TECHNICAL SCIENCES

MAIN TRENDS IN THE CREATION AND USE OF ALTERNATIVE ENERGY SOURCES

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Abstract
The article explores various types of alternative energy sources, examining the positive and negative aspects of their use. It also identifies key trends in the creation and utilization of alternative energy sources. The evolution of alternative energy sources is presented, highlighting leading countries in alternative energy production and reviewing regional production aspects. The study draws conclusions on the necessity of innovative economic tools stimulating the creation and use of non-traditional energy sources that replace conventional fuels. The role of utilizing alternative energy sources in the era of digitization is also discussed.

Keywords: alternative energy sources, innovative potential, non-traditional energy sources, energy carriers, digitization.

In the modern era, digitization has profoundly impacted daily life, especially in the development of radio, television, aviation, robotics, chemistry, physics, and biotechnology. Advancements in biology, medicine, and even agriculture have not only increased the global population but also extended the average lifespan on Earth. However, this progress has unexpectedly placed humanity in a global ecological crisis over the next 100 years. It is no secret that mass production of minerals, oil extraction, industries, tunnels, highways, and other achievements of the century have caused significant disruptions and changes across the planet.

The challenges do not end there. Among the primary tasks is the economic-oriented utilization of energy resources (oil, natural gas), necessitating the adoption of new energy sources (geothermal, nuclear, solar) due to the close relationship between human material prosperity and energy production. The production and consumption of energy based on traditional sources provide significant perspectives for the energy industry relying on conventional energy, which, in turn, is one of the instruments for managing humanity. Today, the system represents a dichotomy between traditional and alternative energy.

Traditional energy is primarily composed of oil products, natural gas, and coal. However, these sources are finite, and there is a looming danger that humanity will face an energy crisis within a few decades. Additionally, research indicates that the traditional method of generating energy, specifically electricity, is inefficient, labor-intensive, and expensive. Moreover, this method poses a significant threat of environmental pollution on a global scale, contributing to a decrease in human lifespan and an increase in cancer and other severe oncological diseases. However, the search for alternative energy sources is not solely motivated by these factors.

Alternative energy sources, on one hand, are replenishable resources obtained through natural processes, and on the other hand, they represent ecologically clean sources that produce heat or electricity for daily human needs when converted and are environmentally restored. Unlike traditional sources, non-renewable and more expensive methods produce these forms of energy. Such energy is also known as "green" energy. "Green" energy is represented by inexhaustible sources with minimal financial costs and no harmful emissions. Alternative energy sources include natural forces such as solar and wind energy, Earth's internal heat, potential energy of water, and biofuels. Their ability to regenerate, environmental safety, cost-effectiveness, and wide usability are their main positive indicators. Unfortunately, they are yet to be fully identified and studied as reliable and productive sources.

Solar energy is the most reliable and fascinating alternative energy source, yet its utilization has consequences for the planet's thermal pollution. It contributes to the destruction of polar ice caps, global warming, and a catastrophic rise in sea levels. Its radiation power is approximately 700 quadrillion kW/h. This is about ten thousand times more than the resource we currently need. Until recently, the most widespread and promising method of converting sunlight into electricity was photovoltaic cells, a technology initially developed only for space missions. Nowadays, we encounter elements using this source in our daily lives: tourist equipment, portable charging devices, calculators, watches, light bulbs, and other small items. For example, the

positive aspect of solar batteries (solar energy): it does not harm the environment at all. The negative side diminishing its usefulness: dependence on weather conditions and seasonality, the high cost of the panel made of gallium, cadmium, helium, and other elements; difficulties in disposal; the use of rare and expensive elements (tellurium and indium) in production. Generally, this is the "cleanest" solar energy, creating no harmful emissions, requiring no technical intervention but dependent on the solar cycle.

Unfortunately, humanity has not yet fully learned to harness the blessings of nature, but is already actively working on it. For example, to reflect the heat energy accumulated on the Earth's surface during the day, the use of "anti-solar" panels, also known as solar panels, or the creation of solar panels (modules) from silicon is employed. It is possible to reduce energy acquisition costs with the help of photovoltaic converters called concentrators (parabolic, refractive, luminescence), which have the ability to collect solar rays over a large area and direct them towards relatively small photovoltaic panels.

