International environmental challenges of solar energy production as an integral part of modern green energy

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Abstract. The article is devoted to the production of solar energy as one of the most environmentally sound types of modern energy. The authors investigate the state and prospects for the development of solar energy in individual European countries (Spain, Germany, the Netherlands, France, Poland), taking into account measures to ensure the reduction of anthropogenic impact on the environment at the national and international levels. The paper analyzes the main aspects of the influence of this type of energy on improving the quality of the environment in scientific research, development and implementation of the latest technologies in the field of renewable and alternative energy sources. Based on the study of foreign experience of state support for the use of solar energy, the team of authors formulated practical proposals for improving the mechanism of environmental protection in the field of energy.

1. Introduction
At present, the attention of the world community is drawn to the problems of sustainable energy security of national economies in conditions of significant climatic changes and depletion of natural hydrocarbon reserves [1-2]. Most of the economically developed countries direct the environmental and economic efforts of the scientific community and the business community to address the most complex issues of our time: independence from energy imports and the development of renewable and alternative energy sources based on the country's territorial natural and climatic conditions [3]. For example, in the European Union, special attention is paid to the development and implementation of solar energy facilities. Solar energy is considered by these countries as a significant contribution to the country's economy and the basis for preventive measures for environmental protection [4]. The study of world experience in the creation of legal mechanisms for regulating the production of solar energy and the application of environmental standards in this energy sector allows us to improve the environmental legislation of various countries and harmonize the norms of national law with the norms of international environmental protection law.

2. Materials and methods
The purpose of the article is to identify international environmental and legal problems in the production of solar energy as one of the types of renewable energy sources and an integral part of modern green energy.

The methodological basis of the study should include the general scientific method and special methods of cognition, such as comparative legal, environmental legal, statistical and empirical.
The paper analyzes the degree and level of development of solar energy in individual European countries and the Russian Federation. The issues of development of legal regulation of scientific, technological and environmental support of the solar energy production process, as well as mechanisms of legal support for solar energy in international and national energy markets are considered. The problems of creating a competitive environment for solar energy in the segment of renewable energy have been studied for sustainable environmental development within the framework of energy supply for modern states [5].

3. Results

The first stage of the study was an analysis of the effectiveness of the introduction of solar energy facilities in individual European countries and the Russian Federation, which allowed us to come to the following results. Taking into account that solar energy in the European Union combines photovoltaic (PV) and solar thermal energy, it seems logical to provide data on total solar energy production and for individual types, for example photovoltaic (PV) in table 1.

| Table 1. Results of commissioning solar energy production facilities in the European Union in 2019. |
|---------------------------------------------------------------|
| **Country** | **Increase / decrease** | **Result (GW)** |
| Spain | increase | + 4.7 |
| Germany | increase | + 4.0 |
| Netherlands | increase | + 2.5 |
| France | increase | + 1.1 |
| Poland | increase | + 0.8 |

Note that, according to experts, 2019 has become the "leader" in the development of solar energy on the European continent [6]. In the countries of the European Union, photovoltaic panels with a total capacity of 16.7 GW were installed. These figures show an increase in capacity by 104% compared to 2018 (8.2 GW).

A schematic increase in the share of energy in the total European energy balance from sources of photovoltaic energy (PV) is presented in table 2.

| Table 2. Photovoltaic power (PV) production in selected countries of the European Union, MW. |
|---------------------------------------------------------------|
| **Country** | **2017** | **2018** | **2019** |
| Spain | 42394 | 45277 | 49016 |
| Germany | 8075 | 9466 | 10576 |
| Netherlands | 4725 | 4751 | 9233 |
| France | 2903 | 4300 | 6924 |
| Poland | 271 | 487 | 1317 |

Comparative analysis shows that the five European countries that are most dynamically developing and implementing green technologies in the energy sector include Spain, Germany, the Netherlands, France and Poland. The authors note that a technological and innovative breakthrough in the development of solar energy in European countries is associated with:

- With a low endowment of natural energy resources;
- With the need to implement national and pan-European climate strategies;
- With economic feasibility, because reducing the cost of solar energy production increases competitiveness among other renewable energy technologies;
- With the ability of consumers to independently generate and accumulate energy in order to supply energy to their households [7-9].
These trends are confirmed by a number of examples. So, in the European Union, the most important Directives in the field of energy have been adopted and "work" - Directive 2009/28 / EC of the European Parliament and the Council of 29 April 2009 "On the promotion of the use of energy from renewable sources" and Directive 2018 / 2001 of the European Parliament and the Council of 11 December 2018 "On the promotion of the use of energy from renewable sources" (recast).

