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Low-Carbon Power Engineering in the Russian Border Regions of Siberia and the Far East: An Analysis of Household Potential

Ekaterina A. Klevakina[1]*, Irina A. Zabelina[2,3], Ksenia V. Shvorina[4], Ksenya A. Yakovleva[5]

[1]Department for Ecological Economics, Institute of Natural Resources Ecology and Criology SB RAS, Russia, [2]Department for Ecological Economics, Institute of Natural Resources Ecology and Criology SB RAS, Russia, [3]Department for Applied Informatics and Mathematics, Transbaikal State University, Russia, [4]Department for Ecological Economics, Institute of Natural Resources Ecology and Criology SB RAS, Russia, [5]Department for Applied Informatics and Mathematics, Transbaikal State University, Russia. *Email: bedew@yandex.ru

ABSTRACT

The main purpose of this paper is to present the results of the analysis of the use of individual solar stations by households in the eastern part of Russia. The population of the eastern Russian regions was surveyed on the attitude towards the use of alternative energy sources and it was made an attempt to define whether it is appropriate to use them in individual households. The article uses colors of growth framework, which is used in the process of analyzing power engineering development in the regions in question. It was found that in most regions of the Russian far east energy sector development brings about air pollution, i.e., economic result increase is associated with the enhancement of general and specific environmental impact on the atmospheric air. Consequently, large-scale use of solar energy by households can significantly reduce emissions to the atmosphere. The article also outlines the main tasks, the solution of which will promote the spread of renewable energy use in the regions of Russia.

Keywords: Green Energy, Colors of Economic Growth, Solar Energy, Willingness to Pay, Eco-intensity, Russia
JEL Classifications: Q5, R5, L94, Q42

1. INTRODUCTION

Currently, alternative power engineering, including solar one, is actively developing all over the world. In 2015, the solar energy sector ($161 billion) contributed the largest volume of new investments in renewable energy, an increase of 12% compared to last year. The recent technological progress has made the use of solar energy more convenient, and its cost has significantly decreased (Global Trends, 2016). In 2015 Bloomberg[1] estimated the average cost of 1 MW of solar energy in the world as $122 that is 17% cheaper compared to last year. In Dubai, the tariff for solar energy is a record-low – $58.5 per MWt. Countries differ significantly in their climatic conditions, but solar energy is developing even in the countries with less suitable insolation parameters. Along with financial constraints, one of the important barriers to the development of solar energy in the world is the availability of the necessary space for the construction of solar power plants.

Russia is characterized by low population density and large areas, but despite the sufficient parameters of solar radiation in a number of regions, alternative power engineering develops slowly lagging behind the leading countries by the number of installed capacities and investment volumes. One of the main reasons for the slow development of the alternative energy market in Russia is the high cost of equipment, especially when it comes to the individual use of solar power plants.

Russia has set a large-scale goal - to develop solar generation in the regions of Siberia and the Far East. These regions are promising for the development of solar power engineering due to the sufficient duration of sunshine. At present, coal-fired power plants is the main source of electricity there. In connection with this it will be shown that the existing energy sector development

1 https://www.bloomberg.com/company/new-energy-outlook/.

trends in some regions are not consistent with "green" economy and "green" growth strategy, which is one of the world's priorities ensuring the maximum preservation of natural resources (de Boer et al., 2014; Glazyrina et al., 2015; Glazyrina and Zabelina, 2016; OECD, 2011; Pearce et al., 1989; Shang et al., 2015; Victor, 2015). We set the task to determine the main prospects for using solar energy at the household level. To this end, their purchasing power, payback period under the existing energy tariffs, conditions for their operation and potential state support measures to promote this technology were assessed, and the population was surveyed on their willingness to pay.

2. LITERATURE REVIEW

The modern literature on solar energy can be divided into several categories. A number of works are related to the study of solar panels use technology. For example, the paper (Jäger et al., 2016) investigated a large number of aspects related to the use of solar energy, including the aspects of payback. Other works consider the use of alternative energy at the level of different groups (state or population) and mechanisms for their promotion. These works concern different countries and groups of countries. The surveys were conducted in various countries, for example in Australia (Ashworth et al., 2013). The people were asked what measures of support for the acquisition of solar power stations they want to be applied. A number of studies show that local adaptation to climate change is rather important and in this case households see themselves as active players in this process (van Kasteren, 2014). In general, there is enough experience of implementing solar systems, in particular, work (Nieuwenhout et al., 2000) summarizes the information on the use of solar panel by rural households in developing countries and analyzes the effectiveness of various promotion mechanisms (Durham et al., 1988; Willis et al., 2011).

