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THE IMPACT OF STARTUP ECOSYSTEMS ON RENEWABLE ENERGY ADOPTION

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Against the backdrop of growing global challenges related to climate change and resource depletion, the need for renewable energy solutions is becoming increasingly important. The purpose of the article is to explore the transformational impact of startup ecosystems on the development, innovation, and widespread adoption of renewable energy technologies, given their key role in shaping clean energy in the long term. The article applies a comprehensive approach that includes a systematic study of the symbiotic relationship between startup ecosystems and the renewable energy sector, with a special focus on the role of startups as catalysts for innovation. It is proved that startup ecosystems play a crucial role in fostering entrepreneurship, stimulating innovation, and accelerating the adoption of renewable energy technologies. The author emphasizes the empirically proven link between the goals of startup ecosystems and global sustainable development initiatives, in particular the UN Sustainable Development Goals (SDGs) – SDG 7 and SDG 13, justifying their crucial role in stimulating innovation and accelerating the widespread adoption of renewable energy technologies. The key factors and mechanisms for the development of startup ecosystems in the field of renewable energy are identified and their importance for strategic decision-making is substantiated. The article outlines the technological problems, regulatory uncertainty, and limited funding faced by renewable energy startups. The findings provide evidence-based strategies for overcoming technological challenges and a deeper understanding of the dynamics of collaboration in startup ecosystems to promote the widespread adoption of renewable energy technologies in line with global sustainable development initiatives.

Keywords: startup ecosystems, implementation of renewable energy sources, innovation, cooperation, sustainability, UN Sustainable Development Goals, technology, entrepreneurship.

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Introduction and problem statement

The transition to renewable energy sources is a global imperative in the pursuit of sustainable development and climate change mitigation. Startup ecosystems, which are centers of innovation and innovation activity, play a key role in this process. This article explores the impact of startup ecosystems on the adoption of renewable energy technologies in different regions and industries.

The authors' analysis shows that startup ecosystems act as innovative incubators in the renewable energy sector. Startup ecosystems help to create advanced technologies and develop innovative solutions aimed at solving urgent problems of the industry. Cooperation within these ecosystems involving startups, corporations, governments, and international organizations enables resource sharing and accelerates the transition to cleaner energy sources.

The authors note that case studies of startups from around the world demonstrate the adaptability of startup ecosystems to regional energy needs. From Silicon Valley, which is a leader in solar energy and electric vehicles, to Germany, which has experience in wind energy, these ecosystems demonstrate their ability to drive change. Importantly, startup ecosystems are aligned with global sustainability initiatives, including the UN Sustainable Development Goals, making them indispensable in achieving affordable and clean energy (SDG 7) and climate action (SDG 13).

At the same time, challenges such as technological risks and regulatory uncertainty remain insufficiently researched and require detailed study.

Purpose of the article

The purpose of this article is to analyze the activities of startup ecosystems in the implementation and integration of renewable energy technologies and practices.

Achieving this goal requires the following tasks:

– to find out the nature of the activities of startups and the renewable energy sector;

– to assess the nature of the startup ecosystem's impact on innovation and acceleration of renewable energy implementation;

– identify critical factors and mechanisms for the development of the startup ecosystem in the field of renewable energy;

– to characterize the technological challenges faced by startups in the field of renewable energy.

The global drive for sustainable development, which involves a transition from fossil fuels to renewable energy sources, has become one of the key challenges of the 21st century. The urgent need to combat climate change, reduce greenhouse gas emissions, and ensure energy security has emphasized the importance of renewable energy in the global energy transition [1; 2].

As the issue of renewable energy implementation is inextricably linked to the global energy environment, it is gaining topical geopolitical importance in the context of Russia's military aggression against Ukraine.

Today, Ukraine, which has become a center of geopolitical tension, has taken significant steps to strengthen its energy security and reduce its dependence on Russian energy carriers [3]. The introduction of renewable energy in Ukraine, including through the support of startup ecosystems, not only meets the generally accepted international goals of sustainable development, but also has important geopolitical implications. The development of renewable energy will help reduce Ukraine's vulnerability to energy supply disruptions and increase its independence from external pressure.

