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TECHNOLOGY AND PROSPECTS OF USING SOLAR ENERGY

Abstract. This article deals with the effective use of solar energy and presents a comparative analysis of different ways of converting solar energy into electrical. Solar energy is the kinetic energy of radiation (sunlight), formed as a result of reactions inside the Sun, its reserves are practically inexhaustible. In natural ecosystems, only a small fraction of solar energy is captured and stored as potential energy of organic matter. Its decomposition meets the energy needs of all other components of ecosystems. Regardless of whether we use solar energy or not, it will not affect the energy balance of the Earth and the state of the biosphere. The main novelty of this work is the introduction of redirecting surfaces which has not been previously used by the solar energy industry. These designs help to distribute light evenly over the surface of the solar cell and do not lead to overheating of the system. They also contribute to a significant increase in its effectiveness. The inspiration for this project has been caused by the recently introduced technology of windows. This window technology is capable to redirect sunlight and provide a high-quality lighting of residential premises. The idea of this technology is based on the achievements of micro-optics using uneven surfaces. The light that passes through the window changes its direction and illuminates the ceiling, which in turn helps to avoid direct contact with the human eye.

Keywords: collector of solar rays, solar system, heat exchanger, energy source.

Introduction. Over the past decades, interest in non-traditional and renewable energy sources has increased significantly and continues to increase, because they areunlimited in many respects. The hydrocarbon fuel supplies become less reliable and more expensive, so these non-traditional sources become more attractive and more economical. The increase in oil and gas prices was the main reason why people started to pay their attention again to water, wind and Sun.

The potential of energy based on direct solar radiation is extremely high.

Using only 0.0005% of the Sun's energy it is possible to meet all the current needsfor energy in the world, and using 0.5% of the Sun's energy we wouldbe able to cover all the demand forenergy in the future.

It is estimated that a small percentage of solar energy is sufficient to ensure transport, industry and household needs not only now, but also in the foreseeable future [1]. Moreover, regardless of whether we use solar energy or not, it will not affect the energy balance of the Earth and the state of the biosphere.

However, the sun's rays fall on the surface of the Earth, never reaching a special intensity. Therefore, it is necessary to catch the energy of the sun rays on a relatively large area, concentrate the energy and turn it into a form that can be used for industrial, domestic and transport needs [2]. In addition, it is necessary to find the way how to store solar energy in order to maintain energy supply at night and on cloudy days. These difficulties and the required costs for overcoming the problem make people think that this energy resource is impractical. However, in many cases the problem is exaggerated. It is important to find the way how to use the solar energy with minimal or even zero cost [3]. As technologies improve and traditional energy resources become more expensive, this energy will find new applications.

Currently, the electricity voltage does not match the pure sine wave and has distortion, that occur when using semiconductor converters. Therefore, solar inverters power plants must be adapted to the mains. The use of microprocessor-based inverter control is necessary for a solar power station, which converts solar energy into electricity. It should be noted, what is a microprocessor control system inverter instantly reacts to changes in mains voltage, excluding emergency conditions. At the same time, solar cells persist and takes place maximum electrical conversion solar power in the mains [4].

When creating information systems for complex object modeling of solar power plant processes based on various methods and algorithms, the most common modern software products are used. The need to process large amounts of information requires the development of new intelligent technologies based on various modern approaches [5].

Current systems:

Today, there are two main large-scale methods of solar energy conversion:

1. Photoelectric converters (PhEC) are semiconductor devices that directly convert solar energy into electricity. This method is based on the phenomenon of photoelectric effect discovered in the far twentieth century by Albert Einstein. The conversion of sunlight into electricity occurs in solar cells made of semiconductor material, such as silicon, which under the influence of sunlight produces an electric current. By connecting solar cells into modules, and those, in turn, with each other, it is possible to build large photoelectric plants. The efficiency of such photoelectric plants is currently about 30%. The biggest model of such construction, "Aqua Caliente Solar Project" is in Arizona, USA. Its capacity reaches approximately 400 mW.

