Solar community bakeries on the Argentinean Altiplano

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1. Abstract

Financed by a BMZ project (German Ministry for Technical and Economic Co-operation) five solar community bakeries amongst other installations where build up in villages in the Argentinean Altiplano. The aim is to replace the use of tola bushes as heat source in traditional ovens. Each family bakes its bread one time per week in its own adobe oven, using in average 30 kg of tola. Due to the extreme arid climatic conditions and growing population, the impact of firewood collection is more and more visible. To protect the sparse vegetation, a solar bakery oven was developed using a fix focus Scheffler reflector with 8 m² reflector area. The oven has a volume of about 200 liters. With an input power of about 3 kW it reaches temperatures of up to 350 °C. Alternatively the oven can be moved aside on rails and permits the use as cooking plate. For cooking use, a new type of cooking plate was developed, using a ceramic stove top to protect the secondary reflector from food dropping down.

2. Introduction

The NGO EcoAndina has been working in close co-operation for around ten years with Solar-Global e.V. in Germany and the cooperative Pirca in Argentina. Solar Global was founded by the Solar-Institut Jülich in order to promote newly-developed "adapted solar technology" in developing countries in a quicker and more direct way. This was made possible by financial support, building of prototypes and organisation of training courses in partner countries. The development of prototypes took place in close co-operation with the local project partners and users. In this way, misguided development was avoided and the user's needs were not overlooked. The aim is to bring into use simple solar devices, which do not depend on imported materials but only on the know–how of manufacturing on-site. This way, the living conditions of the people in terms of economic welfare, general health and ambient protection can be vastly improved. The projects have been financed by private sponsors, members of Solar Global, the Ministry for Technical and Economic Co-operation (BMZ), member organizations and the local project partners.

3. Background

3.1. Project region and project aims

The project region lies in the Argentinian province of Jujuy on the Altiplano, near the Bolivian border (Fig. 1). The Altiplano is a mountain plateau with an average altitude of 3500 m. The Altiplano spreads over a large part of the Chilean, Argentinean, Peruvian and Bolivian Andes. Weather conditions are extreme due to the high altitude. Except for a short rainy season, the region is dry the whole year round. In winter, temperatures range from 10 °C to 15 °C during 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 in the world, at around 6-7 kWh/m² per day in average. The high percentage of direct sun light is in favour for using concentrating solar devices.

The target groups are the people living in around 60 villages in the Argentinian Altiplano. The population is without exception of Indian origin. In these communities, population lives in a subsistence economy (stock farming, little agriculture, small scale mining). Many of these areas are affected by social, economic and ecological problems. The region is amongst the poorest in Argentina.

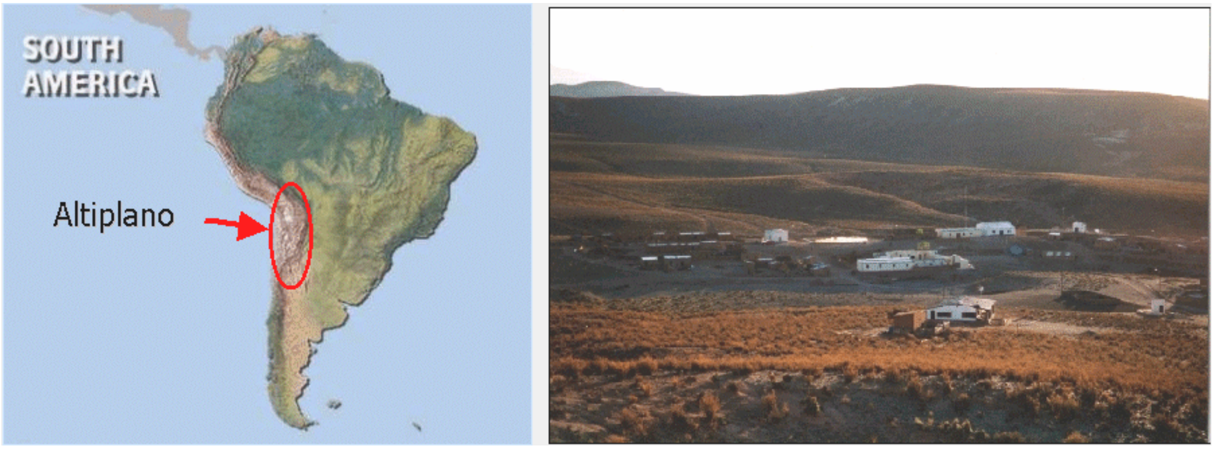

Fig.1 Geographical location of Altiplano and a typical village with 150 inhabitants (Misa Rumi)

