Recommendations for the
Development of Alternative Power
Generation in Rural Areas of Tyva Republic

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Oxfam is a global movement of people working with others
to overcome poverty and suffering.

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AEnergy was established in Moscow in 2008
AEnergy’s mission is to support the development of renewable energy and energy
efficient technologies in Russia.
The primary business activities include analytical research in renewable energy markets
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WWF’s vision is to halt the degradation of the planet’s natural environment and to build a future in which humans live in harmony
with nature.

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Information and recommendations presented in this publication are devoted to the development of renewable energy sources in rural areas of Tyva Republic. The study demonstrated that the most cost-effective renewable energy option at present are small solar power plants that can be used in a single household, herder camp, nature reserve outpost, etc. This publication is intended to assist appropriate decision-makers in making a timely and economically reasoned choice in favour of small-scale solar power generation in Tyva Republic. In addition, this publication can be of use to other regions of Russia by giving an example of an integrated cost-benefit analysis in using various renewable energy technologies that are tailored as much as possible to the needs and realities of specific regions.

This publication has been prepared by the Altai-Sayan Ecoregional Office of WWF Russia within the Integrated Community Development and Biodiversity Conservation in the Republic of Tyva Project supported by Oxfam GB.

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Case studies:
- Experience of the Kyzyl-Khaya Small Hydropower System in Tyva Republic
- Solar PV system operation in Tyva Republic, Mongolia and China
- Regional Special Purpose Program “Energy Saving and development of alternative sources of energy” in Tyva Republic
- Renewable Energy for Rural Access in Mongolia, World Bank Program
## Abbreviations

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<th>Abbreviation</th>
<th>Definition</th>
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<tr>
<td>CIS</td>
<td>Commonwealth of Independent States</td>
</tr>
<tr>
<td>COP</td>
<td>Coefficient of performance</td>
</tr>
<tr>
<td>GEF</td>
<td>Global Environment Facility</td>
</tr>
<tr>
<td>HV</td>
<td>high voltage power line</td>
</tr>
<tr>
<td>ICUF</td>
<td>Installed Capacity Utilization Factor</td>
</tr>
<tr>
<td>IDA</td>
<td>International Development Agency</td>
</tr>
<tr>
<td>IFC</td>
<td>International Financial Corporation</td>
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<tr>
<td>PV</td>
<td>Photovoltaic (system, cell)</td>
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<td>REAP</td>
<td>Renewable Energy Action Plan</td>
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The World Wide Fund for Nature (WWF) has been working in the Altai-Sayan Ecoregion for more than 10 years. Much has been achieved during this period, e.g. new protected areas were proclaimed and are now fully-functioning, conservation strategies for endangered species, such as snow leopard and argali, were developed and are being implemented and protected areas are gradually being linked with ecological corridors. During recent years, WWF has paid special attention to climate change and energy efficiency issues and also to helping to resolve social and economic problems in the region.

In 2008, WWF and Oxfam GB began a joint project Integrated Community Development and Biodiversity Conservation in the Republic of Tyva. The project is aimed at identifying and demonstrating opportunities for the development of integrated utilisation and processing of agricultural produce and for the development of sustainable micro-funding mechanisms to support small businesses. Increasing income for local people will help combat poaching and unsustainable resource use. The principal reason for these at present is the low standard of living of local communities caused by unemployment and lack of entrepreneurial opportunities.

Without addressing these issues and creating environmentally-sustainable jobs and alternative sources of income it will be impossible to convince people for the need to truly care about Nature.

The current study was also a part of the WWF/Oxfam GB project. Development of renewable energy generation is recognized as an effective step for both addressing energy security and the creation of environmentally-sustainable jobs. As this publication suggests, this is fully relevant to the remote rural areas in Tyva Republic. Exploitation of renewable energy is a key component in future world power generation without greenhouse emissions and subsequent significant human impact on the Earth’s climate system. A lot is currently being said about the renewable energy development. Frequently, one hears that it is Russia’s sluggishness that prevents the country from developing renewable energy generation systems as widely as it is done in Europe and China. In reality, the situation is more complex. Rather than importing energy, Russia exports energy and the state does not face any urgent necessity to develop renewable energy to rid itself of imported energy carriers. In addition, without state subsidies it is unprofitable to generate power from renewable sources for subsequent sale to the electricity grid because wholesale prices are still too low. The generation of power and heat for the country’s own needs, however, is a different matter. In Russia, there is a huge gap (3-4 times) between the wholesale price at which power can be bought by the electricity grid and the retail prices for end-users or consumers.

In many areas, there are signs of mass renewable energy development for own needs. This is especially relevant to remote areas such as Tyva where fuel is transported and where electricity is transmitted over a long distances. In such cases, it is especially important to urgently overcome the information barrier and demonstrate in what situations and which kinds of renewable energy can be profitable even now. Exactly this type of analysis has been undertaken in this study. Ultimately, the aim is the practical introduction of those types of renewable energy that can already be profitable. In the case of Tyva, solar power generation is already more cost-effective for small consumers than is connection to the grid or the use of diesel...
generators. This study shows specific examples of business plans for various consumers that demonstrate how long it will take to return investments spent on the installation of solar power plants. Other advantages, such as non-dependency on fuel delivery and opportunity to make independent decisions are also important. It is apparent that this study can be of relevance and use to other areas, particularly as an example of an approach towards renewable energy development and integrated ways of tackling various factors affecting decision-making. It is important to stress that such development of renewable energy at local level should not be assessed only from the point of view of reducing greenhouse emissions. Reducing emissions may be very insignificant in absolute figures. It would be much more effective to modernize one thermal power plant than to convert several hundred farms to using renewable energy. From only the carbon emission point of view, it is not advisable to develop small-scale renewable energy projects.

One has to look at the issue from a different angle, ie. small-scale renewable energy projects as a means of adapting local economies and communities to changes in the economic, social and climatic environments, all of which are very much inter-related. This is why WWF considers this study to be very timely and recommends it to a wider circle of readers. These include decision-makers and small- and medium-size businesses, not only in Tyva, but also in other regions of Russia. In other areas, different forms of renewable energy may be cost-effective with differing periods of return and different problems needing to be addressed. These all represent parts of one process of the technological modernization of our country in changing economic and climatic environments.
Introduction

Reduction of rangeland and a shortage of power for primary processing of agricultural produce determine the extent of development of agriculture in Tyva Republic. In the dry steppe zone, this results in degradation of ecosystems and a reduction in biodiversity. Extensive agriculture also results in negative social implications, e.g. personal income in Tyva Republic is one of the lowest in Russia.

Improving power supply in the area through the development of conventional energy generation is not possible due to the low density of the population and the nomadic way of life. It is necessary, therefore, to develop and introduce power supply technologies from other sources, including renewable energy.

This report has been prepared for the WWF Altai-Sayan Ecoregional Office. The report provides an assessment of the potential of renewable energy resources in Tyva Republic and analyses the most efficient technologies of decentralized power supply for herder camps. Special attention is given to funding issues and the successful experience in the development of solar power generation of neighbouring Mongolia. Information obtained from the NASA Surface Meteorology and Solar Energy Database and the Ministry of Economics and Ministry of Agriculture of Tyva Republic was used in this report.

Economic characteristics of various technologies were calculated using data from the following producers: gas generators (Honda, Generac Power Systems); diesel and gasoline generators (Honda, SDMO, Gesan); wind turbines (SouthWest Wind Power, GRC-Vertical); PV systems (VIECo); small hydropower plants (Toshiba, INSET); and biogas generators (AgroBioTech, EcoRoss).

Other sources of information used include the World Bank, RusHydro, Federal Statistics Service and other companies, organisations and the media, as well as the websites for Flickr, Panoramio and AEnergy.ru.
About the authors

The report *Recommendations for the development of alternative power generation in rural areas of Tyva Republic* was completed in March/April 2011 by the Analytical Department of LLC AEnergy, a Russian company specializing in the field of renewable energy projects in Russia and CIS countries.

