UNIVERSITY OF HOHENHEIM

200 YEARS 1818 2018

Mission Report

Assessment of business opportunities through the introduction of solar milk cooling in rural Colombia

SYNERGY
Alianzas para la sostenibilidad

Desarrollo Rural y Agronegocios | BPG Asesores

POWERING AGRICULTURE:
AN ENERGY GRAND CHALLENGE FOR DEVELOPMENT

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DEUTSCHE ZUSAMMENARBEIT
Implementado por giz

University of Hohenheim

Institute for Agricultural Engineering in the Tropics and Subtropics (440e)

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Content

1. Daily report

The business trip was carried out from 15th January to 16th February 2018. Local partners provided logistic support for performing all the activities shown in Tab. 1.

Tab. 1: Daily activities and descriptions of achievements during that day

Date	Activities	Descriptions
15.01.2018	Arrival in Bogotá	
16.01.2018	Meeting with José Miguel and Diana:	Talking about the different Milestones (Installation, microbial testing, temperature monitoring) Explanation of the function and data of ACU and sensors
17.01.2018	Meeting with José Miguel:	Practical training of sensor usage Looking for ideas of the Colombian prototype of cans and insulation
18.01.2018	Home office working	Reports, summaries
19.01.2018	Trip to La Calera Meeting at Carmen Garcia´s farm:	Introducing timelines, practical management, details about the system Discussion of further development
	Visiting Miryam Garcia´s farm:	Checking local situation and possibilities of installation
20.01.2018	*>> Free day for visiting Bogotá <<*	
21.01.2018	Trip to Cumaral	
	Visiting the Milk transformation company "La Catira":	Production of Cheese and other milk products Meeting with the owner, talking about our projects
	Visiting two Farms in Cumaral participating in our project	Checking local situation and possibilities of installation Information about Milk production and value chain
22.01.2018	Home office:	Summary of Information from farm visitations Developing further timeline
23.01.2018	Meeting JM and Diana	Discussing the Self-made Colombian Freezer Discussing time management because of missing equipment
24.01.2018	Meeting JM and Diana	New activities after Axels message
	Technical shopping with JM	Components for "Colombian Freezer" Tools and Stuff for Installation and Monitoring the Systems
25.01.2018	Skype Meeting with Victor	Discussion "Plan B"
	Meeting with José Miguel	Testing the Colombian can with ice-compartment Discussion on Colombian freezer
26.01.2018	Meeting with José Miguel	Working on the insulation jacket and cap Planning further activities
27.01.2018	Home office:	Facebook post with our cans Work on report and protocol

28.01.2018	Trip to San Juan Arama	Visiting three Farms in San Juan
29.01.2018	Meeting with JM	Set up first simulation experiment
		Looking for dataloggers, thermocouples and PV-cables
		Discussing new agenda without German systems
30.01.2018	Skype meeting with Victor	
	Simulation Experiments with Colombian Prototype	
31.01.2018	Meeting with Oswaldo	discussing the measures of the second ice-compartment
	Trip to La Calera	Taking some stuff to Ninivé
		Discussing experiments at Ninivés or her aunts farm
01.02.2018	Skype meeting with Juan Felipe Espinosa – GIZ	Security talk
	Meeting with José Miguel	Discussing further experiments
		Checking availability of Colombian Prototype Components
02.02.2018	*>> Free day with Axel <<*	
03.02.2018	Meeting JM	Ordering Thermocouples and Freezer
		Planning Buying and Installation of Kits
04.02.2018	*>> Free day with José Miguel, Ana and Angela <<*	
05.02.2018	Skype Meeting with Victor	
	Buying components for Colombian Cooling Kit	
06.02.2018	Buying stuff, tools for installing Kits	
	Transport of Kit to La Calera	
07.02.2018	Installing Kit at Carmen´s Farm in La Calera	
	Starting first experiment	
08.02.2018	Construction of wooden structure for German Panels	
	Working on installed kit	
09.02.2018	Skype Meeting with Victor	
	Meeting with Diana	Talking about last activities
		Further activities
	Testing new thermocouples	
10.02.2018	Discussions with JM about further activities in La Calera	
	Travel to La Calera	
11.02.2018	Working on Charge Controller Experiments	

12.02.2018	Experiments Repair CPT-Kit with new Charge Controller
13.02.2018	Experiments
14.02.2018	Experiments
15.02.2018	Experiments Preparing new insulation jackets Travel to Bogotá
16.02.2018	Home office: preparing schedules for coming experiments Skype meeting with Victor, Ana, Diana, José Miguel *Leave to Airport* *Flight to Germany (cancelled)*
17.02.2018	*Flight to Germany*
18.02.2018	*Arrival in Germany*

2. Study site

2.1. Theoretical work and development

As shown in the daily reports, most of our theoretical work, organizational discussions, development of the Colombian insulated milk can, and first experiments were done in our Hotel (Hotel Morazul) in Bogotá (Fig. 1).