Wind energy represented by wind turbines (generators) with aerodynamic structures and constructions located on land, in the sea, etc., can be considered as a promising source. However, they are mainly represented by wind turbines with rotating blades, which create infrasound within a radius of several kilometers, urging animals and birds to leave their natural habitat, and also do not withstand continuous storms due to their weak construction. The advantages of this technology include: minimal impact on the environment; the use of renewable and inexhaustible energy sources; fuel production and cost savings in the absence of transportation; ease of exploitation and minimal losses during technical service. Negative aspects include: significant investment required, dependence on wind energy for energy production, and noise at a distance of 30-40 meters approaching the background level.

Another perspective source is water energy (river flow, ebb, and flow). Water rising or falling throws the turbines of pumping power stations, which in turn transmit energy for its subsequent utilization. This method of obtaining energy is costly or suitable for supplying heat and electricity to large areas without central water supply and also reduces harmful emissions into the atmosphere. The positive aspects include no harm to the environment and low energy production costs. However, there are some drawbacks, such as the impossibility of providing equal power throughout the day.

The advantages of alternative geothermal stations (located above geysers and volcanoes) include independence from weather conditions, practical inexhaustibility of water reserves, and economic efficiency. Conflicts include the instability of seismic zones, which is risky not only for construction but also for station operation; it is relevant only in certain places on the planet.

Hydropower stations with additional constructions built on dams (sluices, ship lifts, water scoops, etc.) allow converting the mechanical energy of turbines obtained through water flow into electrical energy. The positive side includes the use of a renewable natural resource and the lower cost of the produced energy without the need for additional fuel imports.

Nuclear energy is an alternative energy source represented by nuclear power plants, which produce both electricity and heat. Both types of stations are constructed and operate similarly: water (or other coolant, including metal alloys) in a closed pipe system enters the reactor's active zone, where particles producing energy by heating the surrounding space are located. The water boils and then enters turbines under pressure, resembling steam. The steam then enters the condenser, where it is cooled back to a liquid state. The cycle repeats [5]. The positive aspects include independence from weather conditions and location, as it operates independently and has no harm to the environment. The negatives include the presence of radioactive emissions that can lead to various diseases and even human death.

Bio-helio energy utilizes the eco-friendly bio-photolysis phenomenon (the splitting of water into hydrogen and oxygen) to create initial product - hydrogen through the combustion of hydrogen. There are several methods for obtaining alternative energy from hydrogen, especially from enzymes and microorganisms, distinct from oil and natural gas. The energy cycle of water can continue as long as the sun shines. Eco-energy technologies focused on low-potential heat (flue gases, heat emissions) without harming the environment are actively applied. As it appears, nature has provided us with everything, allowing us to obtain energy for the benefit of humanity without harming it. However, fuel combustion technologies artificially applied in the early 20th century are harmful to the world and human development.

Current geography and energy demand trends shape the architecture of innovations in the field of non-traditional energy sources. The efficiency of beneficial reserves and recoverable resources directly influences the possibilities for the innovative development of alternative energy sources. Countries with a broad resource base of beneficial reserves tend to have lower incentives for the innovative development of the alternative energy sector. Traditional energy carriers have relatively low production costs, do not require significant expenses for technology development, and contribute significantly to the national economy due to stable demand. The quality and geographical distribution of recoverable energy resources have a visible impact on the development of alternative energy in the country.

The share of alternative energy sources in the world is continuously increasing. One significant factor contributing to the growth of this energy type is government subsidies. For example, Brazil, a global leader in bio- and hydroenergy, pursues a state-level investment policy in the field of wind energy.

China, the world's largest energy consumer, leads in the production of alternative energy (hydro, wind, bioenergy, solar energy, geothermal, and tidal energy). The development of alternative energy production is closely tied to meeting domestic energy demand. The United States leads in providing tax and other incentives to producers in the field of alternative energy

sources. When it comes to energy production from alternative sources, Asian countries are the undisputed leaders, followed by European countries, which have relatively less access to hydrocarbon resources.

Countries with a resource base of traditional energy carriers possess significant economic advantages in modern conditions. Consequently, these countries have higher investment opportunities. Thus, it becomes evident that when some countries need the development of non-traditional energy sources, others rich in hydrocarbon resources have development opportunities. Developing markets or regions with unmet demand and a low fuel-energy balance create investment attractiveness for both national energy companies and foreign corporations.

The development of the innovative potential of alternative energy sources is one of the priorities of the global community. In many countries, government decisions have been made to exploit alternative energy sources, and key development indicators have been approved. The development of the innovative potential of alternative energy sources aims to distribute the participation share of interested parties in this process at the national level. This, in turn, leads to the clash of mutual interests and various constraints related to economic, legislative, social, and other factors.

