The World Electricity Production and the Current Global Energy Crisis in Brief

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Abstract

This paper shows that the fossil fuels still account for over 60% of total global electricity generation and highlights how the current global energy crisis has placed electricity security and affordability high on the political agenda, favouring renewable solutions.

The global energy landscape has changed radically since Russia's invasion of Ukraine. Countries around the world have faced rising prices that have hit consumers hard, all against a geopolitical backdrop with energy security at its center and the world's dependence on fossil fuel consumption often supplied by only a few major producers. An accelerated transition to low-carbon energy sources such as renewable and nuclear sources is therefore necessary. In Europe, the ripple effects of the war were acutely felt due to the historical dependence on Russian gas imports. The risk of shortages has been and continues to be avoided through greater efforts to improve energy efficiency, deploy renewables, install heat pumps, promote energy savings and increase gas supplies.

Key words: global energy crisis, electricity, renewable solutions
J.E.L. classification: F51, L7, O13, P18, P48, Q3, Q4

1. Introduction

The energy industry is an important branch of the world economy that deals with the exploration, exploitation and use of energy carriers. Along with the economic development and the growth of the world population, the energy consumption has also increased. At present, energy is part of all economic and social processes. The superiority of an economy does not result from the amount of energy consumed, but from the efficient way it is used.

Russia's invasion of Ukraine in February 2022 caused a global energy crisis. Energy security has emerged as an additional strong motivation to accelerate the use of renewable energy. Fossil fuel supply disruptions have highlighted the energy security benefits of domestically generated renewable electricity, prompting many countries to strengthen policies to support renewables. Meanwhile, higher fossil fuel prices worldwide have increased the competitiveness of solar PV and wind generation against other fuels.

The energy crisis hit the EU while it was already discussing ambitious renewable targets under the Fit for 55 package. At EU level, the European Commission's REPowerEU plan launched in May 2022 proposes ending the bloc's dependence on Russian fossil fuels by 2027. REPowerEU plan aims to increase the share of renewable sources in final energy consumption to 45% by 2030, exceeding the 40% previously under negotiation.

The current global energy crisis brings both new opportunities and new challenges for the renewable energy. The International Energy Agency's Renewables 2022 report provides an analysis of the new policies introduced in response to the energy crisis. This year's report shows the current policy and the market evolution, given the current energy price increases and energy security challenges.

2. Theoretical background

Currently, electricity has become irreplaceable in all economic and social fields. Its advantages are multiple: it is non-polluting, it can be used at long distances from the place of production, it can be easily transformed into other forms of energy (mechanical, thermal, chemical).

Over time, progress has been made in the production, transportation and use of electricity. In the 17th century, Isaac Newton introduced the notion of energy, and in 1791 Luigi Galvani discovered the electric current. In 1840 heat was identified as a form of energy by the German Hermann von Helmholtz and the Englishman James Prescott Joule. The first power plants in the world came into operation in the 19th century: the Lancey hydroelectric plant in France (1869) or the thermoelectric plants in London and New York (1882). In Romania, the first thermoelectric power plants were built in 1882 in Bucharest, in 1884 in Timisoara (public lighting service) and in 1887 in Caransebeş. In the 20th century, large power plants were build, starting with the hydroelectric plants in the USA. New technologies were also developed that used new sources of energy: the first geothermal power plant in Larderello (1904, Italy), the first power plant that used the temperature difference of ocean waters in Matanzos (1930, Cuba), the first nuclear-electric power plant in Obninsk (1954, Russia), the first tidal power plant in the La Rance estuary (1967, France), the first solar power plant in Adrano (1981, Italy), the first wind power plant in the Crimea Peninsula (Ukraine).

The **primary sources of electricity** are especially the fossil fuels (coal, natural gas, oil), running water energy, radioactive ores and less geothermal energy, wind energy, solar energy, ocean water energy, biomass (Erdeli et al ., 2009).

The energy production involves the use of raw materials or energy sources, classified as follows:

• *conventional energy sources (classical sources)*: fossil fuels (coal, hydrocarbons, bituminous shale, asphalt sands), vegetable fuels (wood), nuclear fuels, running water energy;

• *non-conventional energy sources (alternative sources)*: solar energy, wind energy, geothermal energy, ocean water energy, plant and animal waste, etc.

According to the criterion of sustainability of exploitation, the energy resources are classified into:

• *exhaustible (non-renewable) resources*: fossil fuels;

• *inexhaustible (renewable) resources*: solar energy, wind energy, running water and ocean energy, geothermal energy, vegetable fuels.