At the same time, the emergence of startup ecosystems, modern interconnected networks that support and develop entrepreneurial activity, plays an important role in accelerating the implementation of renewable energy solutions, which fundamentally changes the structure and dynamics of the energy sector. A thorough analysis of this relationship aims to highlight the innovative potential of startup ecosystems in the context of renewable energy and sustainable development.

The key issue underlying this paper is a comprehensive study of how startup ecosystems influence the adoption of renewable energy solutions and drive relevant changes in the industry. This study covers various aspects, including:

– the role of startup ecosystems as a driver of innovation and technological progress in the renewable energy sector;

– prospects for startups in transforming traditional energy markets and accelerating the adoption of clean energy technologies;

– opportunities for cooperation, access to capital and entrepreneurial potential provided by startup ecosystems that enable the development and implementation of renewable energy solutions;

– legal and regulatory frameworks that facilitate or impede the development of renewable energy startup initiatives;

– economic and environmental impacts of startup innovations in the field of renewable energy.

As such, the research presented here combines the theoretical foundations of entrepreneurship, innovation, and sustainability with practical insights that inform the transition to renewable energy, offering a comprehensive understanding of the symbiotic relationship between startup ecosystems and the implementation of renewable energy solutions.

Analysis and research of publications

The introduction of renewable energy sources has become an extremely important imperative in addressing global energy challenges, reducing greenhouse gas emissions, and advancing sustainable development goals. In this context, the role of startup ecosystems in influencing and accelerating the adoption of renewable energy technologies has attracted considerable attention from scholars.

A study conducted by Bocken N. M., Short S. W., Rana P., Evans S. [4] emphasized the important role of startup ecosystems in promoting the adoption of renewable energy in Europe. The authors of the study emphasize the importance of

government support, technological innovation and market demand for the development of renewable energy, and also note the significant contribution of startup ecosystems.

The study by Bocken N. M., Short S. W., Rana P., Evans S. [4] focused on the impact of startup ecosystems on the adoption of renewable energy in developing countries and confirmed the significant role that these ecosystems play in promoting the adoption of renewable energy. The authors emphasize the importance of political support, technological innovation, and market demand as factors shaping the adoption of renewable energy, with startup ecosystems acting as a tool [4].

Kivimaa P., Kern F. [5] conducted a study that emphasized that startup ecosystems can make a significant contribution to a sustainable energy transition. The authors identified the most important factors influencing the adoption of renewable energy, such as political support, technological innovation, and market demand [5].

Niesten and Jolink [6] conducted a long-term study of the development of the Dutch biogas sector and the role played by startups in shaping its dynamics. Based on specific examples of innovations in a particular renewable energy subsector, the authors conclude that startups have a significant potential as catalysts for sectoral transformations [6].

Sytnyk [7] studies startups as an important element in the innovation ecosystem. The author analyzes the features of startup ecosystems and their impact on innovation, as well as the risks and opportunities caused by startup ecosystems [7].

Chandra Y., Garg S. [8] conducted a systematic literature review focusing on the role of startups in the adoption of renewable energy technologies. This study summarizes the results of current research, providing a detailed understanding of how startup ecosystems affect the development of renewable energy [8].

Presentation of main material

Today's global landscape is characterized by an increasingly acute imperative to address the complex interrelationship between energy sustainability, environmental protection and socio-economic development.

In this context, the integration of renewable energy sources is a key strategy for achieving a more sustainable and resilient future. This is based on global realities, where the implementation of sustainable energy solutions is harmoniously combined with international initiatives and goals. The main one is the UN Sustainable Development Goal 7 (SDG 7), which calls for "affordable and clean energy for all" [9]. The introduction of renewable energy sources, facilitated by startup ecosystems, is inherently consistent with the imperatives of SDG 7. It is the desire to provide affordable, clean and cost-effective energy solutions for the world's population, thereby making a significant contribution to the realization of this key goal.

In addition, the complex set of issues on the sustainable development agenda embodied in the SDGs emphasizes the interconnectedness between various social and environmental challenges. The adoption of renewable energy, facilitated by startup ecosystems, has a cumulative impact on the achievement of many of the SDGs. It makes a significant contribution to reducing the effects of climate change (SDG 13), promotes economic growth and decent work (SDG 8), stimulates innovation and catalyzes industrial progress (SDG 9) [10].

