Small-Scale Energy Development in Northeast Asia: Experience, Prospects and Social Implications of Solar PV in Mongolia

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The priority for small-energy development in many cases is economic growth and the alleviation of poverty. As of today, one-third of the world's population has no access to commercial energy. Many live in low-income developing countries, including some in Northeast Asia.

Small-scale energy development may play a key role in the eradication of disparities in standards of living, per capita electricity consumption, access to information and modern communications, and medical and educational services. On the other hand, it is necessary to develop renewable energy resources. The development of small-scale energy systems may play a part in increasing social stability. Government subsidies, incentives encouraging the utilization of renewable energy sources and the inclusion of these in the national energy policy portfolio are needed.

This paper looks at the utilization of solar PV (photovoltaics) in Mongolia as an example of small-scale clean energy.

1. Introduction

The priorities for small-scale energy development in many cases are the support of economic growth and alleviation of poverty. At present, such as the 40% or so of the Mongolian population that currently has no access to electricity.

Small-scale energy development may play a key role in the eradication of disparities in standards of living, per capita electricity consumption, access to information and modern communications, and medical and educational services. On the other hand, it is necessary to develop and use renewable energy resources, including solar energy.

2. Renewable energy sources

Wind energy: In Mongolia, the wind blows anywhere and at any time. The potential reserve of wind energy is 836.8 billion kilowatt hours (kWh), with an average possible utilization period of 3,500-4,600 hours each year. An average wind velocity of 4-5 m/s prevails in the southeastern part of the country, covering 60% of the territory with a wind energy reserve of over 100 Watts per square meter (W/sq. M).

There are 52 soums[1] in this part of the country, where 100-150 kW wind turbine generators could be installed. Some projects for evaluating wind generators operating in tandem with existing diesel generators or the grid network are under consideration.

Smaller 50W windmills manufactured by the domestic company Monmar Co., Ltd. are available for 167,000 togrog (MNT)[2], for use in pastoral livestock farming, but not in sufficient quantity. 3-5 kW windmills have been approved for use in activities involving greater consumption, such as water pumping and powering some facilities at summer settlements. Winter settlements are usually established on windless, sunny sites. The publication of the Wind Energy Atlas of Mongolia by the National Renewable Energy Laboratory (2001) of the U.S. Department of Energy will be very useful for designing wind power generators.

Solar energy: Mongolia, the "Land of Blue Sky", enjoys more than 260 sunny days a year, typically between 2,250 and 3,300 hours each year. There are no more than two consecutive days without sun. Its average altitude of about 1,600 meters above sea level provides comparatively favorable conditions for the utilization of solar energy (Tsegmid 1969). It is estimated that the southern part of the country receives on average between 4.3-4.7 kWh/sq. m of solar energy per day. Solar PV research work, which started at the beginning of the 1970s, showed that, compared with diesel/gasoline generators, PV modules are just as feasible for the purposes of powering radios, portable TV sets, lighting ger[3], meeting soum hospitals' needs, pumping water, and for radio relay transmission trunk lines. Currently about 3% of herder families use solar PV modules for lighting purposes.

Hydro-energy: In Mongolia, about 20 hydro sites have been identified, with installed capacities ranging from 5 Megawatts (MW) to 110MW. However, these are mainly situated in the mountainous western part of Mongolia, far from the central grid. Therefore, these resources would probably be expensive to develop. A couple of projects have been devised, which involve constructing hydroelectric power stations to be connected to the existing network in order to decrease the peak hour load and reduce imports of electricity from abroad. Some micro hydroelectric generators are in use at summer settlements.

Conventional ovens for cooking in and heating ger: For cooking purposes, the utilization of gas stoves with an appropriate scheme of gas provision could also be considered. Fuel (wood, coal, animal dust, etc.) fuller burning and smokeless ovens are chosen for local

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1 Rural district in Mongolian prefectures
2 Mongolian currency unit: MNT 1124 = US$1, as of late 2002
3 Tent made from felt forming the traditional residence of herders

production and distribution to those living in ger. (Khuldorj 1999). On the other hand, recent proposals[4] for cooperation with Russia in the field of natural gas allow its practical use in households (cooking and heating).