Other sources of energy may be added to these, some based on physical and chemical technologies, some known only experimentally, others little exploited, but very promising: biomass ("energy plants") for obtaining some fuels, the energy of ocean currents, the energy resulting from the temperature difference between surface and deep ocean waters, the hydrogen obtained by dissociating water, etc.

The EU's dependence on the Russian gas has grown steadily over the past decade. The bloc's gas consumption fell only marginally during this period, but production has fallen by two-thirds since 2010, and the gap has been filled by rising imports. As a result, Russia's share of total EU gas demand increased from 26% in 2010 to an average of over 40% in 2018-2021. The International Energy Agency (IEA) was among the first to raise concerns about this growing dependence.

The transition to clean energy has accelerated given the security concerns. After Russia's invasion of Ukraine in February 2022, the energy security emerged as an additional strong motivation to accelerate the use of renewable energy. The European Commission's REPowerEU plan, launched in May 2022, proposed ending the bloc's dependence on Russian fossil fuels by 2027. In direct support of Ukraine, the International Energy Agency signed a two-year joint work program to support its recovery, including short- and long-term energy priorities such as energy system security, hydrogen, renewables, biogas and collaboration on data and statistics. The IEA member countries agreed to release oil from their emergency reserves to ease market tensions and send a unified message that there will be no supply shortage as a result of the Russian invasion (62.7 million barrels of emergency oil stocks oil in March 2022 and an additional 120 million barrels from emergency reserves in April 2022; this action coincided with the release of additional barrels from the US Strategic Petroleum Reserve).

Russia has more than halved its gas supplies to the EU in the past year. But the European gas market has proven resilient as nations have been able to fill their storage sites to more than 95 percent capacity by increasing supplies from outside Russia and rapidly reducing consumption. As a result, Russia's share of European gas demand fell from 23% in 2022 to below 10% in January 2023.

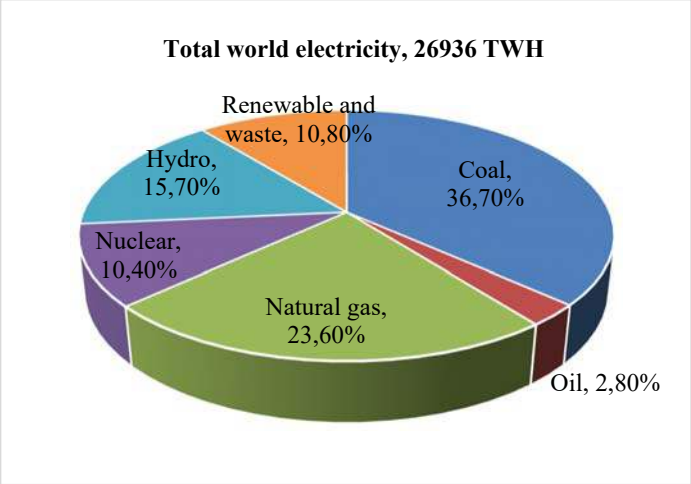
3. Research methodology

The theoretical research, the analysis and the synthesis were used in drafting this paper. The theoretical research consisted in the study of the specialized literature. The study was conducted based on the analysis, processing and interpretation of the most significant indicators of energy production. The research methodology was based on the analysis and interpretation of the latest data provided by the International Energy Agency (IEA), using descriptive statistics.

4. Findings

Most of the electricity production worldwide (Figure 1) comes from the use of fossil fuels (63 %). Running water energy accounts for 16% and nuclear fuels 10.4% of the total electricity production. The other non-conventional, inexhaustible and environmentally friendly sources of energy (solar, wind, geothermal, waste, etc.) still count for low shares (10.8%).

Figure no. 1. Electricity sources worldwide, in 2020



Source: Key World Energy Statistics, International Energy Agency, 2021

The classic **thermoelectric power plants** provide 67% of the world's electricity (17,007 billion KWh) and use coal, oil, natural gas, oil shale, wood, straw, waste as energy source (Table no. 1).