The use of renewable energy sources is a key element of the modern energy system, which has a significant impact on social, environmental and economic progress by:

– conservation of natural resources: The use of renewable energy, such as solar, wind, hydropower, and others, reduces dependence on exhaustible natural resources such as oil, coal, and natural gas. This contributes to the preservation of natural reserves and ecosystem diversity;

– reducing greenhouse gas emissions: The use of renewable energy helps reduce greenhouse gas emissions such as carbon dioxide and methane, which contributes to the fight against climate change and global warming;

– economic benefits: Renewable energy development creates jobs, fosters innovation and supports sustainable economic development. It also reduces energy import costs and dependence on foreign energy markets;

– ensuring energy security: The diversity of renewable energy sources helps to reduce the risks of energy crises related to limited sources and geopolitical conflicts;

– regional development: Renewable energy can be produced locally, which contributes to the development of rural and remote areas and reduces energy losses during transportation;

– opportunities for innovation: The development of renewable energy opens up new opportunities for research and technological innovation that support technological progress and create new markets.

Long-term sustainability: Because renewable energy sources are naturally renewable, they are

sustainable sources of energy for the long term.

Given the world's growing energy needs and increasing awareness of environmental issues, the development of renewable energy is becoming an important task for the global community. The transition to renewable energy will help ensure a sustainable, clean, and reliable source of energy for future generations and will help preserve natural resources and reduce the impact of climate change [1].

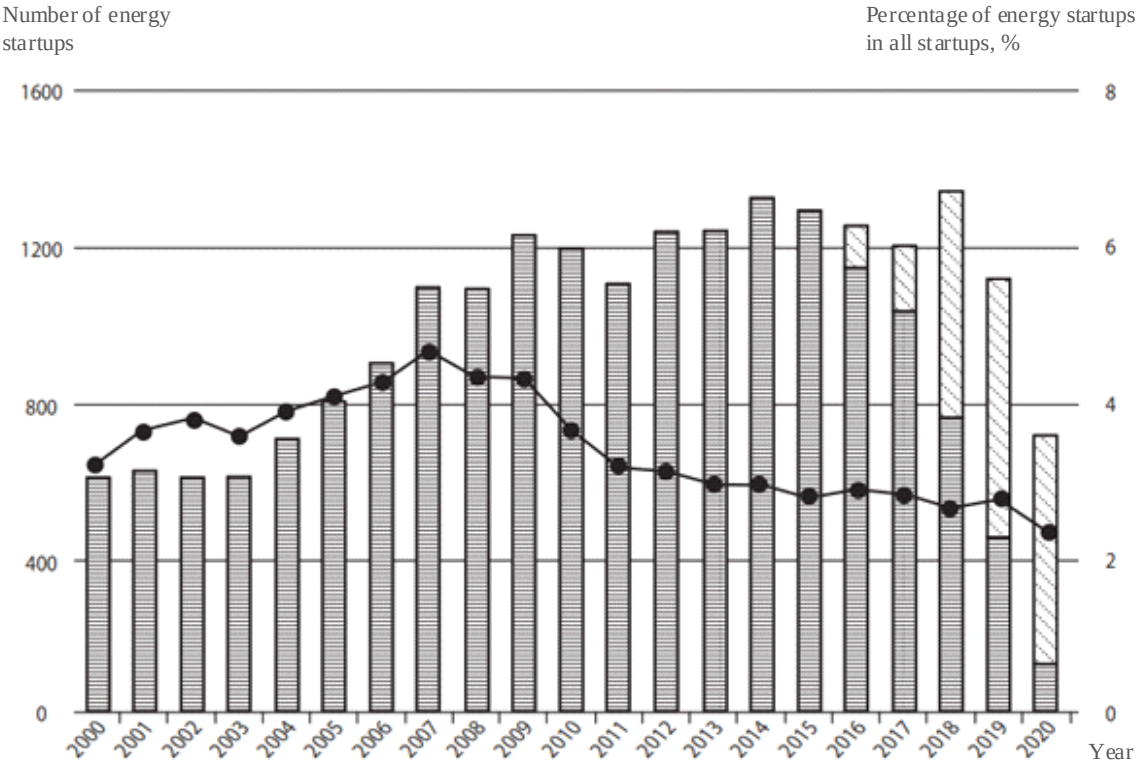
Renewable energy startups are distinguished by their specifics and characteristics compared to other business sectors. The main feature is the focus on energy conservation, as renewable energy specializes in the use of clean and sustainable energy sources that help reduce greenhouse gas emissions and conserve natural resources. Startup ecosystems, characterized by their inherent dynamism, innovation, and entrepreneurial spirit, are increasingly becoming active actors in the renewable energy paradigm transformation. They encompass a wide range of stakeholders, including newly established businesses, venture capitalists, research institutions, and support organizations, which together contribute to creating an environment conducive to innovation and accelerated implementation of sustainable energy solutions [5].