Fig. 1: The Hotel Morazul is in the east of Bogota, where we worked in the first weeks

2.2. Field work in La Calera

The two Farms of observation are in Siberia, close to La Calera in the province Cundinamarca, 20 km from Bogotá. The exact position of the farm of Carmen Garcia is **4°42'33.4"N 73°56'37.4"W** and of Miryam Garcias farm is **4°42'43.4"N 73°56'34.1"W**. Both Farms are at an altitude of more than 2700 m above sea-level with daily average temperatures of around 14°C during the whole year (Fig. 2).

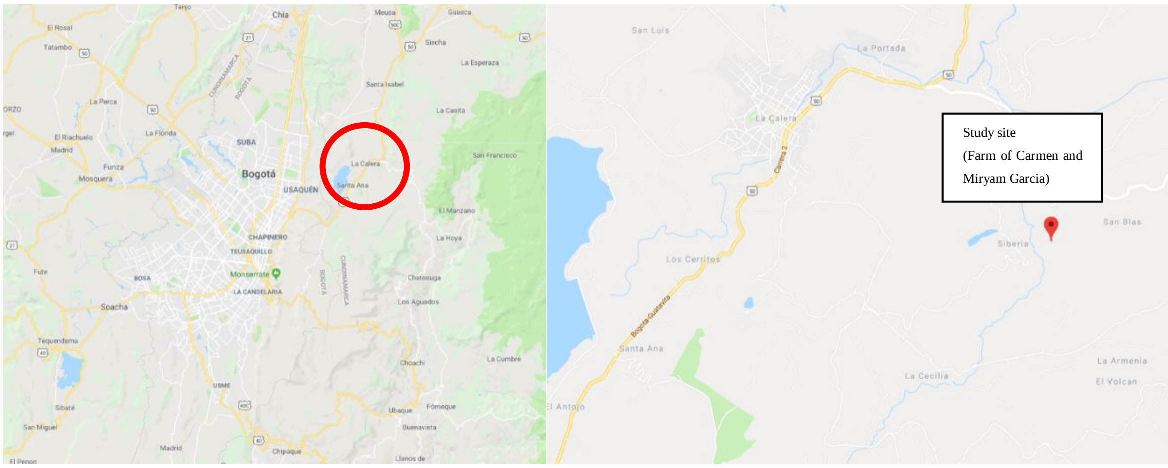

Fig. 2: La Calera to the east of Bogotá (left) and the two farms in the countryside of Siberia (right)

3. Hohenheim System

The plan was to install the 3 Hohenheim Kits first in La Calera then in Cumaral and San Juan de Arama at three different farms in each area, respectively. Unfortunately, our Kits arrived on the 8th January in Bogotá, but they were not available in the whole time of the programed stay in Colombia. Therefore, it was not possible to install them and train the local assistants how to carry out the installation and use the kits. Therefore, theoretical plans were discussed and explained on how to install the solar milk cooling system. At the same time, it was instructed how testing of the technology can be performed at different farms selected.

4. Colombian Prototype

Instead of the testing of the Hohenheim Kits we developed a Colombian prototype of a solar milk cooling system (SMC-System). The components of the Colombian Prototype were chosen relating to our Hohenheim Kit. These components were bought from local producers or local traders. All parts of the insulated milk can were produced in Colombia and the parts of the Cooling Kit were available in Colombia at local traders.

4.1. Solar cooling components

<u>The solar cooling components are:</u>

- Freezer (available in Colombia)
- Solar panels (avail. in Col.)
- Charge controller (avail. in Col.)
- Batteries (avail. in Col.)
- Ice tins (made in Col.)

4.2. Milk can components

Fig. 3: Colombian milk can components from left to right with the ice compartment and the insulation jacket

The milk can is a Colombian standard aluminum can that is used nearly by every farmer in Colombia. It has a 40 l capacity and normally a rubber tap for closing the can and prevent milk from entering dirt or insects.