Many studies focus on rural households as potential users of this technology. There are model studies that show the impact of various economic and demographic variables, such as tariffs on electricity, taxation, income, education, age and size.

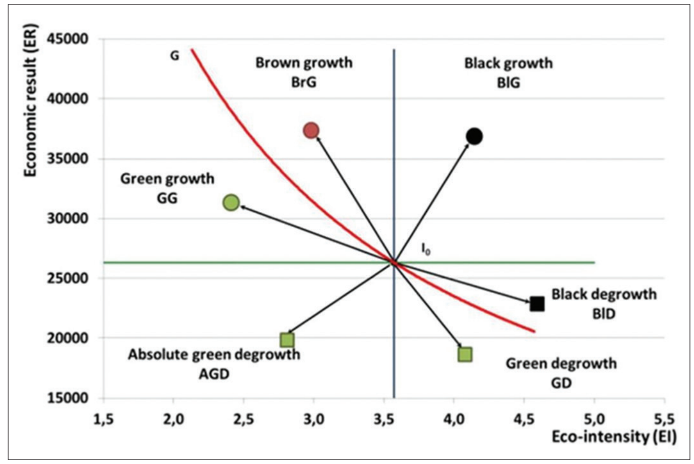
Additionally, the studies show that both households and state benefit from the use of solar energy. Thus, work (Ayompe and Duffy, 2013) discusses the introduction of reduced tariffs for the electricity produced by the photovoltaic (PV) systems connected to Irish electricity networks at household scales. The conditions that can induce households to make investments in solar systems were determined, they in turn will allow reducing government spending by a considerable amount during the 25-year period.

3. DATA AND RESEARCH METHODOLOGY

3.1. Survey Design

Using a set of data obtained from the survey of people living in individual houses in the Trans-Baikal territory, the attitude of people towards the use of alternative energy sources and threshold price of solar power plants, at which their use will be accessible to the population, was investigated. The survey was conducted in 2016. The questionnaire was filled out by 187 respondents from different settlements of the region. The respondents were of different age groups and had different levels of income.

Figure 1: The graphical representation of the trend and colors of growth framework



3.2. Quantitative Indicators of "Growth Color"

Following (Victor, 2015), the direction and "color" of energy sector economic growth in several regions of Siberia and the Far East were estimated. In contrast to Victor's work, which analyzes the data on CO_2 emissions, the total amount of emissions into the air from the power supply enterprises were considered. In the eastern regions of the Russian Federation, electricity and heat are produced mainly by coal plants, the emissions of which in addition to carbon monoxide contain such pollutants as particulate matter (soot), sulfur dioxide and nitrogen oxides.

Graphical representation of the research results allows analyzing the system development direction in time and, depending on this, defining in which ecological and economic zone it falls and determining the correspondence of the observed changes to the green growth vector. Ecological and economic state of the system at the initial point of time is taken as the point of origin Io, which is crossed by G curve, the locus of points that characterize a permanent negative impact on the environment.

The vertical axis represents the economic result (ER), the amount of produced electricity and heat. The horizontal axis represents one of the most common eco-intensity indicators (EI), which represents the amount of pollutant emissions into the atmosphere per unit of ER (Figure 1).

Eco-intensity is calculated by formula (1):

$$E_i = \frac{P_i}{Y} \qquad (1)$$

Where:

E_i - Eco-intensity of i^{th} type of negative impact,

P_i - Negative impact of i^{th} type,

Y - ER, in this case, the amount of 1 electricity and heat produced.

The calculations were made using the official statistical data of the Federal State Statistics Service on the amount of electricity and heat produced, as well as the shares of pollutant emitted by the regions of the Russian Federation[2].

3.3. Purchasing Power and Payback Periods of Power Plants

The purchasing power and the feasibility analysis of the investments in the purchase of power plants were calculated on the basis of official statistics on the average monthly accrued wages of the organizations employees and the results of solar power plants regional market analysis, current tariffs of energy service companies and credit products.

Value Z, an important characteristic of purchasing power, was calculated according to formula (2). It shows how many months are needed for the average consumer to have the opportunity to purchase a solar power plant at the existing price level.

$$Z = \frac{C}{I}, \quad (2)$$

Where:

C - Equipment cost,

I - Nominal wages.