AEnergy extends its gratitude to VIECo [http://www.viecosolar.com/](http://www.viecosolar.com/), and in particular to its Director Pavel M. Mikhailov, for the information provided on solar energy.

**Since 2007, the analysts at AEnergy have completed more than 15 large research projects, including:**

- An economic value estimation of the biogas market in Russia
- Studies on the potential of bioenergy development in several regions
- Alternative energy in Russia in 2009 and 2010
- Gas and energy supply crisis in Russia
- Energy conservation and supply in housing projects in Russia
- Energy efficiency in the building sector: technologies and economic effect
- Associated petroleum gas in Russia: production profiles and utilization potential.

Information and expert opinions in this report were obtained from sources considered reliable. This report, however, cannot serve as a sole basis for management decisions.
Chapter 1 - Power supply needs for agriculture in Tyva Republic

1.1 Current state and trends in the development of agriculture in Tyva Republic

Tyva Republic is one of the least economically-developed regions of the Russian Federation and is the least developed region in eastern Siberia. Principal characteristics of its economy include infrastructural and economic isolation from adjacent regions, undeveloped industries and a high dependence on the federal centre (up to 70% of its budget comprises federal subventions).

Low economic development and a traditional nomadic way of life account for the low level of urbanization. Although since 1989 the proportion of urban population has grown by 5% and now exceeds the proportion of rural population, this figure is still much lower than the average for Russia. In fact, except for those the towns of Ak-Dovurak and Kyzyl, the entire population of the Republic is classified as rural.

FIGURE 1: Proportion of the rural population in Tyva Republic and Russia in 2010
There are two main types of agriculture practice in the Republic. The first is suburban agricultural production around the towns of Kyzyl and Ak-Dovurak. This includes cropland and poultry and livestock breeding both on commercial farms and in private households. Due to the collapse of the collective farming system and the degradation of arable land this form of agriculture is in deep decline. Only a small portion of the produce is marketable, eg. only after modernization in 2009-2010 was the Yeniseiskaya poultry plant for 70,000-80,000 birds reopened.

FIGURE 2: Total area of farmland in Tyva Republic

The second type of agriculture is found in the Ubsunur Basin, along the Sayano-Shushenskoe Reservoir and River Khemchik valley. This is represented by nomadic herding (mostly of sheep) that generates most of the marketable agricultural produce in the Republic.

FIGURE 3: Changes in livestock population size over time in Tyva Republic
The size of the sheep herd in the Republic is increasing faster than those of other animals, at present exceeding the level of 1991. The amount of sheep and goat milk produced has also almost recovered to the high levels of earlier times. These products form the basis of local people’s diet and are being used to produce traditional cheeses and wool, the main export items for the Republic.

Over 70% of the sheep herd belongs to private households and small farms. Agricultural companies owning the remaining 30% have lowest index of employment in Russia. A typical agricultural company in Tyva employs an average of only 13 people.

A greater proportion of commercial agricultural produce (wool and milk) derives from small agribusinesses and private households that mostly practise sheep herding in the steppe regions in southern and western Tyva.

This sector contributes 11% to the gross regional product of Tyva, lying in third place with respect to total added value to wholesale trade and state services.
The urgent need to modernize agriculture is necessary not only because of its high contribution to gross regional product, but also because of the rapidly worsening environmental conditions. Extensive development of agriculture over the previous decades has caused a large-scale degradation of farmland.

**FIGURE 7: Degradation of farmland in Tyva Republic in the early-1990s**

Natural degradation of soil and desertification, caused by shallow topsoils and severe continental climate, has been aggravated by human impacts, mostly through overgrazing by livestock. The rangeland area in the last 20 years has shrunk by 70%, while the size of the livestock population has remained the same. The mobility of the rural population has dropped significantly. These all resulted in the emergence of patches of disturbed ecosystems adjacent to settlements. Degradation of steppe in the Ubsunur Basin is of international concern as part of this area has UNESCO World Heritage Site status.
1.2 Development of power supply infrastructure in Tyva Republic

Infrastructural isolation, poor use of local natural resources and agricultural backwardness account for the underdevelopment of the energy infrastructure in Tyva. Lack of power generation capacity impedes the implementation of any investment projects which could help both the economic and social development of the region.

Less than 10% of power demand is met from local sources. These comprise the Kyzyl cogeneration power plant (8 MW), which is currently working at only half capacity because of its aged equipment, and small diesel power plants in remote areas in the Republic that have a total capacity of 5.5 MW. Following the accident at the Sayano-Shushenskaya hydro-power plant, the power generating system in Khakassia was not able to provide the necessary amount of electricity to Tyva or to maintain the required level over time. Consequently, a mobile gas turbine with 22.5 MW output was delivered to Tyva as a temporary measure.

The remaining amount of electricity is provided from Khakassia through the high-voltage (HV) transmission line 220 from the Sayano-Shushenskaya hydro-power plant. During peak demand (in winter), the Republic experiences a power demand deficit.

Electricity rates in the Republic are subsidized through regional budget subventions to those municipalities using diesel generators (more than RUB 100 million a year) and also through the setting of non-market rates by the Federal Tariff Service.

Another specific feature of the power generating system in the Republic is the low coverage of its electrical grid (over 40% of Tyva is not covered by a centralized power supply). Over 80% of existing power lines are also largely worn-out.

Construction of power self-generating facilities and the renovation of electrical infrastructure are hindered by the Republican budget deficit (3%), non-payment (debts represent 37% of electricity sold, equivalent to RUB 790 million) and the regulation of rates for private consumers and companies by the Federal Tariff Service. Tyva Republic is listed among those regions where, despite ongoing liberalisation of markets, federal regulation of rates still takes place.

The Government of the Republic of Tyva is looking at several options of overcoming the power deficit and providing a stable power supply.
1. Construction of the HV line 220 Kyzyl-Chadan within the federal special purpose program of the Federal Grid Company (in 2014-2016)
2. Renovation of the Kyzyl Cogeneration Power Plant funded by Yenisei TGC (TGC-13) together with increasing its capacity up to 45-48 MW.
3. Construction of a new 300 MW thermal power plant on the Kaakhem coal field funded by private investors and the republican budget.
4. Construction of four small hydroelectric power plants of 150 MW total capacity funded through RusHydro's investment program.

1.3 Efficiency of the existing power supply system for agricultural producers

Implementation of the above-listed projects would considerably improve power supply in Tyva, but only for suburban agriculture.

**TABLE 1: Power supply for various types of agricultural producers and prospects for their improvement**

<table>
<thead>
<tr>
<th>Way of life</th>
<th>Suburban agricultural production</th>
<th>Nomadic pastoralism</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Districts (kozhuns)</strong></td>
<td>Private households &amp; small farms not producing their own fodder</td>
<td>Private households, small agribusinesses &amp; farms of nomadic type</td>
</tr>
<tr>
<td><strong>Power supply</strong></td>
<td>Kyzyl, Barun-Khemchin</td>
<td>Erzin, Sut-Khol, Mongun-Taiga, Bai-Taiga, Ovyur, Barun-Khemchin, Chedi-Khol</td>
</tr>
<tr>
<td><strong>Centralized, with deficit of heat &amp; electricity capacity</strong></td>
<td>Without power supply/decentralized power supply from diesel generators in settlements</td>
<td></td>
</tr>
<tr>
<td><strong>Prospects of improvement relating to implementation of 'large' power generation projects</strong></td>
<td>Deficit of heat &amp; electric power capacity will be partially covered &amp; power supply will be generated to develop factory-type cattle farming &amp; poultry breeding</td>
<td>Generating plants will be constructed in a limited number of areas. Construction of new power distribution grids is not planned &amp; is not efficient with the current low population density. Power supply for such farming will not be affected</td>
</tr>
</tbody>
</table>

New power generation plants will make possible the construction of large factory cattle and poultry farms around the towns of Kyzyl and Ak-Dovurak. Improvement of power supply in those areas where electricity is currently generated using diesel fuel is not likely due to the following reasons:

- **Location of new power generating plants**
  All power generating plants, excluding two small hydropower plants on the Khemchik and Tes Rivers, are planned to be built near the town of Kyzyl. Power generation will be linked to the development of mineral resources in the eastern part of the Tyva Basin where agriculture is not developed.