The ice compartment was produced by a private manufacturer that produces technical solutions for milking, milk cans and other farming necessities. The compartment is made of stainless steel and has a rubber ring for tightly closing. There is also a cap for closing the ice compartment. As prototype, the can has no closing support and therefore a provisory solution was found to close the can with a small lashing strap.

The insulation jacket contains the same material as used for the jackets for the Hohenheim System. It is a 25 mm Rubatex® elastomeric foam that covers the wall of the milk can for preventing energy losses due to temperature equilibrium, as it is shown in Fig. 3.

4.3. Installation of the solar milk cooling system

All components were bought and paid from the budget of BPG Desarrollo y Agronegocios, represented by José Miguel Acosta Barbosa (Fig. 4).

Main components:

4 Solar panels (140 Wp)

Wooden structure (10°)

Freezer (12/24 V; DC; 220 l)

Charge Controller (30 A, 150 V)

2 Batteries (12 V; 65 Ah)

Fan

25 ice tins (2 kg)

Cables and Connectors:

2 PV-Cables (10 m; 6 mm^2)

Connector MC4 PV-KST4

Connector MC4 PV-KBT4

2 30 A Fuses

2 Cables for Battery-CC connections

Cable for Battery connect. ($6m^2$)

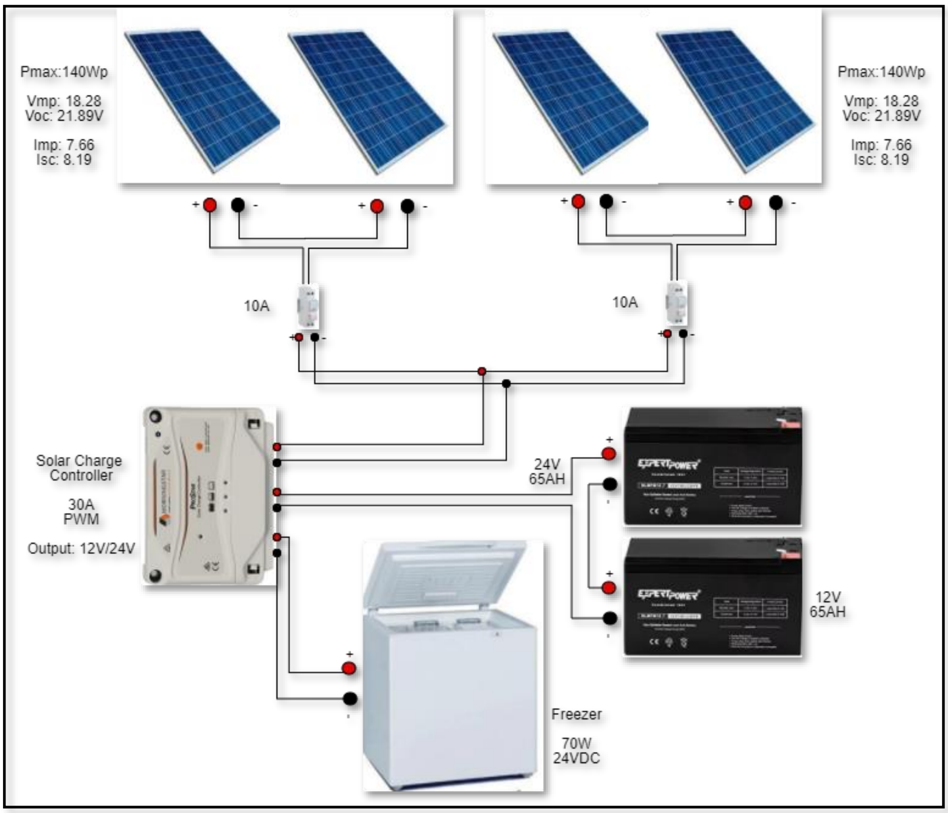

Fig. 4: The Colombian prototype of the Solar Milk Cooling System (Graph: Angela Losada, Electrical Engineer, BPG Desarrollo Rural y Agronegocios S.A.S.)

4.3.1. Solar panels installation

It is observed in Fig. 5 how the PV-Panels were placed in the roof of the house of Carmen. First two wooden sticks were fixed with wire to the holders of the roof plates. On this wooden “structure” the four panels were screwed with special aluminum holders.

Fig. 5: Provisory fixation of the panels on the roof with a wooden structure

The Panels were connected like the Hohenheim System: Two pairs of serial connected panels were connected in parallel. Two 10 m PV-Cables left the roof and entered the living-room through a window and connected to the Charge Controller of the Kit.

