



Article

Economic Challenges and Management Strategies in Modern Power Plants

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Abstract: This study examines the economic and operational aspects of alternative energy sources, including solar, thermoelectric, biogas, and wind power systems, focusing on their development, design, and large-scale implementation. It evaluates the advantages, challenges, and financial constraints associated with these technologies while addressing key management strategies for efficient deployment. The research also explores entrepreneurship opportunities to expand the labour market for young professionals in the energy sector. The findings highlight the necessity of integrating economic planning with engineering expertise to ensure cost efficiency, sustainability, and regulatory compliance. By analyzing operational principles, material costs, and environmental impacts, this study provides insights into the feasibility of renewable energy sources. The results contribute to informed decision-making, supporting the transition to a sustainable and resilient energy framework.

Keywords: Economic challenges, power plant management, renewable energy, alternative energy sources, sustainable development, energy efficiency, environmental impact, cost-benefit analysis, energy entrepreneurship, technological innovation.

1. Introduction

The advancement of science and technology, along with the growing demand for electrical energy, has led to a large-scale transition to alternative power sources. Not only civilized and economically stable developing powers, but also relatively undeveloped countries have begun to direct their efforts to the practical application of nature's gifts to obtain electrical energy. Of course, in addition to electrical energy, thermal energy is also in demand among the population. There are many sources for obtaining such types of energy in nature, and if they are well studied and skillfully used, perhaps in the near future there will be no need for natural resources, from which these two types of energy have been obtained until now. The main reasons for the transition to alternative energy sources are the importance of caring for our younger generation, whom we have no right to leave without natural resources, using the latter mercilessly for our purposes, as well as the environmental disaster that has arisen on planet Earth. In general, as is known, there are several types of non-traditional energy sources: solar, wind, biomass energy, sea waves, rivers and thermoelectric. Although solar power plants (SPP) and wind power generators have become widely used in recent years, there are still many unsolved problems facing specialists and researchers in this field. The totality of the problem consists of technological, design, and theoretical-experimental actions. Putting aside these listed problems for solution by electric power specialists, let us pay attention to other problems: they consist of economic and environmental issues, which ultimately lead to financial problems for any country [1].

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At present, these issues have not yet been fully studied and resolved. This situation is due to the fact that economists are poorly oriented towards solving technical and energy problems, and electric power specialists usually limit themselves to conducting not very scrupulous technical and economic calculations and determining the payback period of the developed devices and other accessories [2].

Based on this, we should conclude that it is important to solve the economic and environmental issues together with specialists in energy fields and economic researchers. On the other hand, it is very important to develop entrepreneurial activity among both business specialists and young specialists who have graduated from higher education institutions. Providing the young generation with employment is the most important strategic task of any state. There are many types of business and entrepreneurship. We focus on the creative activity of the management direction, which takes into account the financial side, i.e. increasing or decreasing the cost of production, productivity, and efficiency and all this is directed for the benefit of the population and consumers. In a word, making money is to produce products without fraud that are subject to the moral and ethical standards of the economy. In this regard, this work is devoted to presenting the results of research into several alternative energy sources, and their application, taking into account the various views and ideas presented in this work, will possibly take into account all the advantages and disadvantages of the designs being developed. Of course, there is a significant justification for this conclusion, which we expect to outline in detail in the structure of this article [3].

2. Materials and Methods

Our primary objective was to conduct a comprehensive analysis of the operating principles of various alternative energy sources, their manufacturing technologies, operational characteristics, material composition, and environmental impact. By synthesizing these factors, we aimed to assess the economic gains and potential losses associated with their real-world implementation. This problem statement also considers human health from a scientific and ethical perspective. Furthermore, in recent decades, specific forms of entrepreneurship within the energy sector have begun to emerge, driven by individual business managers. Any commercial endeavour that generates revenue or public benefit is directly linked to its competitiveness in a market-driven economy. Market competition demands high-quality products—greater reliability ensures stable profits, which in turn drives higher consumer demand. Therefore, it is crucial to evaluate both the advantages and limitations of manufactured energy technologies [4].

