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The Use of Solar Energy for Improving the Living Conditions in Altiplano/Argentina

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Ecoandina e.V.	(Jujuy, Argentina)
Pirca e.V.	(Tilcara, Argentina)
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1. Introduction

Solar-Global e.V. has been working in close co-operation for around seven years with the **NRO ECOANDINA** of Salta and the local co-operative **PIRCA** in Tilcara, Argentina. Solar Global itself was founded around 12 years ago by the Solar Institute Jülich in order to promote the spread of newly-developed "adapted solar technology" in developing countries in a simpler, quicker, and more direct way. This was made possible through financial commitment and support, the setting up of training courses for craftsmen and technicians in partner countries as well as through the building of prototypes. The development of prototypes took place in close co-operation with our local project partners. In this way, development blunders were avoided and the users' needs were not overlooked. The aim was to bring into use simple solar technology, which does not require the transfer of the product but only the know–how of manufacturing on-site. Using this technology, an improvement in the living standards of the people of the region in terms of their economic welfare and general health as well as the local ecology could be vastly improved.
The projects have been financed by private sponsors, the members of Solar Global, the Ministry for Technical and Economic Co-operation (BMZ), the member organizations and local project partners.

2. Geographical area and aims of the project

The region of interest lies in the Argentinian province of Jujuy on the Altiplano, near to the Bolivian border (Fig. 1). The Altiplano is a mountain plateau with an average height of 3500 to 4000m. The region is spread over a large part of the Chilean, Argentinian, Peruvian and Bolivian Andes. Weather conditions here are extreme due to the high altitude of the land. Except for a short rainy season, the region is unusually dry the whole year round. In winter, temperatures range from 10 °C to 15 °C during the day and may fall as low as –20 °C at night. On the other hand, the area receives one of the highest amounts of solar radiation energy in the world, at around 6-7 kWh/m² per day in average. The target groups are the people living in around 20 villages in the Argentinian highlands. The population is without exception of Indian origin. Farming conditions allow cattle breeding and arable farming along with the quarrying of minerals. The region is amongst the poorest in Argentina. The annual average per capita income of the inhabitants is below 700 US$.

Fig.1 Geographical location of Altiplano and a typical village with 150 inhabitants (Misa Rumi)

The sole energy source in the region is the sparse vegetation provided by tola bushes. Increasing population numbers and over-grazing has lead to the growing disappearance of this plant. This causes an increase in work and time needed to collect fuel. The project aim is thus to make solar technology available to the villagers as an alternative to the traditionally used fuel for cooking, heating and hot water production. The use of solar pumps together with irrigation systems ensures the provision of vitamin-rich vegetables and basic foodstuffs, such as potatoes. Predominantly, women and children are seen to benefit from these solar projects, as their living conditions are directly improved as a result. The following technologies were introduced and used in the framework of our co-operation with the local NROs during pilot projects in the region:

- Solar heating with hot water storage tank
- Solar cookers (domestic and community)
- Solar ovens
- Solar hot water supply
- Solar pumps and irrigation systems

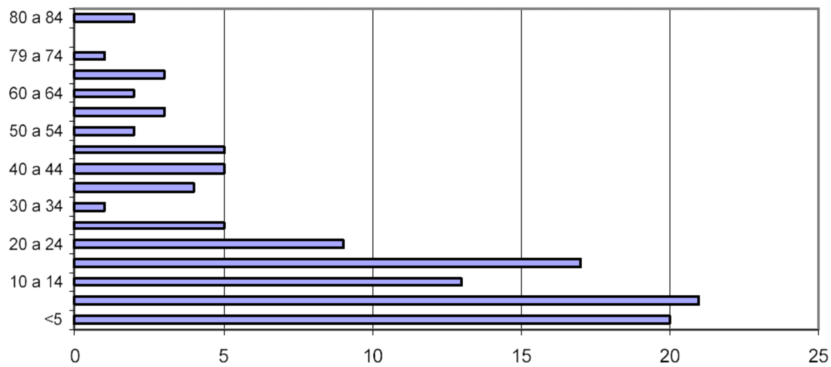

Fig.2: Demographic breakdown of a typical Village on the Altiplano (Misa Rumi)

