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Social and Institutional Change in Agricultural Development

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Bachelor Thesis

Challenges of Implementing a Small-Scale Solar Milk Cooling System

A Case Study in Western Kenya

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This version contains editorial changes made after submission.

Declaration

We Aline Mack and Sarah Graf, declare that this thesis is our original work accomplished independently without outside help. All sources of consulted materials are duly acknowledged in this thesis. This work has not been submitted for evaluation to any other assessment institution for an award or any academic qualification.

Furthermore, we agree with displaying the document in the library of the Institute of Agricultural Economics and Social Sciences in the Tropics and Sub-Tropics of the University of Hohenheim, implying the possibility of exploration and borrowing by others.

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Sarah Graf	Date

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List of Abbreviations

FAO Food and Agriculture Organization of the United Nations
GDP gross domestic product
IDA international development agency
ILO International Labour Organization
KCC Kenyan Cooperative Creameries
KNBS Kenya National Bureau of Statistics
KSh Kenyan Shillings
NGO Non-Governmental Organization
WTP willingness to pay

1 INTRODUCTION

Rising incomes and urbanization have led to an increased demand for meat and milk in developing countries. This is seen as an opportunity for poor farmers in developing countries, as they get a higher share of their income from livestock, than do better-off rural people (Delgado, Rosegrant, Steinfeld, Ehui, & Courbois, 1999). As meat and milk are highly perishable, refrigeration is crucial to ensure food safety and reduce food waste due to spoilage. Yet, refrigeration already consumes about 15% of all electricity (Coulomb, 2008), and 1% of all CO2 emissions worldwide (James & James, 2010), even though less than 10% of perishable foodstuff1 are refrigerated. Both the high energy demand of cooling and leakage of refrigerants contribute to global warming (Coulomb, 2008). In short, there is a trade-off between the benefits of refrigeration and its environmental costs, which could be reinforced by increasing demand for animal products as well as increased cooling in developing countries.

A great number of technological solutions have emerged recently, that use renewable energy for milk cooling. They range from solar powered milk storage tanks with a capacity of 1000L (REEP, 2017) to a 15,5 L portable biogas cooler (Ndyabawe & Kisaalita, 2014). Solar-, biogas or hybrid systems address the challenges of remoteness, vulnerability to energy markets and the need for climate-friendly technologies. Much has been written about how these technologies can contribute to make dairy value chains energy smart in theory. But while the technical aspects of these systems are well known (for example Edwin & Sekhar, 2015; Erickson, 2009; Torres-Toledo, Meissner, Täschner, Martınez-Ballester, & Müller, 2016; Wayua, 2011), there is very limited knowledge about impact of these interventions on the beneficiary level. In fact, there is only limited data on the quantities and causes of milk spoilage for most developing countries, the very problem these “solutions” want to address. Project descriptions therefore often state data that addresses the whole agricultural sector not only dairy or that relate to overall losses without differentiating between spoilage, spillage and lack of market (REEP, 2017).

To address these issues, we researched implementation and outcomes of three pilot projects that introduced small-scale solar milk cooling in western Kenya. The main outline of all three projects was that donated solar coolers were imported by an international development agency and then given to a dairy cooperative. We used the comparative case study approach to address the following research questions:

- Did these value chain interventions achieve the project goals to reduce spoilage and increase farmers income?
- What are the challenges and opportunities, when implementing small-scale solar milk cooling?
- Under what conditions can the researched small-scale solar cooling systems be implemented successfully?

To answer these research questions both qualitative and quantitative methods were used: Semi-structured interviews, focus group discussions and direct observations were used to get an in depth understanding of the mechanisms that enabled or limited impact in the different cases. A consumer survey provided insights into the local milk market. The quantitative part of the research comprised of a household survey and a discrete choice experiment. The household survey was used to compare

[1] fruit and vegetables, dairy products, meat, fish and seafood

household and farming characteristics as well as milk marketing practices between the three cases. On the basis of the discrete choice experiment we estimated farmers willingness to pay for cooling.

This thesis has the following structure: In chapter 2 we present a short literature review that gives a basic overview of the Kenyan dairy sector and the basic principles of milk cooling. Furthermore, the main technical aspects of the small-scale solar cooling systems (solar coolers) will be explained. Chapter 3 provides information about the research approach, the study area and the qualitative and quantitative methods applied. Chapter 4 provides the results: Section 1 describes the farming systems used in dairy production, the general procedures of milk handling observed during the research and the results of the consumer survey. Section 2 then provides an overview of the three cases, before describing each case in detail. For each case information is provided about the respective dairy cooperative, the channels for daily milk marketing and the impacts (or lack thereof) of the solar coolers. In Section 3 we present the quantitative results including a statistical case comparison and the discrete choice experiment. Chapter 5 discusses, why some of the systems are not in use, while others are and how implementation can be more successful. In chapter 6 the thesis is completed by drawing conclusions from the findings with regard to the research objectives.

2 LITERATURE REVIEW

The following sections are supposed to give an overview of the existing literature on the topic. In Section 2.1., we introduce the dairy production in Kenya. We outline the state of the Kenyan Dairy sector in Section 2.1.1, the historical evolution of the dairy sector in 2.1.2 and the milk market in Kenya in Section 2.1.3. Section 2.2 explains the logic of solar milk cooling: In section 2.2.1 it gives an overview about the milk quality and in 2.1 potential risks along the supply chain will be explained. Lastly Section 2.2.3 describes the solar milk cooling systems assessed in the research.

2.1 Dairy Sector in Kenya

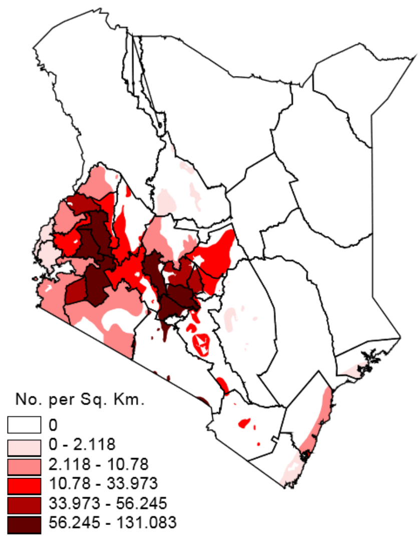
2.1.1 Dairy Production in Kenya

Agriculture is of key importance in the Kenyan economy: It contributes 25% of the gross domestic product (**GDP**). Over 80% of the people are employed in the agricultural sector. Livestock contributes 10% of the national GDP. Within the livestock sector dairy production is most important (Muriuki, 2003).

The dairy sector in Kenya is well developed compared to other countries in Eastern Africa. The milk amount per capita is four to seven times higher than in other countries in the region (Thorpe, Muriuki, Omore, Owango, & Staal, 2000).

The milk production in Kenya is an important economic impact that contributes 14% to the agricultural GDP and 4% to the national GDP. In addition, it provides an income for over 1.8 million small-scale farmers (Kenya Dairy Board, 2014). In a study done by (Omore, Muriuki, Kenyanjui, Owango, & Staal, 1999) has been shown that for every 100 litres of milk produced per day, two or three Kenyans are employed. Milk production is dominated by cattle who are responsible for 70% of the total milk production, the remaining milk is produced by camels and goats (FAO, 2011). The production of dairy can be devided by the dairy cattle and the indigenous cattle. Within the dairy sector the dairy cattle contribute 60% of the national milk production whereas indigenous cattle produce 40% (Birachi, 2006). The distribution and density of the dairy cattle population in Kenya is shown in Figure 1.

Figure 1: Dairy cattle distribution and density in Kenya, from FAO (2011)



Kenyan dairy production is mainly based on small-holder production. Smallholders produce 80% of all milk (Auma, Kidoido, & Kariuki, 2016). They often use a crop-livestock system, having a few acres for crop production and the production of natural grass and planted fodder(Muriuki, 2003). An average cow produces about 5kg of milk per day; an average household would sell less than 10kg of milk per day (FAO, 2011).

2.1.2 Historical evolution of the Dairy Sector

The Kenya dairy sector has a long history, starting with non-commercial milk production from Zebu cattle before market orientated milk production started (Mudavadi et al., 2001). Market-orientated milk production started in the early 20th through European settlers who imported dairy cattle breeds. Large scale dairy production by European settlers dominated the sector. These settlers successfully lobbied for a range of government financial and policy support, including quarantine laws, veterinary laboratories, artificial insemination services, and marketing and price controls managed through the Kenya Cooperative Creameries. Only after the Swynnerton Plan of 1954 indigenous small-scale farmers were allowed to participate in commercial agriculture (Muriuki, 2003).

After independence in 1963 many European farmers left the country and sold their farms to Africans or to the government. Many of these farms were then rapidly sold to smallholder farmers (Thorpe et al., 2000). The government supported the small-holder farmers with production and marketing services, like highly subsidized artificial insemination (Thorpe et al., 2000). Until 1969 markets were open with independent dairies, then the dairy market changed to a monopolistic market. The abolishment of the contract and quota system from the government to Kenyan Cooperative Creameries (KCC) in 1971 lead to the monopole of KCC (Birachi, 2006). Smallholder farmers profited from this process as they had been excluded from selling milk to KCC by the quota system (Thorpe et al., 2000) and as KCC would now buy all milk for a fixed price irrespective of location (Birachi, 2006). During this period only KCC had the right to procure milk directly from farmers. The sale of raw milk was prohibited in urban areas.

The government strategy that combined subsidized livestock services and statutory market control greatly benefitted smallholder dairy production (Muriuki, 2003) . Yet, the system was not sustainable. Budgetary constraints lead to a decline in the quality of the provided services in the 1980ies (Muriuki, 2003). In 1992, the milk market was liberalized price controls were abolished and KCC lost its monopoly (Birachi, 2006). In addition, the government artificial insemination services were privatized and the sale of raw milk in urban areas was decriminalized (Ngigi, 2004). The privatization of artificial insemination services lead to a decline in service coverage and to a sharp increase in prices, that are considered prohibitive to the majority of farmers (Omiti, 2001). Furthermore, KCC was increasingly unable to pay farmers, which lead to the insolvency of cooperatives that delivered milk to KCC (Birachi, 2006). Since liberalization both formal and informal market have grown rapidly. Milk production and the number of people employed in agriculture increased (Omore et al., 1999).

2.1.3 Milk Marketing in Kenya

The dairy value chain in Kenya includes production level, milk collection, transport and selling. Muriuki, (2003) shows a simplified visualization of different marketing channels. Almost half the milk produced remains at home for self- or calf-consumption. 55% of the milk is marketed. Milk can be directly sold directly to consumers (23%), or sold in cooperatives, to traders or shops (32%) and also to processors (1%).

The value chain can be divided into an informal and formal sector. Staal et al. (2003, page 11) defined the formal milk market as those "*who follow modern Western-style processing technology and who are conform to milk market regulations and licensing*". The formal market is licensed by the Kenyan Dairy Board. Milk bars, cottage industries, mini dairies, processors, producers and distributors can be licensed by the Kenyan Dairy Board (FAO, 2011).

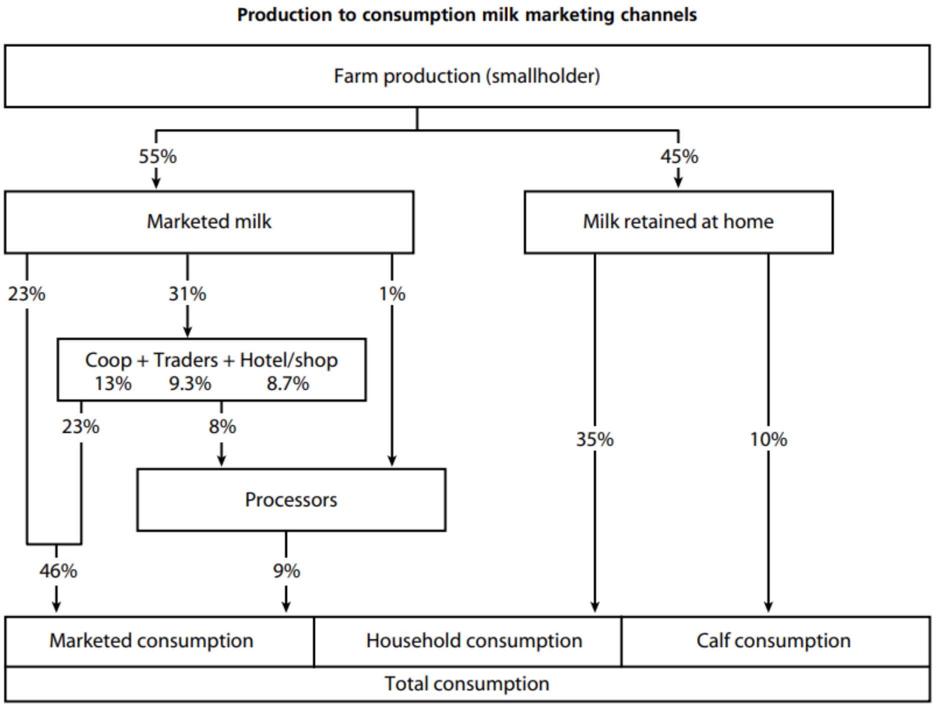


Figure 2: Production to consumption milk marketing channels in Kenya, from Muriuki 2003

However, licensed processors[2] handle less than 20% of the total market milk (Steven J. Staal, Pratt, & Jabbar, 2008).The informal market is characterized through direct sales from smallholder producers to consumers or informal milk traders. About 90 % of milk is sold this way (Omore et al., 1999). Selling milk directly to consumers is especially common in areas of low production relative to the number of consumers and among small-scale milk producers in rural areas (Omore et al., 1999). Kenyans prefer to drink raw milk and 75% of the produced milk is consumed raw (Ngigi, 2004). The main reasons for this are that raw milk has a higher fat content and is 20 to 50% cheaper than processed milk (Muriuki, 2003).

[2] 45 licensed processors in Kenya (Steven J. Staal, Pratt, & Jabbar, 2008)

2.2 Potentials of solar milk cooling

2.2.1 Milk Quality

The spoilage of raw milk is a known risk if milk is not cooled, temperatures are high and the storage period is long(Kurwijila, 2006a). However, these are not the only sources of contamination. The increase of spoilage bacteria in milk depends also on the hygiene measures applied during the milking process and during transportation. If raw milk gets immediately cooled below 10°C it may be storable up to 3 days (Kurwijila, 2006a). Kurwijila (2006) defines clean milk in the following key words:

- Low bacterial count
- Pleasant creamy smell and colour
- No obnoxious odours
- No dirt and extraneous matter
- No residues of antibiotics, sanitisers or pesticides

There is also a potential risk of due to milk-borne diseases, especially zoonosis of brucellosis and to some extent, zoonotic tuberculosis. This risk is mainly associated with the informal milk market (Omore et al., 1999). Consumer can protect themselves from the consequence of low quality milk through boiling milk before consumption. In a study by Arimi et al. (2005) all urban and 96% of rural consumers indicated that they boiled milk before consumption. As a result, health risks from bacterial pathogens are considered to be low. Consumption of soured milk is a concern though, as well as the exposure to pathogens in communities that frequently consume raw milk from communally grazed herds, such as the Maasai in East Africa These communities have much higher risks to contract milk-borne (Arimi et al., 2005).