Figure shows the number of startups in the energy sector and their share in the total number of startup projects.

A key characteristic of startup ecosystems is their flexibility and adaptability, qualities that provide them with a unique opportunity to navigate the dynamic environment of renewable energy development. This adaptability is an important tool in addressing the complex challenges faced by the renewable energy sector, including improving energy efficiency, reducing costs, and ensuring access to clean energy. It is in this context that startup ecosystems are becoming powerful drivers of technological progress, catalysts for change that are inherently consistent with the main goals of sustainable energy implementation [8].

Another feature that is valued in the 21st century is high technology, as startups in this area usually work on the development and implementation of high-tech solutions, such as solar panels, wind turbines, batteries for energy storage, energy efficiency management systems, etc.

Of course, just as technology and innovation are now valued by finance, startups are inherently designed to raise funds to implement ideas, but renewable energy startups tend to attract significant investments from



Dynamics of the number of energy startups in the world and their percentage share in all startups

Source: compiled based on [13]

venture capitalists, sustainability funds, and other large sources. Such financial injections are not comparable to funding for startups in any other industry.

Like every product, startups have their own specialized market, i.e., the renewable energy market. The specifics of the markets depend on the technology (solar panels, hydropower, wind turbines) and the regional context (for example, if a country is located near the coast, then hydropower and wind turbines can be actively used, etc.), these two components «dictate» the market for each startup, company, or even country. Since the problems related to energy are global in nature, startups in this industry can also be called global, and this can be attributed to the peculiarities of this phenomenon [13].

Another feature related to the financial component is the balance between profitability and sustainability. As we all know, money is invested with the aim of multiplying it, and this is perhaps the biggest problem for renewable energy startups, because the investments required for implementation are extremely large and in order to get them, you need to interest the sponsor, and most importantly, prove to him that in the future your project will be able to bring the desired profit (unfortunately, not all projects are profitable upon implementation). The growing awareness of environmental issues and the increasing popularity of sustainable development create great potential for renewable energy startups, and many companies in this field are demonstrating innovative solutions aimed at providing clean, reliable and affordable energy for the whole world.

A startup ecosystem is a large and interconnected network of resources, companies, investors, accelerators, coworking spaces, universities, and other participants that contribute to the development and successful operation of startups. This ecosystem creates a favorable environment for innovative entrepreneurs and helps them grow and compete in the market. Of course, one of the components of the startup ecosystem is the startup itself, which is an innovative company that usually starts with an idea or concept and develops into successful enterprises. They are the main actors in the ecosystem. Secondary and no less important actors are investors. These are usually venture capitalists, corporations and funds that provide financial support to startups in exchange for a stake in the company. It is these investments that give the main and so important first impetus in the life of every startup, it is a prerequisite for the start of development, however, no one knows how events will develop further and how the startup will be accepted in society/business and what results it will show. At the very beginning, in addition to finances, knowledge is also needed to help avoid certain problems at the initial stage and accelerate the process of development and growth [7].

Access to resources, mentors, and training programs is provided by so-called accelerators and incubators. All of the above help a startup grow, so it needs a space that will bring everyone together in one place, where each of the co-founders can express their opinions, exchange ideas, and establish connections, so we would also include shared offices (or coworking spaces) in the ecosystem, because nothing can replace live communication.

I would like to highlight research centers and universities as a separate item. They can be used to conduct research, expertise, testing, etc. This is important because there is a big difference between theoretical and practical product development, and such centers make it possible to minimize this difference, which means that the product will reach the consumer, if not in an optimal state, then at least in a state close to it.

