Greener Pastures from the Sun: Solar Photovoltaic–Driven Irrigation in Qinghai Province

By Carey Yeager and Frank Radstake

- **Pastures are being degraded in the People's Republic of China.**
- **Solar power can be cheaper than diesel fuel, and reduces greenhouse gases while increasing incomes.**
- **A 2-kilowatt-peak[1] solar powered water pumping system can supply both drinking and small-scale irrigation water and help reclaim degraded pastures.**

Background

Valuable pasture lands in the People's Republic of China (PRC) are being degraded through overgrazing, conversion, and reduced levels of precipitation as a result of climate change. Desertification of these grasslands is a major threat to productivity, and constrains local communities from achieving sustainable development. Ensuring sufficient water supplies for remote pastures is a priority in many locations, but obtaining access to power sources is often difficult in off-grid locations.

Qinghai Province is tackling this problem through the innovative use of solar photovoltaic (PV) power for irrigation; a solution that has enormous capacity for up-scaling within PRC, and throughout Asia. Recent significant reductions in the price of solar panels, combined with new technical designs for small-scale irrigation systems, are making PV economically viable in comparison with diesel engine pumps.

In 2009, the Asian Development Bank (ADB) supported the Gangcha County of Qinghai Province in developing and demonstrating improved pasture conservation, formulating water management strategy, and promoting awareness of ecological management of pasture land.[2]

Solar PV for Irrigation: The Basics

Harvesting solar power makes sense for much of Asia and the Pacific. With the large areas of the region endowed with abundant solar radiation, many countries have ideal conditions for producing solar energy. Solar PV systems make this possible.

PV systems use solar panels to convert sunlight into electricity. A system is made up of one or more solar panels, usually a controller or power converter, and interconnections and mounting for the other components.

This technology provides environmental, social, and financial benefits that enables the protection and sustainable development of remote pastures. In addition, its use reduces carbon emissions.

Desertification prior to irrigation and vegetation after planting and irrigation

A 2-killowatt-peak PV water pumping system can supply drinking water and limited irrigation. It can cover approximately 60 mu[3] of grassland, or provide drinking water for about 1,000 people; 600 heads of cattle; or 4,000 heads of sheep. A system can be used for a household farmer or multiple households with connected grasslands.

Applied technologies for small-scale pasture irrigation include canals, pressure pipelines, surface irrigation, sprinkler irrigation, and micro irrigation. With the introduction of water-saving technologies, such as sprinkler irrigation and micro irrigation, the productivity of irrigated pasture areas can be increased significantly. In Qinghai Province, micro-irrigation technology worked well for grassland irrigation when integrated with solar PV water pumping.

The Qinghai Experience

ADB's technical assistance was designed to improve pasture conservation and water management in Qinghai Province. It was based on the assumptions that increased productivity would reduce overgrazing,

[1] Kilowatt peak stands for peak power. This value specifies the output power achieved by a solar module under full solar radiation. Solar radiation of 1,000 watts per square meter is used to define standard conditions. Source: http://www.solar-is-future.com/faq-glossary/faq/photovoltaic-technology-and-how-it-works/what-does-kilowatt-peak-kwp-actually-mean/index.html

[2] The activity was jointly supported by the Clean Energy Financing Partnership Facility DC00010 and Water Financing Partnership Facility DC-00012, and managed by Tun Lin, Natural Resources Economist, ADB. The Final Report (ADB REC-C91300 [PRC]) is entitled "Qinghai Pasture Conservation using Solar Photovoltaic–Driven Irrigation".

[3] 1 mu = 0.0667 hectare

and provide an economic incentive for sustainable management through increased local incomes. Previous research had shown that irrigation increased yield by 400% to 2000% in pasture land.

In 2009, a solar PV demonstration system was installed. The Qinghai Institute of Water Resources and Hydropower Research, supported by ADB consultants, led the installation and data collection until project completion in 2010. Activities included the design and installation of the solar PV system, assessment of irrigation technologies and impacts on productivity, as well as economic analyses.

Requirements. Solar PV technology for irrigation generally requires:

- an annual precipitation of 300–600 millimeter (mm),
- a depth to groundwater of 30 meters or less (for wells),
- a water supply within 500 meters (for open water),
- adequate water quality: salt mineralization lower than 2 gram per liter and suspended solids of less than 200 milligram per liter,
- a slope of less than 5 degrees, and
- adequate sunlight.

The potential for solar energy in the north and north-western part of the PRC is high.[4] In Qinghai Province, given the dynamic groundwater storage and safe groundwater exploitation, the upper limit of water pumping for irrigation is set at 40% of the available groundwater resources. Considering the impacts of water extraction and the ecological use of available surface water resources, the upper limit of surface water abstraction is set at 30% of the available surface water resources.

Additional measures were implemented to prevent negative effects of water extraction. These included adjusting the composition of livestock, crops, and rates of water extraction; improving water efficiency; establishing an ecological warning system; and restricting groundwater extraction in the vicinity of important infrastructure (buildings, dams, and roads).

Costs. Back in 2010, the initial unit cost for a solar PV alternating current (AC) water pumping system in Qinghai Province was about CNY96,000 (roughly US$15,000), with an annual cost of about CNY105 per mu per cubic meter of water provided. The initial unit cost for a solar PV direct current (DC) water pumping system was CNY129,000 (roughly US$20,000), with an annual operation and maintenance cost of CNY145 per mu per cubic meter.

The costs for AC systems were lower as they do not require a converter. The diesel engine system, despite a lower initial investment of about CNY46,000 (approximately US$7,200), was the most expensive solution, with annual operation and maintenance costs of CNY231 per mu. This is almost twice as expensive as the solar PV pumping systems, the added expense being due to fossil fuel costs. The calculations are based on a total annual irrigation water volume of 280 cubic meter, equivalent to seven rounds of irrigation with 40 cubic meter per mu for each round.

Enjoying the Gains

The pilot test in Gangcha County, Qinghai Province was successful. Compared with the controlled land, the treated land provided drinking water for 2,000 goats and sheep and increased fresh grass by 300 kg/mu and forage grass by 1,500 kg/mu. Grass production in PV-irrigated areas in the Qinghai Demonstration Site increased by over 300 kg per mu and has the potential for further improvement through better management.

Solar lift irrigation appears to be most economically feasible when precipitation levels are between 300 mm and 600 mm. The highest economic benefit of solar lift irrigation is found in areas with precipitation between 350 mm and 400 mm.

Compared to diesel- or wind-driven pumps, the solar PV-driven system has lower maintenance and operation costs and a longer operational life. The price crash of solar panels in recent years has significantly reduced the investment cost and made the replication of the system financially viable. PV pumping systems will become even more competitive if fossil fuel costs increase.

The Qinghai Province pilot demonstration shows that the solar PV irrigation system is a cost-effective way to supply small-scale irrigation and drinking water for both surface and groundwater. In addition, solar PV irrigation of the grassland around the Qinghai Lake is helping prevent land desertification and degradation; increased production is reducing overgrazing and degradation leading to desertification.

[4] In North and North-Western PRC, annual radiation is greater than 600 kWh/square meter, sunshine is greater than 3000h, and annual sunshine percentage is higher than 65%.

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