4.3.2. Solar freezer

In Fig. 6 is shown the rest of the Kit (freezer, charge controller and batteries) were placed in the living-room. Inside the freezer a fan (usually brought as exchange fan for the Hohenheim System) was installed for circulating the freezer air inside for a better energy distribution and therefore more efficient cooling.

Two batteries were connected in serial for a 24 V run of the system. The heart of the kit was the charge controller that controls the charge and discharge of the batteries and prevents it from overload and discharge below 50 %.

Fig. 6: The self-combined cooling kit placed in the living-room at Carmen Garcias house.

4.3.3. Ice production

25 Ice tins were bought at local plastic stores. They have a 2-liter capacity and are suitable for nutrition. The measures are a bit different to the Hohenheim ones but suitable for the ice production. The second ice compartment (Can2) was adapted to these new ice tins, so that only 1 liter of additional water is necessary for activating 6 kg ice inside the ice compartment Fig. 7.

Fig. 7: 25 ice tins in total for the CPT-Kit for producing 2 kg-ice-buckets

4.4. Testing the insulated milk cans

4.4.1. Temperature profiles

The temperature profile of milk was measured both during overnight storage (12 h) and the morning (1 h). At Miryams farm a milking machine was used and after milking in two milk cans, the milk was sieved into our milk can, where thermocouples in the bottom and the top of the can were installed before (Fig. 8).

Fig. 8: Position of the thermocouples (left), sieving of the milk (middle) and measurement during overnight storage (right)

At Carmen´s farm, the cows were milked manually and only in the morning. The milk is collected in different pails and finally sieved into the aluminum milk can. From that time, it takes only 15 to 25 minutes until the milk truck collects the milk at the farm (Fig. 9).

Fig. 9: Manual milking in the morning (left), collecting milk from different plastic pails (middle) and final collecting and sieving of all the milk in the aluminium milk can (right).

Tab. 2 shows three repetitions of a milk cooling experiment of evening milk at Miryam´s farm with around 22 liters of milk and 6 kg ice on three following days. The milk was stored overnight in an insulated and cooled can at the milking place at the farm and collected the next day after 7 am.

Tab. 2: Experimental descriptions of the monitoring of afternoon milk cooling and overnight storage at Miryam´s farm with the Colombian Prototype

Experiment	Date	Start	End	Durat.	Milk	Ice	Water
Col_CPT_Can2_pm_1.1	12.02.2018	6:40 pm	7:20 am	12,5 h	22 kg	6 kg	1 kg
Col_CPT_Can2_pm_1.2	13.02.2018	6:40 pm	7:15 am	12 h	22,5 kg	6 kg	1 kg
Col_CPT_Can2_pm_1.3	14.02.2018	6:40 pm	7:20 am	12,5 h	21 kg	6 kg	1 kg

Fig. 10 shows the temperature profile of the overnight storage of 21 liters of milk, cooled with 6 kg of ice for 12 hours (Col_CPT_Can2_pm_1.3) with the Colombian milk can and the Colombian prototype of an ice compartment. In the first hour, the milk could be cooled down from 30 to 15 degrees Celsius and after 2 hours below 10. Due to the low ambient temperatures (around 10°C) the milk could be kept at 7°C until the next morning.

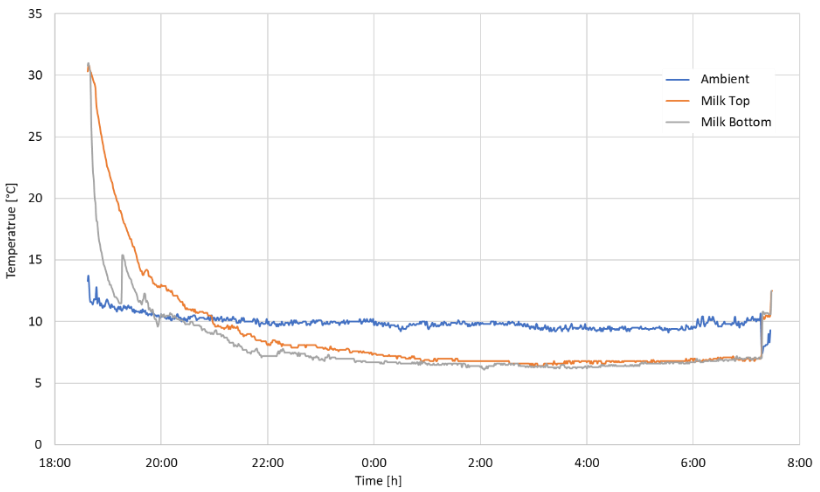

Fig. 10: Evening milk cooling with 21 l milk, 6 kg ice and 1 kg additional water for around 12 h. (Experimental code: Col_CPT_Can2_pm_1.3)

