	1429.6	1596.4	1861.9
	Solar	582.8	724.1	846.2	1032.5
	Other	615	651.8	703.9	762.8

Table 8

The ratio of wind + solar energy in electricity generation for 2018–2021 (TWh).

		2018	Share (%)	2019	Share (%)	2020	Share (%)	2021	Share (%)
OECD	Wind + Solar	1075.3	95	1229.0	110	1377.9	126	1500	134
	Total	11,310.9		11,191.3		10,900.7		11,210.2	
Non-OECD	Wind + Solar	777.5	51	924.8	58	1064.9	67	1394.4	81
	Total	15,366.4		15,845.3		15,988.5		17,256.1	
EU	Wind + Solar	504.4	172	569.1	197	540.6	195	550.1	190
	Total	2935.3		2894.0		2779		2895.3	
World	Wind + Solar	1853.0	69	2153.7	80	2442.6	91	2894.4	102
	Total	26,677.3		27,036.6		26,889.2		28,466.3	

in 2021. Also, approximately 7.4% of the total electricity production in the world was met from renewable energy in 2016, and this rate increased to 12.8% in 2021.

However, the world's renewable capacity, which was 480 GW at the end of 2012, reached 1945 GW by the end of 2021. In particular, PV capacity has reached 942 GW, with an increase of 842% in the 10-year period. As a result of the values examined, it is observed that the use of renewable energy is widespread in other parts of the world as well as in EU countries. In 2021, there are EU countries that met more than a quarter of their electricity generation from renewables. For example, in 2021, 37.2% of Germany's electricity production, 33% of the Netherlands' electricity production, 35.2% of Spain's electricity production, and 38.5% of the United Kingdom's electricity production were met from renewable energy sources (BP, 2022).

There are studies on the contribution of renewable energy to sustainable development, environment, welfare level, and economic development. These studies have been mentioned in the previous sections. The

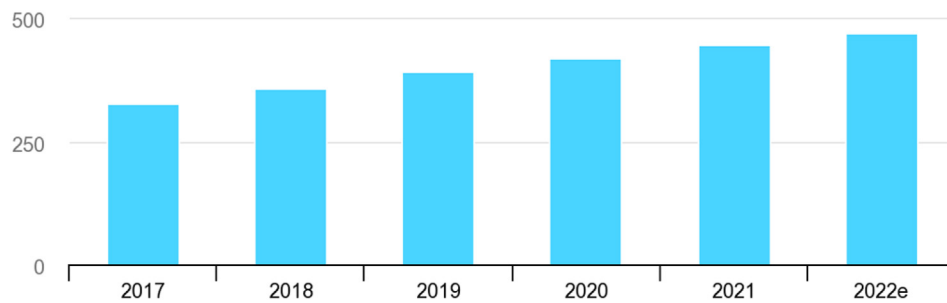


Fig. 1. World renewable energy investment by years (billion \$) (IEA, 2022).

present study mentions the situation of renewable energy use in the world over the years. It is observed that the share of renewable energy in primary energy consumption and electricity production is regularly increasing.

While not all countries have fossil reserves, almost all have renewable energy potential (Pierre-Louis, 2017). This is one of the crucial advantages of renewable energy. Renewable energy investments should be encouraged to reduce the energy dependency of countries.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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