In recent years, environmental considerations have become a significant factor in the production of new energy technologies, alongside economic benefits. Since all scientific research ultimately serves humanity, it is essential to account for its impact on both the environment and human well-being. Additionally, many unresolved issues remain—not only regarding the structural design of energy components and practical devices but also concerning the disposal of outdated installations once they reach the end of their service life. The risks associated with such infrastructure cannot be ignored, as many of these technical structures have the potential to undergo chemical reactions with environmental elements, contributing to pollution and hazardous conditions. The planet's pollution levels have reached alarming thresholds, triggering drastic shifts in global climate patterns, often to the detriment of human societies. The greenhouse effect, which has intensified in recent years, presents severe risks with potentially catastrophic consequences. Manifestations of this phenomenon include climate change, the rise of natural disasters, and an increase in congenital health conditions and developmental defects in newborns [5].

3. Results

Scientific publications and open research studies often focus on factors such as efficiency ratings, pollutant-free operations, ease of use, durability, and other functional parameters of energy systems. While these characteristics partially address consumer concerns, a more precise and systematic evaluation of the strengths and weaknesses of

these technologies is necessary. Ultimately, all such considerations lead back to economic costs in various forms and degrees. When systematically documented in scientific databases, such information becomes instrumental in guiding informed decision-making regarding energy selection and practical application. A portion of future scientific research may be dedicated to addressing the negative aspects of energy production that we aim to uncover. These findings will be invaluable in refining the development and manufacturing of energy technologies. Beyond the electrical and structural performance of various energy-producing units, it is equally important to analyse economic losses and inefficiencies that often go unnoticed by developers and researchers [6].

This approach establishes a robust foundation for the advancement of entrepreneurial ventures in the energy sector. By creating highly efficient and economically viable energy sources, we can work toward resolving the modern energy crisis. It is important to note that in Uzbekistan, efforts to develop alternative energy sources and innovative power conversion systems have yet to be integrated into mainstream entrepreneurship or business initiatives. Only by cultivating expertise in energy infrastructure can we effectively address the challenges outlined in this study. As a starting point, conducting detailed economic assessments of newly developed energy systems will be essential. In line with these objectives, we will perform a macroscopic analysis of the costs associated with the development of selected energy systems and power plants utilizing non-traditional electrical and thermal energy sources. The primary goal is to identify and quantify all expenses incurred during their development, ensuring a more informed and strategic approach to sustainable energy solutions [7].

The image presents a monocrystalline solar cell placed atop a polycrystalline cell, highlighting structural and material differences. The monocrystalline cell exhibits uniformity and higher efficiency, while the polycrystalline base reveals a grainy texture due to multiple silicon crystals. This contrast illustrates key distinctions in photovoltaic technology performance and manufacturing techniques (Fig 1)

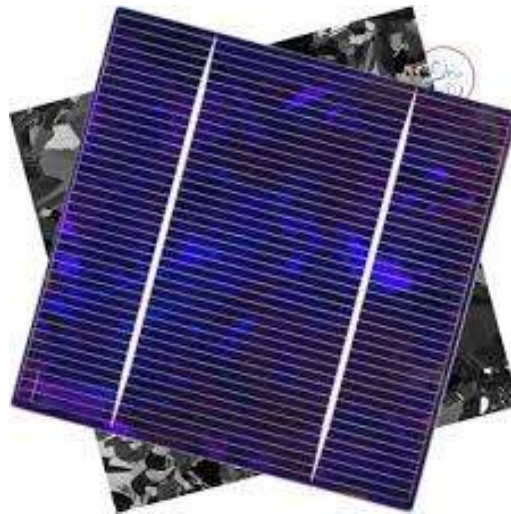


Fig. 1 [1]. General view of a small solar cell

Macroscopic Analysis and Economic Feasibility Assessment of Solar Power Plant Development

As is widely known, solar power plants primarily consist of photovoltaic converters made from semiconductor materials, which are abundant in nature (Fig. 1). Given that solar energy is an inexhaustible resource, one might initially assume that the problem of sustainable energy generation has been effectively solved. In many ways, this assumption holds true. However, certain considerations highlight the importance of revisiting several critical issues that require immediate attention. The first of these concerns lies in the manufacturing technology of solar cells [8].

A significant gap in the existing body of research is the lack of transparency regarding the energy consumption and mineral resources required to produce photovoltaic converters. The manufacturing process involves several energy-intensive steps, including

annealing, melting, and maintaining high temperatures for extended periods in industrial furnaces. Beyond furnaces, other equipment such as sputtering devices, vacuum systems, and numerous measuring instruments also rely heavily on electricity. Despite the extensive scientific literature on solar energy, there is a notable absence of detailed data quantifying these energy and resource inputs [9].