The three experiments of cooling morning milk are shown in Tab. 3. The usual milking time at Miryam´s farm was at around 6:00 am so that the cooling experiments could start at 6:30 am. Here the settings are like the overnight storage, except the additional water. Here the first ice compartment was used, which needs 3 instead of 1 liter activating water. In general, the cooling time took around 1 hour until the collecting truck arrived at around 7:15 am.

Tab. 3: Experimental descriptions of the monitoring of morning milk cooling at Miryam´s farm with the Colombian prototype

Experiment	Date	Start	End	Durat.	Milk	Ice	Water
Col_CPT_Can1_am_1.1	13.02.2018	6:25 am	7:20 am	55 min	21,5 kg	6 kg	3 kg
Col_CPT_Can1_am_1.2	14.02.2018	6:35 am	7:15 am	40 min	23,5 kg	6 kg	3 kg
Col_CPT_Can1_am_1.3	15.02.2018	6:25 am	7:20 am	55 min	21 kg	6 kg	3 kg

The temperature profile shown in Fig. 11, shows the same behavior as the profile in Fig. 10 for the evening milk. After 1 hour cooling the milk temperature has around 15°C when the milk is collected because the ambient temperature and initial temperature are similar to the cooling experiment of overnight storage of evening milk.

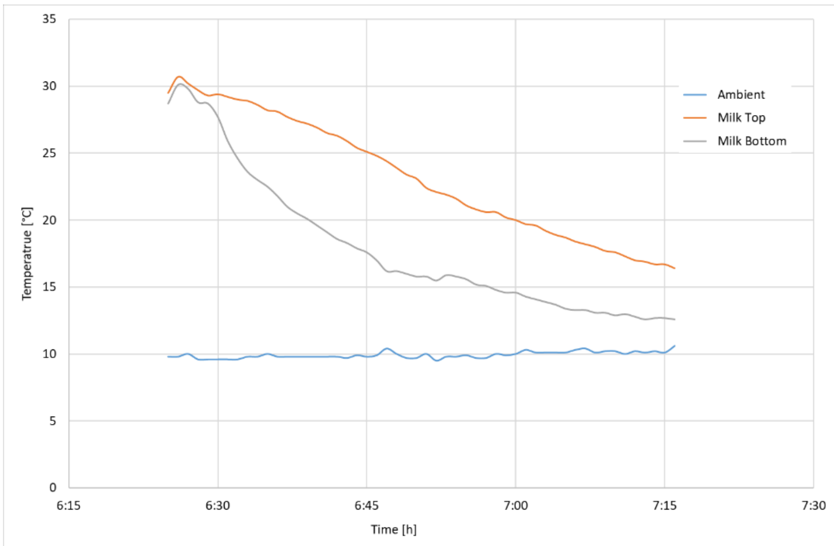

Fig. 11: Morning milk cooling with 21 l milk, 6 kg ice and 3 kg additional water for nearly 1 h. (Experimental code: Col_CPT_Can1_am_1.3)

4.4.2. Milk microbiology

For estimation of milk quality by measuring the microbial growth, samples were taken immediately after milking (fresh sample) and shortly before the milk truck was collecting the milk in the morning. So, for the evening milk, samples were taken at around 6:30 pm and 7:15 am and for morning milk at 6:30 am and 7:15 am. Sample taking was done just with a sampling spoon and a plastic tube directly after milking and before collecting in the morning the milk was mixed first and then the sample was taken (Fig. 12).

Fig. 12: Sample taking with sampling spoon and storage in plastic sample tube.

Milk sample tubes were put into a polystyrene insulated box with refrigeration gel for keeping the samples below 4°C (Fig. 13). The sample from the evening milk was put there also for overnight storage and in the morning the other samples were added, and the gel was exchanged. In these boxes the samples were sent to a Laboratory in Bogotá for microbial count.

Fig. 13: Milk sample storage with the tubes, the polystyrene insulated box and refrigeration gel for keeping the samples below 4°C.

