

Brief information about the project

Name of the project	AP26197983 Study of concentrating silicon bifacial solar cells with a new cooling system under various environmental conditions
Relevance	With the increase in the total population in Kazakhstan and around the world, the number of electronic devices increases and the need for generated electricity grows. As a result, the energy sector has enormous development potential, and as measures to combat environmental problems, methods of generating electricity using renewable energy sources (RES) are also being developed. A striking example of an environmentally friendly and relatively efficient device for generating electricity from RES is solar panels. Solar concentrators are used to improve solar panels output characteristics. However, despite their advantages, the use of concentrators leads to significant heating of solar cells, which in turn accelerates their degradation. It is important to note that the temperature of solar cells is also affected by the ambient temperature. Thus, creating an optimal system that takes into account the state of the external environment and the characteristics of the solar cell, aimed at improving the output characteristics and extending the lifespan of solar cells, is an urgent task. In this context, the technology of bifacial solar cells (BSC) can be especially useful, as it is capable of generating 10-20% more electricity due to the rear photosensitive side. Thus, the integration of optical and cooling systems with the BSC will increase the amount of electricity produced.
Purpose	The goal of the Project is to study the parameters and output characteristics of the BSC with low concentration and various temperature conditions, in order to build an optimal optical system, tracking system, and cooling system, capable of creating a stable environment for the BSC in order to generate the maximum amount of electricity and increase their lifespan.
Objectives	Task1. Study of optical systems consisting of mirrors and lenses that form a low concentration ratio on both sides of the BSC with varying solar radiation uniform distribution degrees using computer modeling. Task2. Study of thermodynamic processes occurring when using a BSC cooling system based on cellular polycarbonates and silicone tubes by applying computer modeling of physical processes. Task3. Study of the heating dynamics of silicon BSCs at a low concentration using an optimal optical system, an initial temperature of 20°C to 40°C, a coolant temperature of 20°C to 30°C and an ambient temperature of -10°C to 25°C. Task4. Study of the cooling dynamics of the solar cell at a solar radiation of 100-1600 W/m² with an optimal optical system, an initial solar cell temperature of 70°C to 40°C, a

	coolant temperature of 20°C to 30°C, and an ambient temperature of -10°C to 25°C. Task5. Mathematical processing of the obtained data to construct an empirical model of the BSC based on the dependence of the heating and cooling rate on the solar radiation, ambient temperature, temperature and flow rate of the cooling liquid. Task6. Study of the influence of non-uniform solar radiation distribution on both surfaces of the BSC on the output characteristics. Task7. Creation of a physical model that ensures the stability of the environment for the operation of the BSC based on the constructed empirical model. Task8. Study of the output characteristics of the BSC under various environmental conditions, cooling systems, concentrations and at various orientations to the Sun. Task9. Creation of an empirical model of the output characteristics of the BSC taking into account data on the non-uniform solar radiation distribution, through data processing and analysis.
Expected and achieved results	The main expected result of the project is the creation of an empirical model of a bifacial solar cell (BSC) capable of providing accurate data on its output characteristics as a function of cell temperature, ambient temperature, cooling system parameters, optical system, and solar irradiance concentration. Additional expected results include the development of an optical system and a cooling system that ensures optimal operating conditions for the BSC. A key feature of the optical system is the uniform distribution of the light flux on both sides of the BSC, which is expected to improve its output performance. The cooling system is designed to rapidly reduce the cell temperature and maintain it at an optimal level over extended periods. The project work is divided into three main areas: computer modeling, experimental research, and development of an empirical model. At the current stage, the following results have been achieved: Using computer modeling in the COMSOL Multiphysics environment with the Geometrical Optics module (ray tracing), a model of a bifacial solar cell has been developed, enabling the formation of light flux on both surfaces of the cell. Optical models based on parabolic reflectors and a Fresnel lens have been created, providing solar radiation concentration in the range of 2-10 suns at an incident flux of 1000 W/m². Optimal geometric parameters have been determined. Using the finite volume method, the processes of heating and cooling of the BSC have been investigated, taking into account ambient temperature, coolant parameters, and radiation intensity. A computational model has been developed to analyze the thermal response of the cell under various operating conditions. Relationships describing the

	influence of key parameters on heat removal efficiency have been obtained. An experimental setup has been developed to study the thermal characteristics of the BSC and to validate the developed models. Experiments have been carried out under varying radiation intensity, temperature conditions, and cooling parameters. Experimental data on the heating behavior of the BSC has been obtained. Currently, the collection and analysis of experimental data on the cooling of the BSC are ongoing, with variation of key parameters including solar irradiance intensity, initial cell temperature, coolant temperature, and ambient conditions.
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Usage	The results of the study have the potential to be used by the commercial and energy sectors of Kazakhstan, with the aim of introducing concentrating and cooling systems for bifacial solar cells, which have the potential to increase the performance and lifespan of bifacial solar cells.
Priority compared to real-world alternatives	The priority of the project compared to existing analogues is defined by a comprehensive interdisciplinary approach that integrates optical modeling, thermal analysis, and experimental validation within a unified system for bifacial solar cells. This enables more accurate evaluation of BSC output characteristics, optimization of operating modes, and improvement of system efficiency and lifetime. An additional advantage is the focus on practical application under the conditions of Kazakhstan, which facilitates the implementation of the developed concentrating and cooling systems to enhance the efficiency and durability of solar installations.
List of publications with links to them	Rustemov A., Ibraimov M., Almen D. *, Svanbayev Ye., Saymbetov A., Nurgaliyev M., Kapparova A., Orynassar S. Modeling output performance of bifacial solar cells based on single diode model // <i>Eurasian physical technical journal</i> , (status: Editor Review)
Patents	-