The sole energy source in the region is the sparse vegetation provided by tola bushes. Only people with better income can afford gas cylinders. Increasing population and over-grazing leads to growing disappearance of vegetation. This causes increase in effort and time needed to collect firewood. The project aim is thus to make solar technology available to the villagers as an alternative to the traditionally used fuel for cooking, house heating and hot water production. The use of solar pumps together with drip irrigation systems ensures the provision of vitamin-rich vegetables and basic foods, such as potatoes. The villagers 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 co-operation with the local NGOs during pilot projects in the region:

- Solar space heating for schools (hot air system with pebble bed storage)
- Solar cookers (domestic and community)
- Solar community bakeries
- Solar hot water supply (community bathing houses)
- Solar pumps and irrigation systems
- Solar dryers

3.2. History of community bakeries and kitchens

Each family bakes its bread one time per week in its own adobe oven, using in average 30 kg of tola. To protect the sparse vegetation, in 2003 a solar bakery oven was developed using a fix focus Scheffler reflector with 8 m² reflector area as heat source. The oven has a volume of about 200 liters. With an input power of about 3 kW it reaches temperatures of up to 350 °C.
During a first pilot installation of a community bakery oven in Misa Rumi in 2006, the surrounding communities expressed great interest in this new technology. In continuation of the project, community bakeries were installed in other 4 villages on the Altiplano. In some of them already existed solar community kitchens equipped with a Scheffler reflector during a previous project in 2003. These were supplying kindergartens, where, depending on the locality, meals for 30 to 40 children, mothers and needy elderly people were prepared. The main meal of the day is lunch, usually made up of a stew and a soup. Also tea was served at around 5 o'clock. The cooking times fit 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 are based on concentrating sunlight, they are ready for use with the first sunrays in the morning. As counterpart the villagers constructed kitchen houses with around 15 m². Each reflector provides the cooker with a maximum power of 3 kW. This permits the use of cooking pots large enough to hold 50 liters. Unfortunately, Argentinean government changed politics and cancelled subsidies for community kitchens in 2005. Instead, every family with children receives a food donation from there on. Many of them are using now small family sized solar cookers (similar SK14). 250 cookers were sold until now. Since 2005 the solar community

kitchens were without use, so a modification for using it as a solar community bakery could be done with little effort.

Fig.2: Solar community oven powered by Scheffler reflector

4. Project

4.1. Oven details

The bakery oven is designed for an 8 m² Scheffler reflector. The latitude of the site is 22° south. With a resulting focus height of 78 cm, the oven must be put on a base of 40 cm, giving a comfortable access to the baking chamber. The baking chamber measures 60 x 60 x 60 cm³. The whole system is built completely out of materials which are available in Argentina. Figure 3 shows a principle of function of the oven. The oven operates without active ventilation. A convective airflow is accomplished by a 1 meter long chimney, which leads the airflow into the top of the baking chamber. From here the air passes through the baking product transfers parts of its thermal energy and leaves the chamber at the bottom. A pebblebed storage is situated in the bottom, which helps to store thermal energy of the circulating air. When the air had passed through the pebblebed it re-enters the receiver of the Scheffler reflector. The receiver is covered by a ceramic glass with anti reflection coating and a size of 30 cm x 30 cm. The receiver itself is constructed from iron sheet which is bent in a zic-zac profile. With 3 cm channel width and 35 cm depth, focussed rays, which enter from the reflector into the zic-zac receiver, are reflected deeper inside. This improves efficiency since the radiation losses at high operating temperatures are minimized and air flow resistance is minimal. Figure 2 shows the efficiency curve over temperature difference between absorber and ambient temperature. At a temperature of 300 degrees the efficiency of the system consisting of the reflector in conjunction with the zic-zac receiver is found to be at approx. 40 percent. So the power available in the oven is around 1200 W. But considering the stored energy in the pebblebed, thermal power can be much more. When the pebblebed is charged, it allows one hour of baking without any heat input. This is to insure that the baking product isn't spoiled when the sun is hidden by clouds. In this case air would flow in reverse direction, entering at the bottom of the baking chamber and leaving at the top.
The temperature measured inside the oven rises up to 360 degrees. To reach working temperature, 1 to 2 hours are needed (depending on the storage capacity of the stones). The measured performance in different working conditions can be seen in the diagram in figure 4. After a heat up time of 75 minutes two pots with 1 liter oil were heated up in the top and in the