Fig. 14 shows the results of the microbial count of milk cooled with the solar cooling system and with the current system in a water bath. With the current system of overnight storage, the bacteria grow within 12 h to a 20 times higher amount (> 900.000 CFU/ml) compared to the initial milk in the evening (40.000 CFU/ml). With the solar milk cooling system, the bacteria only grew to a three times higher amount (75.000 CFU/ml) compared to the initial milk (18.000 CFU/ml).

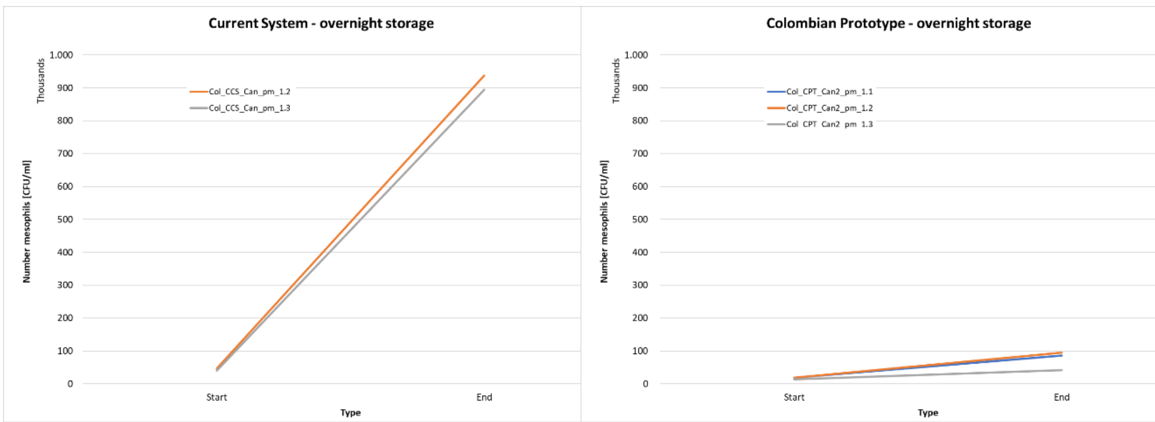

Fig. 14: Microbial growth of milk during overnight storage (12 h) with the current system in water bath (CCS) at Miryam´s farm (left) and Microbial growth of milk during overnight storage (12 h) with the Colombian prototype of SMC system (CPT) at Miryam´s farm (right).

4.4.3. Freezer performance

Freezer performance is the ice production in kg per day. It was measured in a “cool-down”-experiment (cd) with 50 kg water (25 tins á 2 kg) and 3 thermocouples in 3 different ice tins in one freezer. After taking the data at the time the freezer reaches -17°C the daily ice production was calculated from the time the first tin started to freeze (first vertical line in Fig. 15) until the last tin finished completely freezing (second vertical line in Fig. 15). The time between these two points is necessary for producing 50 kg ice. In La Calera this cd-experiment was done at Carmen Garcia´s farm where the system was installed the first time after buying the components. In that experiment it took 117 hours for cooling down and freeze 50 kg of water. That means per day 10.3 kg of ice can be produced with that system at the location around Carmen´s farm.