The efficiency and feasibility of investments in the purchase of a power station were analyzed on the basis of a payback period assessment. It is defined as the period during which the sum of the reported revenues reaches (or exceeds) the costs discounted by the initial instant. It can be calculated by the formula 3:

$$\sum_{t=0}^{L} \frac{Y_t - I_t}{(1+\frac{i}{12})^t} - I_0 \geq 0 \quad (3)$$

Where:

I_t - Investments at time t,

Y_t - Benefit at time t,

i - Annual discount rate,

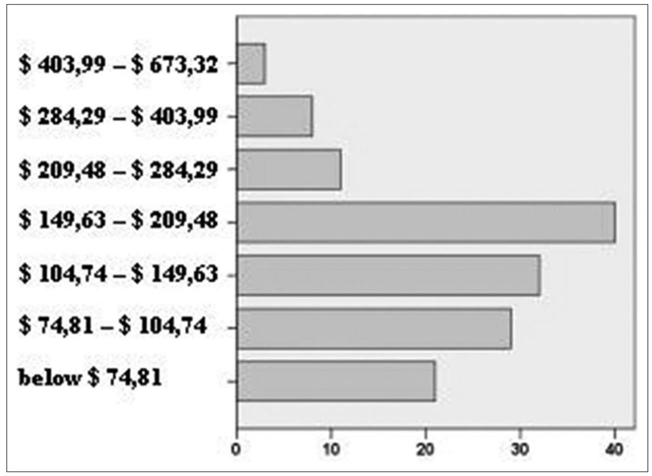
t - Number of months,

I_0 - Initial investments,

L - Pay-back period.

The calculation of a payback period took into account the cost of a PV panel credit funds included, battery replacement costs during

Figure 2: Distribution of respondents wishing to use solar panels to power their households, according to per capita income



a life cycle, as well as savings from the use of solar energy taking into account the step-by-step increase of tariffs by marketing companies for the purpose of benefits receipt.

4. EMPIRICAL RESULTS

4.1. Willingness to Use Solar Energy

The attitude of the population towards the development of solar energy in the model region (the Trans-Baikal territory) was studied. The survey on the population attitude towards the environment quality showed that only 6.25% of respondents are indifferent towards this aspect. Thus, the local population understands that there is a need for comprehensive care for the environment. However, at present most of the population uses traditional sources of electricity. Only 5.35% of respondents use solar panels for power supply of premises, while the desire to use solar panels to cover their own electricity needs was expressed by a much larger number of residents – 77%. At the same time, preferences vary depending on the distance of a settlement from a regional center: The further a district is from a regional center, the fewer are there the interested.

The questionnaires revealed that the group with lower levels of per capita income expressed greater interest in the use of alternative energy sources (Figure 2). A possible explanation is that mainly the population with a lower income level desires to receive electricity without monthly payments while the tariff increases. At the same time, the number of respondents in the sample with a higher per capita income is significantly lower (Table 1) than of those whose income does not exceed the subsistence wage (10,465.16 rubles in 1st quarter of 2016)[3].

Thus, the residents of the Trans-Baikal territory understand certain advantages of using solar energy. However, at present, there are a number of barriers to its use. According to the research, only 42.4% of those wishing to use alternative energy are planning to buy PV panels in the near future, 4.2% of which (the most likely potential

2 http://www.gks.ru.

3 http://www.garant.ru/hotlaw/chita/723641/#ixzz4WXpnJ9WG

consumers) plan to do it within the next year, 38.2% - over a 5-year period. At the same time, potential consumers are in 26-35 and 36-55 years age groups.

The survey data showed that the main reason why respondents do not plan to buy PV panels is the high cost of equipment. However, there are other reasons, the lack of available information, as well as organizations providing servicing of this equipment are among them (Figure 3).

The majority of those wishing to install solar batteries are ready to buy them at a price below $150 that is 10 times lower than their market value in the eastern regions of the Russian Federation. The plants producing the equipment in Russia are located mainly in the European part of the country and their products are relatively expensive in addition to significant transportation costs. China is one of the world leaders in PV system production. However, the population of Siberian and Far Eastern regions bordering with China does not have the opportunity of acquiring PV power panels at a lower price than in the domestic market. Unfortunately, current low incomes of the population do not allow most households to purchase such expensive equipment (Table 1).