Currently, researchers and manufacturers are actively promoting the environmental benefits of solar energy systems, particularly their clean operation with no harmful emissions or residual waste. While this is undoubtedly a positive aspect, a comprehensive assessment of solar energy's sustainability must also account for the energy and resource costs incurred during production. This is especially relevant when considering the large-scale manufacturing of solar panels and the construction of solar power plants spanning several hectares. In such cases, the economic and environmental costs become not only significant but potentially excessive. While this discussion does not aim to oppose the adoption of solar energy, it is crucial to acknowledge and address these factors to ensure a balanced evaluation [10].

Another critical issue is the operational efficiency of solar power plants, which is highly dependent on temperature. Solar cells perform optimally within a temperature range of +20 to +30 °C. However, regions with abundant solar radiation typically experience much higher ambient temperatures, leading to overheating and reduced efficiency. To counteract this, solar power plants must be equipped with cooling systems to maintain optimal operating conditions. Designing and implementing these cooling systems incur additional costs, including the use of materials, labour, and energy. Furthermore, cooling systems often rely on water or other liquids as heat-transfer mediums, which introduces concerns about water consumption, transportation, and the continuous supply of coolant [11].

Finally, the issue of recycling decommissioned or damaged solar panels remains unresolved. To date, there is a lack of scientific research addressing the recycling of waste generated by solar power plants. This gap is partly due to the relatively recent deployment of large-scale solar installations and the limited volume of end-of-life solar panels currently in circulation. However, as the industry grows, the accumulation of waste from semiconductor-based solar cells will become a pressing concern. It is essential to investigate the environmental impact of such waste and explore potential methods for recycling or repurposing these materials. Even if the issue appears minor at present, proactive research is necessary to determine whether these materials can be safely disposed of or converted into useful by-products for secondary applications [12].

In light of these considerations, the economic costs associated with the creation and operation of solar power plants can be preliminarily expressed by the following formula:

$$Z_{EC} = C_m + C_{eq.fu} + C_{ad.eq} + C_{ser.per} + C_{tr}^{SPP} + C_{cool} + C_{conv} \quad (1)$$

Where C_m - the cost of the raw material used to make the solar converter;

$C_{eq.fu}$ - the cost of the equivalent fuel consumed for heat treatment in the technological process of SPP manufacturing;

$C_{ad.eq}$ - the cost of additional power plant equipment: supports, frames, current-carrying wires, etc.;

$C_{ser.per}$ - the cost of salaries of service personnel;

C_{tr}^{SPP} - cost of transportation of parts and elements of a solar power plant;

C_{cool} - SPP cooling unit cost;

C_{conv} - the cost of DC to AC converter units.

Note that the value of $C_{ser.per}$ includes the cost of wages of technologists C_{tech} for the production of SPP and the personnel who service the power plant C_{serv} during the period of operation:

$$C_{ser.per} = C_{tech} + C_{serv} \quad (2)$$

Thus, with the development of interests in the use of solar energy, solar cell manufacturing technology, and methods for obtaining new semiconductor compounds as the base material of a solar cell, it is necessary to study problematic issues that remain in the shadows today. Unfortunately, researchers around the world have not yet paid attention to this. Perhaps this is a problem for the next generation. Because it is still impossible to accurately assess the sufficiency of semiconductors for the manufacture of solar converters that allow the construction of solar power plants that can meet the needs of consumers of electrical energy on the planet [13].

Economic Performance Metrics of Thermoelectric Power Sources

Thermoelectric power sources (TEPS) are also one of the types of alternative energy [7,9]. Because with the help of these converters, there is a possibility to use usefully the thermal energy of secondary resources. TEPS converting any type of thermal energy: fire, sun, water, heat released as a result of the decay of radioactive substances, etc., gives electrical energy at the output. Modern technology uses them in small and medium power engineering. The general appearance of TEPS is shown in Figure 2.

