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ENERGY INDUSTRY DEVELOPMENT: KEY TRENDS AND THE CORE DETERMINANTS

Olena Chygryn, ORCID: https://orcid.org/0000-0002-4007-3728
Dr. Sc., Associate Professor, Department of Marketing, Sumy State University, Ukraine

Kateryna Shevchenko, ORCID: https://orcid.org/0000-0003-4558-7792
Student of the Department of Marketing, Sumy State University, Ukraine

Corresponding author: Olena Chygryn, o.chygryn@biem.sumdu.edu.ua

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Abstract: *Energy underpins the development and enables investment, innovation, and new industries that drive jobs, inclusive growth, and the shared prosperity of entire economies. The COVID-19 pandemic and the war in Ukraine have led to a sharp rise in energy prices, increasing concerns about energy shortages and energy security, and slowing progress toward universal access to affordable, reliable, sustainable, and modern energy by 2030. The purpose of the article is to study key trends and trends in the development of the global energy sector. Ex-post-economic analysis was used during the retrospective analysis. The conducted analysis made it possible to single out three main trends in the development of the global energy sector: decarbonization, digitalization, and decentralization. The results of the evaluation of statistical information on the development of alternative energy allowed us to draw the following conclusions. The global weighted average current cost of electricity for solar photovoltaic and onshore wind decreased by 77% and 35%, respectively, between 2010 and 2018. Global electricity production from renewable energy sources also increased by 7% in 2018. led by China, which accounted for nearly 37% of offshore wind growth and 44% of solar PV growth. However, significant progress in the use of renewable energy sources is still concentrated in the power industry. The share of renewable energy sources in the transport and heating sectors is still limited, although showing moderate growth. The study of forecast indicators confirmed the steady trend of growth in the demand for renewable energy. Between 2018 and 2030, global demand for renewable energy is projected to grow by 64%. The results of the provided research can be used further in the study of the development of various sectors of the energy industry, in particular, alternative electricity, wind energy, etc.*

Keywords: renewable energy, energy sector, global energy market, solar energy, wind energy, green technologies.

JEL Classification: O30, Q41, Q42

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1. Introduction

Much of today's prosperity rests on secure and stable access to energy. Without requisite energy infrastructure, modern production grinds to a halt, as can be witnessed in parts of the developing world. Africa is a case in point. For example, only one in four Africans has access to electricity. Yet, less than five percent of the continent's hydropower potential has been tapped. Evidence of the dependence on energy was also clear from the recent oil price peak in 2008, which spurred innovative activities to come up with alternative energy sources. The global energy market today cannot be compared with the past ten or five years. Can't even compare it with last year. The global desire for energy independence, environmental friendliness, and global price fluctuations irrevocably change the usual "rules of the game". Renewable sources are no longer alternatives. They are no longer the privilege of developed countries: in 2015, for the first time in history, developing countries spent more on renewable energy sources than developed ones (Andrișan, G. et al., 2022; Djalilov, K., 2022). Therefore, the articles presented statistics, forecasts, and trends in the energy sector of the world. Namely: three major trends that promise to revolutionize how we produce energy, Renewable energy market size worldwide in 2021, with a forecast for 2022 to 2030, Top-ten countries' share of total installed renewable capacity, Renewables consumption worldwide from 2000 to 2018, with a forecast until 2050, Solar power market size, 2020 to 2030, Floating wind power market size, 2021 to 2030, Estimed values of gross capacity additions per annum of major renewables players, Enterprise IOT Market, 2019-2027, Green Technology and Sustainability Market Size, Global energy investment, 2017-2022, Energy produced by small-scale facilities vs utility-scale facilities in USA, Investment spending on electricity grids, 2015-2021 etc.

2. Literature Review

Writing the article, the following publications were analysed. Aušra Pažėraitė et al. (2021) investigated the combined effects of energy sector development on research and innovation by considering a novel approach that integrates different methods in its assessment. This assessment reveals that the green scenario of the Lithuanian energy sector's development contributes the most to increasing research and innovation. The author used methodological approach that based on the Delphi Technique, expert evaluations and quantitative description of chosen impact factors. The developed approach can be applied in both technology screening and analyses of comprehensive energy-development scenarios prepared with energy system models.

Reilly J. (2015) investigated energy as a component of the economy and the main factor of production. Described the relationship of higher E/GDP elasticity in developing countries. For a deeper understanding of these connections, the author uses examples of the interaction of energy development in China.

W. Zhang et al. (2019) explored the spatial agglomeration effect of renewable energy development. The article builds a spatial panel econometric model to explore the driving factors of renewable energy industry development on the basis of analysing the spatial correlation of renewable energy. As a result, it was determined that the development of the renewable energy industry has path dependence and spatial stability, and there is an effect of industrial agglomeration in spatial development. In addition, exhaust gas emissions are negatively correlated with the development of the renewable energy industry, and renewable energy consumption and non-renewable resource reserve will greatly contribute to the development of the renewable energy industry. Meanwhile, public investment in environmental protection does not significantly correlate with the development of the renewable energy industry.

