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Possibilities of Solar Energy Utilization for the Development of Rural Areas of the Republic of Kazakhstan

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ABSTRACT

One of the strategic goals of rural energy today is to reduce the energy intensity of agricultural production by using renewable energy sources. Solar photovoltaic panels are rightfully determined as the most perspective and knowledge-based. The current paper considers the possibilities of solar energy application to advance the agro-industry of the Republic of Kazakhstan. The authors analysed the potential of solar energy in rural areas of the Republic of Kazakhstan: The average monthly solar radiation (insolation level) on a horizontal area; gross input of solar energy by region; duration of the daylight by months.

Keywords: Solar Energy, Rural Areas, Agriculture
JEL Classifications: Q4, Q48

1. INTRODUCTION

The energy of the agroindustry is the most important component of the material and technical base of rural areas, that determines the efficiency of production development, the level of labour productivity, the quality of manufactured products and the social conditions of life of the population.

Modern agro-industrial production requires high energy consumption. In this regard, one of the strategic goals of rural energy today is to reduce the energy intensity of agricultural production, by means of the widespread application of new advanced technologies for the generation and consumption of energy resources. A promising way to solve the problem is to expand the use of renewable energy sources.

In renewable energy solar photovoltaic panels are rightfully considered as the most perspective and knowledge-based types. This fact is evidenced by the constantly growing positive experience of the introduction of solar energy power plants in the electricity supply system all over the world.

According to Global Status Report Renewables (2017), during 2016, at least 75 GWdci of solar PV (solar photovoltaics) capacity was added worldwide – equivalent to the installation of more than 31,000 solar panels every hour. More solar PV capacity was installed in 2016 (up 48% over 2015) than the cumulative world capacity 5 years earlier.

Solar energy is characterized by maximum ease of use, the largest resources, ecological purity and ubiquitous distribution. Consequently, to use solar energy for the greatest benefit to develop rural areas of the Republic of Kazakhstan it is necessary to determine the solar energy resources. Therefore, the main aim of this study is to establish the possibilities of solar energy utilization for the socio-economic development of rural areas of the Republic of Kazakhstan.

In order to reach the goal, it is necessary to perform the following tasks:

- Review the literature on the use of solar energy in agriculture;
- Consider the current state of rural areas of the Republic of Kazakhstan;

- Analyze the potential of solar energy in rural areas of the Republic of Kazakhstan.

2. LITERATURE REVIEW

The development of environmental science shows that the use of traditional fuels leads to negative effects like regional and global climate change, air pollution, especially in big cities. (Peng et al., 2013; Sampaio and González, 2017). For this reason, new renewable energy technologies are demanded to be applied to generate electricity. Photovoltaic panels as a resource of electricity are in the attention of many policymakers and researchers all over the world (Tyagi et al., 2013; Bhattacharya et al., 2014).

Features of solar energy use in agriculture are considered in a number of applied works. Thus, Amerkhanov and Garkavy, 2011; Gusarov et al., 2013; Sarsikeyev et al., 2016 examined the technical possibilities of using renewable energy sources in autonomous systems. Khazimov and Sagyndykova, 2015 studied the intensification of the plant products drying by means of solar energy; Saplin, 2000; Alferov et al., 2004; Akhmetshin, 2015 analysed the efficiency of autonomous solar photovoltaic installations for electricity supply to agricultural consumers.

According to Kazakhstan conditions, researchers identify the alternative energy as an important reserve for enhancing the efficiency of agriculture (Omarbekova et al., 2017). But despite the considerable potential of renewable resources, their contribution to the overall volume of power generation in Kazakhstan remains low. Some regions of Kazakhstan feel a shortage of electricity supply. High energy intensity of the country's economy and other problems lead to the irrational use of fuel and energy resources (Smagulova et al., 2017). There are still only few scientific studies on the possibilities of using renewable energy sources in regions and rural areas that take into account time, geographic and climatic factors. In view of all that has been mentioned so far, one may suppose that the research of opportunities of solar energy for Kazakhstan territory and its implementation is very urgent issue for the country.

3. METHODOLOGY

For the accurate estimation of the solar energy potential at a particular point in a rural area, it is necessary to know the hourly values of all the components of solar radiation reaching the earth's surface. The main initial data for the calculation are the geographical coordinates of the studied region or a particular location.