This conversion method consumes only that part of the solar energy that gets directly to the surface of the photoelectric cell. This is one of the main drawbacks of this method. To use it more effective, there is a need to focus sunlight [6]. This idea is widely used in solar structures, which are described below.

2. Solar power plants (SPP) are solar installations, using highly concentrated solar radiation as energy to drive thermal and other machines (steam, gas turbine, thermoelectric, etc.). The basis of this design is a system of mirrors concentrating sunlight [7].

One of the largest focusing solar installations "Mojave Desert California" is located in the United States of America. Its capacity is about 350 MW, which is enough to supply electricity to one large city. However, such systems also have significant drawbacks. These disadvantages are the need to install additional elements to convert solar energy, which inevitably leads to some financial costs and huge energy losses in the conversion process.

Concentrated photoelectricity:

Taking into account the advantages and disadvantages of the structures described above, a new system based on the concentration of sunlight on photoelectric cells with help of parabolic mirrors was proposed in the 1970s.

Based on the property of the parabolic mirror, the reflected light is concentrated on the surface of the solar cell, which can significantly reduce the cost of its production. However, this design has two significant drawbacks.

1 - The light is focused on the solar cell and spreads unevenly across its surface, which leads to a decrease in the efficiency of the system.

2 - Due to the concentration of a huge amount of light, the surface temperature of the solar cell increases significantly, which also leads to a decrease in the efficiency of the design [8].

In view of these drawbacks, there is a need for a modern system in which the redirected light is distributed evenly over the solar cell surface and would be in the amount that would not lead to overheating of the structure. The main idea of this project is to improve these drawbacks.

The main novelty of this work is the introduction of redirecting surfaces which has not been previously used by the solar energy industry. These designs make it possible to distribute light evenly over the surface of the solar cell and do not lead to overheating of the system. They also contribute to a significant increase in their effectiveness.

The inspiration for this project has been caused by the recently introduced technology of windows. This window technology is capable to redirect the sunlight and provide high-quality lighting of residential premises. The idea of this technology is based on the achievements of micro-optics using uneven surfaces [9]. The light that passes through the window changes its direction and illuminates the ceiling, which in turn helps to avoid direct contact with the human eye. The glass used in such a window has a rough surface, which causes the redirection of light.

A detailed description of the light redirection process is shown in figure 1 below.