- **Building of new power distribution facilities is not planned**
  If all planned power generating capacities were built and the Republic had an excess of power, power delivery to agribusinesses would still be very difficult because of the low coverage of the electricity grid. Nowadays, power lines connect Kyzyl to only the largest settlements in Tyva and these are 80% worn-out.

- **Low human population density and nomadic economy**
  Human population density in the main agricultural districts of the Republic is very low (1-2 people per km² compared to the average in Russia of 8 people per km²), so making the development of power distribution infrastructure unprofitable.
Consequently, plans for the development of power engineering in the Republic do not include the construction of new power transmission systems in rural areas. The provision of power supply for agricultural producers can only be made possible through a decentralized generation of power.

At present, this is mostly done using diesel generators, but these are very costly to run. In Tyva, their effectiveness is even lower than average.

On the one hand, this is related to the high price of diesel fuel in the region (in Spring 2011, this was RUB 29 per litre, one of the highest prices in Russia). Even when the Kyzyl-Kuragino railway is completed and diesel fuel can be transported in tanker cars from the Achinsk oil refinery, transportation costs will still be very high. In the near future, the poor condition of roads will also not allow for a reduction in diesel delivery costs to remote areas.
On the other hand, the budget of one of the poorest provinces in the Russian Federation is currently overburdened with costs relating to the maintenance of the existing 'diesel' infrastructure. This makes it unlikely that a new infrastructure development project will be implemented.

Another reason for the low efficiency in diesel power generation in Tyva is the reduced mobility of agricultural producers caused by their need for a reliable fuel supply. This results in a reduction in the area of rangeland and its concentration within a distance that is accessible by road from settlements that are equipped with diesel power generators or connected to the central electricity supply grid. Such concentration of grazing in limited areas leads to overgrazing. Rangeland productivity and biodiversity decrease significantly and eventually decrease the productivity of agriculture.

The above-mentioned reasons explain why there is a need for technologies in distributed power generation from renewable energy sources in Tyvan agriculture. Power generation based on renewable energy is mobile and independent. It allows for the power base of agriculture to be expanded within the region without transforming traditional farming practices and without increasing the adverse impact on the environment. It is also in line with the criteria of sustainable development.
Chapter 2 – Evaluating potential renewable energy resources in Tyva Republic and the feasibility of their exploitation

Renewable energy derives from natural resources such as sunlight, wind, water streams, biomass (e.g. forest, energy crops, organic wastes) and geothermal heat. Tyva possesses a considerable potential for renewable energy that is several times more than the demand for power in the Republic. Let us examine the most promising sources of renewable energy and the feasibility of using them in the agricultural sector of Tyva.

2.1 Evaluation of the power generation potential of biomass and organic wastes

The most efficient renewable energy resource for agriculture is biogas which is obtainable from all forms of organic waste. The main features of biogas production are the general availability of resources and the possibility of accumulating them, the opportunity to produce organic fertilizers as a byproduct of the technology, the utilization of potential pollutants and the absence of greenhouse gas emissions. There is also considerable experience in using the technology in both developed and developing countries, in particular neighbouring China.

Potentially, the total amount of agricultural organic waste in the Republic is between 100,000-150,000 tonnes a year, equivalent to one third of the annual fuel and energy demand in Tyva. The major portion of such wastes comprises manure from sheep and goats.

Realizing this potential in Tyva, however, is difficult as it faces a number of technological and production risks and limitations relating to the small size of farms, the nomadic way of farming and the climate.

Mobile biogas digesters of low capacity being produced in several countries, including Russia, are very vulnerable to low temperatures. The air tightness and heat insulation of the digesters are not sufficient in extreme continental winters to prevent anaerobic digestion from stopping and this can lead to breakdown.
Despite the relatively small size of such units, transportation of them between herder camps is rather difficult. The herding of cattle over large areas also makes it difficult to supply a biogas plant with manure in an efficient manner.

Among large industrial biogas plants, the most efficient are those digesters with 300 kW capacity or more. Such digesters require 40 tonnes of organic wastes per day, equivalent to the daily waste from a herd of sheep numbering 15,000-17,000 head kept in a paddock that is equipped with a system for automatically removing waste. The Republic does not have any farms on such a scale. Even the Yeniseiskaya poultry factory, the largest in the region, produces only 10-15 tonnes of waste a day. Using biogas technology would therefore not be sufficiently profitable.

![FIGURE 11: Return on investment of biogas projects in Tyva Republic](image)

As tariffs for electricity increase and if large poultry plants and cattle factory farms develop in the suburbs of Kyzyl and Ak-Dovurak, biogas production could become more profitable.

The main renewable energy resource of forest biomass are wood pellets. These are produced from wastes during logging and wood processing and can be used as a fuel in municipal boilers and also for electricity generation.

Forests cover 80,000 km² in Tyva, or almost half of the Republic’s area. Despite the considerable potential of this resource, forest logging is not well developed (felling comprises less than 5% of allowable cutting rate in designated areas) and almost half of the felling is undertaken to obtain firewood.

Constructing a railway line between Tyva and Krasnoyarsk Province should stimulate the development of a forest processing industry. This may create a sufficient amount of forest cutting and wood processing waste to begin producing wood pellets and to subsequently establish wood pellet power generation plants. This is the direction in which municipal power generation is developing in some provinces of European Russia, such as Vologda Province, Karelia Republic and Krasnodar Province.
2.2 Evaluation of the power generation potential of small rivers

Tyva is one of the leading regions of Russia with regard to the potential of hydro-power development. The total hydro-power potential of Tyvan rivers is estimated to be around 8 GW. This is 40 times more than the Republic’s current electricity needs.

The main hydro-power potential is concentrated in the eastern part of the Republic where the largest rivers, namely the Greater and Lesser Yenisei, and their tributaries flow. Rivers in the western part of the Tyvan Basin, for example the Khemchik River with its tributaries the Tes-Khem and Mogen-Buren Rivers, are also suitable for installing small hydro-power plants. Streams that are suitable for micro hydro-power engines with capacities of 50 kW and greater also exist in the main agricultural areas.

There are two main types of small hydro-power plant: conventional plants, which require the construction of a dam and reservoir, and run-of-the-river plants where water is diverted through pipelines or along special diversion channels.

There are also submerged and portable micro hydro-power engines with 5-15 kW capacity. Small hydropower projects that do not need dams have a number of advantages over those that need dams, eg. a shorter period for installation, no areas flooded, ease of operation and ability to generate small amounts of power that do not require being connected to the grid (up to 200 kW).

A serious hindrance to the development of small hydro-power projects in Tyva is the seasonal irregularity of the stream flow in most of the rivers, ie. 80-95% of the flow occurs during the summer period. Therefore, the possibilities of constructing diversion hydro-power plants or submerged hydro-electric units are very limited. Stream flow during winter months would hardly be sufficient to start up a turbine and the installed capacity utilization factor (ICUF) of the plant would be less than 30%. To enable small hydropower projects to become efficient, dams and reservoirs would have to be constructed.

Experience of the *Kyzyl-Khaya* Small Hydropower System in Tyva Republic

Tyva already has some experience in running a small hydropower plant of the diversion type. In 2001, in the village of Kyzyl-Khaya (Mongun-Taiga District) on the Mogen Buren River, a small hydropower plant with 150 kW capacity was installed. It consists of three hydroelectric units each with 50 kW capacity produced the St Petersburg-based company, MNTO INSET. This plant took the place of a diesel generator that was operating before in the village.

The total cost of the plant amounted to RUR 27 million, or RUR 180,000 per 1 kW of installed capacity. This is considerably higher than the average market price. The high costs were linked to high transportation costs in delivering the machines and equipment to the region, difficulty in access and high administrative costs.