Designing solar installations, either the measurement data of solar radiation received at the proposed site of operation of the installation are used or the value of solar radiation based on relevant meteorological data is estimated. Among the sources of actinometrical data, the most accessible source is the National Aeronautics and Space Administration (NASA) electronic database, based on Earth sounding data from meteorological satellites.

For forecasting the use and development of solar energy, it is necessary to build on concrete figures. At the present time, one of the most common methods for assessing the potentials of solar resources in the region is to calculate the efficiency of solar systems based on the arrival of total solar radiation and the availability of data on the gross solar energy potential, both for a particular taken point and for a given rural area.

Vissarionov et al. (2008) notes that the gross solar energy potential for a given territory is usually understood as the magnitude of the arrival of the average annual total solar radiation entering a horizontal receiving area of 1 m² for a period of one calendar year:

$$E_{gross}=T\sum_{i=1}^{n} E_{sumi}^{HR} F_i \text{ (kW*h)}$$

Where T is the number of days per year; E_{sumi}^{HR} -arrival of total solar radiation entering a horizontal receiving area of 1 m² for the i-th region $\left(\frac{kWh}{m^2\ day}\right)$; F_i is the area of the region (km²).

For calculation of the solar energy reserves of rural areas of the Republic of Kazakhstan we used:

- Data on the arrival of total solar radiation from the NASA electronic database;
- Report of the Committee for Land Management of the Ministry of Agriculture of the Republic of Kazakhstan on the areas used for agricultural purposes.

4. CURRENT STATE OF RURAL AREAS OF THE REPUBLIC OF KAZAKHSTAN

Rural territories play a significant role in shaping the image of the state on the world stage since it is agriculture that ensures the food security of the country and is a part of national security.

As stated by the Committee of Statistics of the Ministry of National Economy of the Republic of Kazakhstan (2016), 14 regions, 2 cities of republican significance, 161 administrative districts, 209 cities and settlements of regional significance, 6.6 thousand rural settlements constitute the administrative-territorial system of the republic.

The territory of the Republic of Kazakhstan exceeds 261 million hectares where 102.6 million hectares (39.27%) belong to agricultural lands (Table 1).

Agricultural lands of Akmola (73.75%), North Kazakhstan (70.55%) and Kostanai oblasts (55.04%) predominate in the total area of these regions. All three specialise in agriculture, but there are resources for developing industrial potential.

On the contrary, Atyrau, Mangistau, West Kazakhstan, Aktyubinsk and Kyzylorda oblasts geographically located from West to East can be defined as oil and gas areas. Their distinctive features: A mono-oriented economy, an underdeveloped manufacturing and agricultural sector.

Nonetheless, Almaty, Zhambyl and South-Kazakhstan regions can be called as agrarian-industrial. Pavlodar, East Kazakhstan and Karaganda regions are industrial. For these areas large resources

Table 1: Geographic coordinates and area of agricultural land by region of the Republic of Kazakhstan

Region No	Regions	Geographical coordinates	Total area, thousand hectares	Of these, agricultural land	
				Thousand hectars	Specific gravity (%)
1	Akmola region	51°92' N-69°41' E	14620,7	10 782,2	73,75
2	Aktyubinsk region	48°78' N-57°99' E	29263,4	10 115,5	34,57
3	Almaty region	45°01' N-78°42' E	22358,3	8 697,3	38,90
4	Atyrau region	47°11' N-51°91' E	11113,5	2 516,6	22,64
5	E-Kazakhstan region	48°71' N-80°79' E	28346,8	10 557,5	37,24
6	Jambyl region	42°89' N-71°39' E	11937,1	4 615,4	38,66
7	W- Kazakhstan region	49°57' N-50°81' E	13668,8	6 225,4	45,54
8	Karaganda region	47°90' N-71°77' E	35644,4	14 021,5	39,34
9	Kyzylorda region	44°69' N-62°66' E	24041,4	2 456,7	10,22
10	Kostanay region	51°51' N-64°05' E	19600,1	10 787,9	55,04
11	Mangystau region	44°59' N-53°85' E	16564,2	5 338,1	32,23
12	Pavlodar region	52°29' N-76°97' E	12470,5	5 497,7	44,09
13	N- Kazakhstan region	54°16' N-69°94' E	9804,3	6 917,0	70,55
14	S-Kazakhstan region	42°27' N-68°14' E	11725,8	4 050,3	34,54
15	Almaty	43°22' N-76°85' E	68,3	9,1	13,32
16	Astana	51°16' N-71°47' E	72,2	12,7	17,59
	Total		261299,8	102 600,9	39,27