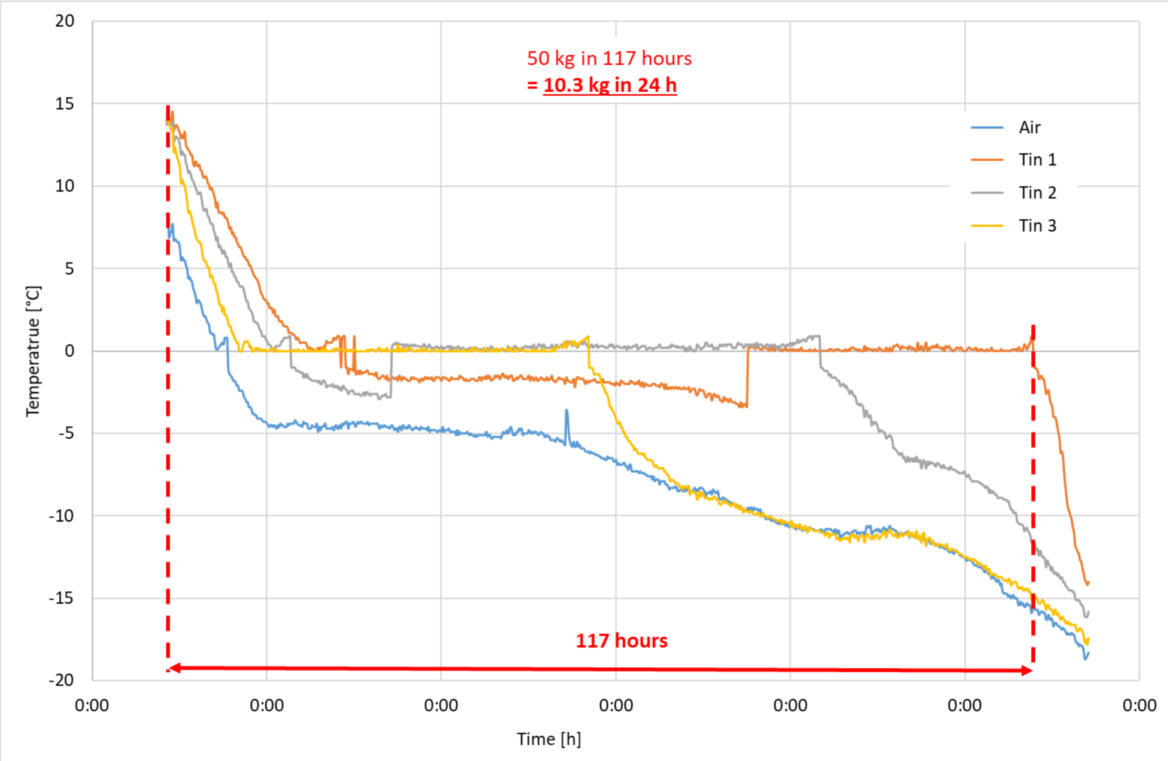

Fig. 15: Cool down experiment with the Colombian prototype freezer and 50 kg of water in around 5 days. (Experimental code: Col_CPT_Fre0_cd_2.0)

5. Diary value chain intervention

5.1. Local production system

Fig. 16 shows how milking is usually done in the rural areas. The farms have in average between **5 and 10 milking cows** per farm and each cow produces around 3 – 5 liters per day. Most farmers just milk only one time in the morning at around 5:00 to 6:30 am and only a few farmers do afternoon milking at 4:00 – 6:30 pm. Most of the milking is done manually and only sometimes they have a milking machine. The milk is collected only one time per day at around 7:00 – 9:00 am.

Fig. 16: Differences in managing milk production are high but geographical close to each other. Manual milking at Carmen´s farm (left) and milking machinery at Miryam´s farm (right) living 500 meters apart each other.

Fig. 17 shows a scheme of the current dairy value chain in Colombia. There is a high diversity of farm structures in Colombia due to the different climates, infrastructures and personal convictions and economical possibilities. Therefore, it is necessary to work considering individual farms. Furthermore, there are promising structures that can help to make the solar milk cooling system affordable to farmers. The dairy industry Colombia could benefit for: a) higher milk quality: up to $ 74 COP (Colombian Pesos)/l at <25.000 CFU/ml (2 ct/l) or b) lower temperature: up to $ 15 COP/l (0.4 ct/l). As described in 4.4.1 and 4.4.2 the solar milk cooling system (SMCS) can manage a higher milk quality and lower temperature of the milk at collecting time.