Table no. 1. Main electricity producing countries in fossil fuel power plants (2019)

Pos.	COAL	bn KWh	Pos.	OIL	bn KWh	Pos.	NATURAL GAS	bn KWh
1	China	4,876	1	Saudi Arabia	168	1	USA	1,640
2	India	1,181	2	Mexico	45	2	Russia	514
3	USA	1,070	3	Iraq	41	3	Japan	385
4	Japan	329	4	Japan	36	4	Iran	270
5	Korea	246	5	USA	36	5	Saudi Arabia	217
6	South Africa	222	6	Kuwait	28	6	China	213
7	Russia	188	7	Iran	28	7	Mexico	193
8	Germany	182	8	Egypt	26	8	Egypt	150
9	Indonesia	174	9	Lebanon	20	9	Korea	146
10	Australia	154	10	Cuba	17	10	Italy	142
Rest of producers		1,292	Rest of producers		302	Rest of producers		2,476
World total		**9,914**	**World total**		**747**	**World total**		**6,346**

Source: Key World Energy Statistics, International Energy Agency, 2021

The thermoelectric power plants offer rhythmicity in operation, high production capacity, short construction time and short term of investment amortization; fuels can be transported over long distances, which offers the possibility of locating thermoelectric power plants not only in the fuel extraction area, but also in large consuming centers. Among the disadvantages we mention: the high volume of fuels used, the need for large spaces for storing them and waste, high water consumption, polluting emissions into the atmosphere. The most widespread type of thermoelectric power plants is the one that operates on the basis of steam, using a large amount of water and fuel.

The thermoelectric power plants are the basis of electricity production in many countries (over 80% of the total), most of them having rich reserves of fossil fuels (China, USA, Russia, Algeria, Libya, Tunisia, Morocco, Kuwait, Australia, Qatar, Saudi Arabia , Iraq, Iran, the Netherlands, Poland, the Czech Republic, UK, India, Indonesia, Mexico) or being large consumers of electricity (Japan, Italy, Germany).

The geographical distribution of thermoelectric power plants shows their concentration as follows:

- high-power thermoelectric power plants were built near the coal-bearing basins: the Appalachian basin, Pittsburg, the Ruhr basin, the Moscow basin, Donetsk, Karaganda, the Upper Silesia basin, the Rovinari basin (Rogojelul and Turceni thermal power plants);
- in regions rich in hydrocarbons or along transport pipes: the Gulf of Mexico, Volga-Ural area, Baku, the Transylvanian Depression;
- in large urban centers that consume electricity, where the thermoelectric power plants mainly use natural gas and oil residues: Paris, London, New York, Chicago, Beijing, Tokyo, Bucharest, etc.;
- in port regions, especially for the fuel importing countries, such as Japan, Italy, Belgium, Germany, but also in some large hydrocarbon producing countries and coastal or submarine areas (Netherlands-Rotterdam, Mexico, USA);
- along large rivers that can provide the necessary amount of water and fuel transport: Rhine, Oder, Ohio, Volga.

The **hydroelectric power plants** use running water as a source of energy, the technology being quite simple: the hydraulic turbines transform the energy of a running water or a falling water into mechanical energy that drives electricity generators. The advantages that hydropower plants offer are multiple: low cost of the energy produced, low degree of pollution, improvement of navigation, the possibility of using water for irrigation, industry, domestic consumption, flood prevention and flow regulation. Among the disadvantages we mention: large investments and long execution time of hydropower facilities (dams, catchments, derivations), the possibility of clogging of reservoirs, changes in the environment, the disappearance of some fauna and flora species and sometimes population displacements.

Depending on the type of construction, the hydropower plants can be high-head (over 200m), medium-head, low-head (under 30m) and waterline (by-pass) power plants. In many cases, dams and reservoirs were built along a river in a chain or cascade, for the maximum exploitation of its hydropower potential (hydropower systems). High and medium drop hydropower plants require the construction of dams, behind which reservoirs are formed that provide the volume of water necessary to obtain energy; in many cases, to obtain the required volume of water, tributaries or neighboring rivers are captured, whose water is directed to the reservoir. Low-drop hydropower plants compensate for the reduced level difference with the high flow rate of the hydrographic artery.

Currently, the hydropower plants produce 15.7% of the world's energy, transforming the primary energy of flowing water into electricity. The amount of energy produced in hydropower plants increased from 1,295 billion KWh in 1973 to 4,329 billion KWh in 2019.

The theoretical hydropower potential of Earth was estimated at 6.2 million MW, but the technical-manageable potential is lower, only 2.3 million MW. The use of these resources is only 26% globally, with higher shares in Europe and North America.

The largest installed capacities are in: China 356 GW, Brazil 110 GW, the U.S.A. 103 GW, Canada 81 GW, Russia, Japan, India, Norway, Turkey, France, Italy, Indonesia, D.R. Congo, Colombia, Argentina.