Other sources of energy: Bioelectricity has been proven to be a feasible option for meeting the current and projected electricity needs of rural areas in many developing countries. There are about 50 remote villages in the northern part of Mongolia where biogasifiers could be feasible.

3. Solar PV cells and their utilization

PV systems can be installed in remote villages or homes. Solar PV cells are proven to be capable of converting 15% of incident solar energy into electricity. Their modularity enables them to deal with loads ranging from a few milliwatts to several megawatts. Solar PV could be the energy technology of choice for many households, hospitals, schools, farmers, and telecommunications companies. Home PV systems are most economical in remote locations and can be used to power lights or small appliances such as radios/TV sets. A 50W solar PV system provides approximately 10 to 15 kWh/month to a household.

PV systems can be used to power vaccine refrigerators, sterilization equipment, emergency radios and other critical loads, lighting and computers. The cost of PV modules per watt of generating capacity has decreased from $15 in the mid-1980s to around $4 today. There has been a rapid expansion in sales of household PV systems, with nearly a half a million installed in developing countries (World Bank 2002).

The use of PV systems results in improved quality of life through access to such services as education, medical care, and information to support small business development. The provision of lighting is the biggest incentive for rural households to introduce PV systems. A typical 50W solar PV system for household use offsets about 400 kg of CO_2 emissions annually (World Bank 2002).

Larger PV systems are used in remote areas to supply power for telecommunications and decentralized drinking water supply systems. Water supply ranges from as little as 0.3 liters per day for drip irrigation to over one thousand liters per day for a village water supply. Both residential and community use of PV can be promoted by such mechanisms as government subsidies. One example of this is the special program implemented in Japan, which subsidized the installation of grid-connected 3.5 kW PV systems in homes. (NEF 2002)

4. Pastoral livestock farming in Mongolia

Animal husbandry based on natural pastureland plays an important role in the Mongolian economy. The problem of electricity supply is the main obstacle to operating wells and increasing water supply. The country's 26 million livestock are farmed in the traditional pastoral way. About a third of pastures (total 129 million hectares) are not being used because of a shortage of water, putting a pressure on the pastureland that is utilized. Of the 24,600 wells built in the period up to 1991, only 8,200 were in operation in 2001 (Table 1). In the husbandry sector, about 185,500 families were engaged in producing primary livestock products, of which, only about 13% had access to electricity in 2001.

Table 1. Some Social Indicators of Herders in Mongolia

	1991	2001
Number of herders	245,000	407,000
Number of herder households	114,900	185,500
Number of herder households with electricity	12,300	24,800
Number of wells	24,600	8,200

Source: National Statistical Office of Mongolia (2002) Mongolian Statistical Yearbook 2001. Ulaanbaatar: NSO.

As a result of the loss of herds during "zhud"[5], the number of these families decreased by 6,000 in 2001 on the previous year. The pasture around urbanized settlements such as district and province centers is practically exhausted, because herders try to keep their herds as close as possible to markets and public services. As a consequence, a large portion of the nation's livestock has been lost. Such a situation should be corrected by all possible means, including better energy provision.

Urban and rural household inequalities are also growing wider. Increased exports of livestock products and the high share of the labor force engaged in the agricultural sector (49%) mean that greater attention should be paid to the problem of supplying electricity to such families. Tables 2 and 3 demonstrate that electricity consumption in Mongolia is at about the same level as in some countries of Central Asia. However, electrical power consumption by households in rural areas is very low and they could be considered to suffer from "energy poverty". The lack of a reliable electricity supply to herder families causes problems. Many families are completely without information about weather forecasts, markets and news due to the lack of power supply. Access to clean water sources is also limited, while the health and education services in remote areas are inadequate.

1) Use of solar PV for pastoral livestock farming

Mongolia's geographical and meteorological characteristics ensure that PV is the first choice in terms of renewable energy sources for use in pastoral livestock farming. Tests of PV modules designed to ascertain herding families' minimum demand for electricity showed that a

[4] Joint communique on the official visit of Prime Minister Mikhail Kasyanov of the Russian Federation to Mongolia, April, 2002, Ulaanbaatar, Mongolia, www.extmin.mn/kasianovCV.htm (30 May 2002).

