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Solar-Electric Stand-Alone Systems

Petra Schweizer-Ries

Special difficulties and high costs are frequently incurred when sources of energy such as kerosene or dry-cell batteries are transported to mountain areas. Moreover, use and disposal of these sources of energy pose risks to health and the environment. On the other hand, the use of local, renewable sources of energy such as wind, water, or solar power ensures that mountain communities can enjoy both greater independence and safety with respect to energy supply. In mountain regions worldwide, local hydropower produced by small water turbines is important for irrigation, grain milling, and other purposes. Water turbines have also long been used to produce electricity to illuminate houses or operate radio and television devices, while direct solar energy has traditionally been used to dry food and clothing. Recently, however, a variety of solar energy systems including special house construction, use of cooking devices such as the well-known cooking boxes and reflector systems, and electricity supplied by photovoltaic (solar-electric) systems have been introduced. Some of these systems are especially suitable for areas with intense sunlight and low temperatures. Solar-electric stand-alone systems have proven useful in the European Alps and the Pyrenees, where there is evidence that they are an important source of sustainable energy (Figure 1).

FIGURE 1 Age-old and modern use of solar energy in the Spanish Pyrenees: while clothes are hung out to be dried by wind and sun, the photovoltaic (PV) panels provide energy for a family's multiple electricity needs. (Photo by SEBA)

Solar-electric stand-alone systems: environmentally friendly and sustainable electricity in mountain areas

As transport in mountain areas is often difficult, it is preferable to use local and decentralized sources of energy. Photovoltaic (PV) cells can convert light into electricity. PV cells are noiseless and do not depend on mechanical or chemical processes. They require no fuel and do not begin to degrade for at least 20 years. They can be easily exchanged and recycled after use. But solar energy systems do not consist only of PV modules. They are comprehensively designed systems that include a

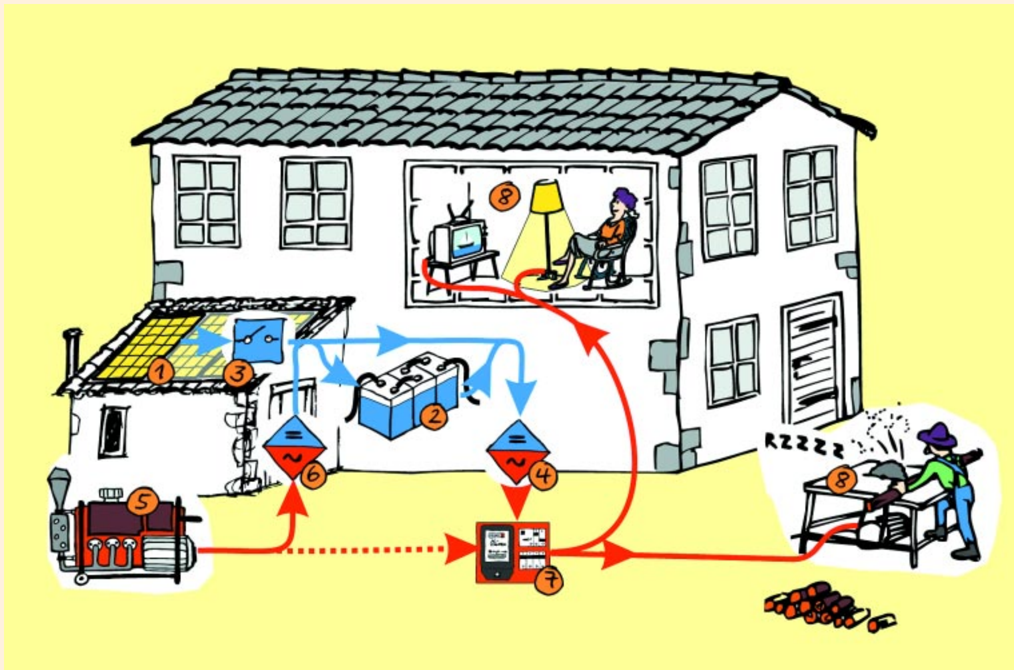

FIGURE 2 Components of a hybrid solar-electric stand-alone system include a PV generator (1), a battery to store energy (2), a solar charge controller (3), and an inverter (4) to use AC appliances. A diesel generator (5) can be added to reduce dependence on weather conditions and increase the availability of power; it can be used to recharge the battery with a rectifier (6). The distribution cabinet (7) constitutes the interface between the energy system and the conventional AC house installation. From a sociotechnical point of view, users (8) are also a significant part of the system. (Graph by Fraunhofer ISE)

storage battery for use during times of less intense sunlight or at night. More advanced systems have a charge controller and/or an inverter that produces alternating current (AC) for electrical appliances designed to operate on this type of current. Larger systems, and those used in the Northern Hemisphere with lower seasonal insolation, often have an auxiliary energy provider such as a generator powered by a renewable source of energy (wind or water) or a diesel generator (Figure 2).