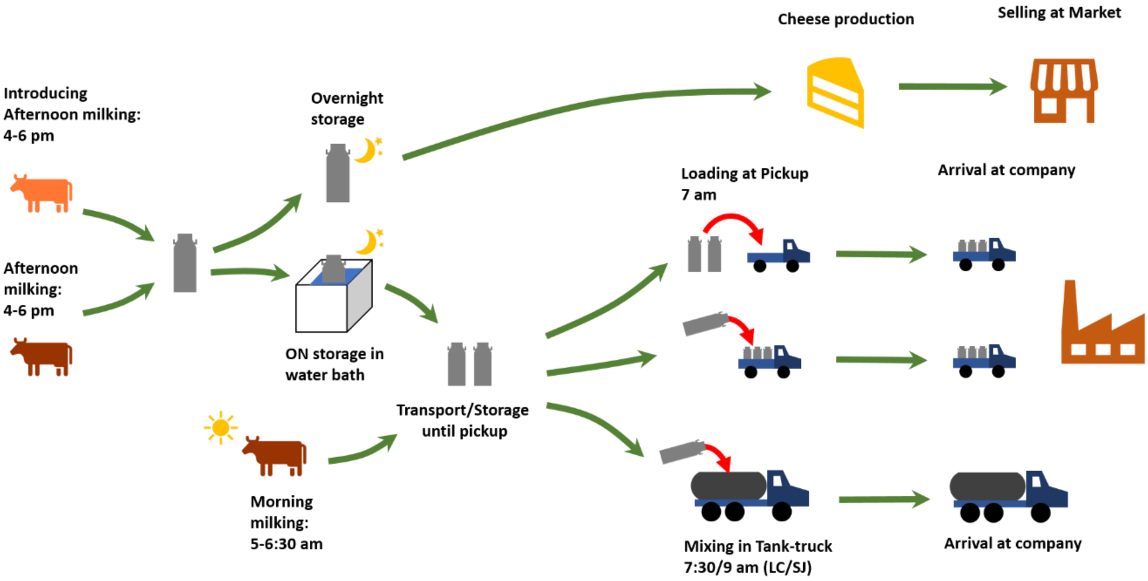

Fig. 17: Scheme of the Colombian milk value chain from milking to transformation Industry

5.2. Potential Profits of a solar milk cooling system

The intervention along the value chain can provide multiple benefits for milk storage, as for example:

- Higher milk production because of introducing afternoon milking
- Higher milk delivery instead of cheese production
- Benefit system for higher milk quality (and lower milk temperature)
- Saving transport cost of cheese selling
- Saving transport costs at 24 h storage (arrangements necessary with diary industry)

5.3. Local Challenges

Due to high density of trees around the farms, farm houses or stables, there is a high occurrence of shadow during the day (Fig. 18). This fact limits the variability of potential places for installation the solar panels. In many cases it is hardly possible to place the panels close to the freezer´s place. Therefore the 10 m PV-cables, mostly in the low tropics of Colombia, are too short and instead of 10 m and 6 mm^2 cables, longer but also thicker cables are necessary (20 m and 8 – 10 mm^2).

Fig. 18: Trees near the house/stable – longer PV-cables necessary

The topography of the area, most of all in the Andes, implicates the construction of a structure (Fig. 19), this implicates that in some regions the installation of the solar panels cannot be done at the roof because of the simple construction of roofs in that areas.

Fig. 19: Topography/slope – wooden construction for PV-structure necessary

It is important to mention the necessity to provide fences around the solar milk cooling system. In nearly every farm, there are a lot of free running dogs, cats, as it is shown in Fig. 20, but also sheep, horses and cows. These animals might damage the systems by playing around (dogs and cats) or just because of the high interest potential of the new system (most of all for cows).

Fig. 20: Lots of dogs/cats/other animals everywhere – fences necessary for preventing PV-structure from damaging by playing animals or interested bigger animals (cows, sheep, etc.)

One of the most challenging tasks in the introduction of SMC-system seemed to be the high diversity of farms (as written in 5.1). In Colombia there is not yet a unique system at markets, availabilities and infrastructure. Therefore, due to the size of the country, the different areas, cultures and climates, a high diversity of farm structure within a farm, between farms in one area and between the different areas in whole Colombia exists.

For introducing the solar milk cooling system in Colombia an adaption of the system to the different areas instead of introducing a unique system seems to be necessary.

6. Acknowledgements

Great thanks to my friend **José Miguel Acosta Barbosa** from **BPG Desarrollos** for his great accompany and supervision of my stay there in Bogotá! We were a very good team and had a great time there during that 5 weeks. There were only a few days without working or staying together. Thank you, José! In you, I found a new friend in Colombia.

Thanks also to **Diana Ramos** from **Synergy** for being my first contact person when I arrived and for supporting us in organizational and practical field work. I learned a lot of Colombian economic structure and milk value chain.

Big thanks to the owners **Omar** and **Margarita** of the **Hotel Morazul** and their workers for their big support in space, time and equipment in the first 3 weeks! Without their support it wouldn’t have been possible to achieve all that goals in such a short time and everything would have been much more complicated.

I also want to thank **Carmen** and **Miryam Garcia** and their families for supporting all our work and experiments in La Calera! Sometimes it was not easy for them with us and our full timelines and lots of activities. But anyway, we were able to take part in their family life for the whole stay there at the farm.

Thanks also to the **GIZ Colombia** for their support and organization of that project and the care of my safety there in Colombia.

But I wouldn´t have had the possibility to go to Colombia to support the project without the **SOLAR MILK COOLING Team,** most of all to **Victor Torres Toledo** and **Ana Salvatierra Rojas**, who allowed me to go and take part in that development process of rural Colombia.