[5] If the "zhud" natural disaster in 2000 resulted in a 10% loss from 33 million herds, then the one in 2001 will mean a 15% loss from 30 million herds. However, the reasons for these losses differ from one case to another. Herds die because of a shortage of feed or no access to dry grass, due to heavy snow fall on pastures covering large areas, or a lack of snow, which is a source of water (black zhud), and/or an extremely low temperature. Losses will also be incurred if there was a drought the previous summer.

Table 2. Electricity Production and Consumption in Mongolia

	1990	2001
Total resources, million kWh	3,576	3,213
Consumption, million kWh	2,719	1,948
-Agriculture, million kWh	116	17
-Communal housing, million kWh	349	476
Total population, million	2.0977	2.4425
-Urban population, million	1.1957	1.3971
-Rural population, million	0.902	1.0454
Electricity produced per capita, kWh	1,664.0	1,235.0
*Electricity consumed per capita, kWh	948.7	797.5
*Household electricity consumption per capita in urban areas, kWh	291.9	340.7
*Household electricity consumption per capita in rural areas, kWh	128.6	16.3

Source: National Statistical Office of Mongolia (2001), (2002) Mongolian Statistical Yearbook 2000 and 2001. Ulaanbaatar: NSO
* - derivative data

Table 3. Electricity Consumption in Some Countries (1999 data)

Country	Population, million	GDP, billion US dollars (1995)	Electricity consumption, kWh/capita
China	1,260.32	1,112.84	936
Mongolia	2.40	0.90	1,253
Kyrgyz	4.87	4.14	1,585
Turkmenistan	4.78	4.63	1,319

Source: International Energy Agency (2001). Key World Energy Statistics from the IEA 2001, Paris: OECD.

system of around 50W PV is economically feasible compared with gasoline generators. Feasibility analyses have also been carried out on other PV applications in pastoral livestock farming (Galbaatar and Nachin 1982).

The feasibility of PV use in ger has also been confirmed by research carried out by international organizations, including UNDP and NEDO (New Energy and Industrial Technology Development Organization), Japan. Based on the results of these tests, a project to construct a solar PV module assembly plant was drafted. This was later approved and 0.5MW PV modules can now be produced domestically. The products from this plant were primarily designed for installation on radio relay transmission trunk lines atop mountains. The government of Mongolia has announced the "100,000 solar ger" project (GOM 1999). Under the project's first stage, solar PV systems were installed in 826 herder homes, with 409 of those systems being capable of receiving TV broadcasts (GOM 2002).

2) PV modules for lighting ger

12W, 24W and 55W PV systems containing an automotive battery with a capacity of 30-70 Ampere hours (Ah), an electronic block to prevent overcharging /deep recharging, and a daylight tube have been designed for lighting ger. Installation costs range between 175,000-347,220 togrog or US$150-300. While 5,100 herder families are considered to have access to electricity, equipping the remaining 180,400 families would cost between US$27 million and US$54 million.

3) PV modules for soums

Currently there are about 200 soums that still have to use diesel generators because they are not yet connected to Mongolia's central electricity grid. Most of these diesel generators (each soum center has 2-3 diesel generator sets with a rating of 100-200 kW) run for a limited period of time, usually between 18:00-23:00, in order to save fuel. Annually, the central government provides about 5 billion togrog (US$5 million) of subsidies to run these generators. Since these diesel generators operate in the evenings, the installation of PV systems in high-priority public service facilities, including hospitals, schools, post and telecommunications offices, and water pumping units is needed.

4) PV modules for hospitals and schools

A 200W PV system, which is able to light 2-3 rooms and power a small refrigerator, is probably the smallest unit that could supply electricity to hospitals located in soum centers. For a school, a 250W PV system may be the smallest feasible size. However, installed capacity could be increased gradually according to the financial means and size of each hospital or school.

As mentioned earlier, because of interruptions to the electricity supply, the use of computers in schools and advanced medical equipment in hospitals is limited, so solar PV systems should be upgraded at least to 3 kW level (NEF 2002)[6]. At present, social services such as education and medical treatment are mainly under state control, so subsidies to purchase PV systems should be provided by the government.