Compiled by the authors on general information on land resources of the Republic of Kazakhstan. Committee for Land Management of the Ministry of Agriculture of the Republic of Kazakhstan (2016)

of ferrous and nonferrous metallurgy, an advanced manufacturing sector, differentiated production, and more developed peripheries are typical.

The cities of the republican subordination-Almaty and Astana are consumer centres. They are distinguished by a high level of population incomes, development of the service sector. In the cities of Astana and Almaty, there are agricultural lands mainly used for subsidiary farming. Thus, when investigating rural areas for the potential of solar energy, these regions are not taken into consideration.

Upon to the report of the Committee for Land Management of the Ministry of Agriculture of the Republic of Kazakhstan (2016), in the agrarian sector of the economy, 100.9 million hectares or 98.4% of all agricultural lands are assigned to non-state forms of management. The republic comprises 219,800 peasant and private farms, 1,500 agricultural production cooperatives, 7,600 economic partnerships and joint-stock companies. In the regions of Kazakhstan there are more than 100 farms remote from the centralized power supply system by more than 17 km and over 500 farms by 30-50 km.

In the light of considered facts, the issues of the autonomous power supply of remote agricultural facilities are of critical importance to the energy policy of Kazakhstan agroindustry. The traditional application of mobile fuel power plants for autonomous power supply is associated with the problems of hydrocarbon raw materials. The use of alternative sources based on renewable energy sources is quite urgent, due to the intensive growth in prices for petroleum products and gas, as well as their transportation.

5. ANALYSIS OF THE POTENTIAL OF SOLAR ENERGY IN RURAL AREAS OF THE REPUBLIC OF KAZAKHSTAN

Solar energy is a source of light and heat and harnessed by a number of constantly changing technologies, for example, solar heating, photovoltaic power, solar thermal energy and artificial photosynthesis. Solar energy is an important source of renewable energy. Besides that, technologies can be classified as passive-solar and active-solar depending on how they capture and distribute sunlight or convert it into solar energy. Active solar methods include the use of photovoltaic systems, solar concentrators and solar collectors for the solar energy utilization. Passive solar methods include orienting the building's location to the Sun, choosing materials with high thermal mass or light dispersion properties and designing a space for air circulation.

Using the geographical coordinates of the rural areas of the Republic of Kazakhstan and data from the NASA electronic base, we determined the arrival of total solar radiation (Table 2).

Compiled by the authors according to General Information on Land Resources of the Republic of Kazakhstan. Committee for Land Management of the Ministry of Agriculture of the Republic of Kazakhstan (2016) and NASA Surface meteorology and Solar Energy - Location (2017).

As can be seen from the Table 2, the highest arrival of solar radiation was recorded in rural areas of the South Kazakhstan region (4.32 kWh/m^2/day), and the lowest intensity of solar radiation is observed in the North-Kazakhstan region (3.28 kWh/m^2/day).

It is apparent from the table that the geographical coordinates of rural areas affect the potential of solar energy, since the regions located closer to the south receive a large amount of solar radiation than the northern.

Consequently, in terms of the intensity of solar radiation in rural areas of Kazakhstan, there are three zones:

- Zones with high intensity of solar radiation (from 3.99 to 4.32 kWh/m^2/day): Almaty, Zhambyl, Kyzylorda, Karaganda and South-Kazakhstan regions;

- Zones with an average intensity of solar radiation (from 3.65 to 3.84 kWh/m²/day): West Kazakhstan, East Kazakhstan, Aktyubinsk, Atyrau and Mangystau oblasts;
- Zones with low intensity of solar radiation (from 3.28 to 3.59 kWh/m²/day): North Kazakhstan, Pavlodar, Akmola and Kostanay regions.

In real terms, the value of the horizontal solar radiation density depends on the latitude of the area, the transparency of the atmosphere, the characteristics of the earth's surface, as well as the time of day and season.

