If no one copies it or tries to steal it – is it worth nothing? State of the art of small automatic parabolic trough steam systems for food processing

Dr. Michael Götz, ExSol and Cocina Solar Mexico, michael@cuisinesolaire.com,

www.cocinasolarmexico.com.mx, www.cuisinesolaire.com/exsol

Key words: Solar food stall, solar steam, concentrated solar power, steam cooking

The development of small automatic parabolic trough systems for steam production for food processing has been started in November 2009 with the 'taquero solar' food-stall in Oaxaca / Mexico. This food-stall quickly became a 'hit' in the internet and international media. TV stations from various countries came to film it. It has its reflector on the roof of a tricycle food-stall and injects steam directly in his pot of consommé with meat for making tacos.

This and the following systems are based on a parabolic trough reflector (between 2 and 9 m² aperture) with a black copper pipe absorber. Steam is produced 'on demand' by injection of small quantities of water every 20 seconds. Steam production and solar tracking are controlled by a unit based on an Arduino board.

The technology has been refined and updated since then and the following systems were installed: A 'gastronomy size' steamer for the kitchen of a permaculture farm, the 2nd generation 'taquero solar', a mobile steam unit for cooking on events and finally a sterilization unit for straw which serves as substrate in mushroom farming.

The paper describes the technological details, the story and media success of the 'taquero solar', the curiosity, fears, experience, success and frustrations of the users of the steam units, the frustration of its designer (the author) to struggle with reliability problems and electronic bugs not getting help and finally discuss the question why – having developed a nice and powerful tool – there seems to be strictly no interest in the solar cooking world to take it over, copy it, better it – or steal it.

The experience showed that it is easy to find short-term help and hints from other people but near to impossible to find experienced people to do debugging and bettering which is a task taking weeks and guarantees its share of frustration.

The conclusion is that the systems are 95% ready, 90% reliable and have a great potential to be copied by other workshops for similar applications. The open question is where to find the help to cover the remaining percentage.

1. History of the small solar steam units

All started with a first three months project to investigate and test how street vendors of food in Mexico could use solar energy in their daily work [1]. There was a restriction that the street vendors in Oaxaca, the city where the tests were done, are only allowed to use about two linear meters of the border of the street for their food stalls. This is the typical size of their vehicles (four wheel carts or tricycles); there is no place for an additional parabolic reflector next to it. Therefore a technology had to be used that can be installed *on top* of the stall and a way found to transport the energy to the cooking pot at a lower level. Producing steam seemed to be a good solution, at least for those vendors who do not need to fry their product. Steam can be easily transported over the small distance from the reflector to the cooking pot.

For the actual test of the proposed technology, a street vendor had to be found who a) was cooking a dish that was appropriate for steam cooking/heating b) sells food at daytime c) has a place with good solar isolation and d) was willing to give it a chance. Our luck was found in Don Alfredo who had been selling tacos with meat in the morning hours for some years. He was using a tricycle in the shade of a tree, but he could slightly move his mobile be be in the sun. This was the chance to build the first prototype of a (mobile) solar steam unit. The story of the 'taquero solar' is told in paragraph 3...

From there on, the logic was reversed. Now there was a steam producing unit at hand and there had to be looked for (food related) applications to it. A household steamer was quite a logic sequel. A neighbouring permaculture farm was running a kitchen for their volunteers, visitors and training participants. They were ready to buy a small gastronomy steamer. This was the second system which has been built, copying the inner size of a small commercial gastronomy steamer, just giving it a much thicker insulation. This unit uses two reflectors of $3m^2$ each (compared to the single reflector of $2m^2$ of the first 'taquero solar').

At this moment, Don Alfredo wanted to change his tricycle for a four wheel caddy with a larger working table. He got help from our project while constructing his new food stall and a new, larger reflector was built for it. His first unit was taken back and transformed it into a foldable food stall for steamed products which is used by the projects team on events and fairs.

The latest and biggest installation is working in a small village far away from the city where a farmer, Don Victor, is cultivating 'Seta' mushrooms for sale. The first step for his cultures is sterilizing the substrate, straw or dry parts of corn plants. This has been done before using an old barrel of petrol filled with water and straw, placed on an open wood fire.