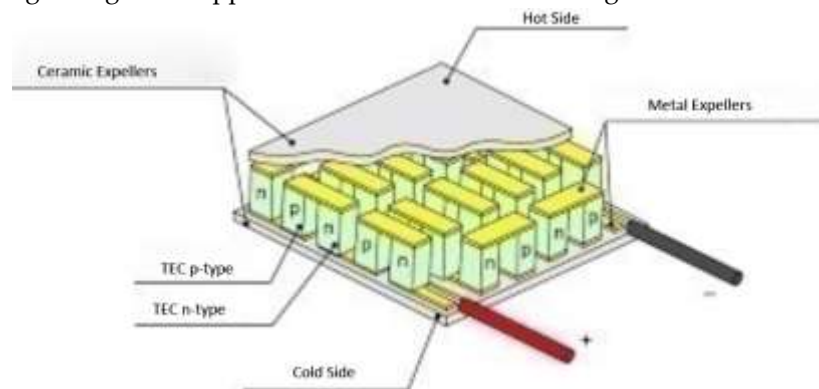


Fig. 2 [9]. General view of a thermoelectric source of electrical energy

Thermoelectric power sources are also made of semiconductor materials. Since the physics of conversion is not our task, we will not dwell on the principles of operation of these sources [14].

Our goal is the economic side of the issue of finding problematic aspects of its development, use and exploitation. As can be seen from the figure, for TEPS to work, a temperature difference is necessary at both ends of the converter assembled from semiconductor materials with electron and hole conductivity. To create such a temperature difference, it is enough to attach the converter from the side of the "hot" switching plates to a heat source. The heat source can be hot steam pipes of thermal power plants, chemical reaction tanks of factories, natural resources - the Sun, radioisotopes and the like. Due to their low efficiency, they are used as sources of electrical energy for low-power consumers. They are also considered environmentally friendly during operation. Because they do not emit harmful gases and emissions into the atmosphere. However, as is known, the production of thermoelectric materials is directly related to the use of electrical energy.

As confirmation of our words, Figure 3 shows the zone melting method for obtaining thermoelectric materials. As can be seen from the figure, the material is obtained, depending on the melting temperature, not just like that, but in furnaces with fairly high temperatures. The working melting temperature is created using heating elements connected to sources of electrical energy. This electricity is obtained in thermal power plants by burning natural resources such as fuel oil, gas, and coal. In our opinion, this phenomenon does not allow, in a word, to consider an alternative source of current of this kind as absolutely environmentally friendly and not to take into account the consumption of fuel materials of this type in economic calculations. Although the non-use of electrical energy for this technology is impossible, the question arises of finding ways to save or alternative options for technological processes.

The method of obtaining electrical energy from thermoelectric sources of electricity using radioactive substances is of no small importance.

The diagram illustrates a geothermal energy extraction system, where heated water from underground reservoirs (1) rises through a well structure (2) surrounded by insulating materials (3). The heat exchanger (4) transfers thermal energy to mechanical components (5), driving a turbine (6) to generate electricity. This setup emphasizes sustainable, renewable resource utilization (Figure 3).

1-melted source material, 2-grown crystal, 3-furnace, 4-seed, 5 and 6-tooth mechanism for pulling the crystal upward, 7-heating elements.

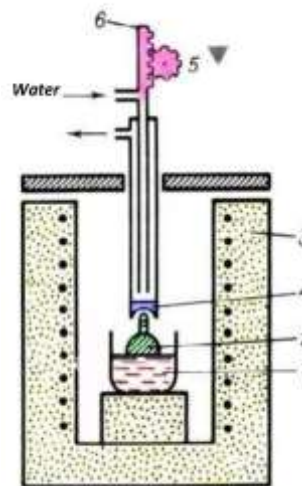


Fig. 3 Technology of obtaining thermoelectric substances by the zone melting method.

During the decay of radioactive substances, colossal energy is released, which allows for good and infinite release of thermal energy for TEPS operating at high temperatures. It is enough to attach a thermoelectric converter to the body of the radioactive decay capsule through a gasket to obtain electricity. However, let's consider the issue from the other side. That is the unexpected occurrence of damage in the radioactive substance capsule. It is impossible in this case to assess the degree of economic and environmental damage. Although such cases are rare, when they occur, it will be difficult to compensate for the amount of loss. Perhaps such a phenomenon is accompanied by human casualties. Let's consider another, more passive case. To obtain electricity in natural or field conditions from TEPS, it is necessary to light a fire. Because TEPS intended for the generation of electricity are manufactured according to the "Partisan boiler" design, and are installed on the bottom of the boiler, as a result of which it is possible to obtain electricity for a person's own needs. And here again, the issue concerns the use of a natural resource. Because the fire is obtained from firewood or other materials. In this case, the cost of these firewood/other materials should also be added to the list of economic calculations.