However, of course, the product does not immediately reach the general public, as it first needs to be evaluated by unbiased people. This is how we came up with another element of the ecosystem: conferences, exhibitions, thematic meetings, etc. Here you can show your product, get preliminary feedback, see the reaction and hear the first comments about the product. Such communication is extremely important, because you can hear criticism, preferably not biased, of course. This will allow you to look at your product from a different perspective and correct any unobvious flaws in time. After the deficiencies are corrected, the product goes to consumers and customers, who are also part of the startup ecosystem. They play a key role in determining the success of the startup by purchasing this product or services. These ecosystems create an enabling environment for innovation and the development of new renewable energy technologies, which helps reduce environmental impact and facilitates the transition to a more sustainable energy future. An effective startup ecosystem fosters innovation, creates jobs, increases economic development and makes the region more competitive.

There are several world-renowned examples of successful startups in the renewable energy sector:

– first, Silicon Valley, California, USA - is one of the most famous innovation ecosystems in the world, and it is also actively engaged in renewable energy. It is home to many startups that develop solar power plants, energy storage, energy efficiency technologies;

– second, energy efficiency and other projects

aimed at reducing environmental impact, including Tesla, SolarCity (now Tesla Energy) and SunPower;

– third, Germany is known for its active support of renewable energy sources and a high number of startups specializing in renewable energy, such as solar and wind energy, as well as energy efficiency;

– fourth, the Israeli startup ecosystem is known for its innovations in various fields, including renewable energy. Companies such as SolarEdge, which focuses on solar energy optimization, and StoreDot, which works on fast battery charging technology, have been recognized for their contribution to sustainable energy solutions;

– fifth, the Nordic countries (Denmark, Sweden, Norway, Finland, and Iceland) have developed startup ecosystems specializing in the production of batteries for electric vehicles and the accumulation of renewable energy;

– sixth, India: India has a fast-growing renewable energy market and numerous startups involved in solar energy, biofuels and energy efficiency, with ReNew Power and ZunRoof being the most prominent;

– seventh, China: China is a world leader in the production of solar panels and wind turbines, and is home to numerous startups developing new technologies and solutions for renewable energy. Companies such as BYD (Build Your Dreams) in the field of electric vehicles and battery technology, as well as LONGi Solar in the production of solar panels, have achieved significant success in the global market.

It is worth noting that the development of renewable energy startup ecosystems in Ukraine is noteworthy, driven by the country's commitment to sustainable and diversified energy development. Ukraine's abundance of renewable resources, including solar and wind energy, has spurred innovation and entrepreneurship in the renewable energy sector. Startups such as SolarGaps, which has launched smart solar blinds that can generate electricity from sunlight while providing shade, and Ecoisme, which specializes in home energy monitoring solutions, are examples of Ukraine's growing commitment to renewable energy innovation.

In addition to domestic initiatives, Ukraine's renewable energy startup ecosystems have already attracted international attention and investment, further accelerating their growth. Partnerships with European countries and organizations, as well as support from international investors and development banks, have facilitated technology transfer, financing, and market access for Ukrainian startups. Despite infrastructure and regulatory challenges, Ukraine's renewable energy development, supported by a growing startup ecosystem, positions the country as a potential leader in the global transition to clean and sustainable energy sources.

At the same time, it should be noted that cooperation between startups and corporations is important and can bring various benefits to both parties, as well as to the overall economy and society.Startups are known for their ability to react quickly to changes and to develop and implement new technologies and ideas quickly.Cooperation with corporations allows corporations to gain access to innovation and accelerate their development, which is especially important in a rapidly changing market environment. At the same time, corporations have significant financial and other resources that can help startups grow and develop.This includes financing, infrastructure, technical support, and access to the customer base [12].

In addition to a customer base, corporations usually also have a distribution network that can be made available to startups through cooperation. This helps startups speed up the introduction of their products or services to the market and increase their chances of success. Such cooperation enables corporations to maintain or increase their market leadership, as new products and services may emerge from the collaboration. New products result in job creation and economic development for both the company and the region. This means that as the number of jobs increases, so will profits, which means that the budget will allow for more funds to be allocated for innovation and sponsorship of more and more new startups.

In general, cooperation between startups and corporations is an important factor in creating innovations and ensuring market competitiveness. It allows them to combine different forces, resources, and expertise to achieve common goals.