3. Presentation of the last project undertaken 2002 - 2004

Within the framework of one of the projects supported by the BMZ (Project no. 2002.1683.8) the technology behind solar energy use was developed further and introduced over a larger area. As an example of this, the two highland villages of Cusi Cusi and Ciénaga can be taken to show how, when the appropriate solar technology is brought into play, the living standards in the Argentinian Puna are improved. The following measures were planned as part of the BMZ proposal:

- Production of two central heating systems
- Production of two water heating units
- Production of two solar community cookers for the Social Center
- 2 solar cookers for Schools (parabola + “heat box”)
- 4 solar pumps complete with connections and solar module
- Construction materials for irrigation system (connections, hosepipes)
- Training

Two central heating systems were installed in the kindergarten in Cusi Cusi and Cienaga to heat an area of between 60 m² - 120 m². This involved the units being installed in the current building in Cusi Cusi and in a new building in Cienaga. Originally it was planned that schools would be equipped with the central heating. However, as the school authorities would first have to check and approve the building plans, time pressures dictated that kindergartens instead of schools would benefit from the installations. The kindergartens are run in association with and under the control of the local councils. By heating the rooms in the kindergartens, the learning and development opportunities of pre-school children are clearly improved, and a healthier environment for the children is provided. As fuel is of poor quality on the Altiplano, wood-burning ovens do not present a tenable alternative to heat a building. The use of gas or oil, brought to the villages using delivery pipes laid over 200 km of mountainous terrain, is beyond the financial means of the community. With the help of reusable energy sources, it is possible to heat buildings at low cost. The heat needed to warm up the buildings is collected by a solar warm air unit on the roof of the building. The warm air travels via a ventilator into the heat collector which is integrated into the floor. This serves not only as a heat storage system, but also as an under floor heating system, which heats the room directly. A large part of the work required in building the heating system was undertaken by the local inhabitants in Cienaga and Cusi Cusi. The costs of the new kindergarten in Cienaga were carried in full by the community. This included not just the cost of materials, but also the payment of the tradesmen.

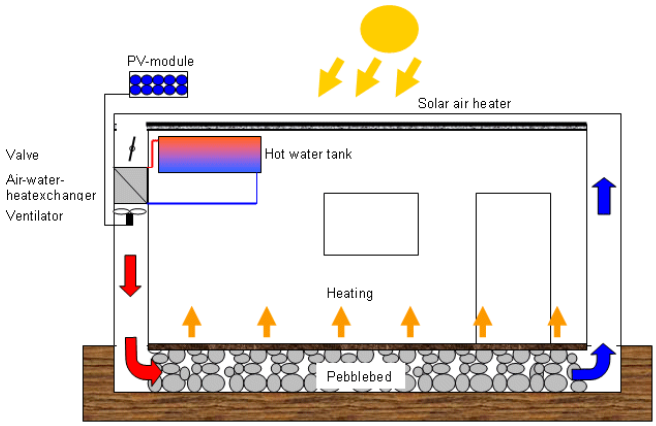

Fig. 3: New kindergarten with hot air collector in Cienaga and schematics of the system

Fig. 4: Recreation room and solar collector under floor heating in Cusi Cusi

In both communities, a **hot water supply** accessible to the public was installed. The hot water supply was integrated in the solar central heating system in Cusi Cusi, and not as planned via a separate hot water system. In a process developed by H.C. Müller, the energy need to heat 300 litres of hot water is withdrawn from the hot air flow out of the air collector. The water temperature was found to reach between 60 to 70°C. The advantage of this system configuration is that no anti-freeze is needed to keep the system running and costs can be lowered. Due to this simplification, problems such as insufficient water, lack of anti-freeze, leakages and breakdowns due to the build up of ice, are thus avoided. In Cienaga, the villagers have organized the building of their own public bathhouse, based on the concept developed by EcoAndina of the Baño Solar Andino (Andean solar bathhouse). Part of the material costs were paid for from the project funding. The bathhouse was built in the traditional way using clay bricks.