One of the most important problems the plant operators faced was low stream flow during winter which caused output to decrease by more than three times. There was also the issue of non-payment by local people who previously had had free of charge access to electricity.

At present, this hydropower plant does not operate. However, RusHydro is considering the possibility of re-launching the plant within its investment program.
The issue of the seasonal irregularities in river flow is also a problem for submerged and portable small hydropower plants with 5-15 kW capacity. For example, the Barlyk River that flows through the agricultural Ovyur and Barun-Khemchik Districts dries up in summer and freezes in winter in its upper reaches where most of the rangeland is located.

Another limitation to using micro hydropower plants is that they are not produced in Russia in marketable numbers. Some American and Japanese companies have undertaken pilot projects, but as yet micro hydropower plants have not been imported from these countries.

The prospects of hydropower generation development in Tyva are mostly related to the construction of dams with hydro turbines with capacities designed to generate large amounts of electricity for the grids. Construction of such plants would not affect the power supply for herder camps.

2.3 Evaluation of the power generation potential of wind

The prevalence of the high pressure Siberian anticyclone during winter, combined with the region’s basin-like topography, generally determine the low average wind speeds experienced in Tyva.

![FIGURE 12: Wind speed in Tyva Republic](image)

Average wind speed at 10 m above the ground in Tyva is 3.2 m/s, this being comparable to the figures for Central Russia. Such speeds are too low even to incorporate wind power plants into hybrid power generation systems (i.e. wind and solar or wind and diesel).

This is due to the technical characteristics of existing wind turbines in that they begin producing electricity at wind speeds of 3 m/s and reach their power rating when speeds exceed 10 m/s. Between 3 and 15 m/s, the output increases exponentially.

Even vertical axis wind turbines are not very effective. Such generators can begin producing electricity at 1.4 m/s. However, with average wind speeds of only 3.2 m/s, they would only operate at 10% of their capacity.
Atmospheric conditions within intermountain depressions create mountain and valley winds. This makes it possible for some areas to experience average wind speeds greater than the average for Tyva. There are five meteorological stations in the Republic that collect climatic data. Analysis of this data can help to identify the most promising sites for exploiting wind energy. The widespread installation of small wind-power turbines to generate a power supply for herder campsites, however, is very limited.

2.4 Evaluation of the power generation potential of solar energy

With regard to levels of solar radiation, Tyva is one of the leading regions in Russia. The Siberian anticyclone ensures the maximum number of sunny days during winter when both the sun’s inclination over the horizon is at its lowest and the length of the day is at its shortest.

If solar panels are installed at 55° to the horizontal, a maximum input of solar radiation per square unit of 4.65 kWh/m² is achieved. Maximum solar radiation input occurs in the southern regions of the Republic within the Ubsunur Basin where nomadic sheep herding is most common.

Another favourable factor with regard to the development of solar power generation in Tyva is the Republic’s low average temperatures (-2°C to -4°C). These allow for maximum coefficient of performance (COP) for solar power systems to be reached.

The average number of sunny days per year in Kyzyl is more than 200, while in southern and western regions this figure is even higher. During the coldest times of the year, almost all the days are clear of clouds. This allows solar PV systems without batteries to be exploited, thus reducing the cost of a solar PV system considerably.
Solar energy can be used by PV generators of any capacity in both a centralized and decentralized manner. Neighbouring China and Mongolia, both of which have comparable figures for solar radiation, have experience in implementing solar power generation projects of various size and capacity.

In 2010, construction of the world’s largest solar power plant with 2 GW total capacity began in Inner Mongolia (China). The plant is scheduled to be completed by 2020. The project is being implemented with support from American and Chinese investors.

Mongolia is implementing the State-funded program “10000 Solar Powered Yurts” and the World Bank’s Renewable Energy Action Plan (REAP) which has helped install more than 40,000 low capacity solar PV systems.

Germany, where solar radiation level is considerably lower than in Tyva, is a leader in Europe with regard to total installed capacity (17 GW).

Tyva has implemented the State Special Purpose Program “Energy saving and developing alternative energy resources”. This has helped to install some decentralized power generation systems, but the potential of this renewable energy is largely not being exploited.
2.5 Analysis of energy resource use for herder camps

Technological solutions for providing power supply to herder camps in Tyva have to meet a number of criteria. For instance, they must be mobile, independent and able to generate electricity all year round.

<table>
<thead>
<tr>
<th>Consumer characteristics</th>
<th>Technological requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nomadic way of life</td>
<td>Mobility</td>
</tr>
<tr>
<td>Remoteness from electricity grid</td>
<td>Independence</td>
</tr>
<tr>
<td>All-year-round farming</td>
<td>All year round generation</td>
</tr>
</tbody>
</table>

Wind power, solar power and, with some assumptions, biogas power generation meet the technological requirements. The feasible technological solutions for supplying power to herder camps are listed below.

![FIGURE 15: Natural and technologically feasible potential of renewable energy use in Tyva Republic](image)

**TABLE 2: Technologies for providing decentralized power supply to agricultural producers – advantages, operational limitations and risks**

<table>
<thead>
<tr>
<th>Power supply technologies</th>
<th>Advantages</th>
<th>Operational limitations</th>
<th>Operational risks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel/gasoline generators</td>
<td>• Rapid start-up • Low capital commitment • Large number of products in the market • Uses commonly available fuel</td>
<td>• Operational life is 3,000-10,000 hours. Subsequently, engine requires thorough overhaul • Impossible to regulate output (operates at 75-100% of power rating) with large proportion of electricity produced being wasted • Non-stop operation time is no more than 8-12 hours a day • High level of noise (70-80 dB) • Generators must be placed indoors in a separate room with a temperature above 0°C, otherwise its operational life becomes shorter • fuel needs to be delivered • high operational costs • atmospheric pollution</td>
<td>• Price of diesel increases • Do-it-yourself repairs &amp; maintenance is impossible • Fuel is unavailable</td>
</tr>
</tbody>
</table>
| **Gas generators** | - Rapid start-up  
- Low capital commitment  
- Large number of products in the market | - Operational life is shorter than for diesel generators (3,000 – 6,000 hours), Subsequently, engine requires overhaul  
- Low-capacity gas generators have much the same limitations as diesel generators | - Risk of restriction in supply of liquefied gas & sharp increase in price if state regulation of prices ceases  
- Difficult to store gas  
- Do-it-yourself repairs & maintenance is impossible |
| **Gas & diesel generators with batteries** | - Requires less operational time a year  
- Requires lower operational costs & less frequent overhaul | - No rapid start-up & higher capital commitment  
- Fuel needs to be delivered | - Prices of gas & diesel increase  
- Do-it-yourself repairs & maintenance is impossible  
- Capacity of batteries reduces in winter |
| **Biogas generators** | - Resources are commonly available  
- Reliability  
- Extra output in addition to heat & electricity | - Require factory-type cattle farming & considerable amount of organic waste that is not easy to collect under nomadic herding | - Are not designed to operate under low temperatures & might not work during winter  
- Do-it-yourself repairs & maintenance is impossible |
| **Wind turbines with batteries** | - Portable  
- No need for regular servicing | - Output starts from 3 m/s wind speed | - IUCF is very low  
- During periods of winter calm, generator would not work |
| **Vertical-axis wind turbines with batteries** | - Can operate at lower wind speeds than horizontal-axis wind turbines | - Output starts from 1.4 m/s wind speed  
- Under Tyvan average wind speed of 3.2 m/s generator works at 10-12% of power rating | - IUCF is too low During periods of winter calm, generator would not work |
| **Wind-diesel hybrid power systems** | - Moderate capital investment | - Due to low wind speed, most of the power supply must be provided by diesel generator (with all its operational limitations) | - Up to 90% of electricity output has to be generated by diesel power (with all the risks involved) |
| **PV systems with storage batteries** | - Do not require servicing  
- Easy to operate  
- Independent | - High capacity PV systems are not portable (take up a large area & require professional installation) | - Capacity of batteries reduces in winter |

Taking into account the considerable limitations of wind, biogas and small hydropower generation in Tyva, a continuous power supply for herder camps can be provided by conventional diesel and gas generators (with or without storage batteries) or by small solar PV systems. Conventional generators involve considerable risks and operational costs relating to the purchase of fuel.
Chapter 3 – Selection of technological options to provide power supply for herder camps and an evaluation of their effectiveness

3.1 Analysis of power supply needs for herder camps and selection of suitable technologies

Three standard technologies of power supply provision based on solar PV systems (polycrystalline modules) and storage batteries were developed for herder farms in the Republic. All three technologies differ according to the capacity of solar PV modules and the capacity of the peak inverter (see Appendix). Technologies with greater power capacity are designed for agricultural producers with large herd sizes and for those interested in more advanced processing of their products.