The Renewable Energy Directive (2009) established a 20% share of energy production from renewable energy sources in total energy production and consumption by 2020.

A novelty in the legal regulation of the production of renewable energy was the European Union Directive of December 11, 2018, which determined the prospects for the development of green energy from renewable sources to 32% of all energy consumed in the EU. These results are expected by early 2030. At the same time, the participating countries are obliged to carry out the correlation of national and European energy legislation.

The achievement of these Directives is the allocation of renewable energy facilities of the municipal level in the priority group of state financial support. This will allow these enterprises:

- Use administrative preferences in terms of replacing the licensing procedure with the notification procedure;
- To establish a minimum cost of energy in order to increase the number of consumers;
- The freed up funds can be used for the implementation of technologies in order to reduce the anthropogenic load on the environment.

Currently, the most important document in individual European countries is the Power Purchase Agreement (PPA). So, in 2019, consumers in Spain and Portugal signed a PPA on the implementation of solar energy projects with a record capacity of 708 MW. In the future, the market for solar photovoltaic systems for the European Union, announced by the international organization Solar Power Europe, will reach 21.0 GW by the end of 2021. Experts predict a significant increase in these indicators by 2023. Spain's significant successes in the production and use of solar energy are associated with the adoption in 2006 of the National Jurisdictional Act of the Technical Building Code, which was approved by Royal Decree 314/2006. In order to carry out applied research in the field of solar energy, the Spanish government at the Technical University of Madrid has established a special scientific group for the study of photovoltaic systems. As a result, the university scientists have developed the Solar Concentra system, which is an advanced high-tech platform for CSP (Concentrated Solar Power).

It should be noted that the development of solar energy in Germany is characterized by the tendency for the dynamic formation of groups of prosumers that independently generate and accumulate solar energy [10]. For the period from 2019 to 2020, about 100 thousand new prosumers were registered in the country. In the long term, by 2040, it is planned to receive more than 15% of the total energy market in Germany from autonomous solar panels on the roofs of houses in the segment of private households. Germany's achievements in the construction of solar energy facilities are associated with the active work of the Federal Network Agency of Germany (Bundesnetzagentur, BNetzA). This agency is a government agency whose main functions are to regulate the electricity market in Germany, including holding auctions for the right to build solar energy facilities. It should be emphasized that since 2017, at the national level (FRG), the cost of solar energy has equaled the cost of energy produced by coal-fired power plants.

Among European industry associations, SolarPower Europe (EPIA) deserves special attention. Among the environmentally significant tasks of the Association is the provision of high-tech services for the installation and maintenance of solar energy equipment.

In this regard, we note that in order to develop technologies for the production of electricity by solar power plants with the greatest environmental effect will be the introduction of AI technologies that are used to stimulate intelligence in equipment of various profiles. The introduction of AI technologies provides a new level of cybersecurity, since unauthorized access to operational
information of energy producers can provoke destabilization of the entire power system and environmental emergencies.

It is typical for the Russian Federation that mainly solar energy is used to provide communal hot water supply and heat supply to remote regions with a poorly developed power grid complex. Currently, technologies for converting solar energy into electricity by thermodynamic and photoelectric methods are being actively developed. Note that the level of development of the legal framework in the field of "green" technologies significantly lags behind the actual development of this segment of the domestic energy sector and is represented by scattered regulatory legal acts: Federal Law of March 26, 2003 No. 35-FZ "On Electricity", Federal Law of 23 November 2009 No. 261-FZ "On energy saving on increasing energy efficiency and on amendments to certain legislative acts of the Russian Federation", Decree of the President of the Russian Federation dated May 13, 2019 No. 216 "On approval of the Doctrine of energy security of the Russian Federation" [11].

4. Discussion
The study of the degree of development of applied solar energy in individual European countries and the Russian Federation determines the possibility of discussing the problems of environmental substantiation of the production of this type of energy in order to preserve the quality of the environment and ensure the full energy potential of national economies. The team of authors studied the opinions of respected scientists with interest and is ready to discuss the proposed discussion issues.

It can be assumed that trends in the development of European and national legislation in the field of production and use of solar energy will become controversial. European legislation demonstrates the widespread use of economic and administrative methods:

- Government support programs (tax incentives, government loans based on preferential interest, a system of guaranteed discounts for electrical equipment for solar power plants);
- State regulation of prices and determination of preferential tariffs in the “producer - supplier - consumer” line in the solar energy segment;
- Adaptation of administrative regulations to the needs of solar energy producers by replacing the permitting procedure with a declarative procedure.