2.2.2 Potential quality risks along the Supply chain

Generally, longer food value chains include more risks of food contamination and they have proven to show higher bacterial contamination (Omore, Arimi, Kang'ethe, McDermott, & Staal, 2002). A concerning risk is the contact of products with contaminated water which could take place in almost every step of the value chain (Todd & Narrod, 2006). Possible reasons for food contamination are shown in Figure 3. Contamination can happen on all steps of the value chain.

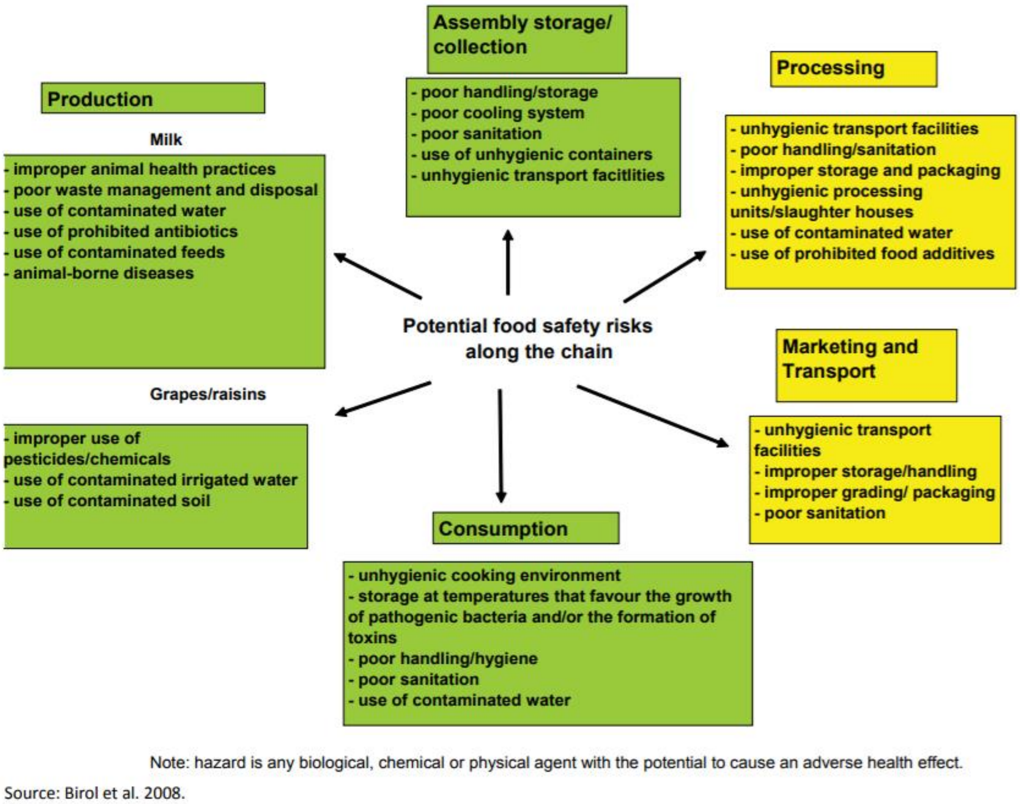


Figure 3: Potential food safety hazards along the value chain, from Trench et al (2008)

2.2.3 Solar milk cooling

The lack of cooling facilities for milk is a concern in milk production. Cooling is often connected with additional costs and only becomes attractive if guaranteeing a cooled milk is economical more efficient, for example trough less spoilage or a price premium (FAO, 2011). The two milk cooling technologies assessed in this study are both based on solar energy produced through a PV panel. In the following section the different technologies are briefly described: first, we describe the "Ice Maker" system of the University of Hohenheim; second, we describe the cooling system developed by SunDanzer.

Ice-Maker

The Ice-maker cooling system was developed by the Department of Agricultural Engineering in the Tropics and Subtropics of the University of Hohenheim. The advantage of using ice as a cooling medium is first, that ice can cool down milk much faster than a freezer and second, that the ice serves as an energy storage thereby reducing the need for batteries. The developed system consists of photovoltaic panels and a commercially available DC freezer with a smart control unit to produce ice in 25 small plastic containers with a capacity of 2 L each. To cool milk, ice is filled into an extra compartment integrated in the insulated milk cans with a capacity of 30 L of milk. During the day, when solar energy is available, the freezer is working at 100% utilization. During night, the solar freezer is in a "sleep mode" and only conserves the ice produced. Depending on the amount of milk in the milk cans the amount of ice needed to cool the milk differs. For example to cool down 30 L of milk, 6 kg of ice is needed and preservation for 2 h is guaranteed (Torres-Toledo et al., 2016). Figure 4 shows the system in practice.

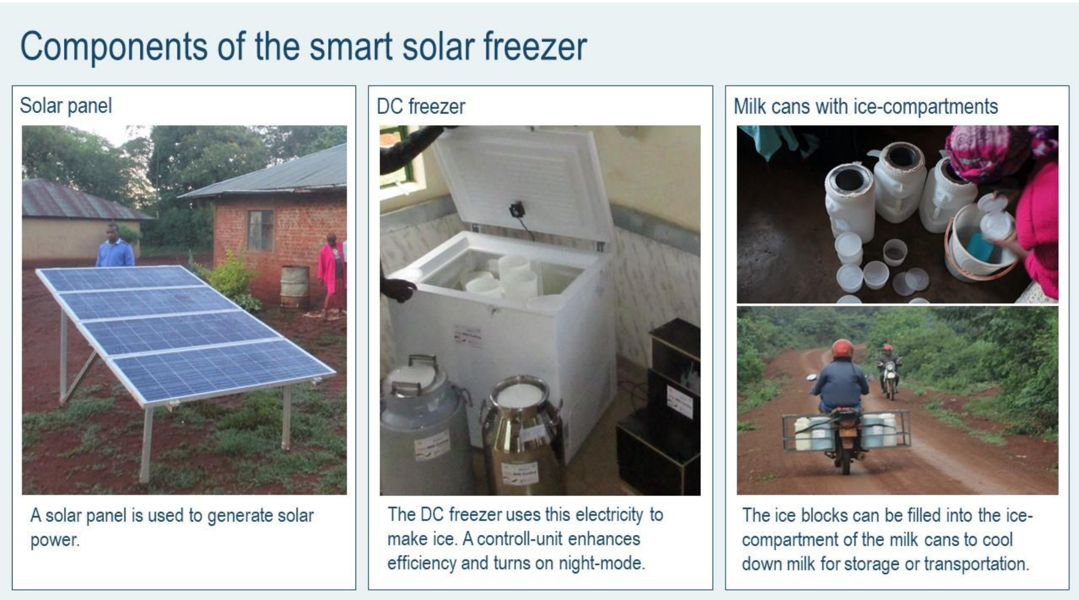


Figure 4: Description of the solar Ice-maker. Pictures from Torres-Toledo, Rojas Salvatierra and Graf

SunDanzer Systems

SunDanzer is a company producing refrigerators. SunDanzer has developed a cooling system based on solar energy, providing an off-grid cooling opportunity. Unlike the system of the University of Hohenheim, the cooling system consists of a double photovoltaic panel that is installed in eastern and western direction to absorb the maximum of solar energy in the morning and evening. The system is not based on the use of ice. Instead milk is directly based in the refrigerator. The refrigerator can cool down 20 L of milk. The intention was to cool down the evening milk. Farmers in Ngorika, where SunDanzer installed its firsts systems, reported an increase of milk sales because of the positibly to store milk overnight due to the SunDanzer System (Foster et al., 2017).

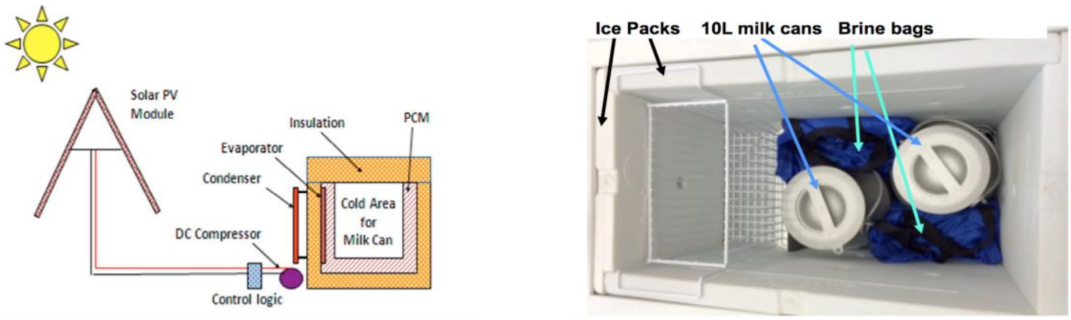


Figure 5: SunDanzer milk cooling system - Theoretical construction and fridge from inside, from Foster et al. (2017)

3 METHODS

This chapter describes how the research was conducted. The first section describes the research approach and gives an overview of the methods used. Section 2 provides basic information on the study area and Section 3 on the study cases. In Section 4 the qualitative methods are explained in more detail. Section 5 describes how the quantitative part of the research, namely a household survey and a discrete choice experiment, were conducted and analysed.

3.1 Approach

The research project is a comparative case study with 3 cases (see Table 1). Originally a single case study was planned. Yet, when we understood, that the actions and impacts observed were highly context specific the approach was shifted to include a second case. The comparative Case study design was selected to replicate findings and get results, independent from the context of a specific study location (Yin, 2003). Later a third case was adopted as it was perceived a success story, which would have contrasted the first two cases. A case was defined as a cooperative that owned a solar cooler. Additionally, the structure of the cooperatives were selected to fit the scenario for which the solar coolers were designed: Milk should be collected at a main dairy plant as well as at collection centres, that bulked milk and then transported it to the main dairy plant. The main dairy plant should offer some cooling and processing facilities. However, it did turn out during the research that none of the cases did actually match the scenario.

Table 1: Overview of qualitative and quantitative methods used during the research

Data collection method	Ice-maker case	SunDanzer case 1	SunDanzer case 2	Total
Quantitative methods				
household survey	**35**	**32**	**21**	**88**
discrete choice experiment	**35**	**32**	**20**[3]	**87**
Qualitative methods				
Participatory Impact Diagrams	**3**	**1**	**2**	**6**
- farmers group	2	0	0	2
- cooperative officials	1	1	0	2
- system caretakers	0	0	2	2
seasonal calendars	**2**	**1**	**1**	**4**
focus group discussion on Implementation Challenges	**0**	**1**	**2**	**3**
- farmers group	0	1	1	2
- cooperative officials	0	0	1	1
Net-Map	**1**	**0**	**0**	**1**
Process-Net Map	**5**	**4**	**1**	**10**
- Cooperative officials	2	4	1	7
- traders	3	0	0	3
semi-structured interviews	**6**	**4**	0	**10**
- cooperative officials	3	1	0	4
- traders		2	0	2
- government officials	3	1	0	4
consumer survey	**19**	**16**	**12**	**47**

To gain a broad and in-depth understanding of the research topic mixed methods were used. Triangulation was used to counteract the weaknesses of different data collection methods and enhance validity (Berg, 2007). It comprised data triangulation, methodological triangulation and investigator triangulation (Bitsch, 2005).

We had planned to use identical methods in all cases but had to adjust the research methods due to unexpected findings. In SunDanzer case 1 a high number of Process-Net-Maps was conducted as respondents gave contradictory answers[4]. Cooperative officials and farmers tried to conceal, that the solar coolers were actually not in use. Hence, for SunDanzer case 1 observations and conversational interviews, that cannot be captured in the table, provided the most valuable data. As soon as we knew, the solar coolers were not in use in, we adapted the participatory impact diagram so it captured differences between expected and actual outcome. This diagram was then used to facilitate discussion on implementation challenges of the solar coolers. This adaptation was also necessary in SunDanzer case 2. In this case we were able to find out the solar cooler was not in use much quicker. In this

[3] One person was excluded from the analysis, as she clearly did not understand the experiment.
[4] The amount of milk being handled by the cooperative varied from 20,000 L per day to 500 L per day; milk collection times differed, for the milk transporter different names were provided etc.

process observations and conversational interviews were also of key importance. Unfortunately, there is less data on SunDanzer case 2 than on the other cases, as we had to leave the field early due to increasing political tensions.

3.2 Study Area

The study area was located in two counties in Western Kenya, more specifically in Siaya and Bungoma County. There is limited data on farming in the region and information could often only found for either of the country. Nevertheless, a short overview of farming in the areas of the three cases is provided.

The Ice-maker case was situated in Siaya county in the semi-humid lower midland zone (Kenya National Bureau of Statistics (KNBS), 2015b). In the lower areas, where the Ice-maker case was situated, the rainfall ranges between 800 – 1,600mm. There are two rainy seasons: the long rains between March and June and the short rains between September and December (Government Of Kenya, 2012). The average annual temperature is 22.2 °C (climate-data.org, 2017).

In the County 44.7% of the labour force is engaged in small-scale agriculture (KNBS, 2016). The average farm size for a smallholder farmer is 1.5 ha and 7.0 ha for a large scale farmer (Government Of Kenya, 2012). According to KNBS (2015b) the main agricultural products are maize (78,132 ha), beans (47,915 ha) and sorghum (15,986 ha). Most cattle kept in the County (492,591) are Zebu cattle kept for beef production. In comparison, there are only 5,698 Dairy Cows. Total milk production is 24,247 t per year. The population density is 333 persons per square kilometre. The average household has 4.2 members. 24.7% of children under 5 years are moderately or severely stunted.