The respondents consider the following as the most appropriate measures for the support of alternative energy use on the part of the state (Figure 4):

- Subsidies for photocells purchase;
- Interest-free loan for photocells purchase;
- Subsidies for photocells installation.

Currently, the state's efforts are aimed at the involvement of small businesses in the development of small power plants, but it was

Figure 3: The frequency of answers about the reasons that prevent the use of solar panels

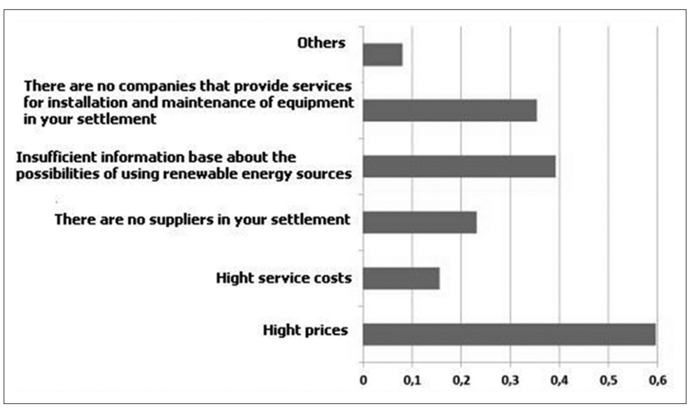


Table 1: Distribution of respondents by income per family member

Average income per capita	Percent
Below $ 74.81	15
$74.81-$ 104.74	20
$104.74-$149.63	21
$149.63-$209.48	27
$209.48-$284.29	7
$284.29-$403.99	5
$403.99-$ 673.32	2

concluded that government support only will allow spreading solar energy technologies among the population. It should be noted that the authorities in neighboring China actively support the development of solar and wind power engineering, as well as at the level of individual use. China set an ambitious goal to make the use of alternative energy sources widespread. The program receives considerable support from the state. It includes a whole range of activities, starting with the support of photocell producers and ending with the desire to make photocells available to ordinary households.

4.2. "Color" of Economic Growth

Using the methodology (Victor, 2015), it was stated that in the majority of the examined regions of Siberia and the Far East energy sector development (2005-2014) is in the zone of "black" growth (Table. 2), i.e., the increase of ER aggravates the total and specific environmental impact on the atmospheric air (Glazyrina and Zabelina, 2016). The most favorable situation is observed in Khabarovsk and Primorye territories, where in recent years one of the main thermal power stations of the region has been reconstructed and coal fuel has been replaced with gas. The most unfavorable situation from the perspective of colors of growth framework is observed in the Trans-Baikal territory and Irkutsk region, where the "black" growth of power engineering prevails. In the Trans-Baikal territory, electricity is produced primarily by TPP using coal. In the Irkutsk region, located along the "hydroartery" of the Angara River flowing from Lake Baikal, coal-fired power plants account for only 30% of electricity generation in the region, the rest is generated by cascades of the hydroelectric power plant.

At present, the transition of energy to "green" growth zone, accompanied by an increase in the ER and decrease in the general and specific indicators of negative impact, is not possible with the existing production technologies. The use of solar power plants could contribute to the improvement of the situation in several regions of Siberia and the Far East. The number of sunshine hours in the most of their territory is sufficient for the use of PVs. Along with industrial projects, at the household level solar innovations are actively applied all over the world. Nevertheless, in the regions of Siberia and the Far East solar energy is used rarely.

4.3. Purchasing Power and Payback Periods of Power Plants

We considered the payback period for power plants for the region's households in rural and urban areas with a population of 1-4 people.

On average, one inhabitant in the region accounts for about 80 kWh/month of electricity consumed. Thus, the costs, which will be saved up for the consumed electric energy has been taken as the monthly benefit, taking into account that rates will increase by 5%[4] every 6 months. Currently, the lower limit of the tariff is 4.13[5] cents for the urban population and 2.89 for the rural population, the upper – 5.9 and 4.13, respectively. Consequently, a power station will monthly save $50.64 per person.

4 http://www.e-sbyt.ru/?page_id=376.