At the same time, for the successful development of renewable energy startups, an important stage for them is their financing through:

– venture capital funds provide funding at the early stages of development, when a startup needs funds to research and develop its technology;

– non-profit foundations and governmental organizations can provide grants and subsidies to stimulate the development of renewable energy projects;

– impact investing, impact investors are interested in financing projects that will bring social or environmental benefits, renewable energy startups can attract this type of investment because of their focus on sustainable development;

– corporate financing, large energy companies can invest in startups that develop renewable energy technology; crowdfunding, raising funds through various crowdfunding platforms;

– investments from individuals, individual investors who are interested in supporting clean technologies.

Government agencies and non-governmental organizations play an important role in the development of a startup. Government agencies can provide not only financial support, but also legislative support, namely the adoption of relevant bills and the granting of benefits. In other words, they create the necessary (favorable) conditions to promote and stimulate the development of startups. An example is the American agency ARPA-E, which helps develop projects that develop new ways to generate, store and use renewable energy. There is also the American government program USAID, which, on behalf of the American people, promotes and demonstrates democratic values abroad and promotes a free, peaceful and prosperous world. USAID's energy programs in Ukraine are aimed at increasing energy efficiency and reducing dependence on energy imports. In order to ensure energy sustainability, the USAID Energy Security Project is working to increase energy supply in Ukraine by promoting private sector investment in renewable energy generation [12, 13].

Non-governmental organizations can provide both financial and technical support, and they can provide more financial support than government agencies.Technical support includes resources that are needed to develop a particular technology that are available to the company.Examples are Breakthrough Energy Ventures, Khosla Ventures, Clean Energy Ventures, these venture capital funds are engaged in investments in the development of renewable energy.There are also other funds that invest in promising startups in the renewable energy sector.

Based on the above, it can be concluded that government agencies and non-governmental organizations are making a great contribution to renewable energy. If one of them stops supporting the industry, the development will be slowed down or stopped. Therefore, for the best development of renewable energy, it is necessary for the government to support it at the legislative level, and for NGOs to invest in promising startups.

At the same time, there are certain technological challenges faced by renewable energy startups, in particular, production efficiency, energy storage innovations, and research into advanced materials are key for several reasons:

– production efficiency. The drive to improve production efficiency in solar and wind energy is consistent with the overall goal of increasing the sustainability of renewable energy sources. More productive and stable solar panels and wind turbines contribute to increased energy production efficiency, even in a changing environment. This is crucial to ensure a stable and reliable supply of clean energy, which is essential to achieving sustainable development goals and reducing dependence on fossil fuels [11];

– innovations in energy storage technologies. Innovations in energy storage technologies are crucial for ensuring the stability of energy supply from renewable sources. Efficient energy storage methods and energy conversion technologies are important for storing excess energy produced under optimal conditions and delivering it during peak loads or in adverse weather conditions. Understanding these innovations is essential to address the intermittent nature of renewable energy sources and maximize their utility in a sustainable energy system [11, 12];

– research on new materials, the use of new materials such as quantum dots or graphene to create more stable and efficient solar cells and other energy systems These materials provide higher energy conversion rates and greater durability, which contributes to the increase in energy production from renewable sources. The introduction of these materials into renewable energy technologies is a key factor for the development of the current level of clean energy production [14].

The renewable energy sector requires constant innovation driven by technological challenges, as they directly affect the competitiveness and sustainability of the sector. Investing in research and development of new technologies is also critical to overcoming the limitations and increasing the productivity of renewable energy.

At the same time, it is necessary to implement incentive policies that include:

a) formation of financial incentives, namely, to promote investment and support the sustainable development of the industry, it is necessary to develop tax incentives and financial incentives for startups;

b) create grant programs. To create favorable conditions at the early stage of startups, it is necessary to introduce grant programs for research in the field of renewable energy;

c) legislative simplification. In order to reduce bureaucratic barriers, it is necessary to simplify the procedures for obtaining licenses and permits for renewable energy startups at the legislative level.

Simplifying the following bureaucratic barriers

could improve the development of startups in the industry:

– adapt regulations to innovation. Support the development and implementation of a legislative framework that takes into account technological innovation and the rapid pace of development of the renewable energy sector;

– reduce the timeframe for obtaining licenses. Implementation of measures to reduce the time required to obtain licenses and permits for the construction and operation of renewable energy facilities;

– information transparency. Openness and transparency of information on regulatory changes should be ensured to help startups adapt to new conditions and determine optimal strategies.