The impact of new energy development on economic growth was studied by Renrui Liu (2021). An important part of sustainable development is the provision of adequate, reliable and available energy that meets social and environmental requirements were investigated by Grigoroudis et al. (2013). Energy Sector in Transformation, Trends, and Prospects were examined by Gerrit Jan Schaeffer (2015). Figure 1 shows the dynamics of publications devoted to the three groups of publications: development of the global energy sector, sustainable energy sector, and smart energy technologies. All groups of publications have increasing dynamics, that illustrate high scientific interest in such thematic.

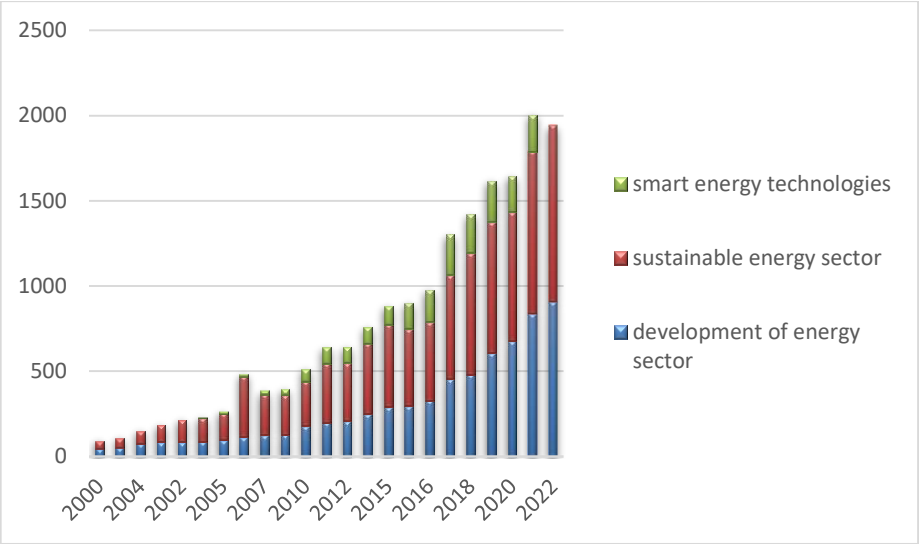

Figure 1. Dynamics of publications devoted to the development of the global energy sector development

Source: created by the authors on the basis of Scopus base.

The results of the bibliometric analysis of scientific publications provided with the VOSViewer tools dedicated to the study of the main trends in the development of the energy sector indicate the existence of seven main clusters of scientific publications (Figure 2).

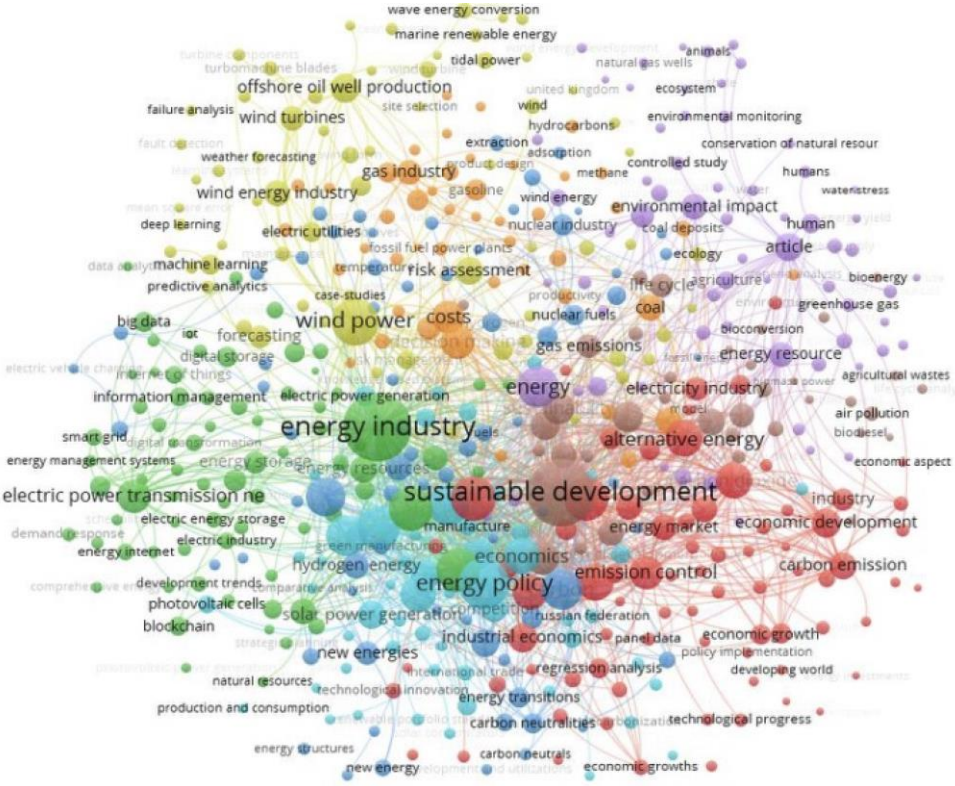

Figure 2. The results of the co-citation analysis of the global energy sector development

Sourse: created by the authors on the basis of Scopus base.

The analysis of a co-citation describes seven big clusters of research teams that had the most significant influence in the sphere of energy industry development. The biggest brown cluster includes the next key categories:

sustainable development, renewables, alternative energy, air pollution, gas emission, ecology, energy market, bioenergy, development, green investment etc. The second green cluster includes categories: electric power generation, energy internet, information management, energy management systems, smart grid, digital storage, solar energy, electric power transmission, natural resources, production and consumption etc. The represented tendencies indicated the huge penetration of ideas, approaches and mechanisms of energy sector greening.