Considering the current global situation, it should be noted that innovative activities in the creation and use of alternative energy sources contribute to solving energy conflicts and ensuring energy security, focusing on addressing climate change.

In the field of alternative energy sources, determining the methodology of tools that helps eliminate global and national systematic obstacles is the most critical component in implementing the strategic potential of innovations. Throughout the past centuries, humanity has made significant leaps in scientific and technological progress in all areas of public economy. Several reasons underlie this progress: urbanization, geopolitical changes, the rise in the quality of life, an increase in per capita energy consumption, changes in political regimes, etc.

However, the common thread connecting all these reasons was financial resources and the bureaucratic forces managing them. Achieving the goals outlined above required substantial investments, and the ways to attract investments have been constantly changing and evolving.

Currently, the main trends in the development of alternative energy sources involve extensive technological innovations. The innovative process for creating and utilizing alternative energy sources encompasses a complex set of measures for the creation, development, dissemination, and application of large-scale technological innovations. It appears that one of the current issues is the gradual replacement and simultaneous use of alternative energy sources with conventional energy sources in the final stage of their creation and utilization. The process of transitioning from conventional fuel consumption by energy-producing entities to the consumption of alternative fuels stimulates processes of creating and utilizing non-traditional energy sources at macro, meso, and microeconomic levels, requiring innovative organizations and economic tools.

A new type of innovation process is forming, based on the convergence of product and management innovations. In the field of alternative energy, one of the main driving forces of technological progress is digitalization. The application of innovative technologies by leaders in the renewable energy sector continues to be partly competitive compared to conventional production methods.

Recently, there has been a growing interest in the transformation of the electricity industry worldwide based on the new concept of Smart Grid, which is rapidly developing. Smart Grid ensures the self-recovery after a power outage, active participation of consumers in the network, synchronous operation of generation sources and electricity storage elements, etc.

Alternative energy can potentially be more cost-effective. Technological development not only affects the cost of alternative energy projects but also contributes to the creation of entire energy complexes in the future. Digital technologies can assist in the calculation and optimization of the exploitation management processes of alternative energy objects. Using distributed generation principles in the future will make it possible to create self-balancing active energy complexes based on technological solutions. These may include elements of intelligent calculation of electrical energy, energy storage devices, microgeneration devices for "active" consumers, etc.

Modern production is an automated high-tech process. Often, high-quality energy supply is required to ensure the operation of technological lines, primarily requiring the rapidity and uninterrupted supply of electrical signals.

Increased energy consumption is frequently observed with the modernization of production. Industrial facilities are medium and high energy consumers, and their modernization necessitates the replacement of equipment network devices. One technical solution is the use of alternative energy sources. Mainly, their use as reserve energy in centralized power supply networks is challenging due to their lower energy content and the seasonality and variability of electricity production. However, energy production is dependent not on load but solely on the initial source, and they can be used as reserve energy in centralized power supply networks.

Until today, the most effective method for utilizing alternative energy sources is the joint use of wind and solar power stations. Environmental conditions and the potential of the primary energy carrier (wind, solar) are prioritized. For example, in coastal areas, wind energy is prioritized, and the installation of wind turbines in the sea along the coastline is possible. In flat areas with water reservoirs, it is possible to install floating solar photovoltaic stations on the surface of the water. Solar photovoltaic stations are more commonly applied in the technological periods of industrial areas that operate during the day.

The main problem in the use of alternative energy is the variability of the primary energy carrier and, consequently, the regular interruption of electrical power, which is unavoidable in modern production conditions.

Therefore, when addressing issues related to the use of alternative energy sources, it is necessary to consider the possibilities of collecting electrical power. The most widespread collection devices are lithium-ion and redox flow batteries.

There is no common opinion on the efficiency of using alternative energy in industry. On the one hand, the use of such power stations allows obtaining additional power, but on the other hand, problems related to the uninterrupted supply of electrical power and the placement of batteries are present. The significant factor is the cost of alternative energy devices.

Digitization does not directly affect the efficiency of alternative energy sources; rather, it impacts their optimal integration into both local and national energy systems. As international experience shows, one of the main mechanisms for balancing energy systems is the management of consumption, which has expanded with the digitization of the electricity industry.