A larger steam unit with a $9m^2$ reflector, a stainless steel sterilization drum and a backup 'rocket' stove steam producer were built for this purpose [2].

One idea for the steam units which is waiting to be tested is distillation of essential oils.

2. Technology

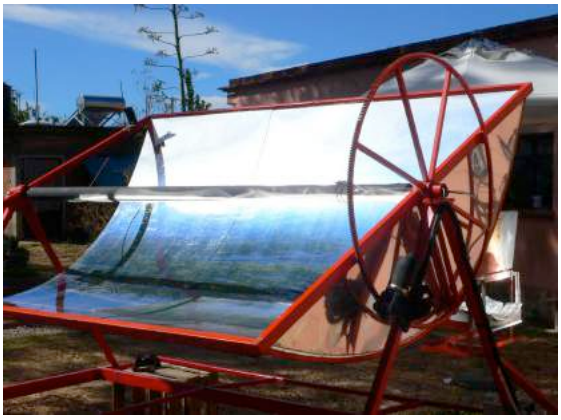
The following paragraph explains the common elements of the described steam units. All details to each system and differences between them are explained in [3].

The heat is produced in all units by linear parabolic reflectors made out of polished and anodized aluminium sheets. Their apertures vary between $2m^2$ to $9m^2$. At the focal point is a two inch wide copper tube which is painted black (mat). The tube is placed in north-south orientation and has an almost horizontal position. A 12V motor does the single axes solar

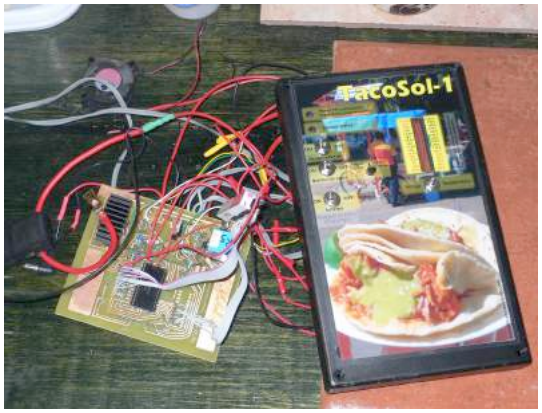
tracking turning the reflector via a large gear-wheel; a light detector helps to find the right angle. As soon as a temperature sensor at the tube reaches the lower temperature limit (about 105°C), water is injected by a small pump in intervals of 15 or 20 seconds. The amount of injected water is regulated by an algorithm which tries to keep the temperature of the tube in the range of 105° to 120°C. The steam leaves through an insulated pipe to the cooking device (pot, steamer, etc.). In the case of the 'taquero solar', the steam is directly injected into his consommé, similar to the large cooking vessels in the 'Abu Road' kitchen in Rajastan, India [4]. For safety reasons, all systems work at atmospheric pressure, i.e. the steam's temperature is near to 100°C.

The solar tracking, the steam injection and a few more optional functions (solar charge controller, data storage, display of information by LEDs or on a small screen, etc.) are managed by a control unit based on an Arduino micro controller [5].

Remark: The units have been built in Mexico using as little expensive 'high-tech' materials as possible. Comparing them to the large through collectors used in solar power plants to generate electricity, the highest potential for increasing the efficiency seems to be in the absorber tube. Selective coating, outer quartz or glass tubes as wind shield, or even vacuum insulation could be added.



Picture 1: The reflector with the central tube and the gear-wheel for the solar tracking.



Picture 2: One of the control boards (the Arduino controller is attached below) and the lid of its protection box.

3. First example: the taquero solar

As mentioned above, Don Alfredo was the first street food vendor in Oaxaca who agreed to try out the solar extension to his food stall. He sells beef tacos; the meat is being boiled in a consommé (which is sold as well). On top of the consommé, the tortillas ('flat corn bread') are kept hot. The chopped meat is served on top of tortilla.

Don Alfredo's main interest to participate was curiosity and he was ready to give it a try as long as his clients wouldn't abandon his offer. Still, he was afraid that the tacos could have a different taste and that people would be reluctant to buy them. It needed some courage from someone who needs to feed a family to put his income 'at a risk' trying a new and 'exotic' cooking method.