3. Results

The term "fossil fuels" is especially appropriate because traditional ways of getting energy were developed for the world of the past. In some parts of the world, dependence on these fossil fuels has gone on much longer than it should. Therefore, the transformation of the energy sector is one of the most important challenges humanity faces today. Analysing scientific approaches created the basis for forming three key trends that promise to revolutionize how we produce energy (Marr, 2023; Bardy et al., 2022; Louis, 2022; Mlaabdal et al., 2020).

Trend 1: Decarbonization. This trend refers to the transition towards a clean, carbon-free world, largely by increasing our use of renewables and increasing premiums on the use of fossil fuels. Electrification is often touted as a significant way to decarbonize energy (switching to electric cars, for example). Unfortunately, for the moment, fossil fuels still make up a huge percentage of electricity generation in many countries – including the US, where fossil fuels are responsible for 60.3 percent of electricity generation (Kolosok et al., 2022). For electricity to become emissions-free, we must move further towards renewable energy solutions such as wind, solar, and biofuels. This alone could eliminate as many as 7 million deaths a year from air pollution and slow (or reverse) the effects of global warming.

Trend 2: Digitization. This trend is associated with the use of digital machines, devices and technologies to optimize production, infrastructure and energy use. We have "smart" everything these days, from smart vacuum cleaners to smart coffee machines, so why not smart grids? This trend is inextricably linked with the previous two. The growing diversity of zero-carbon energy sources will mean our energy networks will become more complex. And decentralized networks will need smart solutions to monitor and manage changing demand. Digital tools will help us overcome these challenges and implement much-needed changes in the energy sector (Koibichuk et al., 2022; Ziabina et al., 2022). Some of the major contributors to digitization in the energy sector will be:

– AI and predictive analytics – particularly when used to analyze and predict demand, and adjust where power is drawn from on distributed grids.
– The Internet of Things – including smart home thermostats that can help consumers cut their energy use.
– Blockchain – which could be particularly useful for creating smart contracts that allow consumers to trace where their energy comes from.
– Digital twins – which can be used to create a virtual replica of a power plant or even an entire grid, allowing providers to model different scenarios, make better decisions, and improve efficiencies.

These and other digital solutions have given rise to the collective term “Energy 4.0” – playing on the term “Industry 4.0.”

Trend 3: Decentralization. This trend is moving away from our current system of highly centralized energy grids operated by monopolistic energy suppliers to distributed energy generation systems. In other words, thanks to a combination of renewable energy sources and localized "micro-grids", consumers can generate electricity for their own needs. Rooftop solar panels are an idea of decentralization. But importantly, decentralized energy schemes can scale much more, serving anything from a single building to an entire housing scheme or even an entire city. This is interesting because it means that individual consumers, organizations and local governments can take responsibility for their own energy portfolio (Saher et al., 2022; Pimonenko et al., 2018).

Analyzing the decarbonization trend, it is important to examine the alternative energy market, the solar and wind energy market, etc.

The global renewable energy market is expected to continue its upward growth over the next years (Figure 3). The market will reach over two trillion U.S. dollars by 2030. Environmental concerns regarding fossil fuels, rapid

urbanization, and economic growth in emerging regions are all major factors that are contributing to the projected market growth.

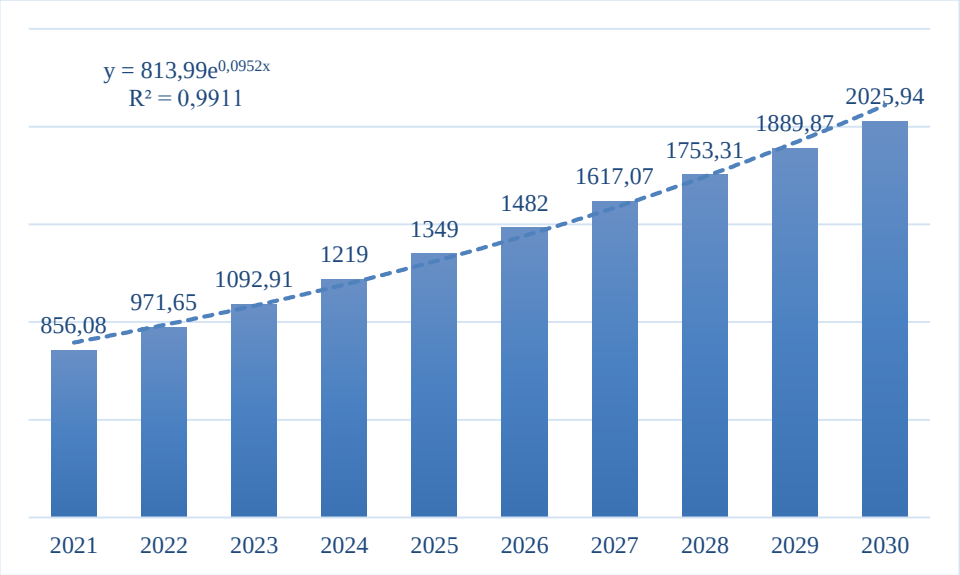

Figure 3. Renewable energy market size worldwide (in billion U.S. dollars)

Source: created by the authors on the basis of Statista (The market, 2023).