Fig.5. Hot water collector in Cusi Cusi and solar community bathhouse in Cienaga

Fig. 6: Hot water collectors built by the co-operative PIRCA/Tilcara

The traditionally-built roof offers the advantage of improved insulation in comparison to modern corrugated tin roofs. Moreover, in the roof, polycarbonate double vertical plates were integrated so that sunlight could enter and thus heat and light were provided. The hot water for the four showers were connected to the solar collector and stored in a 400 litre stainless steel tank. The waste water would then be cleaned in a natural water cleaning plant. Solar collectors and the storage tank were developed and produced in co-operation with the local co-operative PIRCA and the company LIBAL. The manufacture of solar hot water systems for mountainous areas is not simple. The considerable changes in temperature put heavy demands on materials and production techniques. The necessary knowledge was passed on to local partners during the course of the project; however, it should be noted that the construction of the stainless steel tank in particular requires improvement in the future.

As planned in the project, two **community kitchens** were installed in Cienaga and in Cusi Cusi. During the course of the first phase of the project, the surrounding communities expressed great interest in the large solar community cookers. Due to the favorable exchange rate for Argentinian peso, the costs of the project were in effect lower than expected. As a result, two more large community cookers were built, with the permission of the BMZ; one was installed in Misa Rumi in December 2003, and the second is planned for the regional capital Rinconada. The solar community kitchens would be built near to the kindergartens, where, depending on the locality, meals for 30 to 40 children and mothers would be prepared. The main meal of the day is lunch, usually made up of a stew and a soup. In Cienaga und Misa Rumi, tea would also be served at around 5o'clock. The cooking times fitted in well with the use of solar energy. The preparation of lunch starts between 8 and 9 in the morning. Because the solar community cookers employ a concentrated system, they are ready for use with the first rays of sunlight. The villagers of Misa Rumi, Cienaga and Cusi Cusi constructed kitchens of around 15 m², and equipped with a fixed-focus reflector, financed by the project. Each reflector provides the cooker with a maximum power of 3 kW. This permits the use of pans large enough to hold a maximum of 80 liters. When smaller pans are used, then two can be used at the same time.

In all three locations, the project participants have trained the users in great detail in the use of the solar cooker. This instruction proved essential, as the new technology seemed at first to be extremely unusual for the villagers. Originally, it was planned that a manual would be produced to this end. However, as the fact became clear that the villagers were not equipped with a sufficient educational standard to enable them to follow the written instructions therein, the personal training given by the co-workers was intensified. This meant of course that higher salary costs were incurred. One of the tasks necessary for the user to learn is how to turn the reflector until it 'catches' the sun. Once the reflector is correctly set up, then it turns automatically towards the sun as the hours pass with the help of an electric motor. It is necessary to make a seasonal adjustment of the reflectors to re-align them with the sun's position in the sky. This is achieved through the visual control of the focus while telescopic poles are adjusted. Achieving the correct positioning does require some experience and is the most difficult aspect for the villagers to grasp. In some cases, such as in Misa Rumi, a member of the community was chosen to take over the responsibility of ensuring the correct positioning.

Fig. 7: Solar community cooker in Misa Rumi shortly before its installation
and the dining room in Misa Rumi

Fig. 8: Solar community cooker for the children's meals in Cienaga under construction, and using it to cook lunch for 40 children

Fig. 9: Solar community cooker under construction in Cusi Cusi, and smaller parabolic cooker in the kindergarten.

As an extra means of support for the kindergarten kitchen, two **small parabola cookers** were also installed. They are able to provide 700 Watts of power with their diameter of 1.2m. This is sufficient to bring to the boil about 10 liters of fluid in the time of 1.5 - 2 hours. The small cookers are suitable for preparing side dishes, sauces or hot water for tea for the meals in the kindergartens. Along with the large community cookers, the smaller parabola cookers were manufactured locally by the co-operative PIRCA in Tilcara using the new technology.

Solar restaurant in Tilcara

Family in Tilcara

The C. Martinez family (Misa Rumi)

The J. Martinez family (Misa Rumi)

Family in Misa Rumi

Family in Misa Rumi

Fig. 10: Examples of private solar cookers manufactured by the co-operative PIRCA

In six different areas, irrigation systems were installed on cultivable land. Members of one or more families have joined together to form groups and are responsible for farming the land over a period of several years. In the main, crops which suit the mountainous climate are sown, such as the local potato (various types), sweet corn, beans, peas, carrots, onions, garlic and quinua. Sometimes lettuce, radishes and various herbs and oats are also sown under certain conditions.

Technicians of the Fundación EcoAndina encouraged the farmers to incorporate the new technology into their farming methods and have advised them on the choice of suitable crops which would lead to a successful harvest. By the end of the project, almost every area was ready for sowing for the growing period 2003/2004.