The SunDanzer cases are located in Bungoma County. According to the KNBS (2015a), the population density is 449 persons per square kilometre. 47.5% of the population work in small-scale agriculture. Only 65.4% of the population are considered food secure. The main crops are maize (98,761 ha), beans (67,620 ha) and vegetables (23,660 ha). SunDanzer case 1 was in a sub-humid lower midland zone, suited for crop production. In the ward, 50.5% of the population are below the poverty line. The SunDanzer case 2 was located in a humid upper midland zone, suited for Maize beans, coffee, tea and Irish Potatoes. The cooperative is mainly a coffee cooperative, that established a dairy branch in 2016 with the help of an international development agency. In the ward 50.3% of the population are living below the poverty line (KNBS, 2015a)

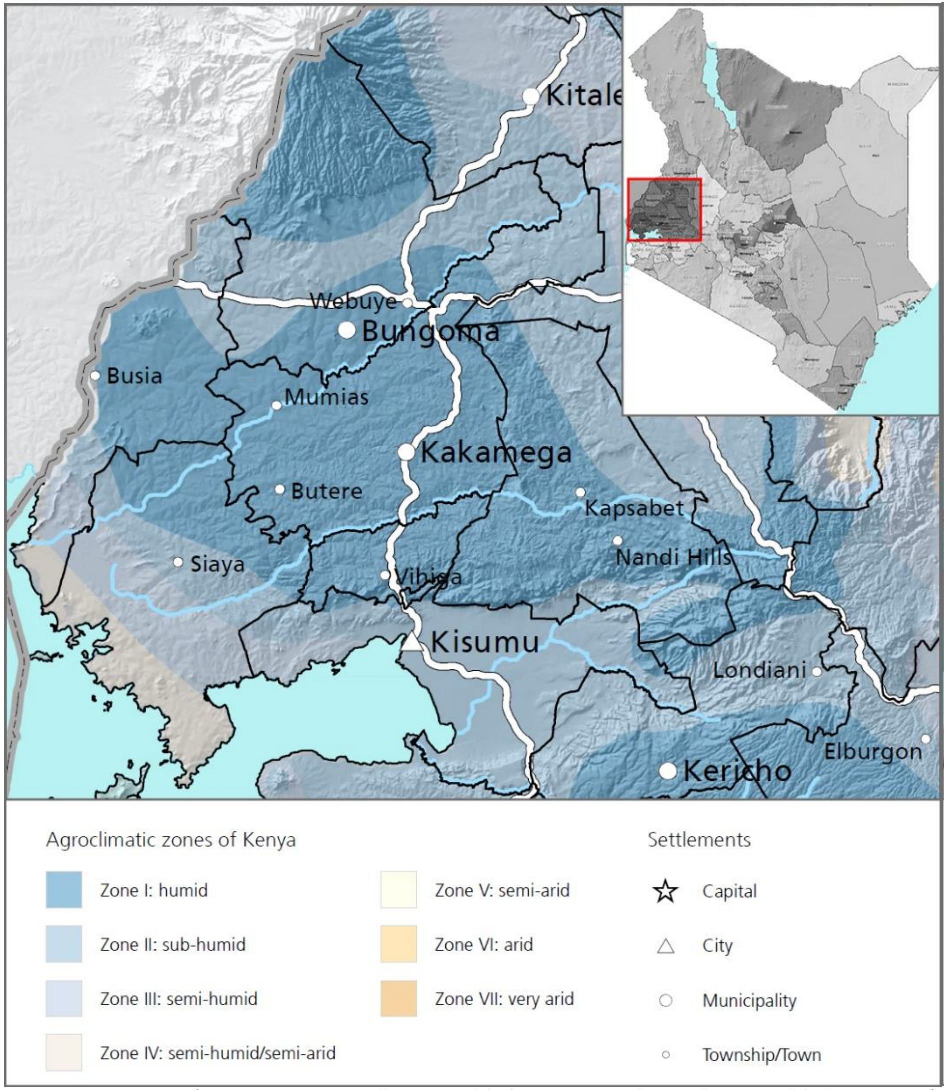


Figure 6: Map of western Kenya showing (a) the agro-ecological zones (b) the sites of the case study; adapted from KNBS (2016)

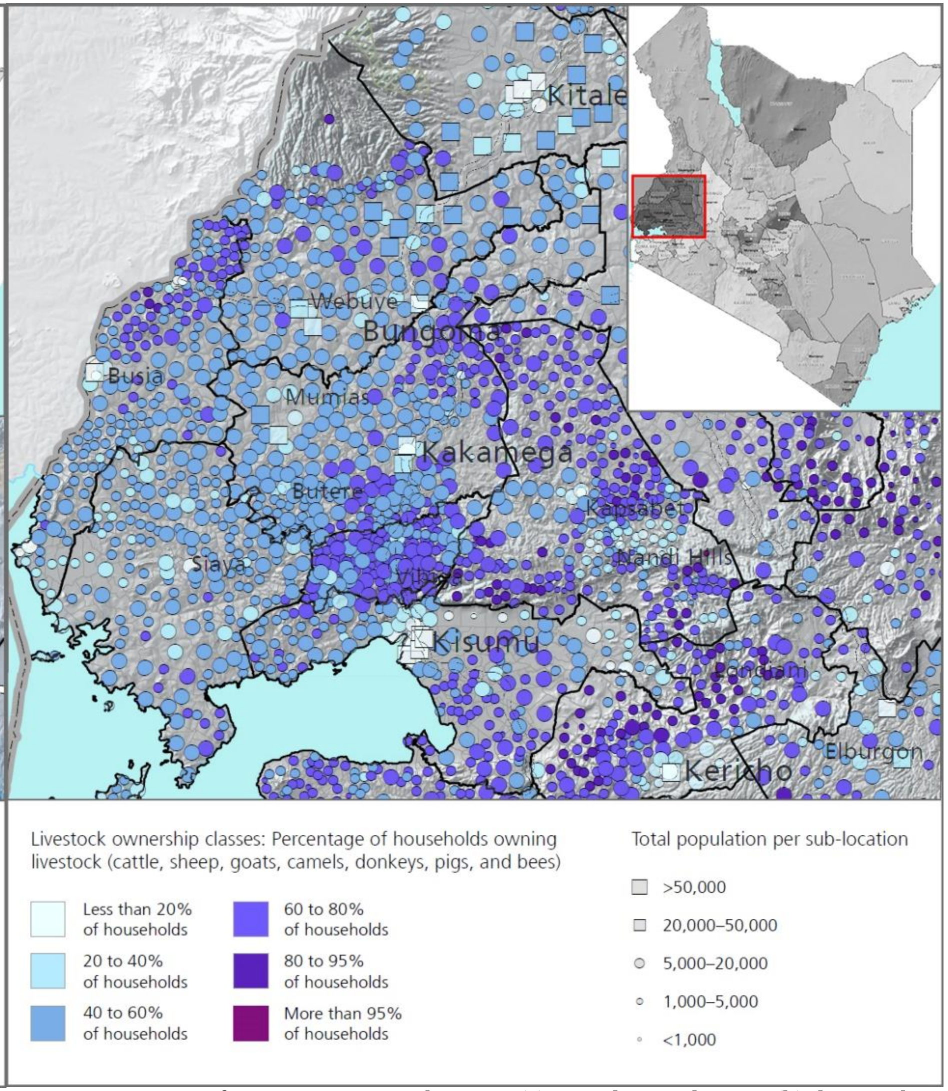


Figure 7: Map of western Kenya showing (a) population density (b) livestock ownership (c) the sites of the case study; adapted from KNBS (2016

3.3 Study Cases

The following provides a short overview of the three study cases. The Ice-maker case was the case first studied. SunDanzer case 1 and SunDanzer case 2 were included in the research later.

The Ice-maker case

In the Ice-maker case three solar coolers from the University of Hohenheim (Ice-makers) were installed in cooperation with a local dairy cooperative: The solar coolers were installed as pilot project. The main intention of the implementers in Siaya County was to test and analyse the technical functions of the solar cooler. The cooperative has been existing for several decades. The rational of the project was to cool milk during transport and thus avoid spoilage. One of these solar coolers had already been established at a homestead, when we started the research. Another was placed at the processing plant of the cooperative. The Universtiy of Hohenheim team installed a third solar cooler was installed at the start of the research. On the long run, it is planned to commercialize the ice-maker.

SunDanzer Case 1

In the SunDanzer case 1 two solar coolers were donated and installed free of charge in farmers homesteads. This is part of a technology project, in which an international development agency (**IDA**) supports a solar company to develop and commercialize a solar cooler for smallholder farmers. The IDA first contacted a farmers group. Eventually a local dairy cooperative served as a legal entity for the project. Evening milk should be collected and cooled at homesteads and later transported to the cooperative. The cooperative had been founded only in the previous year and currently has 59 active members. It is run by a manager with the help of 5 volunteers.

SunDanzer Case 2

In SunDanzer case 2 solar coolers were implemented within the same project as in SunDanzer case 1. Two solar coolers were donated and installed free of charge in farmers homesteads in cooperation with a local cooperative. This cooperative, originally a coffee cooperative, had established a dairy branch with the help of an IDA only the previous year. Currently it has about 145 active members. The area is very mountainous and in the afternoons heavy rains are frequent. In meetings farmers had explained they found it hard to deliver milk during rain, as the mountain paths get very slippery. Thus one solar cooler was installed in a homestead on a mountain so milk could be stored overnight in the fridge and then gets picked up the next day when the conditions are better to get up a mountain. A second solar cooler was installed in a homestead in the valley. The installation had taken place three months before the research. However, farmers still waited for the project to be officially launched.

Figure 8: Drawing a seasonal calendar during a focus group discussion with local farmers

3.4 Qualitative Methods

In the research a range of qualitative methods was used, including different forms of focus group discussions, semi-structured interviews and observations.

3.4.1 Focus Group Discussions

In all focus group interviews visualization was used to help respondents follow the discussion and capture data in a meaningful way. Participatory impact diagrams were used to understand the impact of solar coolers for farmers and cooperatives (Kariuki & Njuki, 2013). When coolers were not in use, the focus group discussion was adapted to facilitate discussion on that captured expectations, challenges and necessary conditions for the implementation of solar coolers. Seasonal calendars were used to obtain information on seasonality in weather, resource availability, farming activities and challenges (World Bank, 2007, p. 256), as we wanted to know whether the observed practises, time-schedules, challenges and impacts were specific for the season when the research was conducted. In the following we briefly describe how the methods were used.

Participatory Impact Diagrams

At the beginning of the discussion a flipchart paper was put on the ground and a photo or drawing of the solar cooler was placed in the middle. In the first stage the respondents were asked to name positive impacts of the solar cooler. For each impact an arrow was drawn from the picture of the solar cooler and the impact noted down. For each impact respondents were then asked about indirect impacts ("what's good about…"). When the interview was conducted with a farmers group, farmers were asked, how many of them experienced the impact. When no new impacts came up anymore, the procedure was repeated for negative Impacts. Negative changes were indicated on the left and positive changes on the right. After all impacts had been documented, the respondents were asked to rank the identified direct and indirect impacts according to importance. Checkers game pieces were stacked to towers from 0-6 to visualize different levels of importance.

Focus group discussions on implementation challenges

To structure the focus group discussion, it was divided into four main parts. *(1) Process of getting a solar milk cooling system:* The participants described the process of getting a solar milk cooling system. Main objective was to determine which selection criteria were used to determine the location of the system and which different stakeholders and supporters of the system were involved in the process. Answers were captured in as a timeline, showing all relevant steps and actors involved. *(2) Expectations of beneficiaries:* In the next step the participants should describe their expectations or hopes due to the solar milk cooling system. The participants were free to speak and could focus on negative or positives issues due to the system. For each anticipated impact an arrow was drawn from the solar milk cooler and the impact was named. If an impact was thought to lead to a follow-up impact, another arrow was drawn from the original impact and the associated indirect impact was noted down. (*3) Expectation that did get fulfilled:* Then the participant should discuss if their expectations and hopes were fulfilled. If anticipated impacts did not materialize, they were crossed out on diagram in a different colour. *(4) Conditions necessary for the technology to fulfil its potential:* Participants were asked, what needs to change, so the system can bring the benefits farmers had hoped for. Identified challenges and bottlenecks were marked in yet another colour next to the respective impacts.

Seasonal calendars

Figure 9: A seasonal calendar while being drawn. Topics: (1) weather (2) season (3) cropping activities (4) milk production (5) feed availability (6) challenges (7) income sources (8) special costs

For the interview 12 columns, representing the 12 months of the year were drawn on a flipchart paper. Another column showing the 8 different topics (*see Figure 9*) and the related symbols was added. At the start of the interview respondents were asked to describe the weather of each month, selecting from “heavy rains”, “some rain” and “dry month”. For each month the symbol of the selected category was drawn. In a second step, respondents were asked which months, they considered wet season and respectively which they considered dry season. Thirdly, respondents were asked about different cropping activities, especially ploughing, planting, weeding and harvesting. For each month, the symbols of undertaken cropping activities were drawn, and the corresponding crops were noted down. Fourthly, respondents determined whether in the different months milk production was “high”, “medium” or “low”. The fifth step was to discuss, which feeds were available in the different months. For grass, the amount of available grass, ranging from “much” to “medium” and “little” was also captured. Sixthly, respondents discussed seasonal challenges. Seventhly, seasonal income sources and eighthly special costs, that only arise in particular months.

3.4.2 Semi-Structured Interviews

Semi-structured interviews were conducted with 17 cooperative members, 5 milk traders and 5 officials of government organisations and IDAs, that were selected by purposive sampling. In most cases, the interviews had lead-questions, specific to the respondent. The Net-Map and the Process-Net-map technique were used, which facilitate interviewing by visualization. A Net-Map was used to get an overview of the linkages between different cooperative members in the Ice-maker case (Shiffer, 2007). In the Process-Net-Map, participants were asked to describe the process of implementing a solar cooler or their daily milk marketing step by step (Raabe, Birner, Sekher, Shilpi, & Schiffer, 2010). Additionally, a consumer survey with n=47 respondents was conducted with unvarying lead questions.

We first describe how we used the Net-Map and the Process-Net-Map and then provide some information on the consumer survey.

Net-Map

We followed Schiffer's methodology (2007) to draw a Net Map: In a first step all relevant actors were identified. Their names were written on actor cards in different colours and distributed on a sheet of paper. The colours of the actors' cards represented different categories, namely cooperative members, cooperative officials, cooperative staff, others. In a second step links between actors were identified and marked in different colours. Links between people included "electing", "overseeing", "informing", "making employment decisions" and "transferring funds". In a last step the respondent was asked to rank the actors according to their influence on the success of the cooperative. For that purpose, influence towers of 1-6 checkers game pieces were assigned to the different actors. At the end, influence levels and possible problem areas were discussed.

Process Net-Map

When the implementation process was discussed the following procedure was used: In step 1, the interviewees were asked to describe the process step by step. For each actor involved an actor card was made in a colour representing his*her function e.g. farmers, cooperative representatives, or foreign government agencies employees. Each step of the process was mapped with an arrow between the involved actors, that was numbered. Also, the acts performed were noted down. In a second step, respondents were asked to rank the involved actors according to influence. Influence towers of 1-6 checkers game pieces were used to visualize influence. In a third step, it was discussed, why actors were more influential than others and how implementation challenges could arise.

Figure 10: Process Net-Map with Influence Towers (the photo was edited to ensure anonymity)

When the method was used to gain information about the dairy value chain respondents were asked step-by-step how milk was transferred, starting at farm level. For each step the names of the actors were put on actors' cards. Different colours were used for farmers, cooperative staff, consumers and others. A blue arrow was drawn to indicate the flow of milk. Additionally, the price received and the time when this step usually occurred was noted down next to the arrow. If quality checks were performed, they were also noted down. The procedure was continued until all milk had reached the consumers. Afterwards, challenges and potentials regarding milk prices, milk hygiene and timescale of activities were discussed with the respondent, using the Process-Net-Map.

Consumer Survey

For the survey respondents were chosen by availability sampling at purposively selected locations:

Table 2: Locations and number of respondents of the consumer survey

	Ice-maker case	SunDanzer case 1	SunDanzer case 2	Total
At Collection Centre	5	5	2	**12**
At Cooperative	0	0	4	**4**
In rural market place	1	11	4	**16**
In Town centre	9	0	0	**9**
Customers buying near homestead	4	0	2	**6**
Total	**19**	**16**	**12**	**47**

The consumers were asked about the amount of milk consumed, the price payed and the seller of milk. In addition, open-ended questions were asked on the way milk is consumed and quality parameters that were relevant for respondents. Respondents could name various answers to each question. Not all consumers could provide answers to all questions. For example, some could not recall they had expectations on milk quality. Afterwards the data was coded, and a content analysis was conducted to gain an understanding of the local concept of milk quality and consumer preferences regarding milk.