The Asia-Pacific region dominated the renewable energy market in recent years. It is likely to maintain its dominance during the forecast period (Table 1). Further, the major countries studied in the market report are China, The U.S., India, Germany, France, Spain, China, Japan, Australia, South Korea, and Brazil

Table 1. TOP-10 countries' share of total installed renewable capacity, 1991-2026

Country	**Percentage share of total installed renewable capacity**
China	43%
United States	12%
India	7%
Germany	3%
Japan	2%
Brazil	2%
Spain	2%
France	2%
Korea	2%
Austalia	2%
Others	23%

Source: created by the authors on the base of IEA (Renewables, 2021).

Global renewables consumption has continuously increased over the years, amounting to 27 exajoules in 2018. Between 2025 and 2050, figures are forecasted to rise further and peak at 161 exajoules in 2050 (Figure 4).

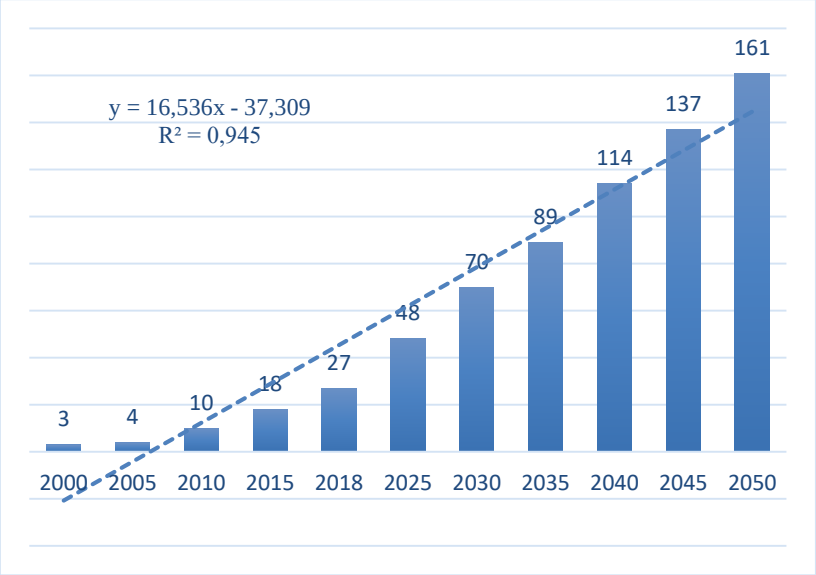

Figure 4. Renewables consumption worldwide from 2000 to 2018, with a forecast until 2050, in exajoules

Source: created by the authors on the basis of Statista (Renewables, 2021).

The rapid development of wind and solar energy is simply amazing. Not so long ago, the development of new solar and wind power plants was usually carried out by small regional players, and their cost was significantly higher than that of a coal-fired power plant. Today, the cost of renewable energy has plummeted, and many solar and wind energy projects are carried out by large multinational companies, which also often announce staggering development goals (Dobrowolski et al., 2022).

The global solar power market size was valued at US$ 197.23 billion in 2021 and is expected to hit around US$ 368.63 billion by 2030, poised to grow at a compound annual growth rate (CAGR) of 7.2% during the forecast period 2021 to 2030 (Figure 5).

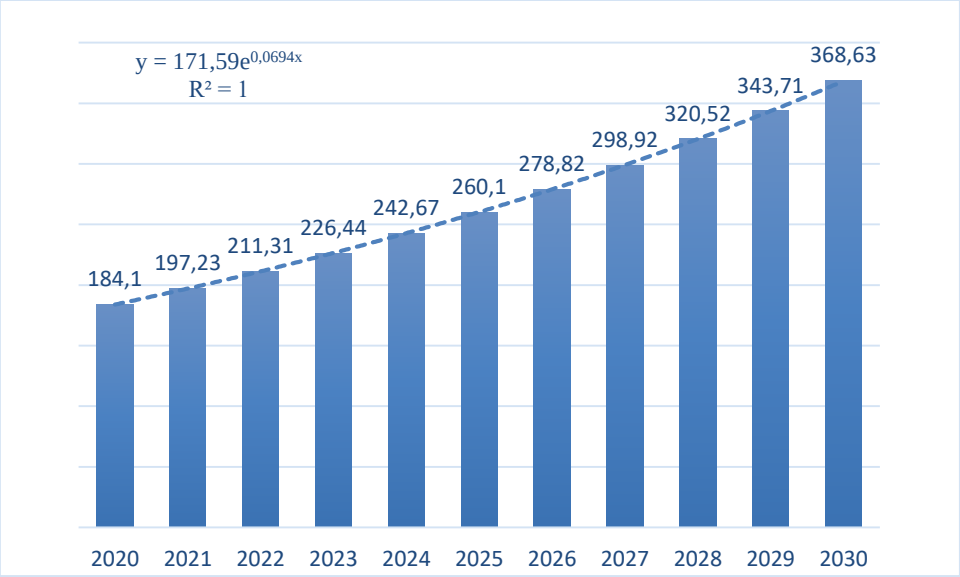

Figure 5. Solar power market size, 2020 to 2030, USD Billion

Source: created by the authors on the basis of Precedence Research (Solar, 2022).