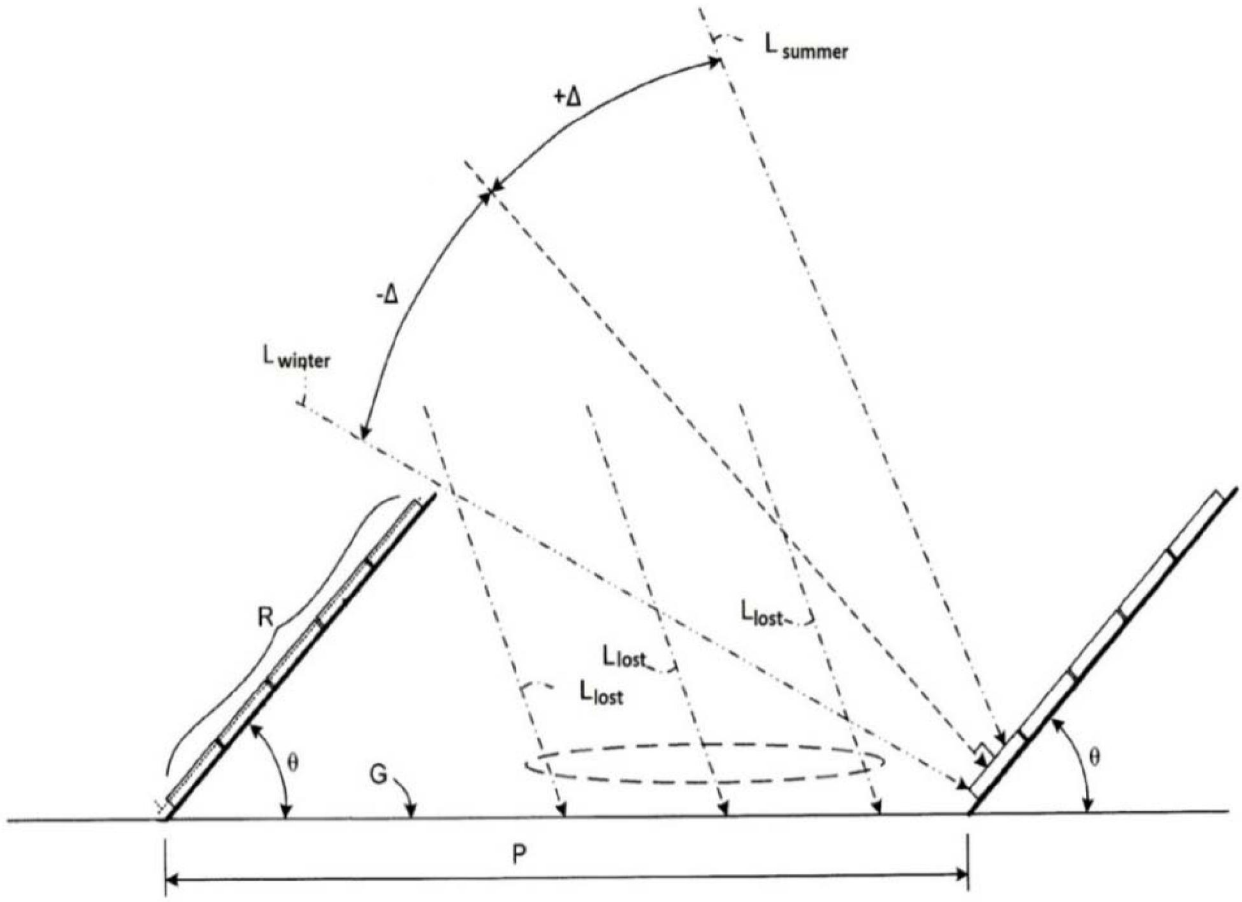

Figure 1 – A model of a photoelectric solar system (PhES system) installed on the earth's surface

A typical model of a photoelectric solar system (PhES system) installed on the earth's surface is illustrates in figure 1.

Figure 1 shows a top view of a similar converter. Here:

R – the surface of the solar cell

G – the surface of the earth

T – the width of the unit

O – the optimal angle of inclination of the photoelectric surface

P – the optimal distance between individual photo panels

This paper presents a low-cost and effective method for improving the model of the photoelectric converter mentioned above. This method is based on the use of lost sunlight L_{lost} cdue to redirecting it by micro-optical surfaces.

The main feature of the redirecting surface S is that, regardless of the position of the sun, the light is reflected from the surface and always gets the photocell R. Therefore, the system will be working the whole year. So, there is no need to use expensive structures that turn the system towards the sun. Its only drawback is the instability to the strong wind due to its volumetric location. In view of this drawback, alternative design models may be proposed.

The principle of operation of the redirecting surfaces is based on the laws of elementary geometric optics when light passes through different media. Depending on the method of action, this paper presents two different models of surface design [10, 11].

Model 1:

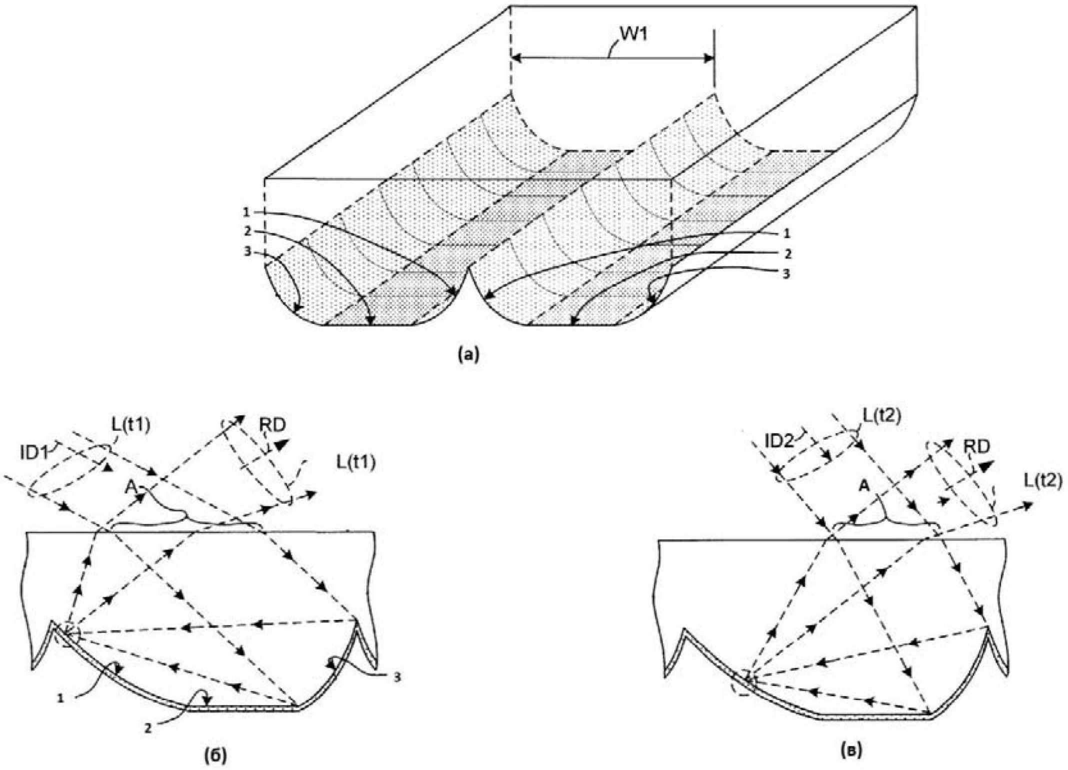

Figure 2 – Surface models: a – Three-dimensional pattern; б – rays are directed at a relatively small angle to the surface of the earth; в – redirecting element in the case of the corresponding time t2

Figure 2 shows a diagram of the first surface model in its three-dimensional design, moreover, the figure shows a several times enlarged element of the structure, where the numbers 1, 2 and 3 indicate the surface of the reflection of light when it passes through the inner part of the redirecting panel. The width of one "tooth part" of the structure is indicated by W1 and can take values from 0.05 mm to 50 mm. When the size of W1 is decreasing, the distribution of the reflected light on the surface of the solar cell is becoming more uniform. However, the production of small-toothed models will be more expensive than large-toothed ones.

The main advantage of the design presented in the model 1 is the presence of a smooth surface on the top layer of the panel, which greatly simplifies the solution of problems arising in the process of cleaning the structure.

Regions 1, 2 and 3 are mirror surfaces, where 1 and 3 have a parabolic shape, such that the light L after its reflection from the surface 3 is directed to the surface 1 and changes its direction so that when it exits the panel medium, it moves along the RD line.

Figure 2 (б) (lower left corner) shows the process of lightpassing through the panel at time t1, when the radiation is directed at a relatively small angle to the earth's surface. The letter A indicates the region of solar radiation, when the sun rays will be redirected to the photoelectric surface. The process of light passing can be described in the following way: the rays of the sun L(t1) are moving along the direction ID1 at the corresponding time t1, after passing through the upper surface, it will be directed to the mirror region 3. After the reflection, the light will be redirected to the surface 1, from which it will again rush to the upper edge of the panel. At refraction through this edge, the radiation will move along the RD line, which corresponds to the direction leading to the photoelectric cell.

Due to the basic property of the redirector in the case of the corresponding time t2 shown in figure 3(в), the light is initially directed along the ID2 line, after passing through the surface, it will also be redirected along the RD line, similar to the previous case described in figure 2(б). This property allows the system to function throughout the year, regardless of the position of the sun that greatly increases the efficiency of the design.