In four of the areas it was found to be necessary to pump water from low-lying springs or canals onto the higher cultivated land. This was achieved using four solar pumps capable of watering around 1.5 to 2 m³ per day, each equipped with 1 or 2 solar panels, depending on the height of the pump, and capable of producing 65 watts of electricity. Generally speaking, polythene piping of different diameters was used for all supply pipes and feeder hoses; the material is known for its high resistance to UV light and is an extremely robust material. For the irrigation system, PE hoses with a diameter of ½" were used with laser holes of a diameter of a few microns every 30 cm. These were laid in rows at intervals of 1.2m, directly into the soil. This guarantees that a minimum of evaporation will occur and enables the crops to be irrigated whilst using a very small amount of water. The following areas were equipped with the irrigation systems:

1. **Cusi Cusi:** 2 hectares of land belonging to the council at the edge of the village. The local council gives out land to families who express an interest in farming them. Irrigation is usually achieved using a canal, but the water supply can also be obtained from a underground spring using a solar pump.
2. **Ciénaga Chico:** 1 hectare farmed by a large family. A solar pump brings water from a spring up to a cistern situated 25 m higher, which feeds the irrigation system.
3. **Sevencaña** near Cienaga: a complex irrigation system on several small, linked terraces, in total an area of around one hectare, farmed by three separate groups of farmers. The water supply employs a mixed system, at times using gravity and sometimes a solar pump.
4. **Pueblo Viejo** near Ciénaga: 1.5 hectares, farmed by two family groups. Water supply provided by a 1.5 kilometer long water pipe (PE hose), stretching from the water source to the fields. Connection pipes for future expansion have already been laid.
5. **Canchamayo** near Cienaga: Repair of irrigation channels by the bridging of a slope. Expansion of the current cultivable land by another hectare. Due to the increase in farming land and the higher water consumption, a mixed water supply system was installed: one solar pump and one mechanical 'Widder' pump. The area should be ready for sowing in August 2005.
6. **Chuspimayo** near Misa Rumi: A hectare of farming land on the high terraces of Chuspimayo. The installation of a solar pump to supply water from the lower lying water supply.

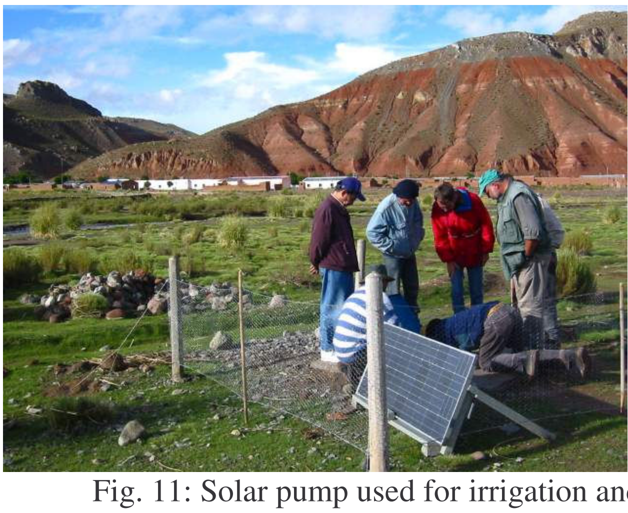


Fig. 11: Solar pump used for irrigation and a 1000 liter tank in Cienaga

Fig. 2: Carrot field without irrigation and potato field with irrigation in Cienaga

Fig. 13: Irrigation in Misa Rumi

4. Improving the Living Conditions of the villagers in the area

The Altiplano villages are currently experiencing a population increase of around 10 - 20%. This is due in the main to the high birth rate (see Fig. 2), improved medical care, but also because of a return of people to these areas from the currently economically unstable cities. The increased pressure on the natural resources on the extremely dry Altiplano leads to an increasingly longer daily search for fuel, water sources running dry and a lack of a balanced diet.
An improvement in the living conditions of the villages in the project area can be achieved in the following ways:

Improvement of the educational development of pre-school children by heating the rooms in the kindergartens. The public buildings in Puma have up to now never been heated due to the cost factor involved. With the help of reusable energy, it is possible to heat buildings at low cost. The room temperature can be kept constant using solar heating at an average temperature of around 12°C. In winter the average room temperature is around 5°C in an unheated building, but using solar heating, it averages 15°C. Although no official evidence has been collected, the influence on health of living in unheated environment is obvious. According to a study of the Bolivian Ministry of Health, every year 11.000 Bolivian children under 5 die each year due to the consequences of respiratory disease. Information from the Argetinian medical services confirms that children in the project area suffer tremendously, especially in winter, from respiratory problems. The hundred children in the project area between the ages of 2 and 5 years can now enjoy the benefits of a pleasantly heated room, where they can play, learn and eat.