We are happy with this limitation of available energy: It makes us feel responsible for our energy consumption. Nobody in this world should behave as if there were no limits on energy consumption. (German user, April 1999)

Increasing the efficiency of solar systems and their use in remote areas where extension of the electricity grid is too costly is a central concern in sustainable development. But this involves more than continuous technical improvement. The Fraunhofer Institute for Solar Energy Systems has shown that it is important to integrate such systems into existing social and economic systems. Accordingly, many aspects of technical systems should be considered. These include issues related to production of technical components and organization of maintenance, dissemination and local adaptation of components and design, and the sociotechnical interface where technology and users are matched in terms of information display and the structure of users' knowledge.

Solar-electric stand-alone systems in the European Alps and the Pyrenees

The Fraunhofer Institute has been gaining experience with solar energy systems for more than 15 years by installing and monitoring solar-electric stand-alone systems throughout the world. In an effort to investigate how effectively such energy systems have been integrated into existing social and economic contexts, we conducted a study based on extensive interviews with users of some of these systems, together with a Spanish users' association (SEBA) and a Spanish company (TTA) that operate hundreds of such systems in the Pyrenees. We talked to several categories of solar energy users, ranging from rural families with minimal energy demands to restaurant proprietors with commercial interests and high levels of demand. The results of these visits and related monitoring and experience with earlier installations are summarized below. The aim is to show what is involved in developing a sustainable supply of electricity in mountain areas using solar energy. This experience can be partially applied to other technical innovations and to other mountain areas outside Europe.

FIGURE 3 A user confidently checks the batteries of a stand-alone system in the Pyrenees. (Photo by TTA)

Successful integration of renewable energy sources in mountain areas

The study confirmed that it is important to work closely with the users of solar energy systems. Innovations cannot succeed unless they are adopted by local communities; only the people in these communities can decide whether a particular system and maintenance program is appropriate to their needs and the mountain environment in which they live. The design and use of new energy systems for such areas is also influenced by local habits and expectations regarding the availability of energy.

Power breakdowns are virtually unknown in many national electricity grids. To the consumer, energy and power seem to be unlimited; this encourages unsustainable use of the supply. With solar-electric stand-alone systems, the situation is different. An upper limit of available energy and power is defined by the allowable investment costs. If the price of a system has to remain low, future users must accept greater limitations. Of course, if users want a virtually unlimited power supply—similar to that provided by the electricity grid—it can be offered at a significantly higher cost since technical limitations are no longer really an issue. But mountain communities are often used to managing on limited resources. It is important to keep this in mind when introducing new energy systems and to encourage further economical and prudent use of resources.

Local participation is crucial when planning a stand-alone system. Active decisions on appropriate and affordable design of energy systems are important. This includes decisions about whether to use small, individual, direct current (DC) systems, larger individual alternating current (AC) systems, or community systems that can be used and maintained by a group.

In successful installations in the Alps and the Pyrenees, the users knew their system very well (Figure 3). They were trained by a competent installation crew and learned about the system while living with it. The interviews showed that initial user training during installation of the system is necessary. User workshops provide further information and lead to a cooperative relationship among users.

User-friendly handbooks adapted to the local culture are also very helpful. Such manuals must be well structured, with many illustrations and guidelines. The most effective support for users is feedback from the system in daily life. Different levels of visualization are needed to display the actual condition of the system to its users. These technical devices must be simple and should show that the system is running properly. This allows users to feel that they have control over their system and can learn to adjust to the available energy supply.