However, systemic issues of environmental protection are resolved through active state and sponsorship support for scientific research, experimental and experimental work on the introduction of the best technologies in solar energy production, which guarantees a decrease in anthropogenic load on the environment and compliance of technologies with international environmental standards.

In modern conditions, a large-scale use of AI technologies is necessary in order to ensure environmental safety in the generation of electricity by solar power plants. This activity significantly reduces the potential anthropogenic load on natural systems and is based on processing (using neural networks) weather maps, satellite information, data from weather stations and video footage of the atmosphere. AI technologies combine predictive meteorological models with general environmental data, specific descriptions of the state of the atmosphere and the planned operation of solar power plants. Table 3 schematically presents certain aspects of the application of AI technologies in clean energy.

Decisions of Russian experts on the allocation of significant territories for the placement of solar energy facilities are debatable. Nevertheless, experts in the field of energy and industrial ecology determine the location of solar power plants in accordance with plans for the development and development of certain territories based on the natural and economic value of land and other natural resources. For example, the Russian Federation plans to significantly increase electricity production based on renewable and alternative energy sources, including solar energy. A schematic representation of the increase in electricity production based on renewable and alternative energy sources is presented in table 4.
Table 3. Application of AI-technologies in order to generate environmentally significant information in the production of energy from solar power plants.

| Prerequisites for the use of AI technologies | AI technologies                                      | Benefits of using AI technologies                      |
|---------------------------------------------|-----------------------------------------------------|--------------------------------------------------------|
| • to forecast the production of energy from solar power plants | • processing using neural networks of weather maps, satellite information, weather station data and video footage of the atmosphere | • processing of significant volumes of environmentally significant information in order to form optimal operating modes of solar energy facilities |

Table 4. Prospects for electricity production based on renewable energy sources.

|          | 2011       | 2020       | 2030       |
|----------|------------|------------|------------|
|          | 0,5 billion kWh | 5 - 6 billion kWh | 35 - 61 billion kWh |

Despite the country's high supply of natural hydrocarbons, these trends are associated with active social and economic development of remote (isolated) territories of the Arctic zone of the Russian Federation. It should also be noted that regions with a large number of land areas unsuitable for agricultural development and located in steppe, semi-desert and desert zones have dynamically begun to build solar energy facilities [12].

5. Conclusion
The results of the study made it possible to draw certain conclusions and proposals.

Environmental and legal problems of solar energy production require a systematic approach to meeting the economic needs of modern states, in terms of energy independence from international suppliers of traditional hydrocarbons, as well as preserving and restoring the quality of the environment in their territories.

The effectiveness of the European Union countries in the development of solar energy as one of the types of modern green energy is associated with the need to implement national and pan-European climate strategies, reduce the cost of solar energy production, dynamic development and the introduction of new technologies in the production of energy from renewable and alternative sources.

Legal support for the reduction of anthropogenic impact on the environment during the operation of solar energy facilities occurs due to the correlation of legal norms of sectoral national legislation with international law. The advantage of these processes is the expansion of the levels of legal regulation. Thus, the allocation of municipal-level renewable energy facilities into a priority group makes it possible to specify environmental requirements for individual solar energy producers, to provide targeted state administrative and financial support, which contributes to a significant reduction in the anthropogenic load on the environment and the fulfillment of international climate obligations.

Russian legislation in the field of energy production from renewable and alternative sources does not have a sufficiently coordinated regulatory legal framework that would provide not only economic, but also environmental justification for the use of green energy. The most important task of the Russian legislator is to improve national environmental standards and legal regulation measures in the energy sector. Therefore, the authors consider it necessary to develop the concept of the Federal Law with the working title "On Renewable and Alternative Energy Sources". This regulatory legal act must contain: definition of energy produced from renewable and alternative sources; definition and list of renewable and alternative sources; basic principles of legislation in the field of production and use of energy from renewable and alternative sources; basic environmental requirements for energy facilities from renewable and alternative sources.

The production of various types of "clean energy" should be classified as a progressive scientific and technological area. Legislative consolidation of the introduction of AI technologies will allow to accelerate the integration of solar energy into national and regional energy systems, to ensure an
optimal balance of capacities while observing environmental standards and requirements. The use of AI technologies in solar energy production reduces the negative impact on the environment in individual countries and stimulates international cooperation in the field of environmental protection and rational use of natural resources.

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