Improvement in the sanitary facilities through the installation of solar hot water supply and the building of public bath houses. Hot water was previously either not available or its production was always linked with high costs, either economically (using gas) or ecologically (burning wood). In addition, the collection of fuel involves a highly labor-intensive effort to collect the fuel and bring it back to the villages. With the solar installation in place, the shower at the kindergarten in Cusi Cusi could be brought into use again as previously the local council could not provide the necessary funds for the gas to fuel the water heater. The hot water is to be used one day a week for bathing the boys, and then on another day for the girls. In addition, hot water would be used each day in the kindergarten kitchen. The availability of solar heated water makes it easier to maintain personal hygiene and is especially important to hinder the spread of skin disease amongst young children.

Saving time and effort: The increasing pressure on the fuel supply means that the villages are obliged to walk further and further each day in their quest to find the wood they need for fuel. This search is usually divided between all family members. Each day men, women and children in the Puna spend around 2-3 hours in collecting and transporting fuel. Loads of up to 30 kilos are carried for several kilometres on the villagers' backs. With the installation of the solar cooker as a result of this project, this daily problem is reduced considerably. The free time which the children now have can be spent engaged in playing or learning activities. The cooker was produced locally by the co-operative PIRCA in Tilcara. A study done in 1998 to assess the acceptance of the solar cookers in Misa Rumi has shown that up to 70 % of the total wood requirements can thus be covered (see appendix). This cooker is enjoying increasing popularity in private homes. Despite costing around 700 pesos, which is around two months' income for the villagers, already over 70 solar cookers have been sold to private households by the co-operative PIRCA. The high rate of acceptance is undoubtedly also due to the very good solar radiation levels on Altiplano which enables daily meals to be prepared quickly and without complications.

Fig. 14: Villagers collecting wood each day for fuel

Fig. 15: Previous kindergarten kitchen using an open fire.

Improvement in the availability of food stuff in terms of quality due to the cultivation of suitable crops. Many of the inhabitants of the Altiplano are malnourished, as their diets are lacking in vitamins and sometimes also protein. Especially at risk are pregnant women and young children. Dozens of families have now been given the opportunity to improve their diet and to grow their own high quality food products such as potatoes, sweet corn, pulses quinua and various other vegetables

Improvement in the availability of food stuff in terms of quantity by extending the available irrigated farmland by a minimum of 6.5 hectares. With the help of irrigation techniques which protect resources, the water supply crisis which occurs at the end of the dry season can be overcome, and in the future, two harvests per year can be achieved. Solar pumps make it possible to expand farm land, which would not be possible with traditional canal-type irrigation, which cannot reach the higher areas of land.

Self-reliance in terms of food production has had the effect **reducing the dependency of families on public welfare systems**. Excess produce can be sold at local markets or exchanged for other necessary goods of daily use. In the long term, self-reliance, a responsible attitude and the ability to take the initiative is encouraged, which in turn creates jobs.

Protection of natural resources, especially with regard to the tola bushes (Parastrephia) and the indigenous Queñua trees (Polilepis) around the villages through the use of solar cookers instead of combustible wood (see the attached study). In the long term, the project will contribute to **the conservation of biodiversity** in the Puna and also to the **stemming of the desertification** in the Andes. In this way, the **natural fundamental structure** of the indigenous people will be protected well into the future.