Compared with the costs of extending national electricity grids, installing solar-electric stand-alone systems is often the cheapest option for providing electricity, especially in remote mountain areas. However, when all operating costs, such as inspections, replacements, repairs, and maintenance are included, the price per kilowatt-hour is considerably higher for the user than prices paid by users of energy supplied by national electricity grids. This is because the latter usually do not include so-called external costs (eg, development, waste disposal,

If the subsidies had not been provided, we could not have bought such a solar-electric system. (Spanish user, June 1999)

FIGURE 4 The stand-alone village power system of La Rambla del Agua in Spain was financed by the local authorities, the European Commission, and the users. A local and a regional users' association (Virgen de la Piedad and SEBA) are in charge of management and maintenance. Productive capacity (10 kWh) caters to the needs of 40 households. (Photo by Fraunhofer ISE)

For us, it is important to have support for maintenance and repair, although we do the most basic things ourselves. If something happens, we can count on our user association. This gives us the confidence we need. (Spanish user, July 1999)

etc) in the overall price. Use of energy-saving appliances is therefore really cost effective and should be promoted. But the high price of solar energy systems also implies that subsidies must be provided for off-grid power supply in remote areas (Figure 4). We believe that people in mountain areas are entitled to support that enables them to fulfill basic needs for fresh water, health care, and energy at the same cost as the bulk of the population in less remote areas. In remote areas of the Pyrenees and the Alps, subsidies for power supplies other than grid extension are still lacking. This situation calls for change if the imbalance between subsidies for urban areas and (marginal) rural areas is to be rectified.

Sufficient infrastructure is another important factor in sustainable use of remote power supply provided by solar-electric stand-alone systems. Problems can be reduced by using components of high technical quality and by carrying out regular maintenance, but they will hardly be eliminated. Sustainable use of solar-electric stand-alone systems therefore requires an effective supporting structure. This is important in order to enable users to do the most basic maintenance and repair work by themselves, especially in remote areas where access is difficult and time consuming. A technical hotline with trained staff and standardized system designs can help in solving most problems. In the Spanish Pyrenees, the users' organization that helped conduct the interviews works with local enterprises to operate and maintain the systems. Any breakdown can be repaired within 48 hours. Therefore, it is important to draw up contracts in order to establish rights and obligations with respect to use and maintenance of solar-electric stand-alone systems and the power they supply.

Outlook

The solar-electric stand-alone systems and maintenance programs evoked here are one option for bringing electricity to remote mountain areas. They function in the Northern Hemisphere (Figure 5) as well as in southern mountain regions. Their sustainability can be greatly enhanced by the fact that users of solar energy who have been involved in planning stand-alone systems for their own use

FIGURE 5 Use of stand-alone solar power is spreading in the European Alps, where tourism has become a very important source of livelihood for local populations. (Photo by Fraunhofer ISE)

tend to be far more conscious of the need to use energy sparingly (Figure 6).

Mountain climates with high insolation and low temperatures are an especially suitable climate for use of PV cells. As a result of reflection from snowfields, insolation rates in the mountains are sometimes even higher than in the lowlands. Other solar technologies such as space heaters or water heaters are also appropriate and especially advantageous in mountain areas. The most important factor for successful adoption and functioning of these systems, however, is integration of these new technologies into existing social, cultural, and economic systems and the creation of a technical and financial infrastructure to support the sustainable use of solar energy systems.

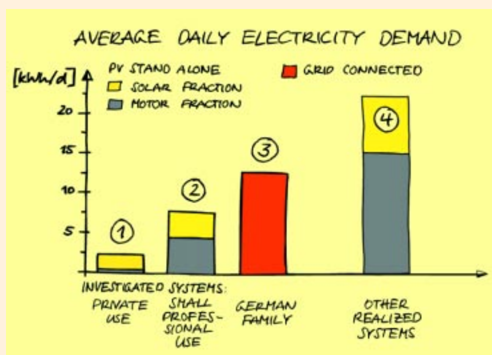

FIGURE 6 Electricity demand drops when solar-electric stand-alone systems are used. An average private household consumes less than 3 kWh/d (1). Twice as much energy supplies 100 guests daily in a mountain lodge (2). The average German family supplied by the grid needs more than four times as much as a family using solar energy (3). Solar systems can also supply sufficient power for businesses or entire villages (4). (Graph by Fraunhofer ISE)

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FURTHER READING

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The web site of the Fraunhofer Institute offers further details on solar-electric stand-alone systems and their implementation (http://www.ise.fhg.de/english/projects/pr-standalone/index.html).

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Petra Schweizer-Ries studied psychology and completed a PhD on energy use in the Himalaya in 1996. Since 1992, she has been working at the Fraunhofer ISE, where she established an interdisciplinary working group on rural electrification and is currently involved in the use and integration of solar energy systems in rural societies in various mountain regions of Asia, Europe, Africa, and Latin America. She teaches environmental psychology at several universities in Germany and Switzerland.