3.4.3 Direct Observation

In the research both scheduled as well as coincidental observations were used. The first included visits to collection centres or trips accompanying milk transporters to see how milk is being handled. Observations made during interviews (e.g. at collection centres) and on other occasions provided an opportunity to cross-check accounts and helped reveal inconsistencies. This was especially important in SunDanzer case 1, where cooperative officials tried to conceal, that the solar coolers were not in use. Conversational interviews created a more informal atmosphere, necessary to talk about sensitive issues, like the problems a cooperative was facing. If considered appropriate, information was recorded as field notes or photographs while still observing. Otherwise records were written as soon as possible after leaving the field. Later notes were elaborated into memos.

3.5 Quantitative Methods

This section explains the quantitative methods used. First, the sampling strategies, questionnaire content and data analysis of the household survey is described. Afterwards we depict the design and analysis of a discrete choice experiment, that was conducted to estimate willingness to pay for cooling.

3.5.1 Household survey

A household survey was conducted with a total of n=88 respondents. Originally it was planned to interview all beneficiaries of the researched cases. Yet this sampling strategy was only used in the Ice-maker case. When it became obvious, that beneficiaries could hardly be found in the SunDanzer cases, we shifted our sampling strategy to random-walk sampling. The sampling procedure was adapted according to area characteristics, such as distance between farms and topography *(See Annex)*.

The household-survey was conducted through face-to-face interviews, usually at the home of the respondent. It comprised of 9 sections on various topics but was later shortened in an attempt to also cover non-beneficiaries and research a third case under time pressure.

Table 3: Number of respondents of the household survey by cases.

Case	Ice-maker case	SunDanzer case 1	SunDanzer case 2	Total
n	35	32	21	88

Content of the questionnaire

The household survey included the standard components household roster, plot roster and livestock roster. Additional sections on animal husbandry focused on the farming system, feeding and water availability. These sections were used to assess animal husbandry practises and potential areas for improvement. Data was collected at the turn from the dry season to the short rains. Yet, Questions were asked about both the wet and the dry season to capture variations during the year. A Section on milk marketing and milk use was also included. Questions on milk handling gave insight, what relevance bacterial milk quality had for farmers: we asked how cows were milked, whom the milk was sold to, how much milk would spoil and how milk was consumed within the household. The data obtained on household consumption was later mixed with and compared to the consumer survey. Data on the price received and modes of payment was used to confirm information provided by cooperative officials.

Data analysis

Means of variables related to household characteristics, farming practices and milk marketing were estimated and compared to illustrate differences between the three cases. For the comparison variables were chosen that were hypothesized to cause differences in outcomes in the three cases. Metric variables were considered significantly different, when the 95% confidence intervals did not overlap. Binary variables were tested for significant differences using proportion tests. To address concerns, that cooling could negatively affect household milk consumption, data from both dry and wet season were used to estimate fixed effects regression models that explain household milk consumption. Households and season were included in the analysis as fixed effects. As explanatory variables we used household-characteristics, milk production and farming characteristics, local milk prices and the availability of solar cooling.

3.5.2 Discrete-Choice Experiment

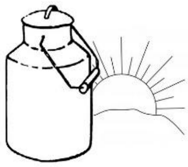
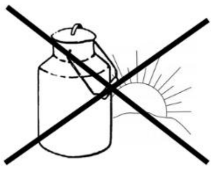
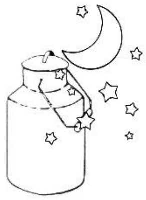
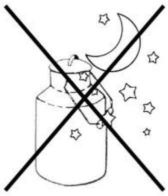
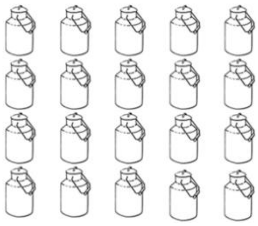
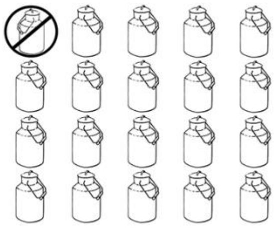
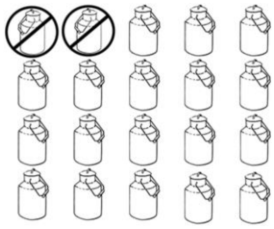
After each household survey interview, respondents were asked to participate in a discrete-choice experiment. Respondents were shown 10 Choice cards, that each showed 3 scenarios, characterized by 4 attributes, namely fee per litre of cooled milk (**fee**), possibility to cool milk during the day for transport (**morning-cooled**), possibility to cool milk for overnight storage (**evening-cooled**), percentage of milk lost to spoilage (**spoilage**). The data was used to estimate the respondents' willingness to pay (**WTP**) for cooling and statistically identify factors that contribute to a higher willingness to pay.

Choosing attributes and attribute levels

Attribute choice was based on theoretical considerations. As we wanted to estimate willingness to pay, fee was included as a numeraire. Morning-cooling and evening-cooling comprise the two main uses of small-scale solar milk cooling systems and spoilage reduction is the supposed main benefit of the cooling technology. The results of the scoring done during the impact map affirmed, that no relevant attributes had been omitted.

Defining the attribute levels, however, needed more consideration. The tested fee needed to be realistic from the viewpoint of both investment costs and ability to pay. For System 1 the price of cooling was calculated to be 5 Kenyan Shillings (**KSh**) for transportation and 10 KSh for overnight storage assuming the system is used to its full capacity (Torres-Toledo, 2017). Our pre-tests showed, that respondents were willing to discuss a fee of 5-10 KSh, even though 10 KSh were considered quite high. As Bracco (2017) reported reduction of spoilage rates from 11% to 6% as a result of solar milk cooling the attribute levels 10%, 5% and 0% were chosen. Morning-cooling and evening-cooling are naturally binary attributes. Visualization was used to help respondents to quickly understand all scenarios offered on the choice cards. For the non-binary attributes, three equidistant attribute levels were used.

Table 4: Attributes and attribute levels of the discrete choice experiment

Attribute	Description	Attribute Levels		
fee	Fee that is payed for cooling per litre of milk cooled	 0 Kenyan Shillings	 5 Kenyan Shillings	 10 Kenyan Shillings
morning-cooled	Milk can be cooled in the morning for transportation.	 yes	 no	
evening-cooled	Milk can be cooled in the evening for overnight storage.	 yes	 no	
spoilage	Share of milk lost due to spoilage	 0% spoilt milk	 5% spoilt milk	 10% spoilt milk

Choosing a choice design

For the research a D-efficient design was chosen, as D-optimal designs can provide better parameter estimates than orthogonal designs at much smaller sample size (Rose & Bliemer, 2013, p. 1026) and less choice sets per respondent (Rose & Bliemer, 2013, p. 1033). This reduced the burden on respondents, who have already answered the household survey questionnaire. A statistically optimal design of 14 choice sets with 2 alternatives was created using jmp (SAS Institute, 2012). As suggested by Telser (2002, p. 43), a status quo alternative[5] was then added to each of the sets as a reference alternative and in order to make the experiment more realistic. In a last step, choice sets were dropped, that were perceived to confuse the respondents: 2 choice sets were dropped, as a fee was payed, even though there was no cooling; another 2 as the status quo appeared twice in the choice set.

[5] This had the attribute levels no fee (0 KSh), no TC, no OC and 10% spoilage

Conducting the choice experiment

Conducting a Choice Experiment after each household survey did not only spare the researchers a second sampling and organising a new set of respondents for the choice experiment. Also, the researchers could use the socio-economic data collected in the household survey to asses which variables influence choice decisions.

Conducting the experiment face-to-face enabled the researcher to check whether the respondents had understood the experiment and to give further explanations when needed. In the beginning of the experiment each respondent first got a choice card, that was used to illustrate the experiment and ensure the respondent had understood the task. This choice card was not included in the analysis. To randomise the order in which choice cards are shown, the choice cards were shuffled before conducting each choice experiment.

Econometric analysis

Mixed logit models were fitted to the data using Stata. When estimating models in order to calculate willingness to pay, we followed the approach of Train (2005) to estimate coefficients in “willingness to pay space”. This involves re-formulating the model in such a way that the coefficients represent the WTP measures. Train (2005), and Hole (2012) have shown that this method can produce more realistic estimates of means and standard deviations of WTP, than the conventional approach.

The model was estimated in STATA using the mixlogitwtp command by Hole (2016). The command implements the reformulation of the mixed logit model to WTP space. It fits mixed logit models in willingness to pay (WTP) space by using maximum simulated likelihood. We used 200 Halton draws. To facilitate calculation, we specified coefficients to be uncorrelated and used the difficult option. Means and confidence intervals for WTP were obtained using the WTP command (Hole, 2007), that estimates WTP as the ratio of attribute coefficients divided by the negative price coefficient. Means and confidence intervals of WTP were estimated using the delta method.

We fitted the following models: Model 1 included all attributes as independent variables, Model 2 considered attributes as well as interactions between the attributes. To assess, which socio-economic characteristics of the chooser influence willingness to pay for morning- or evening-cooling, can be included as interaction terms (A.R. Hole, 2007): Due to time constraints we did not fir models including socio-economic variables.

3.5.3 Use of secondary data

In addition to data gathered through the household survey, it was tried to get existing records on milk flows and use them for the analysis. We obtained available records on milk delivery from the three cooperatives. For the Ice-maker case we were also able to get records of the collection centres, as well as records of one milk transporter. It has to be mentioned, that most records were inconsistent and that records from before the intervention only existed in one cooperative. To estimate the scale of milk production, a sample of 3 days were drawn from the available records of August and September 2017 for the 3 cooperative. All persons who delivered milk more than twice during this period were considered active member

4 RESULTS

Qualitative and quantitative results are reported separately. In section 1 we give a general overview of dairy production and marketing in the study area. Then, in section 2, we provide an in-depth description of the three cases, that include an analysis of the marketing channels of milk on micro level and the opportunities and challenges of the solar coolers in each of the three cases. Lastly, section 3 presents first a statistical case comparison, followed by a fixed effects regression model for milk consumption and the results of the discrete choice experiment.

4.1 Contextual Data

The first section is the analyse of the qualitative data. First an overall overview about the dairy systems in the study area, the different production systems, the milking process and about the milk handling and testing is given. A consumer survey shows the preferences and quality parameters of raw milk. It is followed by an overview of all three cases. Then the three cases are described in detail. The implementation process of the solar cooler will be explained and the opportunities and challenges farmers are facing with the solar cooler. To get an understanding of the milk market, the marketing channels of farmers and of the cooperatives are described.

4.1.1 Dairy systems in the study area

The Ice-maker case and the SunDanzer case 1 and 2 show similarities in production system (see Figure 11-14), milking process (see Figure 15) milk quality measures (see Figure 16**Fehler! Verweisquelle konnte nicht gefunden werden.**) and preservation (see Figure 17 & Figure 18) that will be explained in this section. The data is based on observation and interviews with farmers.

4.1.2 Production systems

Four small-scale production systems could be observed in each case. Means about the production systems in each case is shown in the quantitative part.

Herding

The cattle are herded outside the whole day. The person in charge walks the animal to areas where there is enough grass for the cows during the day. At night they are tethered near the homestead or kept in a shed.

Figure 11: Herded cattle

Tethering

Cattle are tethered with a rope fixed on one feed. Water is always provided for the cattle.

Figure 12: Tethered cow

Zero Grazing

The cattle are kept in cow shed which is build out of wood day and night. Feed and water is provided for them.

Figure 13: Cow in a zero-grazing system

Mixed

The cattle are kept outside during the day tethered or herded and additional fodder is provided. During the night they are tethered or in a stable where water and feed is provided.

Figure 14: Cattle in a mixed system

4.1.3 Milking Process

In the three studied cases farmers usually milk their cows around 6:30[6] in the morning and sometimes again later in the afternoon or evening. If cows give little milk, milking was only done in the morning.

The steps undertaken are mainly observed in the Ice-maker case. In comparison to the SunDanzer Cases 1 and 2 farmers in the Ice-maker case received trainings in milk hygiene and milk handling. The following steps are undertaken to ensure a good milk quality: Farmers prepare warm water on fires or on small gas stoves. They use local water sources like borehole´s, springs, or catchment from the roof, as most of them are not connected to a water tap. The warm water is used to wash the hands of the farmers, the milking container and the udder of the cow to avoid the contamination of milk. Before or after the milking, milking salve (petrolatum) is applied on the utter. According to farmers, this simplifies the milking and prevents udder inflammation and diseases. The milking itself is done manually. The cows are usually tied or fixed. To motivate the cow and to signalize that it is milking time, some feed is provided during the milking process. If Zebu cows are milked, the calve would suck first to start off the milk flow. The milking of one cow takes about 10 min and the milk is milked in a plastic bucket. Occasionally milk gets filtered to remove dirt from the milk. After milking, the milk is transported to a collection centre, sold directly to neighbours or/and directly to the cooperative.

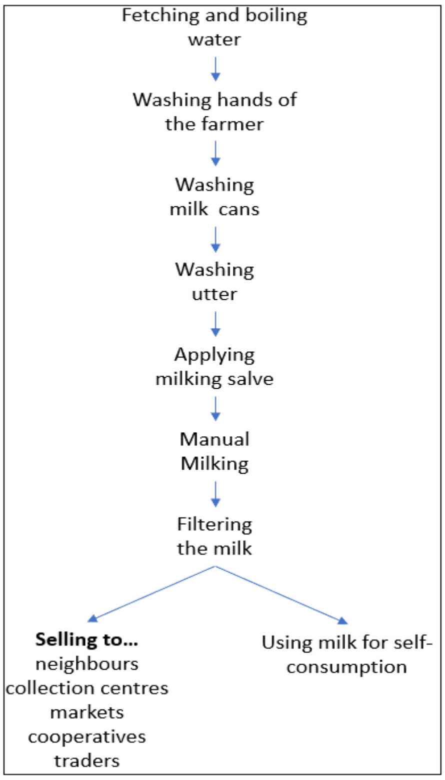


Figure 15: Milking process

[6] Data is based on observation and can vary, because of different daily routines of farmers

4.1.4 Milk Quality and Testing

The milk seldom gets tested in the collection centre, in the cooperative, by milk traders and by consumers buying the milk directly. The most commonly used method for testing the milk is an oligolectic evaluation. This evaluation relies on the smell and on the appearance of the milk. The milk has to be clean[7], and should not have a sour smell. This testing method was observed in each case by all participant of the supply chain. However, there are testing methods that are only used by the cooperative, by the collection centre and by the milk handlers The density of the milk is tested with a lactometer to make sure that the milk has not been diluted. If the lactometer shows a value below 26, the fat content is too low. In consequence, the milk is considered to be diluted and will be rejected. An alcohol gun is used to prove that milk is fresh. If the milk is acidic and alcohol is added it will curdle. A popular testing method for traders is to heat up a small portion of milk on a spoon. The milk curdles if it is spoiled. The lactometer test was mainly observed in the Ice-maker case in the collection centres and in the cooperative. The impression that the alcohol gun is not used in any case came up because the usage of alcohol gun did not seem familiar and in stressed moments the alcohol gun was not used by the milk handers.