Model 2:

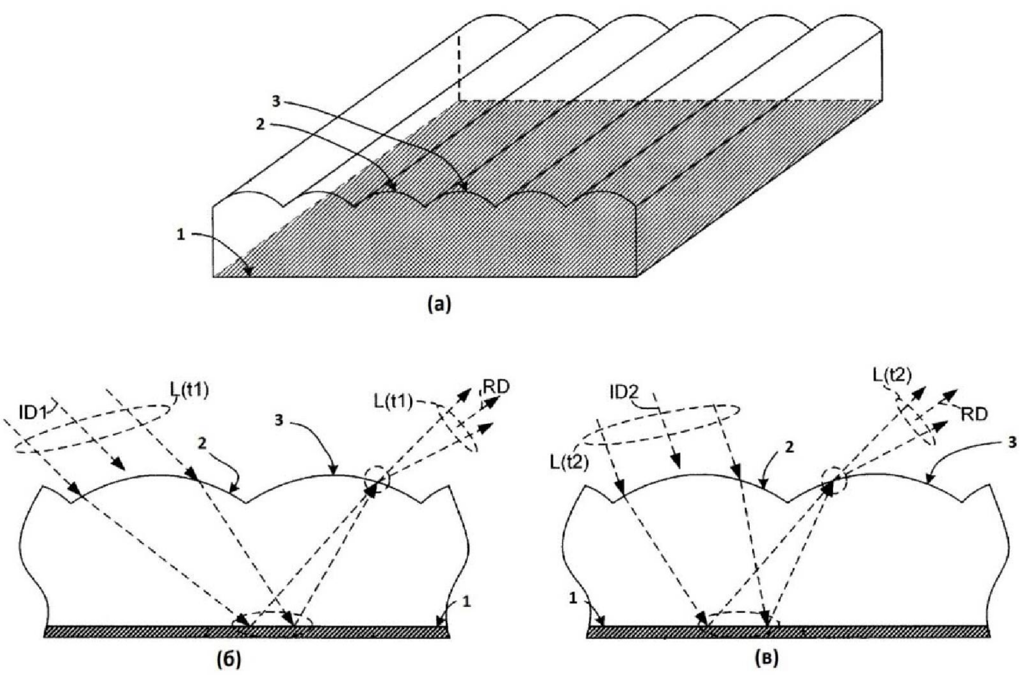

Figure 3 – Design model of the redirecting surface:
a – Three-dimensional pattern of the element; б – movement in the direction of ID1; в – the initial direction of ID2

Figure 3 shows the second possible design model for the redirecting surface. This model has a parabolic and rounded top surface. The bottom surface is like a smooth mirror. Three-dimensional pattern of the construction is presented in figure 3 (a). Here, the number 1 is the lower mirror layer of the system. And figures 2 and 3 show alternating parabolic circles.

The process of operation of this model is similar to the previous one: the sunlight L(t1) corresponding to the time t1 moves in the direction ID1,which has a relatively small angle of inclination to the horizontal plane (see figure 3(б)). After refraction through the surface 2 the rays move to the mirror layer 1. Reflected from this layer, the light is redirected to the parabolic region 3, refracted through it the light will have the direction RD and the ray moves directly to the photoelectric surface. For the moment t2, the ray will have an initial direction ID2, which is steeper relative to the horizontal plane than at the moment t1 (see figure 3 (в)). However, after passing through the redirector, the radiation will be directed along the RD line, the same direction as for the time t1. Thus, regardless the position of the sun, the structure will redirect the light to the surface of the photoelectric cell throughout the year.

A clear advantage of model 2 over model 1 is that it redirects almost all of the light falling on its surface, while model 1 uses the amount of light passing through the limited region- A. However, a significant drawback of the 2nd model is in convenience during the process of cleaning the upper surface, because it does not have as smooth shape as the 1stmodel.

Conclusion. So, in conclusion, it would be reasonable to consider all the advantages of the proposed system in this work. Firstly, as mentioned earlier, the design will operate 70% of time in a year, which in turn will increase the generation of photoelectric power by 25-30%. For example, let's assume that the system is installed on the world's largest photoelectric converter (AquaCalienteSolarProject),its power is 400 MW. If this capacity is increased by 30%, the amount of additional generated energy will be about 120MW, which is enough to provide electricity to the city with a population of 150-200 thousand people. In addition, it is possible to consider the reduction of electricity prices as a result of the installation of redirecting systems. Today, 1kW*hour of photoelectric energy costs about $ 0.15. Using the additional systems presented in this work, the price for 1 kW*h of energy of photoelectric converter will fall to about 0.1 dollars.