The growth of the solar energy market is majorly driven by a rise in the governmental provision of impulses & duty rebates to install solar panels and environmental pollution. In addition, the drop in the footprint of water

associated with solar energy systems has propelled their demand in power generation sectors. The solar cells demand has gained huge traction due to a rise in rooftop installations, which is further followed by a rise in operations in the sector of architecture (Khalatur et al., 2022).

The scale and scope of the development of the renewable energy market primarily depend on the existing technological capacities and opportunities for alternative energy production. The tables 2 -3 present the results of regression analysis of the dependence of solar energy production on the area of installed solar collectors for such EU countries as Belgium, Denmark, Germany, Greece, Spain, France, Italy, Austria, Poland, and Portugal. The calculation is given for 2020.

Table 2. Descriptive statistics

Variable	Mean	Standard Deviation	Median	Dispersion	Minimum	Maximum
Surface of the solar collectors, S_{sc} (thousand square metres)	11707,96	1875,63	3816,70	35180218,5	740,3	21416

Source: created by the authors.

Table 3. Regressive statistics

R_{mult}	R^2	Standart error	Observation
0,921300083	0,848793843	6654,971682	10

Source: created by the authors.

Table 4 shows the results of the variance analysis, which tested the model for the adequacy

Table 4. Analysis of variance

Variable	*df*	*SS*	*MS*	*F*	*Fsign*
Regression	1	1988910116	1988910116	44,907	0,000152496
Residual	8	354309184,7	44288648,08		
Total	9	2343219300			

Source: created by the authors.

The value of Fisher's F-test is 44.907, and its p-level of significance is 0.00015. This means that the multiple correlation coefficient between the dependent and two independent variables is statistically significant and the regression model can be meaningfully interpreted.

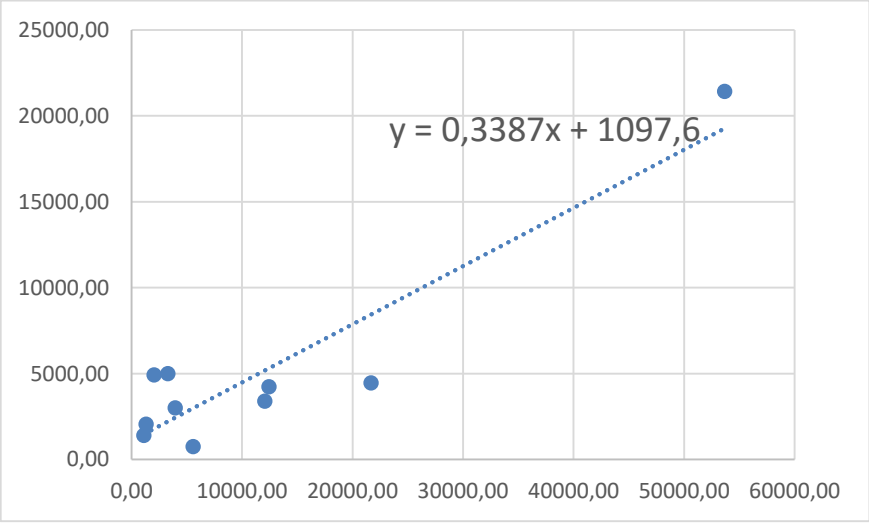

Figure 6. The results of the regression analysis

Source: created by the authors.

The obtained regression coefficient indicates a significant influence of the surface of solar cells on the amount of solar energy production. At the same time, the global floating wind power market size was estimated at USD 2.9 billion in 2021 and is expected to hit around USD 69.8 billion by 2030, poised to grow at an impressive CAGR of 42.4% between 2022 and 2030 (Figure 7).

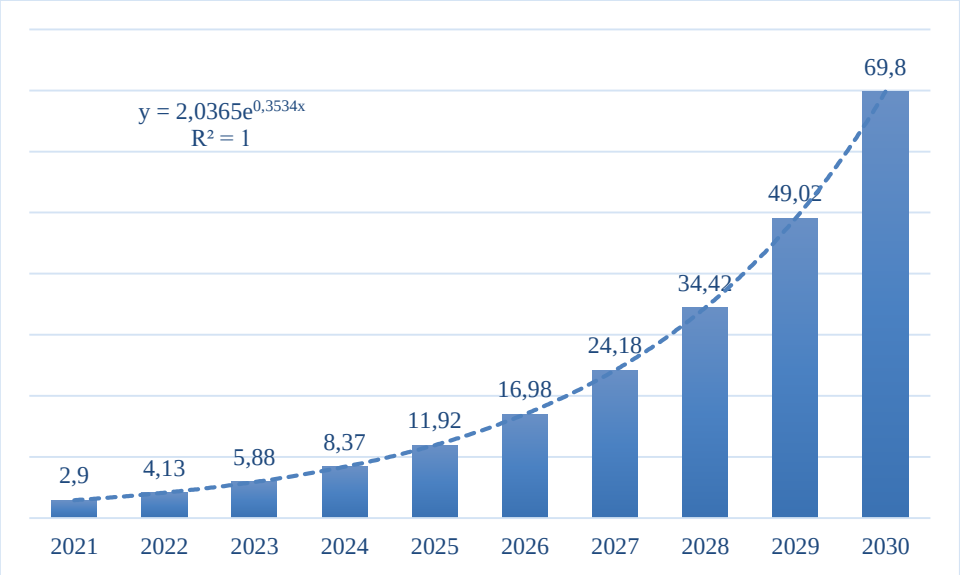

Figure 7. Floating wind power market size, 2021 to 2030, USD Billion

Source: created by the authors on the basis of Precedence Research (Floating, 2022).