The above considerations and the predictive analysis of the state of affairs dictate the importance of assessing the cost of using thermoelectric current sources, even if not on a large scale. Depending on the purpose and area of use, all factors that exist within the immediate vicinity of this type of energy should be taken into account. To have an idea, it is necessary to first make theoretical calculations to assess the scale of an accident or environmental pollution and the cost of its restoration, as well as losses from the consequences of accidents.

So, the assessment of the listed costs can be described by the expression:

$$Z_{TEPS} = C_m + C'_{eq. fuel.} + C_{ad.eq} + C_{ser.per} + C_{tr}^{spp} + C_{acc.} + C_{conv} + C_{prev.} \quad (3)$$

Where $C'_{eq. fuel.}$ - the cost of the required amount of conventional fuel for heating the hot junctions of the thermopile;

$C_{acc.}$ - economic losses in the event of accidents when using certain heat sources;

$C_{prev.}$ - costs for systematic preventive medical work of service personnel when working with a radioactive isotope heat source.

The last indicator can be replaced by the cost of protective housing made of special coatings or materials. Modern technology allows the creation of such installations, in which the probability of accidents is reduced to a minimum. However, to meet the requirements for the accuracy of such calculations, it is necessary not only to perform them but also to implement them using modern computer programs of information technology.

Cost of biogas plants for methane production

The acute shortage of methane gas has led to the study and limited use of biogas plants. Biogas plants are a comprehensive solution for the disposal of waste from the food industry, the agro-industrial complex, and the production of heat, electricity and fertilizers. Methane production in a biogas plant is the implementation of a biological process.

As is known, biogas plants operate on waste obtained from animals, birds, tree leaves, and the like. It cannot yet be considered that these plants are sufficiently advanced and suitable for safe use by the population of the country. Work in this direction is pioneering. To date, scientists have proven the possibility of obtaining this type of fuel in this way. There are several dozen such sources, but they have not yet gone beyond laboratory buildings and structures.

Let's consider the advantages and disadvantages of this type of alternative energy source. Biogas plants are good because they allow you to process the listed waste. This waste, polluting the atmosphere, negatively affects nature and humanity. However, this does not mean that the waste is completely eliminated. Even after processing and obtaining gas fuel, the waste remains. However, they can be used as mineral fertilizers for plants in the agro-technological industry.

Figure 4 clearly shows how biogas products are obtained and what they are used for. So far, the productivity of this method is still low and requires solving several technical, technological, economic and environmental problems. Although the waste is loaded into bunkers for processing, it is still impossible to get rid of air pollution with unpleasant gases if odour-isolating sealed casings are not used.

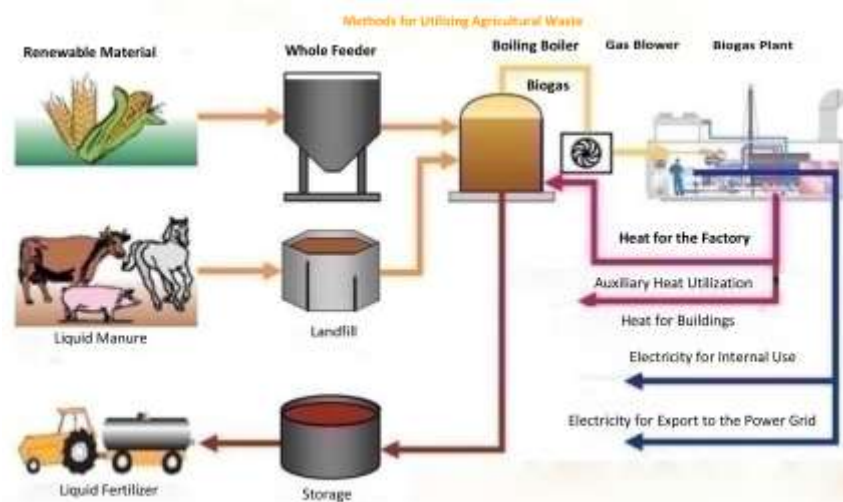


Fig. 4.[2]. Scheme of biogas and electricity production

At present, there is no list of wastes in the scientific literature that are specifically recommended for use in certain plants as mineral fertilizers. Agricultural technology requires precision in determining the composition of the "mineral waste" from the plant. Because the content of chemicals in the composition of livestock or other waste, after several chemical treatments, of course, can change the composition of the elements radically. Therefore, it is impossible to say in a word that all "mineral wastes" are