The greatest producers of hydropower are: China (1,304 billion KWh), Brazil (398 billion KWh), Canada (380 billion KWh), USA, Russian Federation, India, Norway, Turkey, Japan, Vietnam, Venezuela and Sweden (Table no. 2).

Table no. 2. Main hydroelectricity producers and the installed capacity in hydropower plants (2019)

Pos	Hydroelectricity production	bn KWh	% of world total	Pos	Installed capacity in hydropower plants	GW
1	China	1,304	30.1	1	China	356
2	Brazil	398	9.2	2	Brazil	110
3	Canada	380	8.8	3	USA	103
4	USA	311	7.2	4	Canada	81
5	Russia	197	4.5	5	Russia	54
6	India	172	4.0	6	Japan	50
7	Norway	126	2.9	7	India	49
8	Turkey	89	2.1	8	Norway	33
9	Japan	87	2.0	9	Turkey	29
10	Vietnam	66	1.5	10	France	26
Rest of producers		1,199	27.7	Rest of producers		417
World total		**4,329**	**100,0**	**World total**		**1,308**

Source: Key World Energy Statistics, International Energy Agency, 2021

The largest hydropower systems are built by Russia on Volga (Volvograd 2,530MW, Samara 2,300MW), Enisei (with 6 hydropower plants, of which Saian-Sushensk 6,400MW, Krasnoiarsk 6,000MW), Angara (Bratsk 4,600MW, Ust-Ilimsk 4,300MW, Boguciani 4,000MW).

Europe stands out for the hydropower installations on the Danube (Iron Gates I 2,100MW and Iron Gates II 850MW), Iller, Isar, Inn (Germany) and others in Norway, Sweden, France, Italy, and Austria.

In Asia, China has the most microhydropower plants (over 100,000), and the largest hydropower plants are built on Huang He (Liujiaxia and Sanmenxia of 1,100 MW each) and Chang Jiang (Gezhouba 2,710 MW) rivers. In October 2008, the largest hydropower plant in the world, the Three Gorges, came into operation, with 18,300 MW of power installed in the 26 functional generators. But this impressive construction on the Chang Jiang river started in 1994 will eventually have 22,500 MW of installed power, 32 generators of 700 MW and 2 generators of 50 MW, and the annual production of electricity will be 100 TWh.

In North America, the U.S.A. built large hydropower systems on the Columbia River (Grand Coulee I, II, III with 11,000MW), Colorado, Tennessee (47 hydropower plants) and Missouri. Canada has important hydropower systems on the rivers Churchill, La Grande (over 10,000MW in 4 hydropower plants), St. Lawrence, Saskatchewan, Nelson and Yukon. Canada and the U.S.A. produce together more than 20% of the world's hydropower.

In South America, although the hydropower potential is very high, only the rivers Parana-Itaipu 12,600MW (Brazil and Paraguay), Parana-Corpus 4500MW (Argentina and Paraguay), Panaraiba (Ilha Solteria 3,200MW), Rio Grande (Paulo Alfonso system with 5,100MW) and Garoni (Guri hydropower plant of 10,300MW in Venezuela) are equipped with hydropower plants.

Although Africa has large hydropower resources, there are few hydropower installations. The rivers Nile (with the Aswan I and II hydropower plants of 350MW and 2,100MW in Egypt), Zambezi (the Kariba hydropower plant of 1,200MW in Zimbabwe and Cabora Bassa of 4,150MW in Mozambique), Niger, Zaire are noteworthy.

Hydropower counts for the largest share in the electricity production structure of many countries (over 80%): Norway, Iceland, Paraguay, Zambia, DR Congo, Ghana, Uganda, Laos, Sri Lanka, Brazil, Peru, Ethiopia, Kenya, Costa Rica, Central African Republic, etc.

The **nuclear-electric power plants** or the atomic power plants provide 10.6% of the world's energy and represent a special type of thermoelectric plants, based on the nuclear fission reaction in which the main fuel is uranium (isotope U-235), but also thorium or plutonium. The energy power is very high, one gram of uranium releases an amount of energy 3 times higher than one gram of carbon. In such an energy system, most of the energy released by the fission of heavy radionuclides is in the form of heat, used to produce steam; the steam sets a turbine in motion, and the mechanical energy is transformed into electricity by a generator.