Analysis of the obtained data makes it possible to determine that from April to the end of August, compared with other months, the period of maximum solar radiation is observed (from 4.34 to 6.87 kWh/m²/day).

During this period, remote farms can make maximum use of the influx of solar radiation to supply electricity to livestock farms and equipment, to maintain the optimum temperature in barns, pumping systems, drying food, growing seedlings in solar greenhouses, etc.

Using the data in Tables 1 and 2, we determine the gross resource of solar energy on the horizontal area of rural regions of the Republic of Kazakhstan (Table 3).

Based on the calculation performed, it can be said that the annual gross inflow of solar radiation in rural areas of the Republic of Kazakhstan is 1412701.88 MW*h. The potential of solar radiation on the horizontal platform of rural areas of Kazakhstan is available, which contributes to the effective use of solar energy.

To determine the potential of solar energy, it is also important to know the average duration of a light day. Table 4 indicates the duration of solar radiation during the day in each of the months.

Table 2: Monthly averaged insolation incident on a horizontal surface of rural areas of Kazakhstan (kWh/m²/day)

Region No	Months												E_{sumi}^{HR}
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
1	0.95	1.83	3.38	4.74	5.90	6.56	6.08	5.13	3.80	2.22	1.23	0.81	3.56
2	1.22	2.13	3.40	4.78	6.00	6.36	6.12	5.49	4.25	2.57	1.44	1.02	3.73
3	1.56	2.46	3.60	5.19	6.10	6.79	6.27	5.84	4.71	3.11	1.92	1.34	4.08
4	1.37	2.29	3.60	4.81	5.92	6.15	6.13	5.40	4.22	2.63	1.51	1.12	3.77
5	1.28	2.15	3.47	4.82	6.00	6.61	6.01	5.63	4.30	2.66	1.55	1.06	3.80
6	1.66	2.33	3.23	4.34	5.51	6.52	6.64	6.19	4.96	3.21	1.94	1.40	4.00
7	1.14	2.02	3.36	4.68	6.12	6.25	6.19	5.32	4.01	2.42	1.33	0.95	3.65
8	1.33	2.25	3.44	5.15	6.28	6.87	6.37	5.88	4.61	2.86	1.66	1.17	3.99
9	1.44	2.31	3.64	5.19	6.11	6.78	6.60	5.95	4.75	3.07	1.87	1.27	4.09
10	0.95	1.83	3.42	4.76	5.97	6.62	6.18	5.22	3.80	2.25	1.26	0.80	3.59
11	1.59	2.45	3.48	4.72	5.77	6.20	6.23	5.43	4.26	2.87	1.71	1.31	3.84
12	0.94	1.84	3.33	4.83	5.93	6.36	5.96	5.11	3.59	2.12	1.19	0.77	3.50
13	0.79	1.65	3.25	4.55	5.63	6.30	5.80	4.63	3.22	1.87	1.03	0.66	3.28
14	1.83	2.76	3.99	5.13	6.28	6.78	6.81	6.02	5.00	3.55	2.11	1.56	4.32

Table 3: Gross arrival of solar energy on a horizontal platform of rural territories of the Republic of Kazakhstan

Region No	Regions	Lands of agricultural purpose, thousand sq. m	Average value E_{sumi}^{HR} $\left(\frac{kW\ h}{m^2\ day}\right)$;	E_{gross} (MW*h)
1	Akmola region	107,82	3,56	140101,31
2	Aktyubinsk region	101,16	3,73	137724,28
3	Almaty region	86,97	4,08	129515,72
4	Atyrau region	25,17	3,77	34635,18
5	E-Kazakhstan region	105,58	3,80	146439,46
6	Jambyl region	46,15	4,00	67379,00
7	W-Kazakhstan region	62,25	3,65	82932,56
8	Karaganda region	140,22	3,99	204209,40
9	Kyzylorda region	24,57	4,09	36679,32
10	Kostanay region	107,88	3,59	141360,56
11	Mangystau region	53,38	3,84	74817,41
12	Pavlodar region	54,98	3,50	70236,95
13	N-Kazakhstan region	69,17	3,28	82810,32
14	S-Kazakhstan region	40,50	4,32	63860,40
	Total	1025.8		1412701,88