Regulatory aspects and legal obstacles can have a significant impact on the development of renewable energy. Creating a favorable regulatory environment and simplifying administrative procedures are important steps to ensure sustainable growth and successful integration of startups into this important sector.

One example of a successful startup is the Danish company Vestas, which was founded in 1945. Initially, it specialized in the production of equipment for agricultural machinery, but in 1978, the company began experimenting in the field of renewable energy, namely with wind turbines. In 1979, Vestas sells and installs its first 30 kW turbine – and the first customers begin to benefit from clean, sustainable wind power. And in 1980, mass production begins. Vestas is constantly improving its turbine designs to ensure greater performance, reliability and efficiency. They are working to increase turbine capacity and reduce production costs. Vestas is actively scaling its operations globally and implementing wind energy projects in different parts of the world. They produce turbines for a variety of conditions and climatic zones. Vestas develops and implements energy storage solutions that help smooth out fluctuations in energy production and make it more sustainable [14].

Another example is Sunrun, an American company that specializes in the development and installation of solar energy systems for residential and commercial buildings. The company was founded in 2007. Sunrun acts as a partner for customers, giving them the opportunity to generate their own electricity from solar energy. One of Sunrun's innovations was the introduction of solar panel leasing for residential customers. This has allowed many people to access solar energy without the significant cost of purchasing and installing solar systems. Sunrun has developed various programs and financial instruments, such as Power Purchase Agreements (PPAs) and Solar Lease, to facilitate the introduction of solar systems for customers, reducing their upfront investment costs. In addition to solar panels, Sunrun is actively working on the introduction of energy storage systems, such as batteries, which allow customers to store excess energy and use it during periods of low solar activity or during grid failures [15].

Conclusions

The growing demand for renewable energy solutions in the context of global challenges related to climate change and resource sustainability emphasizes the need for a thorough study of the interaction between startup ecosystems and renewable energy. Consideration of this interaction becomes important in the context of finding effective strategies and innovative approaches that will facilitate the rapid and effective implementation of new technologies that meet the challenges of sustainable development and reduce greenhouse gas emissions. Such analysis is key to understanding and addressing current environmental issues and ensuring energy sustainability in the future.

Thus, the scientific novelty of this article lies in a comprehensive study of the peculiarities of the functioning of startup ecosystems as catalysts for innovation in the renewable energy sector, which demonstrates their adaptability to regional energy needs, emphasizes their relevance to global sustainable development initiatives, and, most importantly, highlights the indispensable contribution of startup ecosystems to global sustainable development initiatives, in particular the UN Sustainable Development Goals (SDGs), and addresses the multifaceted challenges they face, and most importantly, emphasizes the indispensable contribution of startup ecosystems to a clean, sustainable and environmentally responsible energy future.

Summarizing the information and considering different points of view, we can draw several key conclusions:

First, startup ecosystems have become dynamic incubators of innovation in the renewable energy sector. These ecosystems foster entrepreneurship, which contributes to the development of new technologies and solutions that address critical renewable energy challenges.

Collaborative startup ecosystems, which include partnerships between startups, corporations, government organizations, and international organizations, have proven to be effective in overcoming barriers to renewable energy deployment. Such cooperation facilitates the flow of resources, expertise and

investment, accelerating the transition to cleaner energy sources.

Second, the case studies and examples presented highlight the diversity and adaptability of startup ecosystems in addressing regional energy needs and opportunities. From Silicon Valley's excellence in solar and electric vehicles to Germany's leadership in wind power, these ecosystems have demonstrated their ability to adapt solutions to the local context.

In addition, the study highlights the alignment between the goals of startup ecosystems and global sustainability initiatives, particularly the UN Sustainable Development Goals (SDGs). Startups play a key role in achieving SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action). Their ability to spur innovation and accelerate the adoption of renewable energy technologies positions them as indispensable players in the pursuit of a sustainable and carbon-neutral future.

Third, it is important to recognize the challenges faced by startup ecosystems, including technological risks, regulatory uncertainty, and limited funding. Addressing these challenges requires ongoing collaboration between government, stakeholders, and academic institutions.

Overall, the impact of startup ecosystems on renewable energy adoption is a multifaceted and dynamic phenomenon with far-reaching implications for our energy future. Given the complex and rapidly changing nature of the energy environment, these ecosystems will continue to contribute to the achievement of the sustainability goals facing business and society as a whole.