Everything worked out fine on the first day, the clients were impressed and nobody complained about the tacos tasting different. Soon passed the first newspaper journalist and a Mexican TV station. After a video shown on US TV which created a lot of interest in the internet [6], other TV crews followed from countries as far as Canada and Germany and one story was distributed worldwide by Reuters.

Don Alfredo is happy being known for his unique offer, but he is suffering from pushing his trolley every morning and every evening (uphill!) between the parking and the sales spot. Actually, the cart became much heavier and harder to manoeuvre by the large solar reflector on its roof. Still he was using the first installation on his tricycle for almost two years and the second one on a four wheel cart for another two years. During the rainy season (northern summer), it was usually taken down for three or four month. For such moments, the gas stove below his cooking pot was never completely removed, he can use either solar energy or gas to boil his consommé.

Due to the daily vibrations, the system got more susceptible to breakdowns and repairs got frequent. For that reason, the reflector has been removed in spring 2016 and is waiting for a complete renovation.

Picture 3: The first 'taquero solar'.

Picture 4: The stall owners with the second 'taquero solar'.

Picture 5: Clients at the 'taquero solar'.

4. Second example: the gastronomy food steamer

This unit has been built for the canteen/cafeteria of a permaculture farm. It holds three trays of a typical gastronomy size and works like a regular kitchen steamer. It has been used for cooking rice, vegetables and fish. A separate part contains a drinking water tank of about 20 litres volume. The steam can either be directed to the food steaming compartment or to the water tank. The almost boiling water of the latter can serve for preparing hot drinks like coffee and tea. Unluckily, heating the water tank creates a lot of noise of vibrating metal and this option has hardly ever been used.

The permaculture farm itself has had many changes of concept and of team members during the five years since its installation. The plan of a public cafeteria has been abandoned and the hole project of the farm was in a 'stand-by state' for a long time. Therefore, the enthusiasm for the solar steamer was quite low and it has not been used many times. Not being used (nor

maintained), it was prone to technical failures and this system as well is waiting for a intensive renovation. This renovation is planned for the winter 2016/17 as a new crew has taken over the complete project.

	
Picture 6: The reflectors of the gastronomy steamer.	*Picture 7: The steaming compartment.*

5. Third example: Steam sterilization of substrates for mushroom farming

Mushroom farming has been promoted in many areas to create income for small farmers. The steps include: sterilizing the substrate (straw, etc.), seed it with 'mycellium' (fungus spores), fill the mixture in plastic bags and keep them first in a dark and later in a light room for given times. The first step, sterilization of the straw, is done the rural way by heating an old oil drum - filled with some water plus the straw - on an open fire.

A sterilization unit has been built in 2015 for the small mushroom farm owned by Don Victor. It is located in a remote area in the state of Oaxaca. A large $9m^2$ solar reflector produces steam which is lead into an insulated stainless steel drum filled with straw or corn leaves. After about 90 minutes of steaming, the drum is reversed and the substrate material is spread over a stainless steel table for seeding. The rest of the process remains the same.

As a second option for days without sunshine, a large 'rocket stove' has been built with a 20 litres cooking pot inside. This stove produces steam which is lead to the same sterilization drum. The steam production of this 'rocket' unit has not been sufficient for successful sterilization, more experiments are needed to find its appropriate size (of the combustion chamber, mainly).

The solar option works perfect under good sunlight conditions. The steam is strong enough to heat up 120 litres of straw in about 20 minutes and keep it at 95°C (boiling point at about 2'000m height). Like with the other systems, there were quickly things to be repaired and the new electronics unit (as described in paragraph 8) proofed not to be sturdy enough. The system can be run in a 'manual mode' (i.e. piloting the motor of the tracking and the water pump with simple switches), but it's use is not comfortable. This relatively new steam unit needs to be fixed with a sturdier control unit.

		
Picture 8: The old way to sterilize the substrate material.	*Picture 9: The reflector of the mushroom sterilizing unit.*	*Picture 10: Opening the steaming drum distributing the corn straw on the table.*

6. Long term experience and changes done for better reliability

The first units were built for a food stall which moves twice a day – to its sales place in the morning and to a safe storage place after work. This daily moving creates a lot of vibrations and everything that can break will break at a time. Adding to this, the units are rather heavy (and the food stall below as well), so the user has a hard time pushing it. One might conclude that these larger solar cookers are more appropriate for a small canteen or restaurant than for a moving food stall. In the first case, there are no vibrations and everything can be built sturdier and heavier.