5 Hereinafter, calculated by the authors based on the statistical data and the average dollar rate in 2016.

Table 2: Heat and electricity production, 2005-2014

Region	Development of energy branch in the according to the colors of growth framework
Amur Region	Brown growth, black growth
Jewish Autonomous Region	Absolute green degrowth, green degrowth, black degrowth
Trans–Baikal Territory	Black growth
Irkutsk Region	Black growth, black degrowth
Primorye Territory	Green growth, green degrowth
Republic of Buryatia	Black degrowth, black growth
Khabarovsk Territory	Green degrowth, absolute green degrowth, brown growth

Table 3: Pay-back period, years

Number of household members	Urban household	Rural household
1	34.9	42.3
2	22	28.6
3	15.4	21.3
4	11.6	17

Under the costs are understood monthly payments for consumer credit at the rate of 17.9% per annum for the purchase of solar 2 kW power stations at the cost of $1663, as well as the costs of batteries replacement every 4 years in the amount of $508. The results of the calculation are shown in Table 3. Thus, it is expedient to use solar energy if in a households live 3 persons or more. In contrast to the countryside, in the conditions of existing tariffs payback matures faster in urban areas.

4.4. Wages Purchasing Power

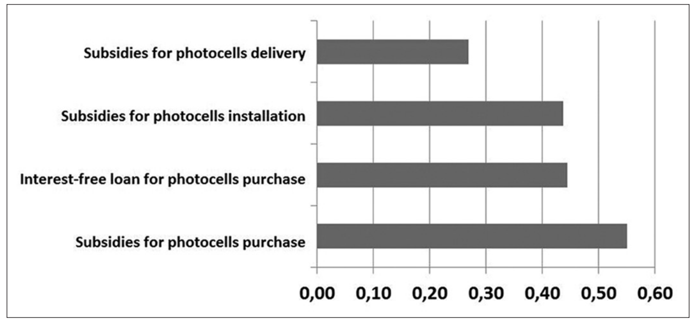
The major deterrent of solar power plants purchase and solar power engineering development in general is the high cost of instruments, ranging from the geographical situation of the regions. The differences in prices of 2 kW solar power plants (as the most suitable to maintain the autonomy of houses electric power system) in different regions were analyzed[6].

Taking into consideration that the socio-economic situation in Russia is characterized by large territorial differentiation in terms of living standards – households incomes and expenditures – the affordability of solar power for a house is limited by average per capita income. Comparative analysis of the average monthly wages in the regions allows calculating the purchasing power of the population in relation to solar power needed per house (Figure 5).

Due to the high prices, the most of the population of the regions consider these goods as expensive. In the regions of Eastern Siberia, only a quarter of the population has a per capita income higher than $404 that means that people can buy PVs on credit or at the expense of their own savings. It should be noted that a significant portion of the population lives in apartment buildings and doesn't require independent power supply. The potential consumer, depending on the region, must pay from 6.5 to 10 of his monthly salaries if he wants to buy the solar station from a Russian company.

6 Including delivery cost.

Figure 4: The frequency of answers about the possible measures of state support



On the territory of Russia there are a few plants for PVs production. They are located mainly in the central part of the country. PVs are produced in the city of Zelenograd, the Moscow region, in the city of Ryazan, the city of Novocheboksarsk, Chuvash Republic and the Krasnodar territory. The significant remoteness of the eastern regions of the central part of the Russian Federation preconditions the high shipping costs of the equipment of domestic production, while proximity to the Chinese border promotes PVs exports from China. Even in the European part of Russia, a large number of ready-made kits are produced using equipment and components manufactured abroad.