But this story of growth is just beginning. As countries strive to meet ambitious decarbonization targets, renewable energy sources, primarily wind and solar, are poised to become the backbone of the world's energy supply.

Today's quick adopters include large oil and gas companies that are looking to change their business models to capitalize on the increased demand for renewable energy and vehicle electrification, as well as private shareholders and institutional investors that are making renewable energy a central component of their investment strategy. Shipping industry leaders are investing in renewable energy to enable the production of hydrogen and ammonia as zero-emission fuel sources; Steelmakers are eyeing green hydrogen to decarbonize their steel production, and renewables are providing green electricity to the process. Automotive companies are also entering into renewable energy deals to power their operations and production, as well as investing in wind and solar projects (Renewable-energy, 2023; Pimonenko et al., 2019).

McKinsey estimates that by 2026, global renewable electricity generation capacity will grow by more than 80 percent from 2020 levels to more than 5,022 gigawatts.1 150 percent (3404 gigawatts). By 2035, renewable energy sources will produce 60% of the world's electricity. But even these projections may be too low (Renewable-energy, 2023; El Amri et al., 2020).

Speaking about the digitalization of the energy sector, it is important to mention the «smart grid». A smart grid is an electrical grid that uses digital and other advanced technologies to monitor and manage the transmission of electricity from all generation sources to meet the various needs of end users for electricity. Smart grids coordinate the needs and capabilities of all generators, grid operators, end users and stakeholders in the electricity market to operate all parts of the system as efficiently as possible, minimizing cost and environmental impact, while maximizing reliability, resiliency, flexibility and stability systems (Gonzalez, 2022).

Despite some recovery from the economic downturn caused by the Covid-19 pandemic, investment in smart grids must more than double by 2030 to meet the Zero Emissions by 2050 scenario, especially in emerging market and developing countries. Investment in electricity grids showed a strong increase of 6% in 2021, with advanced economies accelerating investment to support and enable the electrification of buildings, industry and transport and to accommodate variable renewables on the power system (Figure 8).

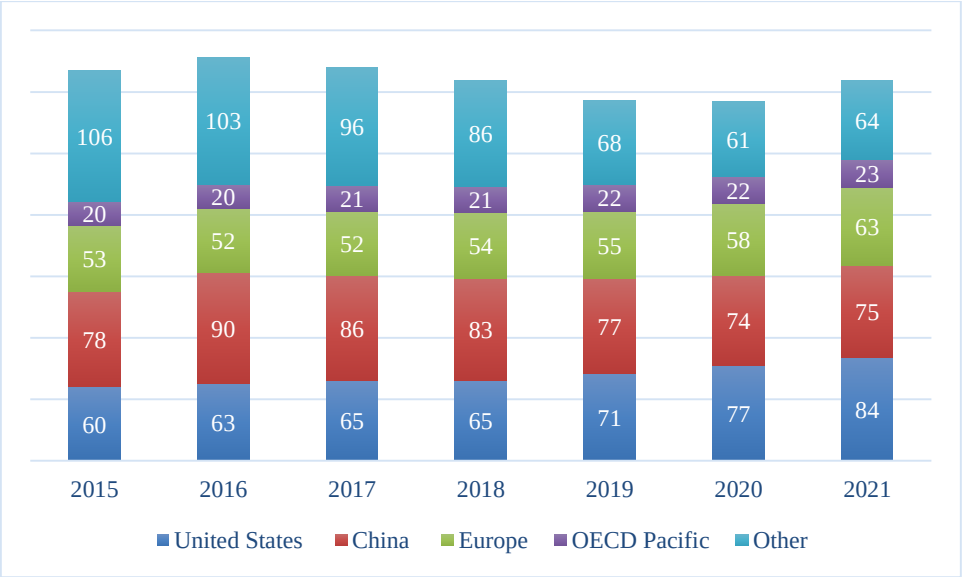

Figure 8. Investment spending on electricity grids, 2015-2021, USD Billion

Sources: created by the authors on the base of IEA (Gonzalez, 2022).

Since 2015 investment in the United States has outpaced electricity demand growth, as increasing capital is devoted to replacing and upgrading equipment and strengthening structures against weather-related damage. China is expected to accelerate investment in 2022, with the State Grid Corporation of China budgeting more than CNY 500 billion for the first time ever and focusing on ultra-high-voltage projects, the upgrading of the distribution network and raising levels of digitalisation of its grids. European distribution system operators and transmission system operators are also foreseeing higher investment needs. The focus is particularly on connecting distributed energy resources and offshore wind farms, the modernisation of aging infrastructure and the digitalisation of grids. Capital spending on electricity networks in emerging markets and developing economies (EMDEs) stood at around USD 60 billion in 2021, similar to 2020. These are very low levels compared to the USD 100 billion spent in 2015 and 2016 (Gonzalez, 2022).