Figure 16: Testing methods for milk

[7] Without soil particles or other dirt

4.1.5 Milk Preservation Methods

The cooperatives and farmers relied on two conventional milk storing methods, because they often cannot finance or do not have enough milk to make the reach the levels of milk need to use a pasteurizer or milk cooler profitable.

Boiling

The boiling of milk is a common method to make milk storable. The fresh milk is put into a huge aluminum can and then put into a water bath. The milk gets heated up until it is boiling. The cream that has accumulated on top can be taken away and sold separately. Because of this, some consumers are sceptic of boiled milk, because they prefer milk with a high fat content.

Figure 17: Boiling fresh milk

Cold water

Cold water from springs and boreholes can be used as a simple strategy to cool down milk. A container of fresh milk is put into another container, for example a bucket that is filled with cold water. This strategy was used by farmers to preserve evening milk and by traders to keep milk fresh longer.

Figure 18: Cooling milk in water, readjusted scenario

4.1.6 Milk Market

We now present the results of a consumer survey, that aimed to assess the quality expectations and seller preferences of consumers, who do not produce milk themselves. Most consumers interviewed in the different study sites stated to consume between 1 and 2 cups (1 cup equivalents 1/3 L) per day. The highest household consumption we found was 1.5L of milk per day. Milk is bought daily and predominantly used to make tea: Milk and water are boiled with tea leaves, with a milk water ratio ranging between 1:1 and 1:2. Some households also add milk when they cook local leafy vegetables such as suja. Seldom consumers let milk to be fermented to make lala.

Figure 19: Milk used for tea

Figure 20: Milk fermenting to lala

Figure 21: Local vegetables cooked with milk (served with Tilapia and Ugali)

When asked about why they choose a certain supplier of milk, most respondents named reasons related to convenience, e.g. that a supplier is near (11%), that milk is only available from that supplier (32%) or that milk is delivered (15 %). Only 10 (21%) respondents stated good milk quality as a reason to choose a specific supplier, even though most consumers did have a concept of what was quality milk for them.

Table 5: Milk quality parameters and reasons for supplier choice

	Milk hygiene		Fat content		Convenience	
Parameters defining milk quality	Not smelly or curdled	23%	not diluted	45%	Does not spoil quickly	13%
	Does not spoil quickly	13%	thick	21%		
	Total	**36%**	**Total**	**66%**	**Total**	**13%**
Reasons for supplier choice	Not smelly or curdled	6%	Not diluted	6%	supplier is near	11%
			Thick	6%	only available supplier	32%
					milk is delivered	15%
	Total	**6%**	**Total**	**13%**	**Total**	**57%**

47 respondents were asked open ended questions. The number of aspects respondents could state was not restricted. Not all respondents did provide answers to all questions.
"Does not spoil quickly" was considered both a milk hygiene parameter and a source of convenience.

For the interviewed Western Kenyan consumers fat content was the most relevant quality criteria: in the consumer survey 21 respondents (45%) stated that milk has a good quality when it is not diluted. Another 10 respondents (21%) linked milk quality to "thick" milk. This means milk is creamy or has a yellowish fat cover. Compared to fat content, milk hygiene plays a minor role. Only 13% of respondents stated to prefer milk that does not spoil easily. A low milk spoilage rate was especially important for shop and hotel owners who do not know how much milk exactly they need every day. Some shop owners do however sell fresh milk, which they boil after delivery in the morning and again before overnight storage. Yet, these activities do take considerable time. Another 11 (23%) respondents related bad milk quality to smelly or curdling milk. Smelliness seems to be mainly a problem in the area where SunDanzer Case 2 is located. Here 8 respondents (67%) reported the problem.

There were opposing opinions on whether fresh or processed milk is of better quality. While milk hygiene problems, like smelliness or an oily cover were only reported for fresh milk, the question whether fresh or processed milk has a higher fat content was controversial. Some respondents claimed that processed milk is creamier, while others claimed the opposite. Not all consumers who wanted to buy fresh milk actually had access to a supplier of fresh milk. Besides quality considerations fresh milk is also considerably cheaper than processed milk, making price a relevant factor when choosing between fresh and processed milk. Within the market for fresh milk, however, there is no variance of prices, neither between the wet and dry season nor between different suppliers. This was observed in all 3 cases. Prices did however differ between the three regions. The stability of milk prices is also reflected in the saying „As long as it does not change the price of milk...“that implies that only if milk prices change something actually is a significant event.

4.2 Overview of the three cases

The following table provides key data about all three cases in Siaya and Bungoma County In the Ice-maker case 35 farmers were studied, in SunDanzer case 1 32 farmers and in SunDanzer case 2 21 farmers. The number of farmers observed differs between the three cases because of different reason. One limiting factor in the SunDanzer cases was the limited research time and farmers and members of the cooperative often try to stage expectation from non-governmental organizations (**NGO**)[8].

The Ice-maker case was implemented by the University of Hohenheim in Siaya County to reduce milk spoilage. The solar coolers are situated on a farm, in a collection centre and in a cooperative. The solar cooler at farm level and collection centre level have been used by farmers but the solar cooler at cooperative level was not in use. Farmers using the solar cooler do deliver to the collection centre. The case will be described in detail in section 3.

The solar coolers of the SunDanzer case 1 and the SunDanzer case 2 where installed in farming household by a IDA as a donation. The solar coolers should give the possibility to store and collect milk from different farmers. The intention was that milk gets collected in the solar cooler and then gets delivered to the cooperative.

In the SunDanzer case 1, two solar coolers are installed in farming households. Out of the two households only one is using the solar cooler to store milk. Both of the farming households where the solar coolers are installed do not deliver any milk to the cooperative. The expected impacts of the solar cooler were only discussed in the farming household who does not use the solar cooler, because the information of the other farmer had to be treated with caution. The farmer confirmed using the solar cooler and delivering milk to the cooperative, but the cooperative did not had any records of the farmer and many other farmers confirmed that the farmer uses the solar cooler only for his own purpose. The case will be described in detail in section 4.

The solar coolers in SunDanzer case 2 were installed in two farming households, one in the valley and on top of a mountain. The solar cooler is not in use in both households. The farming household on top of the hill is delivering milk to the cooperative the other farming household in the valley is selling the milk locally. The case will be described in detail in section 5.

[8] Questionnaires could not be evaluated because of wrong information’s.

Table 6: Key Data of the three cases

	Ice- maker case	SunDanzer case 1	SunDanzer case 2
Farming in the Region[1]			
Location	Siaya County	Bungoma County	Bungoma County
Agro-ecological zone	Semi-humid lower midland	Sub-humid lower midland	Sub-humid upper midland
County Population density [persons per km²]	333	449	449
Percentage of cattle-owning households	36.5	46.1	46.1
Consumer price of milk in KSh/L the entire year	70	60	50
Cooperative			
Active members [2]	28	59	145
Number of staff	7	1 staff + 5 volunteers	5
Collection Centres [3]	2	0	1
Milk handled per day in L [4]	110.8	169.0	390.5
Milk Price for farmers in KSh/L	50	45	35
Type of solar cooler	Ice-maker	SunDanzer	SunDanzer
Number of solar coolers installed	3	2	2
Number of solar coolers in use	2	1	0
Use of solar cooler	Transport, Storage	Storage	Not in use
Production System 5			
Herding [%]	6	22	19
Tethering [%]	6	50	67
Cut and Carry [%]	77	9	9
Mixed[%]	11	19	5

[1] *data from KNBS* (2016) *except from consumer price of milk in KSh/L, which was obtained from interviews and observations*
[2] *Active Members are members who delivered milk in September 2017 at least 3 times*
[3] *Collection centre who are active and regularly deliver to the cooperative*
[4] *Refers to the records of the cooperatives, the mean of 6 randomly selected days was determined*
[5] *Production System during the wet season; during dry season two more farmers use cut and carry in Ice-maker case*

4.2.1 Ice-maker case

The first case was situated in Siaya County. The cooperative, two farmer groups were studied. Farmer groups in the Ice-maker case are defined as a group of farmers delivering to the collection centre with a solar cooler.

Implementation of the solar cooler

Three solar coolers from the University of Hohenheim (Ice-makers) were installed, one at farm level, one at collection centre level and one at cooperative level. The solar coolers were installed as pilot project. The rational of the Ice-makers is to cool milk during transport and thus avoid spoilage. The partnering cooperative was suggested to the engineers by an international development agency, as it reported that milk from the collection centres often arrived at the cooperative spoilt. Nevertheless, the main intention of the implementers in Siaya County was to test and analyse the technical functions of the solar cooler. When the first two coolers were installed the engineering team spent 2 months in the cooperative conducting a technical assessment and training the farmers in the use of the equipment.

For the first testing an Ice-maker was installed at the cooperative and the ice was transported to the collection centre. This proofed to be inefficient though, as milk was only cooled during transportation, which was much shorter than milk collection. Therefore, the next solar coolers were installed at collection centres, so milk could already get cooled during collection and then the cooled milk gets delivered to the cooperative. The advantage is that milk arrives cooled in the cooperative and milk does not get spoiled because of a lack of cooling. One of these solar coolers had already been established, when we started the research. A second cooler was installed at the start of the research with the help of the University of Hohenheim team. This cooler was owned by a local University and only placed at the collection centre for one month for a technical assessment. It was planned to move the cooler from the processing plant to the collection centre afterwards.

Dairy Cooperative

The cooperative officially consists of a management committee and a supervisor committee. The management committee is built up out of a chairman, a vice chairman, a secretary, a treasure and 5 committee members. The supervisor committee consists of a chairman, a secretary and a committee member. There is no overlapping of persons between the two committees.

The cooperative has two buildings, the “old dairy” and the “new dairy”. In the old dairy a milk amount of about 110L per day is received, tested and sold. The new building was equipped with a pasteurizer and packaging machine from the World Bank in 2015 which was not in use during the research period, however. Cooperative members frequently complained about the quality of the equipment in the “new dairy”, for example, claiming that the packaging machine never actually worked. They mentioned that the milk amount they receive is too low to run the cooler economically. In fact, they could not even cover the operation costs.

The cooperative is characterized by various governance challenges in the previous years that were usually referred to as “mismanagement”. According to various respondent, it involved petty corruption of staff members on all levels of employment and the inability to react appropriately when the previous cooler of the cooperative broke down in 2012. This inability to react has led to considerable amounts of spoilt milk until 2015. As a result, the cooperative has lost about 3 million Kenyan Shillings and was unable to pay farmers for several months. To the farmers it was explained, that they were not payed, as their milk got spoilt. Many farmers then stopped delivering milk to the cooperative.

Currently, only two collection centres (out of 7 before) deliver milk to the cooperative but only since they have the solar cooler. Another solar cooler is installed in the new dairy. As the system was tested, ice was delivered from the new dairy to the collection centre, so milk could be cooled during transport. This way of using the system proved to be ineffective, as milk was not cooled during collection, which takes much longer than transportation. The solar cooler is therefore not currently in use.

Milk Market

The milk value chain is a complex and continuously changing network of producers, consumers and various intermediates. The daily dairy process[9] is described in detail in Figure 23.

It explains the different marketing channels used by the farmer Group 1 and the farmer Group 2 and individual farmers to sell their milk. A farmer group in this case, is a group of farmers delivering the milk to a collection centre with a solar cooler. The farmers groups differ in many aspects and operate independent from each other. The milk that is delivered by farmers to the cooperative is sold to consumers buying directly in the diary and sold to costumers, e.g. hotels or public institutions.

Farmer Group 1 – Solar Cooler at Farm Level

The farmers organized themselves as a group of 18 members delivering their milk to the collection centre 1. The solar cooler was installed at a farming household close to the collection centre 1. The solar panel is situated in front of the house and the fridge with the equipment inside the house of the farmer. In the morning the transporter collects the cleaned cans filled with ice and transports them on a motorbike to the collection centre. The farmers deliver their milk to the collection centre where milk gets occasionally tested with a lactometer. The quantity delivered by the farmers is recorded before the milk is then filled into the chilled milk cans.

Figure 22: Flow of ice, farmer group 1, Ice-maker case

[9] The activities within the process show a high variance, because the daily routine can become interrupted through climate conditions (heavy rains) or a change of consumers.

During the time milk is collected in the collection centre, milk is also directly sold to consumers for 70 KSh/L. When all farmers have delivered their milk, some of the milk remains in the collection centre to be sold directly to consumers and some is taken by the transporter. The transport of milk is conducted with a motorbike. On his way to the cooperative the transporter sells milk to teachers of a school as well as different households and hotels. Occasionally people on the street ask him if he could sell some milk. Sometimes he also sells milk to trades. The remaining milk is taken to the cooperative. The transporter sells on his way to the cooperative because the direct consumers pay a better price and pay immediately. The usual consumer price is 70 KSh/L. Some regular customers, however, get a discount: When milk is delivered to the staff of the school or to some hotels, they pay only 65 KSh/L. At the cooperative the transporter receives 50 KSh/L upon delivery. The milk is measured, tested with a lactometer and then the quantity is recorded. In the cooperative, the chilled milked gets poured in a big aluminium can which already contains milk that was delivered from other sources. The money the transporter collects from the direct customers on his way and from the cooperative is handed to the recorder at the collection centre. The money is distributed in the collection centre every Saturday. The farmers receive 50 KSh for each litre delivered. However, the farmers have to pay a fix price of 70 KSh per week for transport, 100 KSh per week for the recorder and 5 KSh per week for the treasurer. The recorder receives about 2000 KSh per month and is paid by the farmers who deliver to the collection centre. If the farmers sell more milk directly the profit of the farmer group increases. This would reduce the fix cost every farmer has to pay.

Farmer Group 2 – Solar Cooler at Collection Centre Level

The solar cooler is[10] installed at a collection centre organized by a farmers' group with 17 members. The collection centre opens at 7:30 in the morning. At least two people are needed to take out the heavy solar panel which is stored in the collection centre overnight. After taking out the solar panel, the caretaker goes to fetch water, which is needed to produce more ice and to put the ice which was already produced into the milk cans. Usually there are some plastic bottles with milk in the freezer that have been delivered in the evening and stored overnight. The milk collection starts at 8 am and ends at 9:30 am. When milk is brought, the milk gets directly poured in the can with the filled ice-compartment to ensure that the milk gets cooled. At 9:30 the milk gets picked up by a transporter. During milk collection milk is also sold directly to customers for 70 KSh/L.

The transporter takes the milk directly to the cooperative where the milk is measured, tested with a lactometer and then recorded. In the cooperative itself the chilled milked gets poured in a big aluminium can similar to the procedure of farmer group 1

The transporter hands over the revenues from selling milk at the to the treasurer in the cooperative, which also get recorded. In a last step the milk can gets cleaned, all milk collected at the main dairy plant is poured into the can and the ice is used to cool down the milk handled at the cooperative. The transporter leaves the cooperative with another empty milk can.

[10] The solar cooler has been taken away from the collection centre after one month because the system was only installed there for testing purposes.