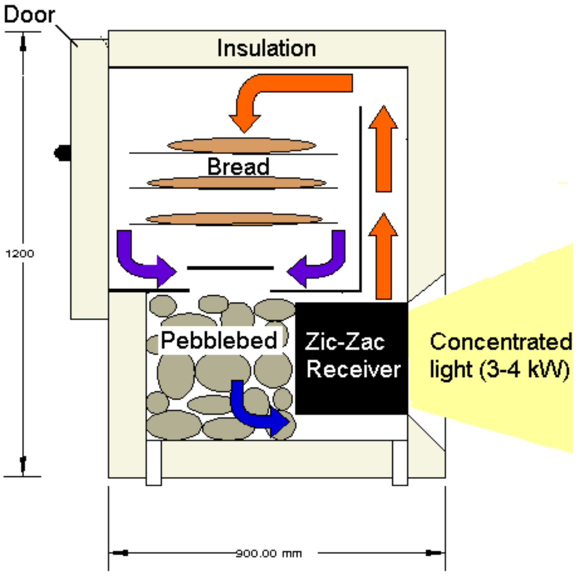

Fig.3: Schematic of bakery oven

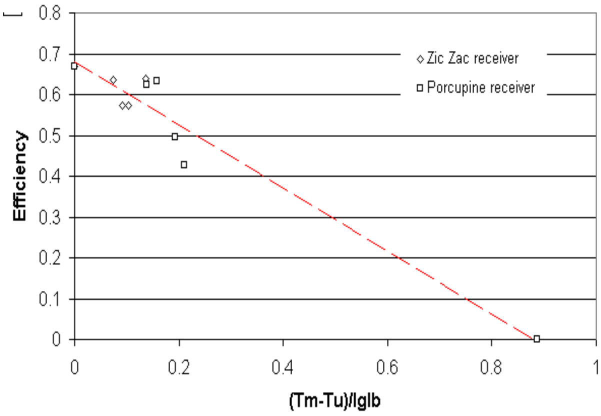

Fig.4: Efficiency curve for the zic-zac receiver

Fig.5: Zic-zac receiver and pebblebed storage

Fig.6: Bakery oven in use

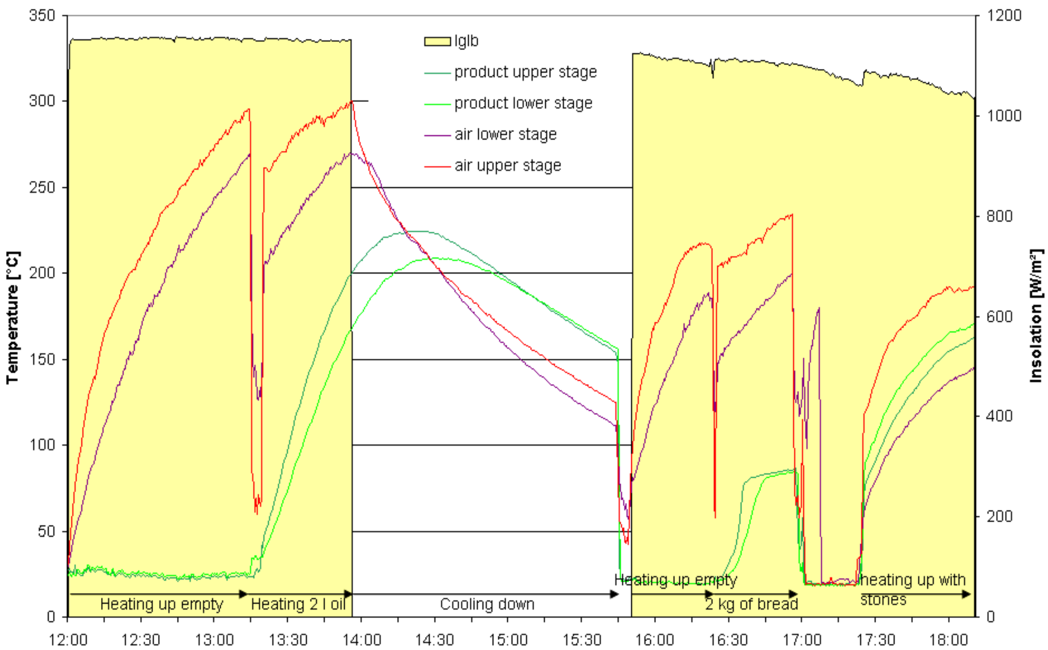

Fig.7: Measurement of different operating conditions

bottom tray of the baking chamber. After 45 min the pot in the upper stage reached 200 °C in the bottom tray 170 °C. So there is a gradient of 30 °C in the oven, which can be explained by the fairly slow airflow by natural convection. A system with forced ventilation would most probably not show such a strong gradient, but has other disadvantages regarding maintenance and dependency on electric power supply. The efficiency of the oven itself depends mostly on the air tightness of the construction. Especially at the door sealing (ceramic band) losses can be significant. Also 10 cm isolation with untreated mineral wool should be attached with much care, so that losses are reduced.