A standard design for providing continuous power supply includes:
• Power generator (solar PV modules, diesel or gasoline generator)
• Electricity accumulation system (charge controller, storage batteries and inverter).

A charge controller is required to regulate the cycles of battery charge and discharge and to prevent them breakdown.

Storage batteries are used to accumulate power that has been generated and the discharge of that power is determined by the consumer’s needs at any one time. During the generation period for solar PVs, power goes directly to the consumer because accumulation and transformation involves a 5-10% loss of electricity.

The inverter transforms DC electricity into AC voltage electricity which is used in household and industrial appliances. During the start-up of a generator, the inverter may temporarily provide higher output than the rated value.

Installing solar panels at 55° to the horizon allows one not only to increase annual solar radiation input per unit surface area, but also to even out the difference between the amount of power generated in winter and in summer (from 5 to 2 times). The remaining difference is evened out by the charge controller. The output amount of electricity therefore remains the same during the year.
The maximum capacity of the solar PV system is determined by the power capacity of the inverter, while the maximum amount of electricity supplied is governed by the power generator. Power source for such a system is interchangeable.

**FIGURE 16: Principal layout of a solar PV and breakdown of capital costs**

![Principal layout of a solar PV](image)

Each system can work independently for 48 hours. One of the principles of this technology is ‘additivity’, ie. power generation can be increased if additional solar panels and storage batteries are connected, or if the generator is replaced by a more powerful one.

In winter, it is advised that storage batteries be placed inside yurts and house belonging to herders to prevent the risk of capacity being lost. According to their technical specifications, storage batteries can work at temperatures higher than -20°C.

**TABLE 3: Basic technical characteristics for solar power systems of various capacities**

<table>
<thead>
<tr>
<th>Mini solar power plant</th>
<th>Basic solar PV system (portable or static)</th>
<th>Extended solar PV system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inverter capacity 1.4 kW</td>
<td>Inverter capacity 5 kW</td>
<td>Inverter capacity 15 kW</td>
</tr>
<tr>
<td>Annual output 900 kWh</td>
<td>Annual output 2,920 kWh</td>
<td>Annual output 10,920 kWh</td>
</tr>
<tr>
<td>Lighting Household appliances Pump Refrigerator to store produce Sheep clippers</td>
<td>Lighting Household appliances Pump Refrigerator to store produce Sheep clippers Wood processing machine</td>
<td></td>
</tr>
</tbody>
</table>
Because of the high number of sunny days a year and sufficient rated capacity of storage batteries, an emergency gasoline or diesel generator is not required for solar PV operation in Tyva.

Herders can optimize their consumption and use of additional equipment. The following principles must be applied:

- **Installing of energy-saving equipment**
  Power consumption of energy-saving and conventional equipment may differ by 2-4 times. For example, using energy-saving fridges instead of conventional ones can help to increase milk production by a factor of two without needing to install additional and expensive solar panels.

- **Using solar PV only for electricity generation**
  Transforming electricity produced through solar PV into heat is not advisable as the COP of the process is less than 10% and the cost of such heat exceeds the cost of electricity. The most economically efficient method of providing heat for herder camps is by burning firewood and other organic materials.

- **Optimization of power consumption over time**
  Smoothing out power consumption peaks during the day helps to increase the efficiency of solar power plants. One of the possible options is to use energy-intensive equipment, such as water pumps and wood-processing machines, at different times of the day.

- **Cooperation of agricultural producers**
  If producers were to cooperate, herders may only need to undertake in their camps the primary processing of their produce which does not require costly and energy-intensive equipment. Further processing can take place at specialized small-scale processing plants that use grid electricity or solar power plants of 15 kW capacity or more and which are located within easy reach of a number of herder camps.

### 3.2 Economic effectiveness of proposed technological options

The economic effectiveness of proposed technologies is assessed through comparative analysis of accumulated operational costs of continuous power supply in systems based on solar PV and other power generation systems. Effectiveness was also assessed for grid electricity and diesel generators.
Accumulated operational cost consists of the initial costs of installation, or capital expenses (CAPEX), and the operational costs throughout the plant’s operational life. Thus:

$$\text{accumulated operational cost of a power supply system} = \text{CAPEX} + \sum_{i=1}^{n} \frac{\text{OPEX}}{(1+r)^i} \cdot D^n$$

where CAPEX = capital expenses, OPEX = operational cost, r = discount rate, D = increase in price of electricity/diesel/gasoline and n = number of years in operation.

### TABLE 4: Calculation of operational expenses for various power supply technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Method of calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV system</td>
<td>RUB 2,000 per year to dust solar panels</td>
</tr>
<tr>
<td>Grid electricity</td>
<td>Electricity supply rate (RUB 3.5/kWh) x consumed amount (kWh)</td>
</tr>
<tr>
<td>Diesel/gasoline/gas generator</td>
<td>Price of fuel (RUB 29-31/l) x servicing inflation index (1.2) x fuel consumption per hour (0.93-3.65 l/h) x average operational time (8 hours a day, 365 days a year)</td>
</tr>
<tr>
<td>Diesel/gasoline/gas generator as part of a continuous power supply system</td>
<td>Price of fuel (RUB 29-31 /l) x servicing inflation index (1.2) x fuel consumption per kWh (0.3-0.9 l/kWh) x generated output (kWh)</td>
</tr>
</tbody>
</table>

The discount rate used in the calculation is 10%. This is 2% higher than the refinancing rate of the Central Bank of Russia (8%) and 1.4% higher than the official inflation index in Russia (8.6%).

The official increase in diesel and gasoline prices in the region is 12% a year, i.e. it exceeds the discount rate by 2%, but is considerably lower than the increase in diesel price in 2010 (23%). The calculation does not include the expense of delivery fuel to herder camps, i.e. the increase in diesel generation costs is viewed as being very conservative.

The increase in the price of gas is taken at 20% per annum, this being lower than the average annual increase in tariff for piped gas (25%). Even now and despite state regulation of the retail price, the price of liquidized gas in Tyva (RUB 31 /kg) is higher than the average for Russia.

The official increase in electricity price in Russia is set at 15%, which is also a conservative valuation. The urgent need to renovate facilities and the problem of non-payment inherent in Tyva only aggravates the negative pricing effects of liberalising the electricity market in Russia.

**Economic effectiveness of installing a solar power plant of 1.4 kW capacity and similar units**

Diesel and gas generators of low capacity (1.4 kW) do not exist. Therefore, the only alternative to a mini solar power plant is a gasoline generator of 1-1.5 kW capacity that has a relatively short lifespan (3,000 operational hours). The cost of a gasoline generator varies between RUB 30,000-40,000 per 1 kW. However, fuel consumption is exceptionally high and reaches 1 litre per 1 kWh. If the system operates without storage batteries, the operational cost of 1 kWh reaches RUB 160, mainly because most of the generated power is wasted.

Therefore, an independent system of continuous power supply comprising a gasoline generator with storage batteries is more effective with regard to accumulated operational cost than when compared with using a gasoline generator only.

A significant disadvantage of a gasoline generator, in addition to its extremely high operational cost and limited non-stop operational time, is the need to overhaul the engine every 1-2 years due to wear and tear.
Economically, gasoline generators are not competitive with either grid power supplies or mini solar power plants.