beneficial to agro-industrial development. Changes in the properties of wastes can generate absolutely opposite effects on the well-being of plants. There is another important stage in accelerating the productivity of biogas plants: this is the ability to accelerate the fermentation process by heating the waste bin. Since heating requires temperature regulation, it should be carried out with electric energy using automatic temperature controllers. This process, of course, requires electricity. The technology for obtaining biogas is still inferior in perfection to methods of obtaining electricity from the sun, and wind and requires accelerating the solution of existing problems. As for emergencies, here too, one cannot neglect the damage caused by accidents on site. In addition to design faults, the spread of dirty and chemically undesirable substances to the environment is expected. So, decisions on economic and technical calculations should be based on such cases of operation of installations. Therefore, we recommend, when calculating the costs of creating such devices, not to limit ourselves to demonstrating the possibility of obtaining electricity in one way or another, but to make appropriate adjustments to formulas (1) and (3), clearly providing information on economic costs and damages in case of possible accidents on site [15].

Evaluation of the creation and operation of wind power sources

Wind turbines are used to convert wind energy into electrical energy. A wind turbine, or wind generator, is a device for converting the kinetic energy of an airflow into electricity.

It is also an alternative energy source. Because of this and the inconstancy of the wind, its independent use is impossible. Figure 5 shows a wind turbine installed in a field in which wind energy can be used. Due to the good value of the efficiency of this type of alternative energy source, in recent years, they have been widely introduced into practice in developed countries. In terms of their applicability and importance, they are second only to solar power plants. In recent years, one major problem has arisen in the operation of wind turbines.

This is due to the, so far, impossibility of recycling failed blades. Since the blades of wind turbines operate almost continuously with mechanical movement and are subject to repelling impacts of varying strength, they are specially manufactured in such a way that they are mechanically durable. Recycling the blade materials has not yet been successful. The chemical properties of the blade materials are very difficult to process chemically and are very expensive. This requires special installations and a new technology that has not yet been recommended by anyone. In addition, the use of wind turbines has led to the death of many birds. Getting into the field of the wind flow formed by the blades of such generators, they died without having the opportunity to save themselves. The damage from the death of birds in European countries has led to significant destruction of the environment in various countries.



Fig. 5. [2].Wind turbines

The image depicts a wind farm situated on a hilly landscape, with multiple wind turbines aligned to optimize wind capture. These turbines convert kinetic wind energy into mechanical power and subsequently into electricity, contributing to sustainable

energy production. The scene highlights the integration of renewable technologies within natural environments to reduce carbon emissions (Figure 5)

4. Discussion

In countries such as Denmark, Germany, and France, due to the significant force of sea wind currents, wind generators of very high power and large-sized structures were installed in the sea. They, generating significant power for enterprises, had blades with a length of about 6-10 meters and created a danger for seabirds. Another disadvantage of such a source of electricity was its noise during operation and the creation of round-the-clock vibration, which led to the spread of nervous diseases among the population. All these listed disadvantages of non-traditional sources of electrical and thermal energy are accompanied by additional costs and expenses for compensation for the damage received. Of course, traditionally obtaining electricity, that is, the construction of thermal, hydro and nuclear power plants, is also not without its drawbacks. However, the main goal of the authors of this work is to attract the attention of researchers to these urgent problems, the solution of which does not require delay.

5. Conclusion

The conducted research and analysis of the creation and operation of non-traditional sources of electric energy of four types showed that modern science has not resolved positively all aspects of economic issues. The development of science and technology cannot be stopped, but without taking into account two important issues related to economic feasibility and environmental safety, it is impossible to achieve energy productivity. From this, it is concluded that energy specialists, in addition to solving design and technological problems, should simultaneously carry out work to take into account the country's economy and the human factor. As it was shown in this work, on the back side of the invention of various kinds of modern alternative sources of electric energy, lies the use of electrical or thermal energy in a certain amount, and they are not taken into account in all technical and economic calculations. Developments that reduce the cost of equipment and damage to the population are important. The questions posed are very important in the implementation of technological, marketing, financial and safety activities by entrepreneurs. In implementing these tasks, it is necessary to skillfully use the theory and criteria of management and at the same time have production management skills.

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