5) New options for rural electric supply

The modularity of PV makes it ideal for use in remote locations, allowing upgrades or increases in installed capacity and circumventing the need for investment in extending the electricity grid.

A memorandum on building a solar power station in Mongolia has recently been signed between the Ministry of Infrastructure of Mongolia and NEDO of Japan. A group of Japanese and Mongolian experts is due to leave for Noyon soum[7] in Omnogov aimag, in order to start construction of this 200 kW solar PV station. The cost of the station, which will provide remote soums and settlements with electricity, is around US$3 million (BBC 2002).

It is estimated that the additional installation of PV systems in 200 soum centers in order to reduce the amount of diesel fuel used by electricity generators would cost US$200-400 million. The total cost of introducing the combined diesel generator and solar PV system for households is estimated at roughly US$250-450 million.

According to JICA's Master Plan Study for Rural Power Supply by Renewable Energy in Mongolia, the second stage (2010), which is aimed at improving the

[6] 3.5 kW PV modules are in use in some Japanese homes

[7] Rural district in the Gobi desert situated 240 km from Omnogobi aimag center (at a distance of about 600 km from Ulaanbaatar, the capital city)

power supply to every household in order to stabilize people's livelihoods in the 167 soums targeted, is expected to save about 5 million liters of fuel annually through the use of renewable energy sources (PV, wind and small hydropower) in combination with existing diesel stations and the realization of planned grid extension. The third stage (2015), which is aimed at achieving community development and a steady power supply to every household, would save 7 million liters of fuel, thereby reducing emissions (JICA, 2000b).

5. Economic and social implications

The alleviation of "energy poverty" in rural areas would have great social impact, such as improved access to information, medical treatment, schools, remote education, clean water, better management and use of pastures, and a decreased risk of mass loss of animals. In addition, for herder families, the introduction of PV would be at the lower end of investment risk, because it is modular and therefore can be installed and expanded step by step.

Animal husbandry accounts for one-third of Mongolia's GDP of US$1 billion and comprises three-quarters of its agricultural output. As of late 2001, the total size of the national herd was 26.1 million livestock, including 11.9 million sheep, 9.6 million goats, 2.1 million cattle, 2.2 million horses and 0.3 million camels. Mongolia produces around 25% of the worldwide output of cashmere, and also exports high-quality skins, hides, wool, meat and other products of animal origin. Cashmere, hides and meat products form the second largest source of hard currency revenue (around one-third of exports) after the export of copper concentrate.

Among herder families, ownership of 100-200 sheep is common. According to the 2001 census, 23.5% of herder families have 51-100 head, while 20% own 101-200 head. The average number of head per herder family is 99 (1 camel, 8 horses, 8 cattle, 45 sheep and 37 goats). Therefore, herd capitalization of 10-20% will give around US$200-800 per year per family. This data, the abovementioned importance of PV utilization in the agricultural sector and the estimated cost of PV implementation efforts would require significant capital investment, including financing from ODA sources and other mechanisms, such as the Clean Development Mechanism (CDM).

As a whole, the introduction of PV will provide socio-economic benefits not only for the rural population, but also for the entire country, and may also earn the public approval that is the raison d'être of policy-makers.

Regional governments recognize the need to balance energy use, economic growth, and environmental limitations and are attempting to realize it both domestically and internationally with varying degrees of success. Under these circumstances, the utilization of renewable sources of energy, especially solar PV, presents a means of supplying electricity to the 40% or so of the Mongolian population that currently has no access to electricity.

6. Conclusions and recommendations

Specific demand is essential to the development of renewable energy sources, which may play a part in increasing social stability.

A strategy for reducing greenhouse gas emissions, which focuses simultaneously on the short- and long-term might be realized, focusing on the development of small-scale energy systems based on renewable energy sources. Inclusion of the utilization of renewable energy sources into the national energy policy portfolio with government subsidies and incentives will be a significant issue.

International cooperation (realization of CDM, as well as governments of industrialized countries encouraging national companies to produce and export advanced technologies involving the utilization of renewable energy sources/natural gas) is important to promote cleaner fuel options such as natural gas and renewable energy, where cost-effective.

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