Secondly, as described earlier, the redirecting surfaces used in this project contribute to the uniform distribution of the reflected light on the surface of the solar cell compared to the concentrating parabolic systems presented above, which will help to avoid overheating of the system, and will cause long-term service of the structure.

Also, one of the most important features of this work is that the production of redirecting surfaces will be simple and inexpensive. In addition, it is important to note the fact that Kazakhstan and many regions of Central Asia are located at the latitudes advantageous for the installation of PhEC structures with additional systems proposed in this work. In view of this, it is possible to propose this project as a possible option for the development of alternative energy in the countries of Central Asia.

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КҮН ЭНЕРГИЯСЫН ПАЙДАЛАНУ ТЕХНОЛОГИЯСЫ ЖӘНЕ ПЕРСПЕКТИВАЛАРЫ

Аннотация. Бұл мақалада күн энергиясын пайдалану, күн энергиясын электр энергиясына айналдырудың әртүрлі тәсілдерін салыстырмалы талдау қарастырылған. Күн энергиясы – күннің терең қойнауындағы реакциялардың нәтижесінде пайда болған радиацияның кинетикалық энергиясы (негізінен жарық шығарудың), оның қорлары дерлік сарқылмайды. Табиғи экожүйелерде күн энергиясының кішкене бөлігі ғана органикалық заттардың потенциалды энергиясы ретінде ұсталып, сақталады. Олардың жіктелуіне байланысты экожүйелердің барлық басқа компоненттерінің энергия қажеттіліктері қанағаттандырылады. Күн энергиясын қолданамыз ба, жоқ па екеніне тәуелсіз, ол Жердің энергетикалық балансына және биосфераның күйіне әсер етпейді. Бұл жұмыстың басты жаңалығы – күн электр станциясы бұрын пайдаланбаған қайта бағыттаушы беттерін енгізу. Бұл конструкциялар фотоэлементтің бетіне біркелкі үлестіріп, жүйенің қызып кетуіне жол бермейді. Олар сондай-ақ оның тиімділігін айтарлықтай арттыруға ықпал етеді. Бұл жоба тұрғын үй-жайларды жоғары сапалы жарықтандыру үшін күн сәулесін қайта бағыттауға қабілетті. Бұл технологияның идеясы біркелкі емес беттерді микро-оптика жетістіктеріне қолдануға негізделген. Терезеден өткен жарық бағытын өзгертіп, төбені жарықтандырады, бұл өз кезегінде адамның көзіне түсетін тікелей сәулелердің пайда болуына жол бермейді.

Түйін сөздер: күн коллекторы, гелиосистема, жылу алмастырғыш, энергия көзі.

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ТЕХНОЛОГИЯ И ПЕРСПЕКТИВЫ ИСПОЛЬЗОВАНИЯ СОЛНЕЧНОЙ ЭНЕРГИИ

Аннотация. В данной статье рассмотрены вопросы использования солнечной энергии, проведен сравнительный анализ различных способов преобразования солнечной энергии в электрическую. Солнечная энергия – кинетическая энергия излучения (в основном света), образующаяся в результате реакций в недрах Солнца, ее запасы практически неистощимы. В естественных экосистемах лишь небольшая часть солнечной энергии улавливается и запасается в виде потенциальной энергии органических веществ. За счет их разложения удовлетворяются энергетические потребности всех остальных компонентов экосистем. Независимо от того, будем мы использовать солнечную энергию или нет, на энергетическом балансе Земли и состоянии биосферы это никак не отразится. Основной новизной данной работы является внедрение перенаправляющих поверхностей, ранее не использованных солнечной энергоиндустрией. Эти конструкции позволяют равномерно распределить свет по поверхности фотоэлемента и не приводят к перегреванию системы. Также они способствуют значительному увеличению ее эффективности. Вдохновением для данного проекта послужила внедренная недавно в производство технология окон, способных перенаправлять солнечный свет для качественного освещения жилого помещения. В основе идеи данной технологии лежат достижения микрооптики с использованием неравномерных поверхностей. Свет, прошедший через окно, меняет свое направление и освещает потолок, что в свою очередь способствует избеганию прямого попадания лучей в глаза человека.