The first nuclear fission reactor was built in 1942 for the U.S. Manhattan Project, to build the atomic bomb. Immediately after the Second World War, nuclear reactors were built for the propulsion of submarines and for the production of electricity. The most significant certain reserves

of uranium are located in Australia, Canada, South Africa, Russia (Ural Mountains) and the U.S.A. (Rocky Mountains).

The first nuclear power plants were those in Obninsk (Russia) in 1954, Calder Hall (UK) in 1956, Mareuil (France) in 1956, Shippingfort (the U.S.A.) in 1957.

The world production of nuclear energy increased from 203 billion KWh in 1973, to 2,790 billion KWh in 2019. The main producers of nuclear energy are: the U.S.A. (843 billion KWh, a third of the world production of nuclear energy), France (399 billion KWh), China (348 billion KWh), Russia (209 billion KWh), Rep. Korea, Canada, Ukraine, Germany, Sweden, Japan and U.K. (Table no. 3).

Table no. 3. Main nuclear energy producers and the installed capacity in nuclear power plants (2019)

Pos	Nuclear energy production	bn KWh	% of world total	Pos	Installed capacity in nuclear power plants	GW
1	USA	843	30,2	1	USA	97
2	France	399	14,3	2	France	61
3	China	348	12,5	3	China	48
4	Russia	209	5,2	4	Japan	32
5	Korea	146	7,5	5	Russia	29
6	Canada	101	5,2	6	Korea	23
7	Ukraine	83	3,6	7	Canada	14
8	Germany	75	3,0	8	Ukraine	13
9	Sweden	66	2,7	9	UK	9
10	Japan	64	2,4	10	Germany	8
Rest of producers		456	2,3	Rest of producers		60
World total		**2,790**	**100,0**	**To World total**		**393**

Source: Key World Energy Statistics, International Energy Agency, 2021

Currently, the largest powers installed in nuclear power plants belong to: the U.S.A. (97 GW in 104 reactors), France (61 GW in 59 reactors), China (48 GW in 28 reactors), Japan (32 GW in 53 reactors) and Russia (29 GW in 31 reactors).

The nuclear energy holds high shares in the structure of electricity production in some countries: Lithuania, France, Belgium, Slovakia, Ukraine (over 50%) and South Korea, Japan, Sweden (over 25%).

The **electricity production** has recorded a continuous increase up to **26,936 billion KWh** in 2019, compared to 6,116 billion KWh in 1973. Most of it is obtained in North America and Europe. Asia, the most populated continent, produces 34% of the world's electricity, more than half being produced by China and Japan.

The main electricity producers are: China (with 7,472 TWh and over a quarter of the world production), the U.S.A. (4,371 TWh), India (1,624 TWh), Russia, Japan, Canada, Brazil, Germany, South Korea and France (Table no. 4). The main electricity exporters and importers are presented in Table no. 5.

Table no. 4. Top 10 electricity producers (2019)

Pos	Country	Electricity (TWh)	% of world total
1	China	7,472	27,7
2	USA	4,371	16,2
3	India	1,624	6,0
4	Russia	1,120	4,2
5	Japan	1,037	3,8
6	Canada	645	2,4
7	Brazil	626	2,3
8	Germany	603	2,2
9	Korea	578	2,1
10	France	566	2,1
Rest of producers		8,294	31,0
World total		**26,936**	**100,0**

Source: Key World Energy Statistics, International Energy Agency, 2021

The world average of electricity production per inhabitant exceeds 2,800 KWh/year. High values of this indicator are recorded in Norway, Canada, Iceland (over 20,000 KWh/year/inhabitant) and Sweden, the U.S.A. (over 10,000 KWh/year/inhabitant). Below the world average are the poorly developed states in Africa, Asia and South America (Mali, Sudan, Chad, Rwanda, etc.).

Table no. 5. Top 10 electricity exporters and importers (2019)

Pos	EXPORTERS		Pos	IMPORTERS	
	Country	TWh		Country	TWh
1	France	58	1	USA	39
2	Canada	47	2	Italy	38
3	Germany	33	3	Brazil	25
4	Paraguay	32	4	Thailanda	23
5	Sweden	26	5	UK	21
6	Laos	23	6	Finland	20
7	Russia	18	7	Iraq	14
8	China	17	8	Hungary	13
9	Czech Republic	13	9	Hong Kong	12
10	Israel	6	10	Argentina	11
Rest of exporters		63	Rest of importers		116
World total		**336**	**World total**		**332**

Source: Key World Energy Statistics, International Energy Agency, 2021

The geographical distribution of electricity industry and production shows great regional disparities depending on the level of economic development of different states. The highest concentration is recorded in Europe, North America, Japan, China, Russia, the largest producers, but also consumers of energy.