**FIGURE 18: Accumulated operational cost of various conventional power supply systems of 1 kW capacity (gasoline generators)**

**FIGURE 19: Accumulated operational cost of various power supply systems based on conventional energy, solar PV and grid electricity of 1 kW capacity**
Calculations show that mini solar power plants of 1 kW capacity are cheaper (RUB 250,000-300,000 per 1 kW) than is connection to the grid. If there are no electricity lines or a substation transformer, the latter costs RUB 300,000 per 1 kW. A mini solar power plant can be repaid within 3-4 years, much faster than a gasoline generator with batteries. Therefore, even for those small-scale consumers who are located within easy reach of grid electricity but who face the high cost of being connected to the grid, solar power generation is cost-effective.

*Economic effectiveness of installing a solar power plant of 5 kW peak capacity and similar units*

There are both gas and diesel generators of 5 kW capacity available on the market. The cost of 1 kW installed capacity varies between RUB 15,000-70,000 and depends on the engine’s fuel consumption and service life. If such a power generator is connected to the grid, the cost increases to between RUB 250,000-300,000 per kW.

Gas prices increase faster than diesel prices, so a continuous power supply based on gas generators is more expensive than one based on diesel. However, the operational expenses of gas generators are currently lower than diesel ones, i.e. RUB 12/kWh and RUB 20/kWh, respectively, if the system includes storage batteries and RUB 60/kWh and RUB 70/kWh if it doesn’t.
Therefore, in this case again, solar power generation is more cost-efficient.
The accumulated operational cost of power supply through a solar PV of 5 kW capacity (at a cost of RUB 400,000 per 1 kW) will be the same as for a diesel generator within a continuous power supply system over a period of 9-10 years. However, it will be more expensive than grid electricity over the whole operational period.

- **Economic effectiveness of installing a solar power plant of 15 kW peak capacity and similar units**

The most cost-effective of all conventional power generation systems of 15 kW capacity and with outputs of 30 kWh per day is a diesel generator supplemented with storage batteries.

The system has a low operational expense (RUB 9/kWh) and the increase in cost over time is moderate (12% per year). However, its cost is similar to that of a solar power plant (RUB 220,000 per kW and RUB 330,000 per kW, respectively).

The lowest capital investment value is again that of the gas generator, ie. RUB 15,000-20,000 per kW.
FIGURE 24: Accumulated operational cost of various conventional power supply systems of 15 kW capacity

FIGURE 25: Accumulated operational cost of various power supply systems of 15 kW capacity based on conventional power generation, solar PV and grid electricity
Solar power generation systems of 15 kW capacity and higher have longer period of return on investment compared with the 13-14 years for diesel power generation. However, within 18-19 years, their operational cost will be comparable to that of grid electricity.

Thus, the accumulated operational cost of solar power generators is lower than those of diesel and gas generators, even if the price of fuel and rates increase moderately. In some cases, their operation can be cheaper than the cost of grid electricity.

With solar power generation, the problem of supplying fuel no longer exists. A diesel power generation system of 15 kW capacity requires 9 tonnes of diesel a year, equivalent to a tanker-trailer load. There are also additional transportation costs. In some situations, delivery of fuel may not be feasible.

**TABLE 5: Rating technological options for providing continuous power supply**

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Mini solar power plant (1.4 kW)</th>
<th>Basic system (5 kW)</th>
<th>Extended system (15 kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowest capital investment</td>
<td>Gasoline generator</td>
<td>Gas generator</td>
<td>Gas generator</td>
</tr>
<tr>
<td></td>
<td>2. Grid electricity</td>
<td>2. Grid electricity</td>
<td>2. Grid electricity</td>
</tr>
<tr>
<td></td>
<td>3. Gasoline generator with storage batteries</td>
<td>3. Gas generator with storage batteries</td>
<td>3. Gas generator with storage batteries</td>
</tr>
<tr>
<td>Lowest accumulated operational cost</td>
<td>Solar PV</td>
<td>Grid electricity</td>
<td>Solar PV</td>
</tr>
<tr>
<td>Least technological risks</td>
<td>Solar PV</td>
<td>Solar PV</td>
<td>Solar PV</td>
</tr>
<tr>
<td>Least technological limitations</td>
<td>Solar PV</td>
<td>Solar PV</td>
<td>Solar PV</td>
</tr>
</tbody>
</table>
3.3 Possible funding mechanisms for providing power supply to herder camps

The average per capita income in Tyva Republic is RUB 80,000-90,000 a year. The largest segment of the population below the poverty line is made up of farmers. This situation limits the possibilities of introducing even the cheapest form of power generation technology, such as mini solar power plants of 1 kW capacity.

Most agricultural producers in the Republic cannot afford to buy power supply systems of over 10 kW capacity. These could help to move from subsistence to commercial farming and form a base for building up a value-added chain.

**FIGURE 27: Possible sources of funding for solar PV installation**

Experience in the implementation of development projects in neighbouring countries, specific features of housing and communal services in Tyva and the possibility of attracting foreign direct investment into the Republic provide a number of opportunities to create funding mechanisms to help develop solar power generation. Necessary funding can be raised from:

- **Republican budget**
  
  Every year, the republican budget pays out approximately RUB 100 million to subsidize electricity rates for those consumers supplied with power produced by diesel generators of 5.5 MW total capacity. If these funds were annually spent on installing independent solar PV systems, the same capacity of solar power generation could be installed within 15-18 years and diesel generators would no longer be needed. Municipalities could either own solar power plants or provide grants to enable them to be bought.

  Budgetary funds can also provide guarantees for loans, thereby facilitating the provision of loans for those farmers who do not have any suitable property to act as collateral.

  Being responsible for providing subsidies to the republican budget, the federal budget will benefit from replacing diesel generators with solar power plants. Therefore, it is advisable to incorporate a set of activities aimed at renewable energy development in Tyva into one of the federal special purpose programs that support agriculture or housing and utilities services.
Regional Special Purpose Program “Energy saving and development of alternative sources of energy” in Tyva Republic

Tyva has experience of stimulating renewable energy developments through state investment. The Program, funded mostly from the regional budget and launched in 2008, was aimed at implementing pilot projects to provide solar PVs for various sectors of the economy. The total amount of funding was RUB 9 million. Some of the Program’s results include the installation of a solar power generation system in the Yeniseiskaya plant and the construction in Kyzyl of lighting systems based on solar energy. Due to budget cuts caused by a reduction in the amount transferred from the federal budget, the Program was not extended. Many of its concepts, however, were included in the Republican program relating to increasing energy efficiency.

- Development institutions

Development institutions can play a key role in the early stages of solar power generation development. They contribute to the building of financial infrastructure and are able to attract private and banking capital into the projects. For example, in late-2010, the International Financial Corporation (IFC), with support from the Global Environment Facility (GEF), launched the Russia Renewable Energy Program. The Program is aimed at *inter alia* developing funding schemes for supporting renewable energy projects through private banks. Another institution that has experience in developing funding mechanisms for renewable energy projects is the World Bank.

Renewable Energy for Rural Access in Mongolia, World Bank Program

Mongolia has a similar problem of supplying power to farmers. In 2006, over 30% of its households had no electricity supply. To develop decentralized solar power generation in isolated areas of Mongolia, the World Bank in 2006 began a USD 23 million project.
A large portion of the Program’s funds was spent on grants to farmers to buy solar PVs of up to 100 W capacity to satisfy household power supply needs. The grants covered up to 50% of the total cost. The remaining portion of the funds was spent on developing a system of loans to farmers (secured by their cattle) by private banks.

The Program also funded the construction of two solar power plants totaling 300 kW capacity in the Gobi-Altai District (aimak). These were opened during the summer of 2010.

• Private sector

A number of foreign companies invest in large-scale (over USD 10 million) infrastructure and mining projects in Tyva. Encouraging the private sector to fund programs to support indigenous people and to pay environmental compensations as part of its social responsibility policies may provide an additional source of funding for renewable energy projects.