It is a hard task to develop a automatised cooking device which has to survive in real life conditions for many years. Vibrations, mice, hail, dust and many many other inconveniences have to be taken into account. Over the years, many broken parts had to be exchanged for stronger alternatives. One example are the motors for the solar tracking. Today's reflectors use strong wind shield wiper motors from cars as compared to the smaller and less powerful motors used before.

One function which was a constant hassle is the solar tracking. Unluckily, no fool prove way to track the sun which is not affected by dirty detectors, lower or higher sun's angles, milky skies, etc., has been found yet. The most reliable systems compare two light detectors at both sides of a shadow plate.

As for any solar cooker using mirrors, the efficiency of the reflectors depends a lot on their cleanliness. In Oaxacan winter there is a lot of dust and the reflector would have to be cleaned almost daily for perfect working conditions. Thanks to the later introduced 'umbrella' position whenever it is not in use, the reflector has only to be cleaned after a week or two.

In one case, a hail storm destroyed the aluminium sheets of a solar reflector. Since then, all reflectors are equipped with a second sheet of cheap aluminium on the back side. This way, the reflector is protected as soon as it is in the 'umbrella' position.

As probably for most developers, the dream of a cheap and simple solar system had to be reviewed with time. All the measures to make it more solid and sturdy added cost and weight. In the real world, long living and reliable solutions have their cost...

7. Struggling with electronics and halfhearted help

The author designed the electronic controller with the guidance of a few friends and 'learning

by doing'. After a long time of struggling with reliability problems and electronic bugs, he had to accept having reached the limit of his capabilities. The search for help did not release his frustration. There is a large 'community' of electronics developers worldwide who are ready to give short-term help and hints. They seem to be fascinated by spectacular prototypes, but not by reliable long living solutions. Indeed, no experienced person who was willing to do the long-term job of debugging and bettering the systems (which guarantees its share of frustration) could be found.

8. The inexistent reaction from the solar cooking community

Information about the project was abundant in the international media (mainly about the 'taquero solar', the solar tacos food stall). On the other hand, it has not been presented at an international conference before (except for [7]). Still, relevant information was sent to the solar cooking communication channels in the internet [8]. To help interested people to work on the concept, all technical details have been compiled in the document [3] and this document has been shared on the above channels. The reaction was – inexistent. There seems to be strictly no interest in the solar cooking world to take it over, copy it, better it – or even steal it. This fact and the problems described in paragraph 7 lead to situation that the whole project has been running on a very low flame for the last two years.

9. Conclusions

The conclusion is that the small solar through steam units presented in this publication are 100% attractive, 95% ready, 90% reliable and have a great potential to be copied by other projects or workshops for similar applications. The open question is where to find the help to cover the remaining percentage and reanimate the enthusiasm of the project members.

References:

[1] 'Solarenergie für Imbissstände in Mexiko, 2009/2010', funded by GloboSol, SolarSpar and the city of Geneva, final report in German available on request from the author
[2] 'Esterilización solar de substratos para el cultivo de hongos Seta', 2015, materials funded by the 'Fundación Alfredo Harp Helú Oaxaca', final report in Spanish available on request from the author
[3] 'Small solar steam production units using linear parabolic mirrors for cooking', Dr. Michael Götz, Victoria Aguilera, Carlos Cruz, Lorena Harp, Gregor Schäpers, 2014, revised 2016, private publication, available on request from the author
[4] http://solarcooking.wikia.com/wiki/Brahma_Kumaris
[5] www.arduino.cc Remark: Nowadays, units sold outside USA are called 'Genuino'
[6] 'Mexico's Solar Tacos', John Dickie, 2010, https://vimeo.com/19710300
[7] 'Promoción de la cocina solar y del procesado de alimentos con el sol en Oaxaca/México: El Taquero Solar, La oficina solar, La Sazon del Sol', 2014, oral presentation by Michael Götz and Victoria Aguilera at the 'Solarquedada' in Cortes, Spain
[8] http://solarcooking.wikia.com, https://www.facebook.com/groups/scwnet/

The author would like to thank SolarSpar and GloboSol from Switzerland for the long lasting financial help to the project in Mexico.