5. CONCLUDING REMARKS

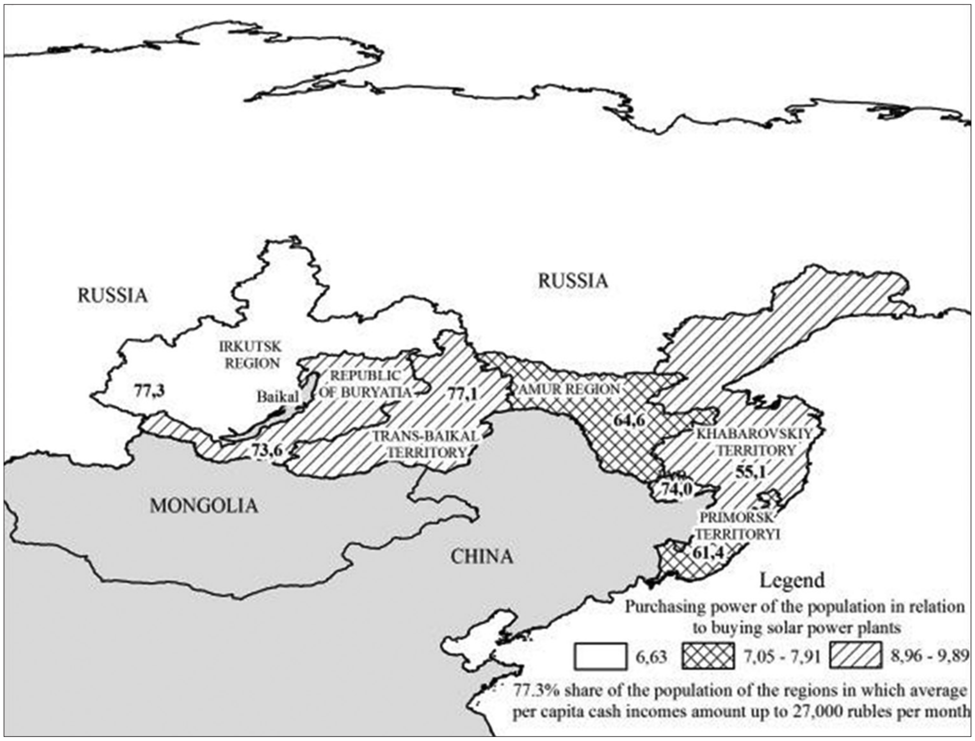
The average household in the Trans-Baikal territory consumes 225 kWh of electricity per month (that is 4 times lower than in the US[7]). On average, the production of 1000 kWh of electricity at coal fired TPP of the region leads to the emission of 2.15 kg of sulfur dioxide, 0.79 kg of nitrogen oxide and 0.12 kg of carbon oxide. Thus, during a 30-year period one individual solar station can prevent the emission of about 174 kg of sulfur dioxide, 64 kg of nitrogen oxides and 10 kg of carbon oxide. Since almost half of the population of the Trans-Baikal territory lives in one-family houses (Regiony, 2015), a few thousands of such power plants can be built only in the region.

Our calculations show that the development of solar energy individual consumption requires state support. Additional energy sources are needed in the domestic market of Russia's eastern regions, but the economic opportunities of the population is significantly limited in terms of their purchase. Of course, the main limiting factor in the use of PVs by households in the regions of Siberia and the Far East is the high price of the equipment. According to the survey the maximum threshold price, at which the majority of respondents agrees to buy solar cells, is $150 that is almost 10 times less than the actual cost of the equipment.

Government programs budgeting depends on macroeconomic stability. However, a number of measures that do not require constant investments can be identified. Among them the following can be highlighted:

7 https://www.electricchoice.com/electricity-prices-by-state/.

Figure 5: The purchasing power of the population in relation to buying solar power plants in some regions of Eastern Siberia and the Far East (27,000 rubles is the lower limit of revenues, which include a monthly per capita income in the Russian Federation)



1. Development of an information portal, which would in a convenient and accessible manner explain the benefits of using alternative energy, characteristics and prospects of its use in a particular region, would allow calculating a payback period by analogy with credit calculations, and would also represent a platform of B2C type which can be used both by the representatives of the regional market, equipment delivery and installation companies.
2. Holding of social awareness campaign, which can help attract attention to alternative power engineering and identify environmental needs of people that together with the growth of per capita income and infrastructure development can promote renewable energy sources in a region. The use of clean energy among affluent population strata may be an integral component of prestige like buying branded goods.
3. Development and implementation of alternative energy promotion mechanisms, in particular the introduction of a special "green" tariff on the purchase of electricity produced from renewable energy sources.

More effective and correspondingly more expensive measures include a reduction in price of equipment for the end user by virtue of technological change, the expansion of delivery ducts and different financing mechanisms. Perhaps the prospects of PV panels leasing should be considered. Currently there is no reason to expect a rapid increase in the use of individual solar stations by households. In this regard, the construction of larger power stations, designed for a large number of consumers would be more expedient. Particular attention should be paid to the development of regional programs related to energy supply of isolated settlements, currently being energized by diesel stations. In this case, the cost of PV panels will be compensated quickly due to the reduction of transport costs on regular fuel delivery. The remote settlements of the Trans-Baikal territory are already energized in the framework of pilot projects. It can be concluded that only strategic approach and desire of the state and society to support technological change can trigger transition to alternative energy sources.

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