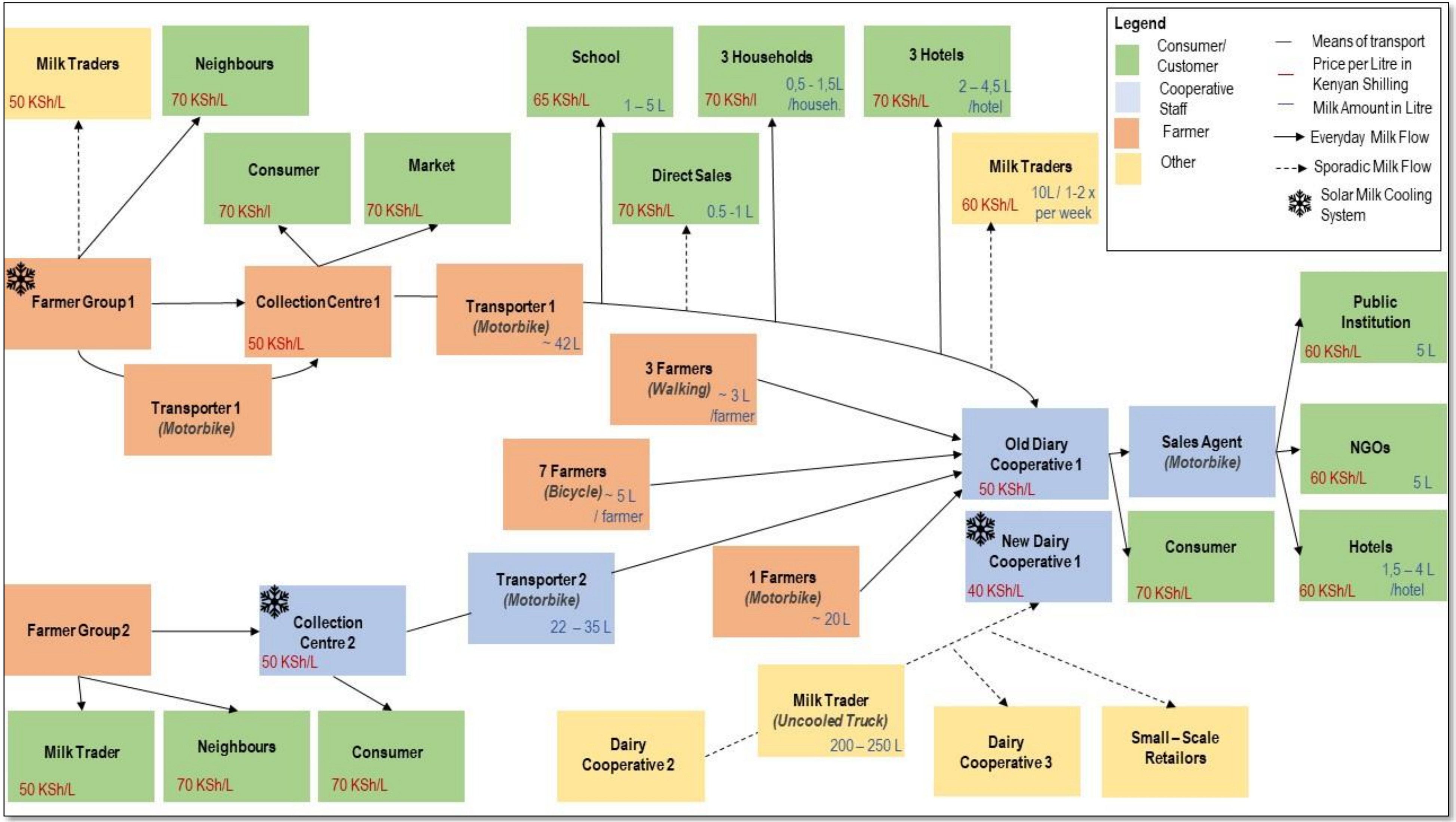


Figure 23: Overview value chain, Ice-maker

Challenges and opportunities of the small-scale solar milk cooling system

This section provides an overview of the challenges and opportunities of the solar cooler obtained through impact maps and cross-checked with observation and interview data. Figure 24 shows the opportunities (green) and challenges (orange) including the value of the aspects for farmers in the right corner (1=lowest impact; 6= highest impact).

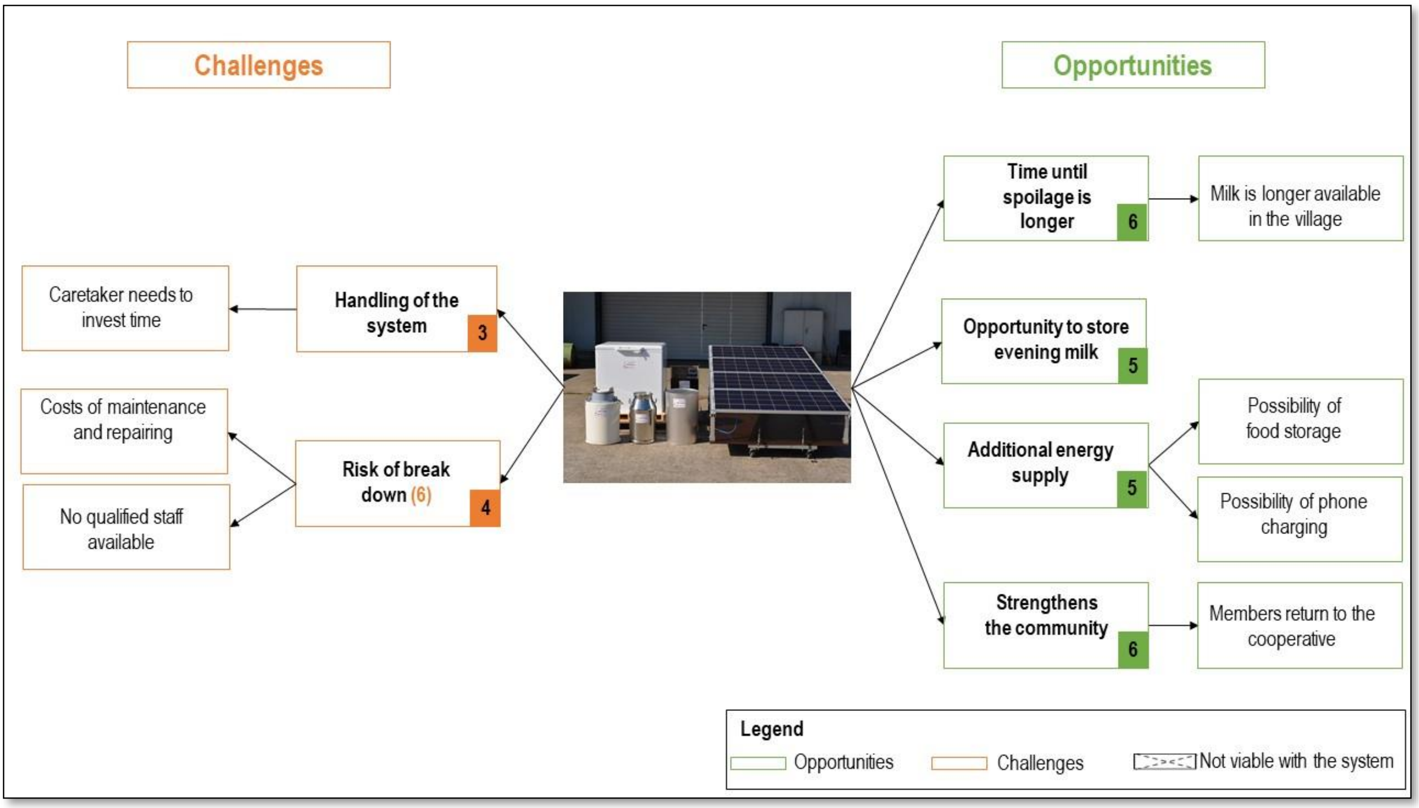


Figure 24: Opportunities and challenges, Ice-maker case

Opportunities

The opportunities are explained more in detail:

Time until spoilage is longer

Milk can be stored longer in the collection centre and is longer available in the villages. Milk can be sold during the whole day to consumers without getting spoiled. Selling directly to consumers allows the collection centre to obtain a higher price (70 KSh) than selling milk to the cooperative (50 KSh). However, this impact only applied for farmers in Farmer Group 2, because in Farmer Group 1 an electrical fridge was already installed before. If milk is cooled there is a certain security for every participant of the value chain that the milk will not be spoiled. This created accountability on the side of the cooperative, as they could no longer use spoilage as a pretext for not paying farmers.

There is considerable doubt, whether the previous high "spoilage" level of milk in the cooperative was indeed due to a lack of cooling during transport. The main reason for spoilage was the reliance on a non-functional cooler for a period of 2-3 years in the cooperative, and the milk transporters' practice to sell milk on their way to the cooperative, often only arriving in the afternoon. Under the new management, the last incident of spoilage that is known happened, when several farmers delivered colostrum milk[11]. In the household survey only 5 (14%) farmers reported rejections, that added up to a monthly monetary loss[12] of 1075 KSh (10.75 USD).

Opportunity to store evening milk

The storage of evening milk was reported to be a relief for the farmers. Farmers can deliver their evening milk to the collection centre where the milk is stored overnight and sold directly to consumers or delivered to the cooperative the following day. Yet, this impact only occurs, if there is no fridge in the collection centre already before, if the collection centre does not deliver to the cooperative in the evening, and if milk hygiene standards are enforced. Some farmers used to put their milk into a bucket of cold water to store it overnight and delivered it the next morning, never having their milk rejected. However, it must be considered that the solar milk cooling system only has a capacity of 30 L of milk per milk can and could be a limiting factor for the cooling of milk.

Strengthening of the community

The cooperative notices a return of the farmers to the society. Before the solar cooler was installed, there was no collection centre that delivered to the cooperative. Since the solar coolers are installed two collection centres started to deliver to the cooperative again. In addition, the number of farmers delivering to the collection centre has increased. The cooperative and the farmers have more confidence in the milk value chain because of the system. At the same time, the engineering team could have contributed to the effect. They seemed very popular: farmers repeatedly asked about members of the team; many claimed, they mainly deliver milk to the cooperative because of the engineers.

Challenges of the solar cooler

The next part describes the challenges that farmers and cooperative members experience with the solar cooler:

Possibility of break down

The solar is vulnerable for a break down. Cooperative members confirmed, if the system breaks it needs a lot of time to get a local professional mechanic who is familiar with the technology of the system. One of the solar cooler of the cooperative broke down before the research team came for a second visit. Instead of repairing the system on their own they waited two weeks for the research team to fix the solar panel. It seemed that cooperative members do not know what to do in case of a break down. Although farmers didn’t claim they had any spoilage during this period, they were concerned, that their milk was of lower quality.

Handling of the system

Currently all work related to handling the systems is done by volunteers thus negatively affecting their time budget. The handling of the system includes the production of ice (fetching water), the cleaning of the milk cans and isolation. The farmers occupying the solar cooler spend about 30 min every day for handling the solar coolers. If the panel needs to be taken out every day it is cumbersome. The solar panel is heavy and can´t be taken out by one person.

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[11] Cows donated by an NGO all gave birth at the same time. The farmers that had received heifers, were not properly trained and did not know, that they should not deliver colostrum.

[12] The cooperative milk price was used for calculations, as this is where rejections happen.

4.2.2 SunDanzer Case 1

The SunDanzer case 1 is located in Bungoma County. The cooperative, the two farming households with the solar coolers and farmer groups were studied. In addition random selected farmers that are not part of the cooperative or of farmer groups were interviewed to align information from the farmer groups and the cooperative. Officially, some farmers organize themselves in 3 main groups. However, they don’t have regular meetings, only if researchers or NGO´s visit. The wrong information were uncovered after interviewing random selected farmers.

Implementation of the solar cooler

The SunDanzer case 1 was implemented by an IDA in March 2017. Two solar coolers were installed in two farming households with the intention to provide a possibility for many farmers to collect milk at a central point and to store it until milk gets sold or delivered to the cooperative. One solar cooler was installed in a household about 40 min with the motorbike away from the cooperative, the second even further. In semi-structured interviews with farmers and implementers the implementation process was described as follows: To choose a homestead for installation multiple households were audited. Data was collected on aspects like distance from the road and the electricity grid. However, the implementing agent could not explain the purpose of all questions and used the questionnaire only as rough guidance. One of the farmers, who had a solar cooler installed at his place was the first contact of the IDA and was well informed about the project. This farmer helped to establish contact with the dairy cooperative, as a legal entity was needed for project implementation. Generally, the solar cooler is part of a broader project that also includes artificial insemination and the promotion of improved cattle feeding. Officially these activities are conducted with several farmers groups. In conversational interviews and during an informal discussion farmers revealed, that these groups only exist on paper. There are no regular meetings. When development agents have announced a visit, farmers are recruited spontaneously to join a meeting. Some also claimed, they had been offered 200 KSh to attend a meeting with us. The second farmer was selected as act of necessity on the day of the installation. This farmer did not get informed about the project or about the installation of a solar cooler in advance.

Dairy Cooperative

The cooperative associated to the project is mainly based on 5 volunteers and one manager. Milk gets collected from 6:30 to 10:00 in the morning and from 4:00 to 6:00 in the afternoon. Around 59 farmers deliver their milk to the cooperative and get 45 KSh/L. It was claimed that milk is tested after reception using a lactometer and an alcohol gun. However, during the observation volunteers did not seem familiar with the testing equipment. Milk is also cooled down, in this case with a –electrical cooler with a capacity of 350 L. In addition, the cooperative has one refrigerator where milk can be cooled.

Daily Milk Marketing

In the SunDanzer case, the dairy value chain is much shorter. Three different marketing channels were observed. There is no connection with the households where the solar coolers are installed and the cooperatives, what was first claimed by farmers. Farmer do not deliver milk to the solar cooler 1. The household where the solar cooler is installed is using the milk mainly for self-consumption or is selling it to neighbours, close markets or hotels. However no milk is ever put into the solar cooler. The solar cooler 2 is also installed at a farmer’s household. Only one close living farmer is delivering milk to this household. The farmer uses the solar cooler to cool his*her milk which he*she then sales to neighbours.

The two farmers where the solar cooler is installed do not deliver to the cooperative because of long distances, because the transport of the milk is not paid by the cooperative and because the cooperative pays low milk prices. In addition, for the farmers it is easy to sell milk locally at a higher price because milk supply is limited in the region.