The main obstacles to the widespread application of alternative energy sources in the country are their intermittency and decentralization, which change the classical scheme of the energy system. In this regard, it is necessary to implement technologies for flexible control of energy flows for the system itself, considering the cost-effectiveness of using a particular source or collection source immediately. To implement such algorithms, "smart" digital execution devices are required. Here, the technologies of the Industrial Internet of Things are more often used. When classic electrical devices (switches, converters, uninterruptible power supply, etc.) are digitized, they can exchange and change their parameters and algorithms immediately, depending on the current situation, using local or cloud applications.

The development of alternative energy and the emergence of "smart" devices that consume energy actively increase the number of active participants in the energy system. All this requires new approaches to ensure the stability of the system. Here, the promising systems of artificial intelligence and "big data" should come to the aid of humans and automation. They should essentially "integrate" all elements of the system, including large and small electricity producers, accumulation systems, active and passive consumers, depending on the current situation.

For example, in Australia, advanced technologies and software-equipped water storage systems are being developed. These storage facilities consist of two large reservoirs located at different elevations. Water is pumped from the lower supply reservoir to the upper collection reservoir, and at this point, the power station collects and transfers energy to consumers.

There is also growing interest in digital twins, where modeling the functions of extraordinary situations, response mechanisms, and testing methods may be involved. Digital twins are essentially computer models that mimic the operations of objects and their reactions to various situations. Through them, planners aim to reduce accident risks, enhance training levels, and identify ways to improve system performance. Market conditions indicate that over time, alternative energy sources will replace conventional energy sources.

One of the noteworthy events causing geopolitical and socio-economic consequences in recent years has been the energy transformation associated with the development of alternative energy technologies. Alternative energy combines technologies that increase energy efficiency and technologies that use energy obtained from renewable energy sources (RES). The use of alternative energy contributes to the acceleration of economic modernization, enhances the economic security of nations, and fundamentally changes the quality of economic growth. Economies using alternative energy sources improve energy infrastructure by replacing outdated equipment with new, more efficient devices. The use of recovered energy enables national economies to achieve high growth rates by reducing the dependence on fossil fuels. Therefore, the development of alternative energy technologies serves as a strong driver for innovative development and forms the basis of the future economy characterized by high technology, energy security, and minimal environmental impact. It can be claimed that the developed countries in the upcoming decades will have new innovative and scientific-technical bases for their economies.

It is known that the current period of societal development is often referred to as the Fourth Industrial Revolution or Industry 4.0. The peculiarity of the Fourth Industrial Revolution, unlike the previous three, lies in the fact that modern society has begun to pay special attention to environmental and ecological issues. As a result, in the modern world, there is an increasing interest in the spread of alternative energy sources in the form of recovered energy sources, as their use can significantly reduce carbon gas emissions into the atmosphere. This means that there is a global interest and increased support for recovered energy sources worldwide.

The Fourth Industrial Revolution or Industry 4.0 represents a new stage in the development of the energy industry, primarily transitioning from the use of fossil fuels to recovered sources. The mechanism of reduced carbon gas emissions into the atmosphere through the use of rational energy technologies can positively impact the environment. The initial stage of implementing recovered energy involves significant investment in the development of alternative energy technologies and corresponding infrastructure, which will eventually lead to a substantial reduction in overall expenditures.

Currently, the use of alternative energy sources faces various technological, economic, and institutional challenges. The production of electrical energy is dependent on uncontrollable natural conditions, leading to instability and imbalance in the supply of electrical energy to consumers. A potential solution to this problem is the use of efficient energy harvesting devices in the exploitation phase. Despite the decreasing trend in the cost of electrical energy produced by alternative sources, its current level is still high in most countries worldwide.

Alternative energy sources are promising paths for energy production, although they are not as widely spread as traditional energy sources. Recovered energy

is an actively developing industry globally, particularly implemented in developed countries, contributing to reduced atmospheric pollution and requiring less time for recovery compared to traditional energy sources [6].

The exploration and utilization of alternative (non-conventional) energy sources are essential in the modern era. These sources involve natural materials and processes that enable the acquisition of the energy needed for human life. An alternative energy source is a recovered source, replacing conventional energy sources such as oil, natural gas, and coal, which emit carbon gas into the atmosphere when burned, contributing to the greenhouse effect and global warming. The search for alternative energy sources is driven by the necessity to obtain energy from recovered or practically inexhaustible natural resources, which is both environmentally and economically advantageous.

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