Under such conditions, highlighting various aspects of the impact of startup ecosystems on renewable energy technologies opens up prospects for further research in optimizing startup support, overcoming technological challenges, and developing strategies to promote the sustainable implementation of renewable energy solutions. That is why, taking into account the results of the study, it is advisable to consider further the possibility of improving the mechanisms for supporting startup ecosystems in the field of renewable energy, developing strategies to reduce technological risks and address regulatory ambiguity, as well as further studying the impact of startup ecosystems on the integration and harmonization of various types of renewable energy technologies in the global context.

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ВПЛИВ ЕКОСИСТЕМ СТАРТАПІВ НА ТЕХНОЛОГІЇ ВІДНОВЛЮВАЛЬНОЇ ЕНЕРГЕТИКИ

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На фоні посилення глобальних викликів, пов'язаних зі зміною клімату та виснаженням ресурсів, потреба в рішеннях у сфері відновлюваної енергетики набуває особливого значення. Мета статті – дослідити трансформаційний вплив стартап-екосистем на розвиток, інновації та широке впровадження технологій відновлюваної енергетики з огляду на їх ключове значення у формуванні екологічно чистої енергетики в довгостроковій перспективі. У статті застосовано комплексний підхід, що містить системне дослідження симбіотичного зв'язку між екосистемами стартапів і сектором відновлюваної енергетики, приділяючи особливу увагу значенню стартапів як каталізаторів інновацій. Доведено, що екосистеми стартапів мають вирішальне значення у сприянні підприємництву, стимулюванні інновацій та прискоренні впровадження технологій відновлюваної енергії. Наголошено на емпірично доведеному зв'язку між цілями екосистем стартапів і глобальними ініціативами сталого розвитку, зокрема Цілями сталого розвитку ООН (ЦСР) – ЦСР 7 та ЦСР 13, обґрунтовуючи їх вирішальну роль у стимулюванні інновацій і прискоренні широкого впровадження технологій відновлюваної енергії. Визначено ключові фактори та механізми розвитку стартап-екосистем у сфері відновлюваної енергетики та обґрунтовано їх важливість для прийняття стратегічних рішень. Окреслено технологічні виклики, регуляторну невизначеність і обмежене фінансування з якими стикаються стартапи у сфері відновлюваної енергетики. Отримані результати дають можливість отримати обґрунтовані стратегії для подолання технологічних викликів і глибше розуміння динаміки співпраці в екосистемах стартапів для просування широкого впровадження технологій відновлюваної енергії відповідно до глобальних ініціатив сталого розвитку.

Ключові слова: екосистеми стартапів, впровадження відновлюваних джерел енергії, інновації, співпраця, стійкість, Цілі сталого розвитку ООН, технології, підприємництво.

THE IMPACT OF STARTUP ECOSYSTEMS ON RENEWABLE ENERGY TECHNOLOGIES

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Against the backdrop of growing global challenges related to climate change and resource depletion, the need for renewable energy solutions is becoming increasingly important. The purpose of the article is to explore the transformational impact of startup ecosystems on the development, innovation, and widespread adoption of renewable energy technologies, given their key role in shaping clean energy in the long term. The article applies a comprehensive approach that includes a systematic study of the symbiotic relationship between startup ecosystems and the renewable energy sector, with a special focus on the role of startups as catalysts for innovation. It is proved that startup ecosystems play a crucial role in fostering entrepreneurship, stimulating innovation, and accelerating the adoption of renewable energy technologies. The author emphasizes the empirically proven link between the goals of startup ecosystems and global sustainable development initiatives, in particular the UN Sustainable Development Goals (SDGs) - SDG 7 and SDG 13, justifying their crucial role in stimulating innovation and accelerating the widespread adoption of renewable energy technologies. The key factors and mechanisms for the development of startup ecosystems in the field of renewable energy are identified and their importance for strategic decision-making is substantiated. The article outlines the technological problems, regulatory uncertainty, and limited funding faced by renewable energy startups. The findings provide evidence-based strategies for overcoming technological challenges and a deeper understanding of the dynamics of collaboration in startup ecosystems to promote the widespread adoption of renewable energy technologies in line with global sustainable development initiatives.

Keywords: startup ecosystems, implementation of renewable energy sources, innovation, cooperation, sustainability, UN Sustainable Development Goals, technology, entrepreneurship.

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