5. Sustainability of the introduced technologies

The high-level of acceptance which the project has in general achieved amongst the general population must certainly be emphasized. The individual aspects of the project have been well integrated into the daily life of the villages, and from this it is safe to assume that this effect will be a lasting one. For this reason, one can expect that the beneficiaries of the project will accept responsibility for its continuation.
As the solar units employed in this project all use a regenerative energy system, the costs associated with their upkeep are minimal. Care has been taken that all technology introduced is of an especially robust nature, simple to use and maintain, and avoiding using imported materials wherever possible.
Prototypes of solar central heating systems developed by our group already exist on the Altiplano, and are running for the last six years. Technical improvements, such as the introduction of new type of ventilator, have increased the expected lifespan of the unit. With a manufacture's guarantee of 100000 h, it is assumed that the unit will run for approximately 40 years. The solar modules used have a guarantee of 20 years. Other components, such as replacement glass parts and the collectors are available locally and are simple to fit, if the need arises. Because the system is based on airflow, breakdowns normally only occur as a result of malicious damage. Repairs are undertaken by the local manufacturer, LIBAL.

The same situation applies to the hot water system. All water carrying pipes are made from copper, and the water tank is made from stainless steel. Corrosion should then not be a problem until many years hence. The hot water system does require a certain concentration of anti-freeze, to avoid damage to the collectors due to the build up of ice during night. Repairs are carried out by the local manufacturer of the collectors, the PIRCA co-operative, or the manufacturer of the water tank, LIBAL.

The solar community cookers and household cookers will, with regard to the reflectors and adjustment motors, be completely furbished by locally available materials by the co-operative PIRCA. The reflectors have a life of several years, depending on how carefully the users treat them. The user must above all take care that when cleaning the surface area, no scratches are introduced. Household cookers bought 6 years ago are still in use. If the surface of reflector does over time become dull, this part can be replaced at a cost of 20 Euros for the household cooker and 150 Euro for the larger community cookers. The reflectors used in the current project were purchased on the understanding that one replacement of the installed reflectors would be made without incurring any extra costs.

No long term studies have been undertaken on the lifespan of the irrigation system under the extreme climate conditions of the Altiplano. It is estimated however, that in normal use, a lifespan of around five years can be expected. It is very important to ensure that the plastic pipes lie under the soil to protect them from direct solar radiation. Under certain advantageous conditions, the producers were able to make a small profit from the sale, which allows them to make the necessary investments in the long term. Replacement materials are available in the specialist shops in the main regional town of San Salvador de Jujuy.

Argentinian local councils are generally very short of funds but have resources for labor. This fact made it possible to construct the new building and should also allow for the maintenance of the solar central heating systems and the solar kitchens. In the case of the Baño Solar Andino in Ciénaga the council decided that a small entry charge would be made. Visiting the bathhouse now costs 50 Centavos (=14 Euro-Cent (1/2004). Using this fee, the financial support for the running, cleaning and maintenance of the installation can be maintained.

6. Solar Ovens

In addition to the technology described above, H.C. Müller developed and tested a solar oven during his last visit, with a capacity of 200 liters and a heat power of between 3-4 kW. This technology (in terms of the plans and so forth) was given over to the local co-operative PIRCA in Tilcara, who plan to market it commercially. Figs 16 and 17 show the developed unit and H.C. Mueller with the first successful batch of bread. The use of the solar ovens mean an immense reduction in fuel is achieved, as the villagers traditionally bake their own bread once a week and require a total of 2kg of fuel for every kilo of bread.

Fig. 16: Solar ovens

Fig.17: First culinary success

7. Conclusion

By employing technology which employs solar energy to heat water, centrally heat schools and community centers, to replace the use of natural fuels for cooking and to power solar pumps for the irrigation of small areas, the living conditions of the inhabitants of the region have clearly improved. The installation of small solar irrigation systems to water vegetable gardens has served to improve the imbalanced diet of many families in the region and to provide employment. By reducing the necessity of burning the tola bushes in the region, a positive contribution has been made to stop the desertification and soil erosion in the semi-desert areas. In the long term, this helps to maintain the traditional, natural fundamental structure of the region. In addition to solar heating, hot water units were installed in a bathhouse which improves the living standards and serves the basic hygiene needs of the people living in the area.

With the help of training courses on the installation of solar cookers, hot water systems and solar central heating units, along with courses on how to install solar pumps and irrigation systems, the local workers were able to learn the necessary know-how to maintain and repair the units, or even to construct new units themselves.

The many requests from regions experiencing similar problems, such as Bolivia, Chile, Peru, Paraguay, and also countries such as Afghanistan, will hopefully lead to the expansion and growth in the popularity of this technology.

8. Acknowledgements

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