The cooperative gets milk from 59 farmers and is selling it to consumers who. buy it directly at the cooperative and on markets. While milk is collected, the milk is directly sold to consumers for 60 *KSh/L. After the milk delivery the milk gets sold by the sales agent on markets.*

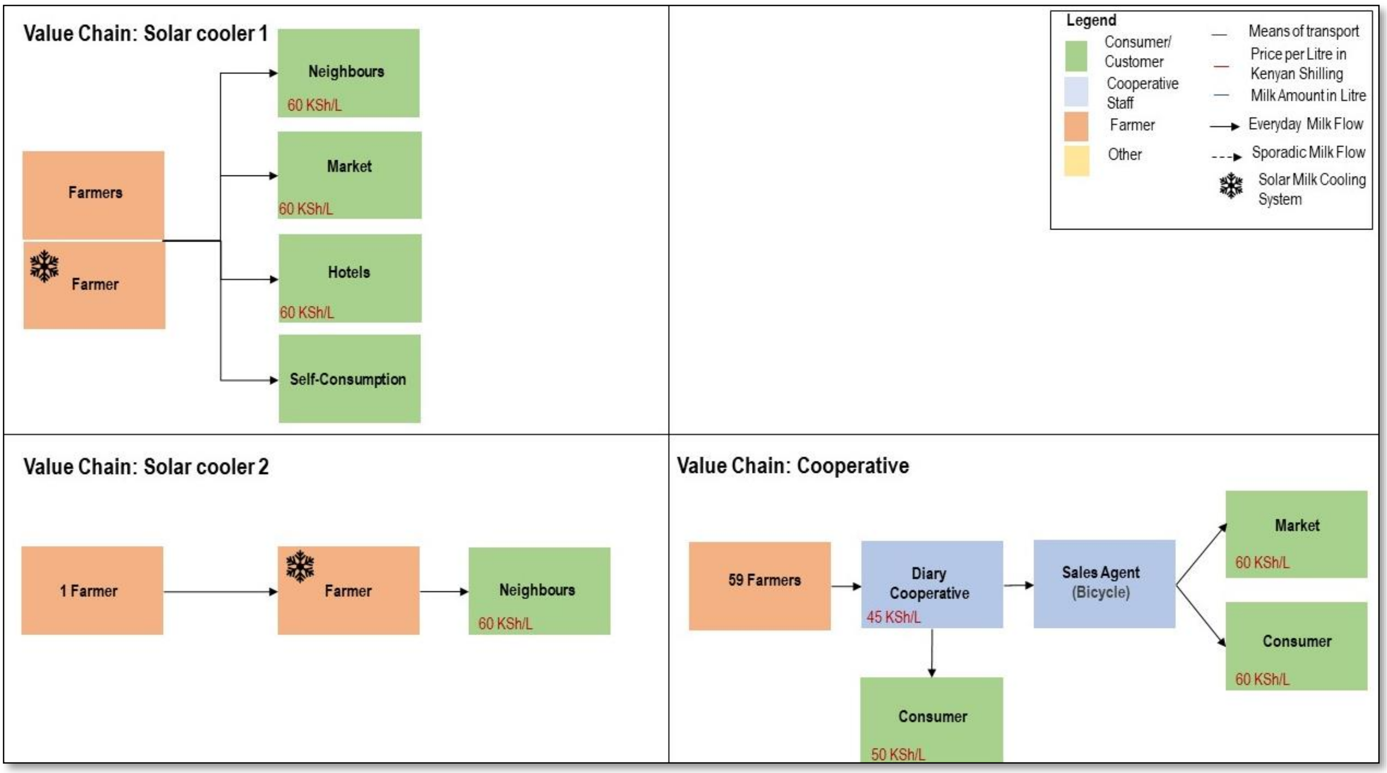


Figure 25: Overview value chains, SunDanzer case 1

Opportunities and Challenges of the small-scale solar milk cooling system

The opportunities and challenges were mainly discussed with farmers who live nearby the solar cooler that is not used at all and with members of the cooperative. In addition observations and interviews with the farmer who uses the system for his*her own purpose. As farmers do not use the solar cooler as it was intended by the IDA the opportunities and challenges are separated in actual or expected opportunities or challenges. An overview is given in Figure 26.

Actual Opportunities

When the solar cooler was installed farmers did see the chance to store and preserve milk in the cooler. Also, farmers saw the possibility to store milk that could not be sold which could then be sold on the following day. The expectation was only fulfilled at one farming household who actually received a solar cooler, where milk was stored for private consumption and direct sales. It shall be noted that during the household survey only 3 farmers (9%) reported milk spoilage, that mainly happened in the dry season. This results to monthly monetary losses of 2925 KSh[13] (29.25 USD), yet these losses mainly affect one big farmer who lost 60L and whose claim must be assessed critically as she seemed trying to appeal to our expectations throughout the interview. Furthermore, the solar cooler is a sign of development for the farmers, because they obtain a new technology and get positive reputation from farmers in the area.

Expected Opportunities

The expected opportunities were only discussed with farmer who do not use the solar cooler and with members of the cooperative. The farming household where the solar cooler is not in use did not get much information's about the "how" to use the solar cooler.

Farmers assumed that the solar cooler "brings more milk" they did not understand that they have to put their own milk inside. However, if they would have more milk, they could produce yoghurt or lala in the collection centre and sell it directly. Another expectation was that all farmers around the area will have light because the solar cooler provides enough electricity for all of them. Challenges were not mentioned. Farmers only complained about the implementation process. The farmer who does not use the solar cooler complained that the solar cooler was installed without her consent and that there was no information provided about the solar cooler. The usage of the solar cooler was for many farmers not clear and the did not know that they can use the solar cooler.

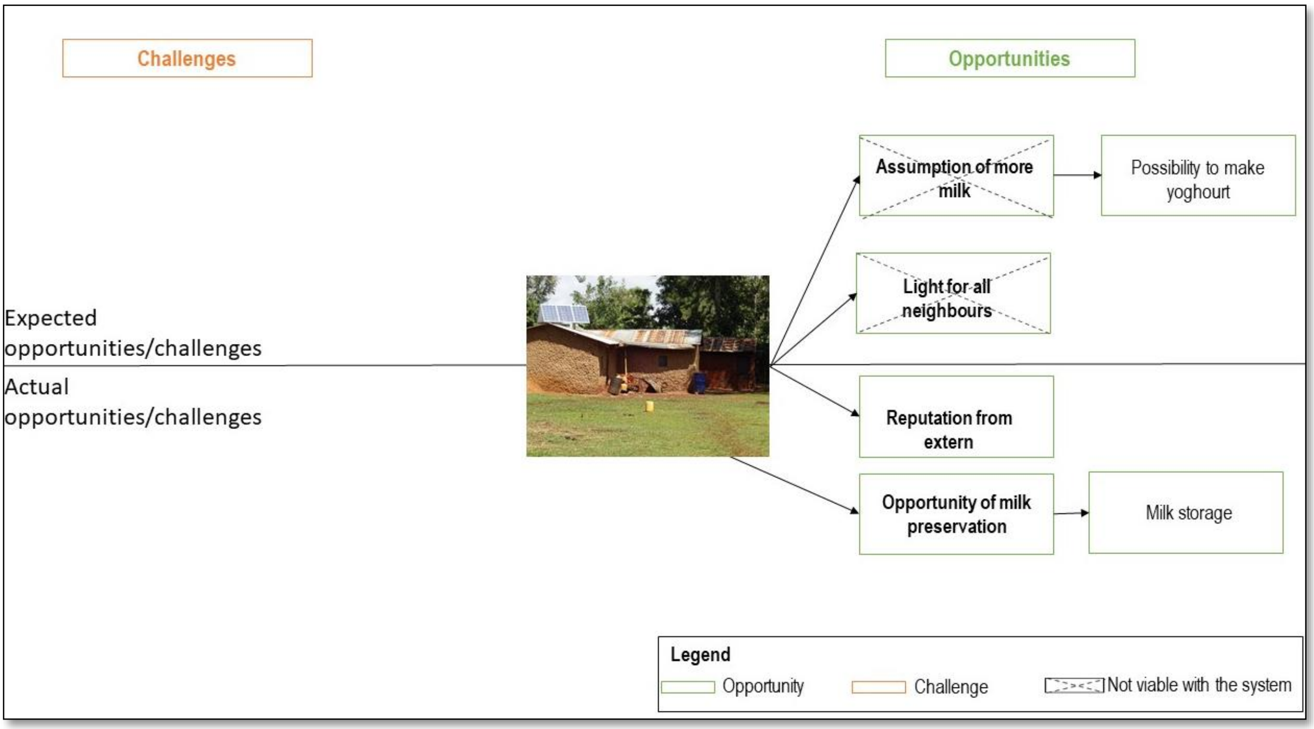


Figure 26: Opportunities and challenges, SunDanzer case 1

[13] The cooperative milk price was used for calculations, as this is where rejections happen.

4.2.4 SunDanzer Case 2

The SunDanzer case 2 is situated in a mountainous region where heavy rains in the afternoon are usual. To study the case the cooperative, the farming households with a solar cooler and random selected farmers were studied.

Figure 27: Study area shortly before it starts to rain

Implementation of the solar cooler

In July 2017 two solar coolers were installed by an IDA as a donation. The solar coolers were installed in two farming households. They were implemented within the same project frame as in SunDanzer case 1. In this case, the audit questionnaires were also used to assess possible locations. Cooperative officials preselected the farms to be audited. The selection criteria in the questionnaire precluded the only existing collection centre of the cooperative: As the nearest electricity grid was less than 1000m away, it was too close to the grid. One solar cooler was installed in a homestead on top of a mountain and the other solar cooler is installed in a homestead in the valley only 5 min away from the dairy cooperative, when traveling by motorbike. The implementation is based on the assumption that the homesteads with the solar coolers will become collection centres and that farmers deliver milk to the cooperative. The idea of the IDA to install the solar coolers on the top of the mountain is mainly based on the frequent heavy rains that come up in the afternoon. The roads get muddy and milk cannot be delivered to the cooperative by the farmers living on the mountain. It was intended that milk could be stored overnight in the fridge and then picked up the next day when the conditions are better to get up a mountain. Farmers are still waiting until the solar coolers get officially launched by the IDA as it, they were told. Farmers themselves, not even the caretakers of the solar coolers have no means of communicating with the development agent about the project, as they do not have her phone number.

Dairy Cooperative

The dairy cooperative was established in July 2015 as a new branch of an existing coffee cooperative. A cooler with a capacity of 5000L was donated by the county government at the same time. The facility and the milk equipment, including small fridges and a pasteurizer, were donated by a IDA in 2016. As the cooperative does neither reach the 800L minimum capacity of the cooler, nor the minimum capacity of the pasteurizer, milk is boiled in a water bath on a wood fire and then stored in a fridge with 50L capacity.

Currently 145 farmers deliver milk to the cooperative. They deliver an amount of average of 390 L per day. Farmers receive a price of 35 KSh/L from the cooperative. The local milk price is 60 - 70 KSh/L. Occasionally the milk gets tested with a lactometer and afterwards with an alcohol gun. The milk is then measured in kilograms and a receipt is provided for farmers.

Daily Milk Market

The studied dairy farming households mainly use milk for self-consumption, deliver it directly to the cooperative, sell it to neighbours, or close markets. Only one collection centre without a solar cooler is active, delivering the milk to the cooperative. Three independent marketing channels could.be observed (see Figure 28).

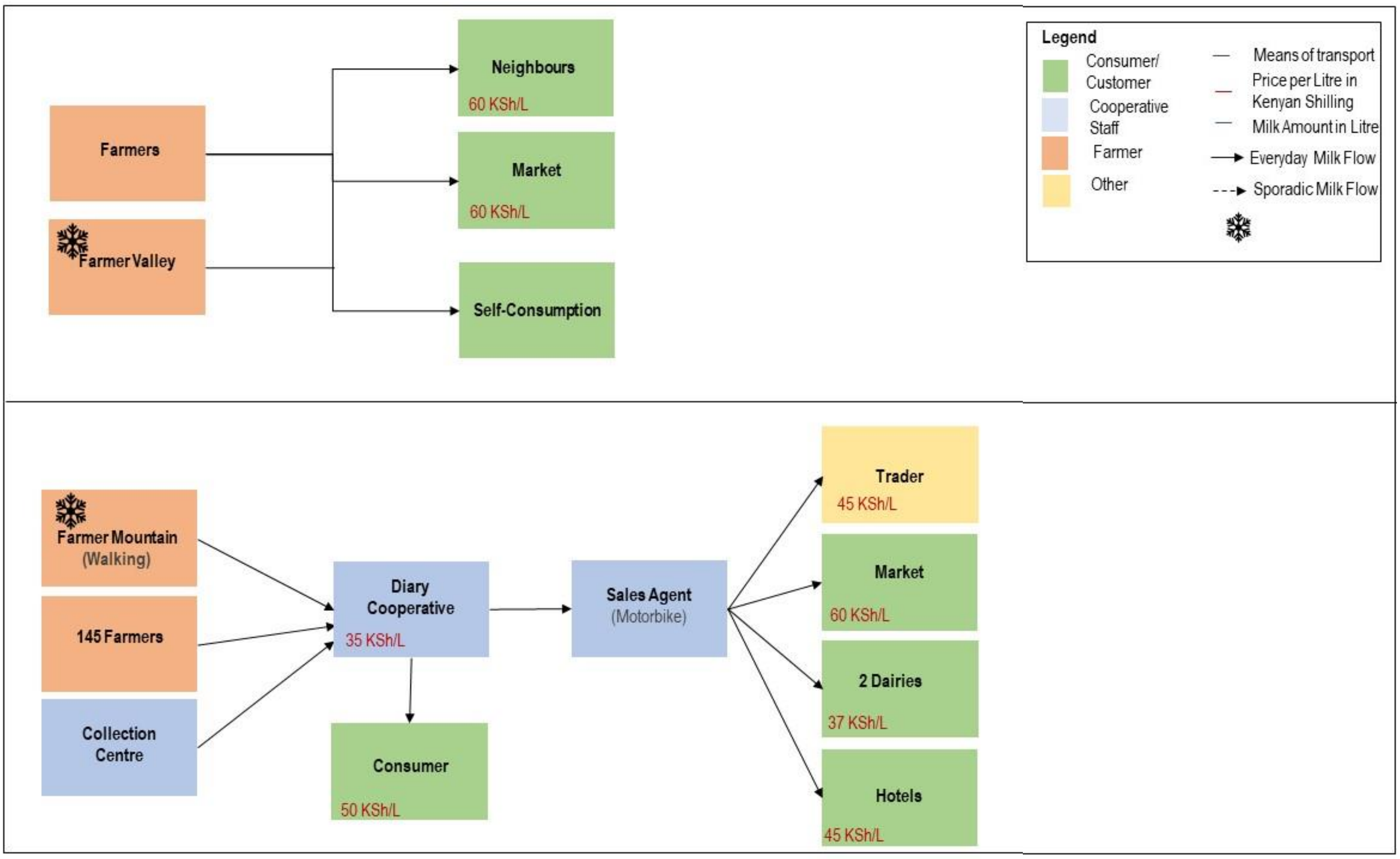


Figure 28 : Overview value chain, SunDanzer case 2

The solar cooler installed in the valley is not used at all by the farmer. The household is selling the milk to neighbours, on markets or using it for self-consumption. The farmer is selling not selling the milk to the cooperative because of low milk prices. The solar cooler installed at top of the mountain is also not in use to cool down milk. The caretaker of the solar cooler delivers the milk to the cooperative. It takes him*her about 2 hours to deliver the milk and to come back. The other households on the mountain are selling their milk to the cooperative, to neighbours or on close markets or use it for self-consumption. The cooperative is selling the milk to market, dairies, traders, consumers and hotels. The cooperative mentioned figures about the amount of litres sold daily but the figures are not proven and unrealistic being excessively high.

Opportunities and challenges of the small-scale solar milk cooling system

The two solar coolers are not used to store milk. However, interviews with farmers and cooperative staff shows opportunities and challenges with the solar cooler. An overview of the actual or expected opportunities or challenges is given in Figure 29.