Growing use of variables renewable energy sources (VRE) and dynamic changes in consumer demand, as well as stresses from weather conditions, physical threats and cyber threats, have shown how increased network flexibility can to ensure continuous reliability, fault tolerance and safety of the electric power system. Obstacles and Challenges Identified (Electricity, 2022):

1. High cost of long-duration storage. Energy storage to supplement VRE during outlier days could require long-term storage, which at present prices can be very costly relative to other solutions.
2. Cost vs. alternatives. Because the levelized cost of various storage technologies varies considerably and are at different stages of technology readiness level, some are better suited to certain use cases than others. Some technologies are more economically suited to near-term applications, while some hold promise for the future, which should be considered across the portfolio.
3. Costly warranties. Lack of or the expense of market instruments to provide warranties/guarantees for early commercial projects.
4. Costly commercial debt. Lack of or the expense of commercial debt to support early commercial projects with technology risk.
5. High network upgrade costs. Storage is assigned unnecessary and unreasonably high network upgrade costs in interconnection studies by erroneously assuming that it will be dispatched in scenarios in which it will never operate.

Digitalization is one of the main trends in the world of alternative energy. Namely: IoT, blockchain, etc. We will investigate the size of the markets of these technologies and determine their projected development.

The company IOT Analytics conducted research on the global growth of the IOT market (Figure 9).

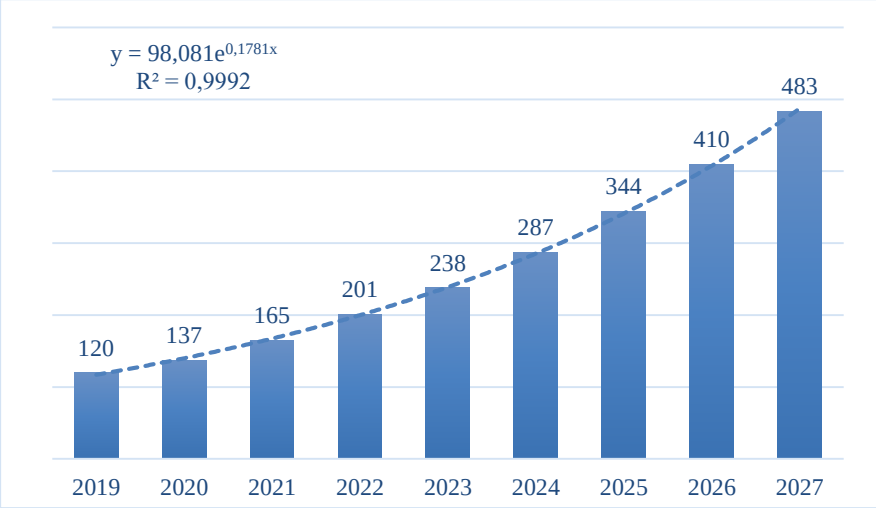

Figure 9. Enterprise IOT Market, 2019-2027, USD Billion

Sources: created by the authors on the base of IOT Analytics (Global, 2022).

The enterprise IoT market grew 21.5% to $201 billion in 2022. IoT Analytics forecasts the IoT market size to grow at a CAGR of 19.4% to $483 billion from 2022 until 2027.

Blockchain In Energy Market size was valued at USD 472.64 Million in 2021 and is projected to reach USD 42681.98 Million by 2030, growing at a CAGR of 75.19 % from 2022 to 2030 (Blockchain, 2022).

Green technologies are considered as eco-friendly technologies. These technologies help to gain sustainability by producing green and clean energy (Vakulenko et al., 2022). The green technology is prominently used for the protection of the environment. That's the reason, government all around the globe is heavily investing in the development of green technology. One of the major factors driving the growth of the global green technology and sustainability market is growing awareness regarding the environment (Kyrychenko et al., 2022). In addition, the growing concerns about global warming and the saving environment from it are driving the growth of the global green technology and sustainability market over the forecast period.

The global green technology and sustainability market size was estimated at US$ 35.5 billion in 2021 and it is expected to hit US$ 417.35 billion by 2030 with a remarkable CAGR of 21.6% from 2022 to 2030 (Figure 10).

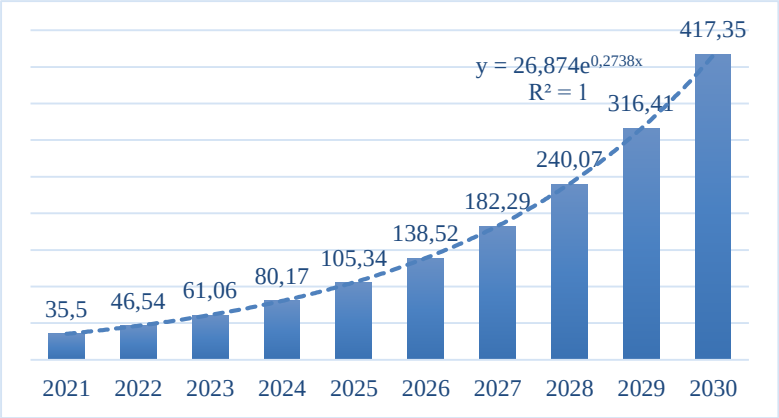

Figure 10. Green Technology and Sustainability Market Size, 2021 to 2030, USD Billion

Sources: created by the authors on the base of Precedence Research (Green, 2023).