Source: Compiled by the authors

Table 4: Monthly averaged daylight hours in rural areas of Kazakhstan by months (hours)

Region No	Months											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1	8.36	10.0	11.8	13.8	15.6	16.6	16.2	14.6	12.7	10.7	8.90	7.88
2	8.78	10.2	11.8	13.6	15.2	16.1	15.7	14.3	12.6	10.8	9.26	8.36
3	9.19	10.4	11.9	13.4	14.8	15.5	15.2	14.0	12.5	11.0	9.61	8.85
4	8.96	10.3	11.9	13.6	15.0	15.8	15.5	14.2	12.6	10.9	9.41	8.58
5	8.78	10.2	11.9	13.6	15.2	16.0	15.7	14.3	12.6	10.8	9.26	8.36
6	9.43	10.6	11.9	13.3	14.6	15.2	15.0	13.9	12.5	11.1	9.80	9.10
7	8.68	10.1	11.9	13.7	15.3	16.2	15.8	14.4	12.6	10.8	9.16	8.25
8	8.88	10.2	11.9	13.6	15.1	15.9	15.5	14.2	12.6	10.9	9.35	8.50
9	9.23	10.5	11.9	13.4	14.8	15.5	15.2	14.0	12.5	11.0	9.65	8.88
10	8.41	10.0	11.8	13.8	15.6	16.5	16.1	14.5	12.7	10.7	8.94	7.95
11	9.25	10.5	11.9	13.4	14.7	15.5	15.1	14.0	12.5	11.0	9.65	8.90
12	8.31	10.0	11.8	13.9	15.7	16.7	16.2	14.6	12.7	10.7	8.86	7.81
13	8.01	9.83	11.8	14.0	15.9	17.0	16.5	14.8	12.7	10.6	8.61	7.48
14	9.46	10.6	11.9	13.3	14.5	15.2	14.9	13.8	12.5	11.1	9.85	9.16

Source: Compiled by the authors according to General Information on Land Resources of the Republic of Kazakhstan. Committee for Land Management of the Ministry of Agriculture of the Republic of Kazakhstan (2016) and NASA Surface meteorology and Solar Energy - Location (2017)

The data presented in Table 4 allow us to determine that during the daylight hours from 07:48 to 17:00 the incoming solar radiation can be directly used for the electricity generation and supply. After the analyses of the table, we can conclude that the sun shines for almost half a day in all rural areas of the Republic of Kazakhstan, regardless of the season. Under these circumstances it is possible to guarantee the generation of electricity during the day, as well as to store excess electricity and use it at night.

Thereupon, the intensity of radiation and the duration of solar fusion, favour the use of solar energy to power agricultural consumers.

6. CONCLUSIONS

The territory of the Republic of Kazakhstan exceeds 261 million hectares, where 102.6 million hectares (39.27%) refer to agricultural lands. The republic comprises 219,800 peasant and private farms, 1,500 agricultural production cooperatives, 7,600 economic partnerships and joint-stock companies. In the regions of Kazakhstan, there are farms remote from the centralized power supply system, which apply mobile fuel power stations.

Using the geographical coordinates of the rural areas of the Republic of Kazakhstan and the data of the NASA electronic base, we determined the arrival of total solar radiation. The highest arrival of solar radiation was recorded in the rural areas of the South Kazakhstan region (4.32 kWh/m^2/day), and the lowest intensity of solar radiation is observed in the North Kazakhstan region (3.28 kWh/m^2/day). The analysis of the obtained data showed that within the rural territory of Kazakhstan the average value of the arrival of solar radiation varies significantly. Therefore, three zones are distinguished: From high (5 regions), medium (5 regions) and low (4 regions) intensity of solar radiation.

The annual gross inflow of solar radiation in rural areas of the Republic of Kazakhstan is 1412701.88 MW*h. The potential of solar radiation on the horizontal platform of rural areas of Kazakhstan is available, which contributes to the effective use of solar energy.

The calculation of the daylight duration of Kazakhstan rural areas by months showed that almost half of the day the sun was shining (from 7.48 to 17 hours per day), regardless of the season. This allows to guarantee the generation of electricity during the day, as well as to store excess electricity and use it at night.

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