Ключевые слова: солнечный коллектор, гелиосистема,теплообменщик, источник энергии.

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REFERENCES

[1] Andreev S.V. Solar power plants. M.: Nauka, 2002.

[2] Vanke V.A., Leskov L.V., Lukyanov A.V. Space power systems. M.: Mechanical Engineering, 1997.

[3] Kharchenko N.V. Individual solar installations. M.: Energoatomizdat, 1991.

[4] Isembergenov N., Taissariyeva K., Seidalieva U., Danilchenko V. Microprocessor control system for solar power station // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technology sciences. 2019. 1(433): 107-111. https://doi.org/10.32014/2019.2518-170X.13

[5] Samigulina G.A., Nyusupov A.T., Shayakhmetova A.S. Analytical review of software for multi-agent systems and their applications // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technology sciences. 2018. 3(429): 173-181.

[6] IEA International Energy Agency, "Daylight in Buildings, A Source Book on Daylighting and Systems and Components," A Report of IEA SHC Task 21 (2000).

[7] Walze G., Nitz P., Eul J., Georg A., Gombert A., Bläsi B., Hoßfeld W. Combination of Microstructures and Optically Functional Coatings for Solar Control Glazing // Solar Energy Materials and Solar Cells. 2005. Vol. 89. 2-3. P. 233-248.

[8] Partain, Larry D, ed. Solar Cells and Their Applications. New York: John Wiley & Sons, 1995.

[9] Klammt, A. Neyer, Helmut F.O. Müller. Microoptics for Efficient Redirection of Sunlight. Germany: TU Dortmund University, 2010.

[10] W.J. M. van Bommel, G.J. van den Beld. Lighting for work: a review of visual and biological effects // Lighting Res. Technol. 2004. 36,4. P. 255-269.

[11] Zweibel Ken. Harnessing Solar Power: The Photovoltaic's Challenge. New York: Plenum Press, 1990.

[12] Volodin V.N., Trebukhov S.A., Kenzhaliyev B.K. et al. Melt–Vapor Phase Diagram of the Te–S System // Russ. J. Phys. Chem. 2018. 92: 407. https://doi.org/10.1134/S0036024418030330

[13] Volodin V.N., Trebukhov S.A., Kenzhaliyev B.K. et al. Melt–Vapor Phase Diagram of the Te–S System // Russ. J. Phys. Chem. 2018. 92: 407. https://doi.org/10.1134/S0036024418030330

[14] Kenzhaliyev B.K., et al. To the question of recovery of uranium from raw materials // News of the National academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. 2019. Vol. 1. P. 112-119. https://doi.org/10.32014/2019.2518-170X.14

[15] Kenzhaliev B.K., Kvyatkovsky S.A., Kozhakhmetov S.M., Sokolovskaya L.V., Semenova A.S. Depletion of waste slag of balkhash copper smelter // Kompleksnoe Ispol′zovanie Mineral′nogo syr′â. 2018. Vol. 3. P. 45-53. https://doi.org/10.31643/2018/6445.16

[16] Kenzhaliyev B.K., Trebukhov S.A., Volodin V.N., Trebukhov A.A., Tuleutay F.Kh. Izvlecheniye selena iz promproduktov metallurgicheskogo proizvodstva // Kompleksnoye ispol'zovaniye mineral'nogo syr'ya. 2018. Vol. 4. P. 56-64. https://doi.org/10.31643/2018/6445.30

[17] Sheriyev M.N., Atymtayeva L.B., Beissembetov I.K., Kenzhaliyev B.K. Intelligence system for supporting human-computer interaction engineering processes // Applied Mathematics and Information Sciences. 2016. 10(3). P. 927-935. https://doi.org/10.18576/aims/100310