The trend of decentralization has been growing rapidly in recent years. One of the best examples of decentralization is the installation of solar panels on one's own house, that is, the production of small solar energy.

For example, solar energy is one of the fastest-growing clean energy sources in the US. Of the more than 3 million solar energy installations in the US, about 1 million were built in the last two years. At the end of 2020, there were about 2.7 million residential solar systems in the US. That growth is especially true for residential-based solar power. In 2005, Congress passed a tax credit for residential solar generation. Since then, the number of US homes with installed solar panels increased by an average of 32% a year (USAFacts, 2022). Solar energy produced through homes, businesses, and other small-scale facilities generated 49 million megawatt-hours, which is enough electricity to power nearly 4.4 million homes in 2021. That level of production is more than four times the amount from 2014 (Figure 11).

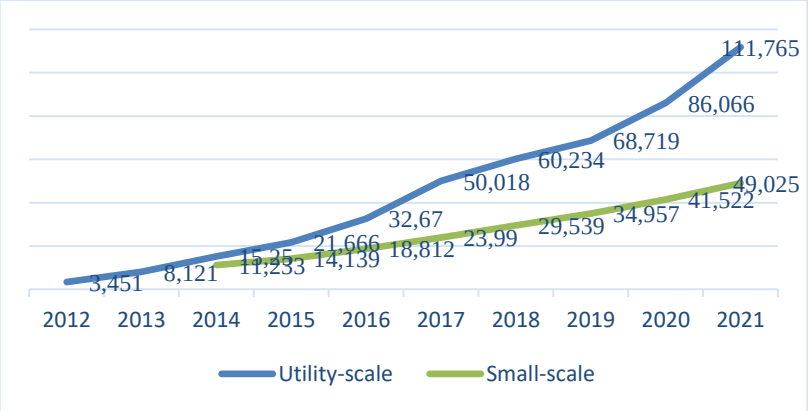

Figure 11. Energy produced by small-scale facilities vs utility-scale facilities in the USA by megawatt-hours, in millions

Sources: created by the authors based on USA Facts (USAFacts, 2022).

A final important aspect is financing the energy transition. Energy consumption accounts for more than three-quarters of greenhouse gas emissions. Financing the massive deployment of renewable energy and energy efficiency while phasing out fossil fuels is critical to addressing climate change (Vostrykov et al., 2022). While global investment in clean energy is growing, investment in low- and middle-income countries remains at or below 2015 levels. To achieve zero emissions by 2050, investment in the energy sector in developing countries must quadruple to $1 trillion by 2030, including a sharp acceleration in investment in solar energy, onshore wind power, and offshore wind power (Energy, 2022; Yang et al., 2021). But in developing countries, limited fiscal space and lack of access to finance make a costly upfront investment in renewable energy unaffordable. In addition, macroeconomic and political uncertainty is discouraging private sector investors from supporting renewables.

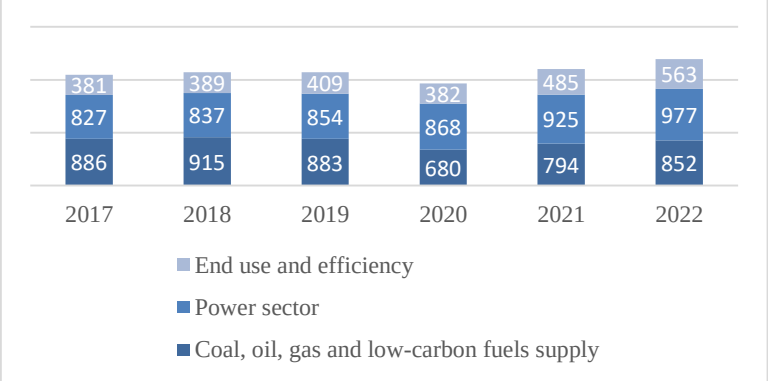

Figure 12. Global energy investment, 2017-2022, USD Billion

Sources: created by the authors on the basis of IEA (Overview, 2022).

Investment is central to tackling the multiple strands of today's energy crisis: to relieve pressure on consumers, to get the world on a net zero pathway, to spur economic recovery, and – for Europe in particular – to reduce

reliance on Russia following its invasion of Ukraine. Governments, companies, and investors face a complex situation as they decide which energy projects to back, with urgent short-term needs not automatically aligned with long-term goals. A lot is riding on these choices.

4. Conclusions

The article considers the statistics of alternative energy markets and trends in the energy sector. An analysis of recent trends has shown that people are becoming more and more interested in the smart use of energy and the markets for solar, wind and other alternative energy sources will become decisive in the energy sector. Also, investments in technologies for the effective use of technologies are growing every year. These successes have been underpinned by the growing competitiveness of many clean energy technologies, as well as policy and fiscal measures taken to support the transition, often as part of efforts to ensure a sustainable recovery from the pandemic. Also, digital technologies such as the Internet of Things and directly Green IoT are gaining popularity. The IoT market is growing every year and will become crucial by 2030. Green IoT will transform our lives into a greener and healthier environment in the future that is socially and environmentally sustainable, smarter, and safer.

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