The U.S.A. focuse on the hydropower potential, especially in the Rocky Mountains and the Waterfalls Mountains, but also on nuclear energy, because they have large resources of nuclear fuels. Canada focuses mainly on hydropower and nuclear power. Thermoelectric energy predominates in Russia (75%), where the power plants are located near coal or oil basins and around the large consuming cities. The hydropower plants contribute 18% to Russia's total energy production, exploiting the immense potential of the Siberian rivers.

In Germany, the electricity is produced mainly in thermoelectric and nuclear power plants. France, lacking fossil fuels, turned to the production of nuclear energy and hydropower. In the U.K., the thermoelectric power plants using coal and hydrocarbons predominate, but also nuclear power plants. Italy relies on the production of electricity from the hydropower plants in the Alps and Apennines, but also from thermoelectric power plants that use imported fuels. Norway, the country with the highest energy production per capita, relies almost entirely on hydropower, and Sweden on both hydropower and nuclear power.

China has large reserves of coal and oil, therefore 80% of its total electricity is produced in thermoelectric power plants. In Japan, the thermoelectric power plants predominate, follwed by nuclear power plants, geothermal and solar power plants. India, the most important energy producer in South Asia, is currently developing hydropower systems on the rivers Indus, Ganges, Brahmaputra and Krishna. Brazil has a production dominated by hydropower (over 80%). In Mexico, Venezuela and Argentina, the thermoelectric power plants predominate, to which hydropower plants are added. Australia relies on thermoelectric energy, but it has also built hydropower systems on the river Murray.

The fossil fuels still account for over 60% of total global electricity generation. Over the last 40 years, the share of oil has decreased and the shares of nuclear energy and alternative energy (biofuel, waste, solar, wind, geothermal) have increased.

The use of fossil fuels as main energy source has had a negative impact on the environment. Internal combustion engines, thermal power plants burning coal or natural gas emit considerable amounts of sulfur dioxide and nitrogen oxides into the atmosphere. When these gases combine with the water vapors in the atmosphere, they form sulfuric acid and nitric acid, and then acid rain. After 1850, the share of carbon dioxide in the Earth's atmosphere was continuously increasing, as a result of the burning of fossil fuels.

Carbon dioxide together with other industrial gases (such as methane or chlorofluorocarbons) can induce the greenhouse effect, which has increased the temperature at the Earth's surface, due to the increase in the amount of heat trapped in the lower atmosphere. This has serious consequences: climate changes and upheavals or repercussions on ecosystems (Simoni, 2015).

Moreover, the fossil fuel reserves are unequal distributed: the majority of oil reserves are located in the Middle East (66%), of natural gas in Russia (34%) and Middle East (31%), and the reserves of coal in Russia and the U.S.A.

5. Conclusions

Economic development and the growth of the world population determined the increase in energy consumption, present today in all economic and social processes. The superiority of an economy does not result from the amount of energy consumed, but from the efficient way it is used.

The fossil fuels still account for over 60% of total global electricity generation, and fossil fuel reserves are unevenly distributed across the globe. The use of fossil fuels as the main energy source has had a negative impact on the environment. Over the last 40 years, the share of oil has decreased and the share of nuclear energy and alternative energy (biofuel, waste, solar, wind, geothermal) has increased. In many states, programs have been initiated for the development of non-polluting technologies and the use of renewable resources that could allow the reduction of fossil fuel consumption and all the problems caused by them. But currently, although the amount of potential energy from renewable and non-polluting sources is greater than the world's energy needs, only a small part is transformed into electricity at a reasonable price.

The transition to clean energy has accelerated given the present security concerns. The high inflation and the supply chain disruptions, resulting from the war in Ukraine and exacerbated by the consequences of the COVID-19 pandemic, have highlighted the risk of energy dependency. Many countries are revising the policy to accelerate a clean energy transition alongside economic recovery and to avoid repeating past mistakes (for example the Inflation Reduction Act in the U.S., the REPowerEU plan in Europe and the GX Green Transformation programme in Japan).

Concerns regarding energy security, the increase in global energy consumption, pollution and the depletion of hydrocarbon and uranium reserves influence the evolution of energy systems and drive the development of alternative and viable energy sources.

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