For example, such social responsibilities are acted upon by the OJSC Gazprom and its subsidiary companies working in oil and gas development in western Siberia. Companies such as ALROSA, Norilsk Nickel, NOVATEK and others take part in programs to support indigenous people.

Combining the efforts of authorities, NGOs, development institutions and the private sector can provide new opportunities for developing a mechanism for funding solar power generation in the Republic. The realisation of the existing potential for solar energy exploitation will not only considerably increase the efficiency of power supply systems, but will also allow agricultural producers in Tyva to successfully develop without changing their traditional way of life.
Conclusions

The bulk of agricultural produce in Tyva is produced by small-scale farms and households herding sheep in steppe areas in the south and west of the Republic and producing marketable wool and milk. This sector makes up 11% of the Republic's regional gross product.

The need to increase power supply for agriculture is caused not only by agriculture's important contribution to the regional gross product, but also by the serious problem of land degradation. Compared to the early-1990s, the area of rangeland has decreased by 70%, while the size of the livestock herd remains the same. In addition, due to the reduced mobility of rural populations, areas of overgrazed land develop around settlements. Degradation of steppe ecosystems in the Ubsunur Basin is of international concern, because part of Ubsunur Federal Nature Reserve is designated as a UNESCO World Heritage Site.

Tyva is 90% dependent for its electricity supply on power generation systems in neighboring regions. There are, however, plans to develop power generation infrastructure in Tyva, e.g. investment projects prepared by FGS UES, TGC-13 and RusHydro. Even the partial implementation of these projects would substantially improve the situation with regard to power supply in the Republic.

Nevertheless, the supply of power in the main agricultural areas of Tyva, which are presently supplied with diesel-generated electricity or have no power supply at all, is very unlikely to improve. The main reasons for this are:

- Location of future generating capacity
- No plans to develop distribution power lines
- Low density of population and nomadic way of life.

The power supply systems that exist in agricultural areas are highly inefficient and in need of modernisation. This is due to:

- High price of diesel fuel in the region
- Budgets are overburdened with costs relating to the maintenance of current infrastructure
- Diesel generators have limited portability due to the need to supply fuel.
All these factors explain why agriculture in Tyva is in urgent need of technological options for decentralized power generation based on renewable energy. From both the local climate and the economic points of view, solar power generation is the most effective option.

With regard to levels of solar radiation, Tyva is one of the leading regions in Russia. If solar panels are installed at 55° to the horizontal, the input of solar radiation per unit area reaches its maximum (4.65 kWh/m²). Southern areas of the Republic within the Ubsunur Basin, that area of the Republic sheep herding has developed the most, enjoy the highest levels of solar radiation.

Power supply for herder camps can therefore presently be provided using conventional diesel generators or low capacity solar power plants.

Three technological options are proposed for use in herder farms in the Republic. They are all based on solar PV and storage batteries, but differ according to solar module capacity and the peak capacity of the inverter.

A mini solar power plant (generating 2.43 kWh per day) is portable, meets most household needs with regard to electricity and can partially provide electricity for pumping water and the temporary storage of milk and dairy products.

The basic option (generating 8 kWh per day) is aimed at meeting household electricity needs and providing a power base for the primary processing of agricultural produce, i.e. storage of milk and shearing of sheep. The equipment can be purchased as a portable unit with a system of easy-to-erect mounts and be delivered by a commercially-hired van.

The extended option (generating 30 kWh per day) is aimed at providing a power base for processing agricultural produce, but includes advanced processing such as a milk separation and pasteurization line, or a cheese production line. Such equipment, however, is not portable.

Herders have the option of optimizing their consumption by installing additional equipment if they follow the principles listed below:

- Using energy-saving equipment
- Using a solar PV system for electricity generation only
- Optimization of energy consumption over time
- Cooperation with other agricultural producers.

The economic effectiveness of the proposed technological options was evaluated by comparing accumulated operational cost of solar PV systems, conventional power generation and grid electricity. The accumulated operational cost of solar power generators is lower when compared with the accumulated operational cost of diesel generators and, in some cases, with grid electricity, even under a conservative scenario of increases in fuel prices and rates.

Low average income and lack of property as collateral when taking out loans bring about the need to develop funding schemes. Potentially, funds can be raised from the following market stakeholders:

- Republican budget
- Development institutions
- Private sector.

Combining the efforts of such stakeholders has already proved its effectiveness in neighbouring Mongolia and could be applied within the Tyva Republic. The realization of the potential for solar power generation will not only raise the efficiency of the power supply system, but will also allow Tyvan agricultural producers to successfully develop themselves without destroying their traditional way of life.
Appendix – Description of technological options for herder camps

Mini solar power plant (inverter capacity is 1.4 kW)

A mini solar power plant (output is 2.43 kWh per day) is portable, meets most household electricity needs and can partially provide electricity for pumping water and the temporary storage of milk and dairy products.

**Minimal household needs:**

<table>
<thead>
<tr>
<th>Appliance or equipment</th>
<th>Capacity, W</th>
<th>Period of operation, hours</th>
<th>Demand for electricity, Wh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refrigerator</td>
<td>150</td>
<td>7</td>
<td>1,050</td>
</tr>
<tr>
<td>Television</td>
<td>100</td>
<td>4</td>
<td>400</td>
</tr>
<tr>
<td>Lighting</td>
<td>30</td>
<td>10</td>
<td>300</td>
</tr>
<tr>
<td>Submersible pump/electric kettle</td>
<td>1,200</td>
<td>0.4</td>
<td>480</td>
</tr>
<tr>
<td>Battery charger</td>
<td>10</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1.4 kW</strong></td>
<td></td>
<td><strong>2.33 kWh</strong></td>
</tr>
</tbody>
</table>

*This option includes the following equipment:*

<table>
<thead>
<tr>
<th>Item of equipment</th>
<th>Number of units</th>
<th>Price (in Roubles including VAT)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto power inverter</td>
<td>1</td>
<td>22,000</td>
<td>22,000</td>
</tr>
<tr>
<td>Charger controller</td>
<td>1</td>
<td>15,000</td>
<td>15,000</td>
</tr>
<tr>
<td>Solar module</td>
<td>4</td>
<td>29,000</td>
<td>11,600</td>
</tr>
<tr>
<td>Storage batteries</td>
<td>4</td>
<td>5,500</td>
<td>22,000</td>
</tr>
<tr>
<td>Connecting wire</td>
<td>20</td>
<td>130</td>
<td>2,600</td>
</tr>
<tr>
<td>Storage battery wire</td>
<td>30</td>
<td>230</td>
<td>6,900</td>
</tr>
<tr>
<td>Battery charger</td>
<td>1</td>
<td>12,700</td>
<td>12,700</td>
</tr>
<tr>
<td>Airtight connectors</td>
<td>8</td>
<td>190</td>
<td>1,520</td>
</tr>
<tr>
<td>Fuse box</td>
<td>1</td>
<td>3,528</td>
<td>3,528</td>
</tr>
<tr>
<td>String Box</td>
<td>1</td>
<td>32,500</td>
<td>32,500</td>
</tr>
<tr>
<td>Set of mounting profiles</td>
<td>4</td>
<td>910</td>
<td>3,640</td>
</tr>
<tr>
<td>Support pillars</td>
<td>4</td>
<td>500</td>
<td>2,000</td>
</tr>
<tr>
<td>Set of fasteners</td>
<td>4</td>
<td>86</td>
<td>344</td>
</tr>
<tr>
<td>Corrugated pipe</td>
<td>100</td>
<td>8</td>
<td>800</td>
</tr>
<tr>
<td>Cost of assembly</td>
<td>12%</td>
<td></td>
<td>28,984</td>
</tr>
<tr>
<td>Other and contingencies</td>
<td>3%</td>
<td></td>
<td>7,246</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>277,762</strong></td>
</tr>
</tbody>
</table>
Basic option (inverter capacity is 5 kW)

The basic option (generating 8 kWh per day) is aimed at covering household electricity needs and provides a power base for the primary processing of agricultural produce, i.e. storage of milk and shearing of sheep. The equipment can be purchased as a portable unit with a system of easy-to-erect mounts and be delivered by a commercially-hired van.