4.2. Improvements on tracking system

Some adaptations were made, to make the tracking system more reliable under the strong climatic conditions on the Altiplano. In the past, strong winds and much dust often lead to failure of the tracking mechanism. The newly developed tracking mechanism consists of a solar module with an electric power of 1 W (270 mA, 6 Volts) and a simple low cost electronic made of green LED's as sensors and six transistors to form a bridge circuit (see www.redrok.com). The mechanical part consists of an electric motor with a 1:6000 gearbox and a clutch. The clutch prevents damages of the mechanism when exceeding forces occur and allows turning the reflector by hand to the starting position. The clutch doesn't use friction principle. It works with a spring, which will be compressed by two eccentric cut cylinders, when forces exceed a well defined value, allowing decoupling of the gearbox.
The simple electronic proofed to be reliable and exact. The sensors can distinguish sun movement of only 0,1° (20 seconds).

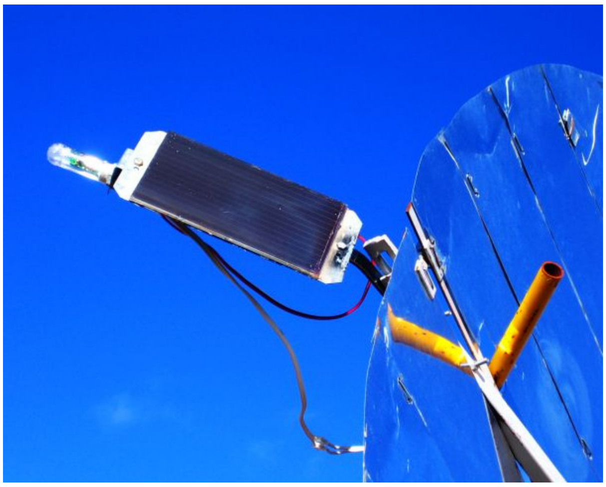

Fig. 8: Solar panel with electronics

Fig. 9: Motor, gearbox and coupling

4.3. Improved cooking plate

Alternatively the oven can be moved aside on rails and permits the use as cooking plate. For cooking use, a new type of cooking plate was developed, using a ceramic glass to protect the secondary reflector from food dropping down. This was a big problem before, because food would stick to the reflectors and burn, spoiling reflectivity. The ceramic glass has low percentage of iron, and is resistant to temperature changes. Its dimensions are 50 cm x 50 cm with a thickness of 5 mm. When light passes glass, losses by absorption and reflection would occur. It was expected, that the glass would lower the efficiency of the solar cooker by at least 15%. But experiments have shown that there was no difference in heating a pot with or without glass protection. The reason seems to be, that the glass also slows down natural convection at the cooking pot, compensating the transmission losses. The one year experience with the new concept was very positive, as it is much easier to clean a glass, then to clean reflectors.

Fig.6: Ceramic glass as protection for the secondary reflector (better use black pots ;-))

4.4. Maintenance and acceptance

In all locations, the project participants have trained the users in great detail in the use of the solar cookers. This instruction proved essential, as the new technology seemed at first to be extremely unusual for the villagers. 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, it follows the sun with the help of the tracking mechanism. It is necessary to make a seasonal adjustment of the reflector to re-align it with the sun's seasonal changes in position. 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 most cases, male members of the community showed strong interest in the new system, so always a motivated person could be found who cares for the correct positioning.
The reflectors have a life of several years, depending on how carefully the users treat them. As the reflector material is highly reflective aluminium sheet, the user must above all take care that when cleaning the surface area, no scratches are introduced. Experience had shown that family solar cookers bought 10 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 40 Euros for the household cooker and 200 Euro for the larger community cookers.

5. Conclusion

Through the use of the solar community ovens an immense reduction in fuel is achieved. As the villagers traditionally bake their own bread once a week and require a total of 2 kg of tola bushes for every kilo of bread, every family can save up to 30 kg of firewood each week. There are big differences in acceptance. Some families, especially younger ones accepted the new technology very fast. Also acceptance depends much on the person responsible for seasonal adjustment. As the oven is available for more than 6 hours each day, up to 60 kg of bread can be baked each day. That means that 4-5 families can do their weekly baking on one day. Over one week a village like Misa Rumi with 20-30 families can substitute its tola bush consumption. Nevertheless the concept of community ovens for villages (not solar though) is very old, as even in Germany they were in use until last mid-century to save firewood.

References

See www.hc-solar.de or www.solar-bruecke.org for construction plans of the bakery oven