Basic household needs, including some farm appliances:

<table>
<thead>
<tr>
<th>Appliance or equipment</th>
<th>Capacity, W</th>
<th>Period of operation, hours</th>
<th>Demand for electricity, Wh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm refrigerators</td>
<td>370</td>
<td>7</td>
<td>2,590</td>
</tr>
<tr>
<td>Television</td>
<td>100</td>
<td>4</td>
<td>400</td>
</tr>
<tr>
<td>Lighting</td>
<td>30</td>
<td>10</td>
<td>300</td>
</tr>
<tr>
<td>Submersible water pump</td>
<td>1,200</td>
<td>0.4</td>
<td>480</td>
</tr>
<tr>
<td>Battery charger</td>
<td>10</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>Electric kettle</td>
<td>1,200</td>
<td>0.5</td>
<td>600</td>
</tr>
<tr>
<td>Sheep shearing equipment/milk separator</td>
<td>370</td>
<td>7</td>
<td>2,240</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3.2 kW</strong></td>
<td></td>
<td><strong>7.4 kWh</strong></td>
</tr>
</tbody>
</table>

This option includes the following equipment:

<table>
<thead>
<tr>
<th>Item of equipment</th>
<th>Number of units</th>
<th>Price (in Roubles including VAT)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto power inverter</td>
<td>1</td>
<td>175,070</td>
<td>175,070</td>
</tr>
<tr>
<td>Charge controller</td>
<td>2</td>
<td>30,000</td>
<td>60,000</td>
</tr>
<tr>
<td>Solar module</td>
<td>24</td>
<td>29,000</td>
<td>696,000</td>
</tr>
<tr>
<td>Storage batteries</td>
<td>24</td>
<td>18,000</td>
<td>432,000</td>
</tr>
<tr>
<td>Control board</td>
<td>1</td>
<td>9,500</td>
<td>9,500</td>
</tr>
<tr>
<td>X-connect panel for 3 inverters</td>
<td>1</td>
<td>68,347</td>
<td>68,347</td>
</tr>
<tr>
<td>Temperature sensor</td>
<td>3</td>
<td>2,050</td>
<td>6,150</td>
</tr>
<tr>
<td>Connecting wire</td>
<td>4 mm²</td>
<td>130</td>
<td>6,500</td>
</tr>
<tr>
<td>Cable for storage batteries</td>
<td>25 mm²</td>
<td>230</td>
<td>11,500</td>
</tr>
<tr>
<td>Cable for storage batteries</td>
<td>50 mm²</td>
<td>805</td>
<td>20,125</td>
</tr>
<tr>
<td>Cable for charge controller</td>
<td>35 mm²</td>
<td>315</td>
<td>50,400</td>
</tr>
<tr>
<td>Battery rack</td>
<td>1</td>
<td>23,500</td>
<td>23,500</td>
</tr>
<tr>
<td>Airtight connectors</td>
<td>4 mm²</td>
<td>190</td>
<td>9,120</td>
</tr>
<tr>
<td>String Box</td>
<td>2</td>
<td>43,580</td>
<td>87,160</td>
</tr>
<tr>
<td>Set of mounting profiles</td>
<td>24</td>
<td>910</td>
<td>21,840</td>
</tr>
<tr>
<td>Support pillars</td>
<td>24</td>
<td>500</td>
<td>12,000</td>
</tr>
<tr>
<td>Set of fasteners</td>
<td>24</td>
<td>86</td>
<td>2,064</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>1,946,809</strong></td>
<td></td>
</tr>
</tbody>
</table>
Extended option (inverter capacity is 15 kW)

Extended option (generating 30 kWh per day) is aimed at providing a power base for processing agricultural produce, but includes advanced processing such as a milk separation and pasteurization line or a cheese production line. Such equipment is not portable. The inverter can provide an AC three-phase current, thereby allowing for the possibly of operating industrial machinery.

**Power supply needs of a small-scale farm processing and storing milk and dairy products:**

<table>
<thead>
<tr>
<th>Appliance or equipment</th>
<th>Capacity, W</th>
<th>Period of operation, hours</th>
<th>Demand for electricity, Wh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm refrigerator</td>
<td>370</td>
<td>7</td>
<td>2,590</td>
</tr>
<tr>
<td>Television</td>
<td>100</td>
<td>4</td>
<td>400</td>
</tr>
<tr>
<td>Lighting</td>
<td>30</td>
<td>10</td>
<td>300</td>
</tr>
<tr>
<td>Submersible water pump</td>
<td>1,200</td>
<td>0.4</td>
<td>480</td>
</tr>
<tr>
<td>Battery charger</td>
<td>10</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>Electric kettle</td>
<td>1,200</td>
<td>0.5</td>
<td>600</td>
</tr>
<tr>
<td>Sheep shearing equipment</td>
<td>370</td>
<td>7</td>
<td>2,240</td>
</tr>
<tr>
<td>Wood processing machine</td>
<td>2,000</td>
<td>2</td>
<td>4,000</td>
</tr>
<tr>
<td>Milk separator</td>
<td>550</td>
<td>5</td>
<td>2,750</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>6.3 kW</strong></td>
<td></td>
<td><strong>26.7 kWh</strong></td>
</tr>
</tbody>
</table>

This option requires the following equipment:

<table>
<thead>
<tr>
<th>Item of equipment</th>
<th>Number of units</th>
<th>Price (in Roubles including VAT)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto power inverter</td>
<td>3</td>
<td>175,070</td>
<td>525,210</td>
</tr>
<tr>
<td>Charge controller</td>
<td>5</td>
<td>30,000</td>
<td>150,000</td>
</tr>
<tr>
<td>Solar module</td>
<td>60</td>
<td>29,000</td>
<td>1,740,000</td>
</tr>
<tr>
<td>Storage battery</td>
<td>60</td>
<td>18,000</td>
<td>1,080,000</td>
</tr>
<tr>
<td>Control panel</td>
<td>1</td>
<td>9,500</td>
<td>9,500</td>
</tr>
<tr>
<td>X-connect panel for 3 inverters</td>
<td>1</td>
<td>68,347</td>
<td>68,347</td>
</tr>
<tr>
<td>Temperature sensor</td>
<td>3</td>
<td>2,050</td>
<td>6,150</td>
</tr>
<tr>
<td>Connecting wire</td>
<td>100</td>
<td>130</td>
<td>13,000</td>
</tr>
<tr>
<td>Cable for storage batteries</td>
<td>100</td>
<td>230</td>
<td>23,000</td>
</tr>
<tr>
<td>Cable for storage batteries</td>
<td>50</td>
<td>805</td>
<td>40,250</td>
</tr>
<tr>
<td>Cable for controller</td>
<td>400</td>
<td>315</td>
<td>126,000</td>
</tr>
<tr>
<td>Battery rack</td>
<td>3</td>
<td>23,500</td>
<td>70,500</td>
</tr>
<tr>
<td>Airtight connectors</td>
<td>120</td>
<td>190</td>
<td>22,800</td>
</tr>
<tr>
<td>String Box</td>
<td>5</td>
<td>43,580</td>
<td>217,900</td>
</tr>
<tr>
<td>Set of mounting profiles</td>
<td>60</td>
<td>910</td>
<td>54,600</td>
</tr>
<tr>
<td>Support pillars</td>
<td>60</td>
<td>500</td>
<td>30,000</td>
</tr>
<tr>
<td>Set of fasteners</td>
<td>60</td>
<td>86</td>
<td>5,160</td>
</tr>
<tr>
<td>Corrugated pipe</td>
<td>200</td>
<td>8</td>
<td>1,600</td>
</tr>
<tr>
<td>Cost of assembly</td>
<td>11%</td>
<td>460,242</td>
<td></td>
</tr>
<tr>
<td>Other parts and contingencies</td>
<td>4%</td>
<td>167,361</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>4,811,620</strong></td>
</tr>
</tbody>
</table>