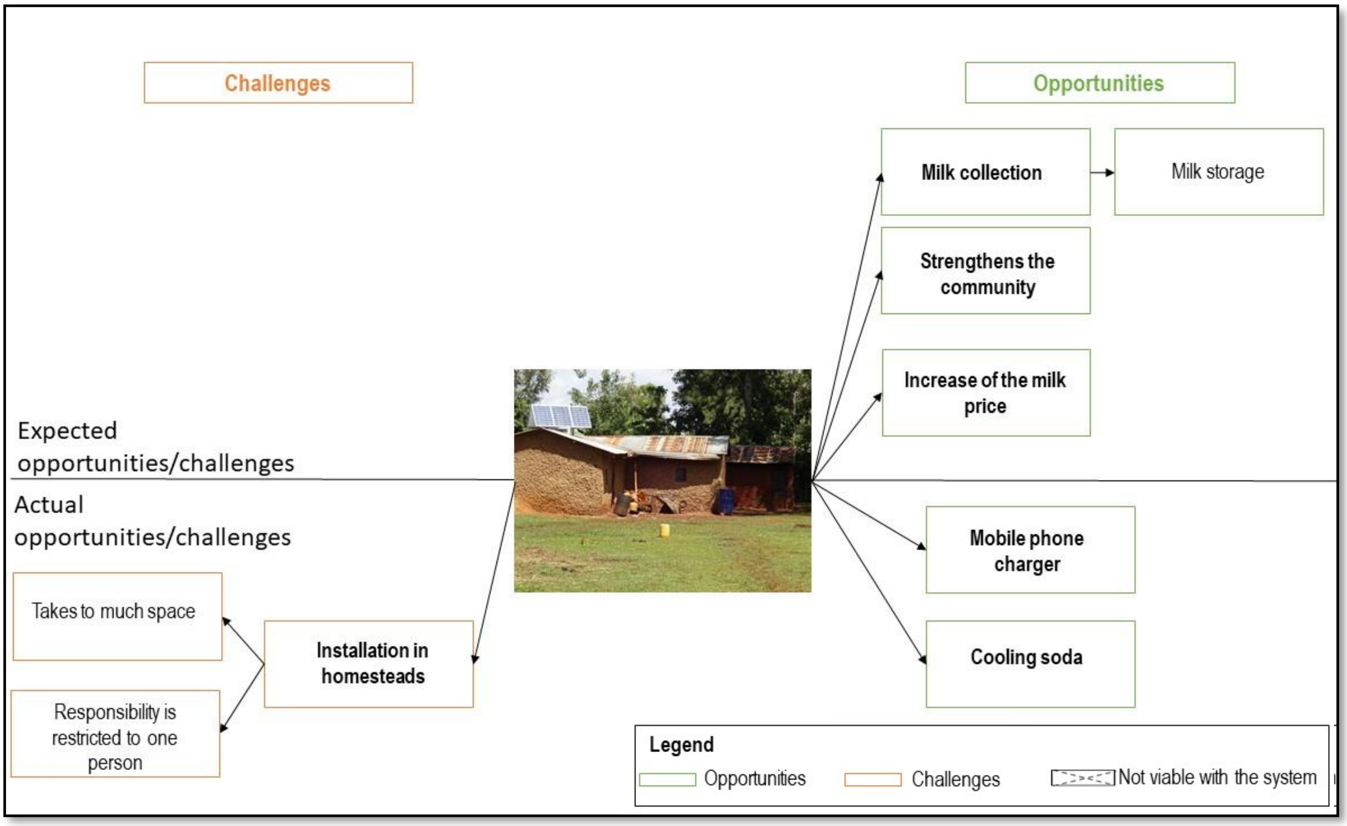


Figure 29: Opportunities and challenges, SunDanzer case 2

Actual opportunities

The usage of the solar cooler is limited to cool soda and to charge a mobile phone. Only the farming household with the solar cooler on top of the mountain uses the solar cooler in that way. The other solar cooler in the valley is not used at all.

Expected opportunities

Farmers expected that milk would get collected in the farming household with a solar cooler and then picked up by a transporter of the cooperative. Farmers could also to store milk. To assess the potential of milk cooling we collected figures on current milk spoilage: In the SunDanzer case 2, spoilage mainly happened in the dry season. Two farmers (10%) reported spoilage, that resulted in monthly monetary losses of 2176 KSh[14] (21.76 USD) respectively. Yet these losses were dominated one big farmer, who lost 60L.

As delivering to the cooperative gets less burdensome, the amount of milk delivered to the cooperative would increase. Farmers, who had been demanding an increase of the milk price for months, hoped

[14] The cooperative milk price was used for calculations, as this is where rejections happen.

that the solar cooler was the change that could finally bring the change in milk price they had hoped for. However, none of these expectations did get fulfilled.

Discussing the opportunities and challenges farmers explained why they don´t use the solar cooler to cool milk. The reasons of farmers why they don´t use the solar cooler are the following:

Insecurity about the system
Farmers feel unsure about the usage of the system because it is not officially launched. They did not get any directions or explanation on how to use the system and why and how they could benefit from it. Farmers and the cooperative want to wait until the system officially gets launched, as promised by the IDA.

Discontent of farmers with the cooperative
The expectation by farmers that milk is delivered by farmers and always available for consumers who live nearby the collection centre did not get fulfilled. One reason is, that farmers object the low milk price of the cooperative. They demand to change the milk price from 35 KSh to 45 KSh per liter. Some farmers currently only deliver the morning milk to the cooperative. The evening milk is used for self-consumption. Farmers thought that the solar cooler would boost the milk prices and would make it more attractive to deliver to the cooperative. In addition, the cooperative has failed to organize the transportation of milk from the place with a solar cooler to the cooperative. In the farmers' view, the transportation should be organized and payed by the cooperative. The person handling the collection of milk in the collection centre should also be paid by the cooperative.

System Caretakers bear the costs and responsibilities without any remuneration
Farmers don not want the system to be installed in a homestead. The houses are small, and the freezer needs a lot of space. One farmer needed to pull out doors to take the freezer into the house and build a new room that the family has space. Furthermore, the system creates insecurities for the caretakers as they feel accountable in case the solar cooler gets stolen or breaks down. It is not clear, who would bear the incurred costs that are way beyond the financial means of the caretakers. So far there is no remuneration for the caretakers and therefore no motivation for the caretakers to start.

Unsuited locations
Another suggestion is that the solar coolers are misplaced. Most dairy farmers, who deliver to the cooperative, live on the other side of the hill where no solar cooler is installed. The cooperative suggested to install another solar cooler on the other side of the hill. The purpose of the solar cooler on top of the mountain was to facilitate milk collection on days of heavy rains when many mountain paths were hard to pass. But farmers explained, that getting up to the top of the mountain is especially difficult when it rains, and the paths get very slippery. Furthermore, most farmers around the solar cooler are also already able to sell all their milk to neighbours. This spares them the cumbersome walk through the mountain to deliver the milk and also allows them to obtain a higher price. The solar cooler in the valley on the contrary is too close to the cooperative, so farmers prefer to deliver their milk directly to the cooperative.

4.3 Quantitative Data

We now present the results of the quantitative analysis. First means of household characteristics, farming characteristics and variables related to milk marketing and use are compared. Then we present a fixed effects regression model of household milk consumption. At last farmers WTP for milk cooling is estimated on the basis of the discrete choice experiment.

4.3.1 Statistical Case Comparison

The following presents a comparison of means over the cases. We compare general household characteristics, farming assets and systems and variables related to milk marketing and milk use.

Table 7: Socio-economic characteristics of respondent household in the different cases

	Ice-maker case n=35		SunDanzer case 1 n=32		SunDanzer case 2 n=21	
household characteristics	**mean**	**CI**	**mean**	**CI**	**mean**	**CI**
Housing quality score[1]	8.2[a] (0.4)	7.4; 9	9,2[a] (0.2)	8.8;9.7	9.4[a] (0.3)	8.7 ;10.0
Household size	5[a] (0.4)	4.2;5.8	8,1[b] (0.3)	7.4;8.8	7,1[b] (0.5)	6.0;8.2
Working age members	2.8[a] (0.3)	2.3;3.3	3,7[a] (0.3)	3.1;4.3	3.5[a] (0.3)	2.8;4.2
Dependency ratio[2]	2.6[a] (1)	0.5; 4.7	2.9[a] (0.3)	-0.2; 6	1.2[a] (0.3)	0.9; 1.4

Mean is arithmetic mean; CI is the 95% confidence interval; Standard errors are given in parentheses under coefficients; means marked with the same letter are not significantly different at 5% significance level
[1] lower values indicate a higher housing quality. For details see Annex
[2] To avoid division by 0 in households with no labour-aged persons +0.1 was added to the numerator and the denominator when calculating the dependency ratio.

In the Ice-maker case the average family size is five persons per household. The household size in SunDanzer case 1 and 2 is significantly higher than in Ice-maker case. The significantly higher dependency ratios of the SunDanzer cases suggests, that the higher household size is probably due to a higher number of dependent children or elderly. The housing quality score and the working age of household members is not significant different between the cases.

Table 8: Farming characteristics of respondent household in the different cases

	Ice-maker case n=35		SunDanzer case 1 n=32		SunDanzer case 2 n=21	
Faming characteristics	**mean**	**CI**	**mean**	**CI**	**mean**	**CI**
Total farm size [acres]	3.6[a] (0.7)	2.3; 4.9	3.6[a] (0.9)	1.8; 5.3	2.4[a] (0.3)	1.7; 3.0
Milk yield [Litres per year]	2564[a] (297)	1974; 3156	1552[ab] (439)	680; 2424	1415.0[b] (264)	891; 1939
Number of cows	2.3[a] (0.3)	1.8; 2.9	2.1[a] (0.3)	1.6; 2.6	1.7[a] (0.2)	1.4; 2.1
Milk yield per day per cow [L]	3.6 [a] (0.4)	2.73; 4.4	2.0 [b] (0.4)	1.3; 2.67	2.3 [ab] (0.5)	1.4; 3.2
Number of improved breed cows	1.4[a] (0.1)	1.1; 1.7	0.9[ab] (0.2)	0.4; 1.3	0.5[b] (0.1)	0.2; 0.8

Mean is arithmetic mean; CI is the 95% confidence interval; Standard errors are given in parentheses under coefficients; means marked with the same letter are not significantly different at 5% significance level
[1]The production systems are stated for the dry season only. Dry and wet season does not differ; except in the Ice-maker case where two farmers use a mixed system during the wet season instead of Cut and carry.

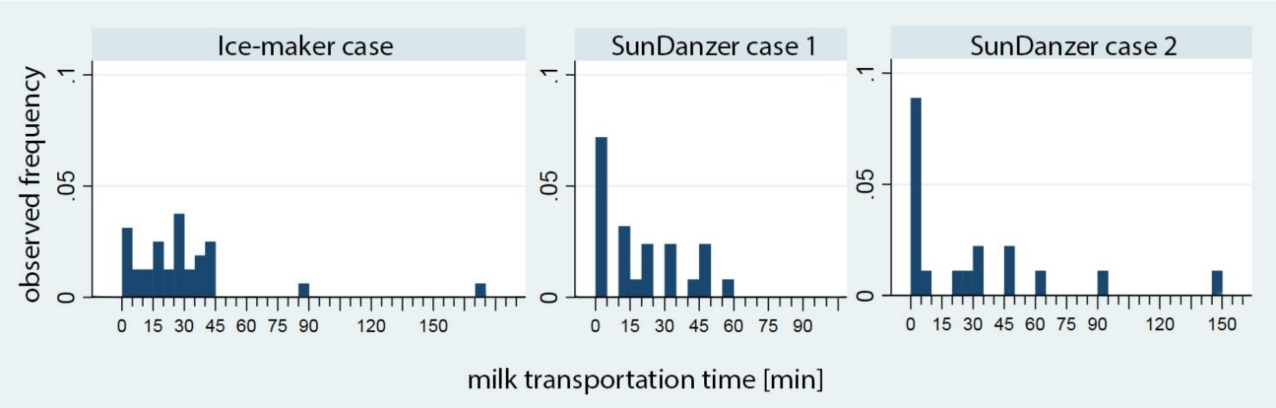
There are no significant differences in farm size, milk yield and number of cows between the three cases. The mean number of improved breed cows in Ice-maker case is significantly different to the number of improved breed cows in SunDanzer case 1 and 3. The number of improved breed cows in Ice-maker case is 1.4. In SunDanzer case 1 only 0.9 and in SunDanzer case 2 only 0.5. While cut and carry is the predominant production system in the Ice-maker case. In the SunDanzer cases tethering is the most common system.

Table 9: Milk marketing strategies and milk use of respondent household in the different cases

	Ice-maker case n=35		SunDanzer case 1 n=32		SunDanzer case 2 n=21	
Milk marketing and use	**mean**	**CI**	**mean**	**CI**	**mean**	**CI**
Share of household income from dairy [%]	68[a] (4.8)	59; 78	53.4[ab] (4.7)	44; 63	41[b] (7.2)	26; 55
Milk production per day [L]	7.0[a] (0.8)	5.4; 8.6	4.3[a] (1.2)	1.8; 6.6	3.7[b] (0.7)	2.3; 5.1
Milk yield per person per day [L]	1.9[a] (0.3)	1.3; 2.5	0.6[b] (0.2)	0.2; 1.0	0.6[b] (0.3)	0.3; 0.9
Milk consumption per person per day [L]	0.15[a] (0.02)	0.10; 0.19	0.11[a] (0.02)	0.08; 0.15	0.13[a] (0.02)	0.08; 0.17
Active cooperative members [%]	77[a] (7)		0[b]		33[c] (10)	
Share of farmers marketing less than 2L per day[1] [%]	35[a] (9)		77[b] (8)		48[a] (11)	
Share of farmers that exclusively market directly to consumers[2] [%]	3,7[a] (3,7)		63[b] (11)		56[b] (12)	
Share of farmers that milk at least twice a day[1] [%]	74[a] (8)		88[ab] (6)		95[b] (0.05)	
Transportation time[1] [min]	32[a] (5.6)	21; 44	17[a] (3.5)	10; 24	28[a] (9.2)	9; 47

Mean is arithmetic mean; CI is the 95% confidence interval; Standard errors are given in parentheses under coefficients; means marked with the same letter are not significantly different at 5% significance level.
[1] Farmers who were not currently milking were not considered in the analysis
[2] Farmer who were not currently selling were not considered in the analysis

The share of income from dairy is the highest in the Ice-maker case (68) and lowest in SunDanzer case 2 (41). In share of income from dairy in the SunDanzer case 2 is significantly different from that of farmers in the Ice-maker case. Furthermore, in the Ice-maker case the milk yield per person per day and the milk consumption per person per day is higher than in the SunDanzer cases. The share of respondents, who were active members of the cooperative, varies significantly between all three cases. In SunDanzer Case 1 the share of farmers that market less than 2L per day is significantly higher than in the other cases. Surprisingly, the share of farmers, who milk at least twice per day is lowest in the Ice-maker case. Mean transportation times hardly exceed half an hour. In the Ice-maker case milk would usually arrive at a collection centre and be further transported. In the SunDanzer cases the milk would have already reached the consumer or the cooperative. It shall also be mentioned, that 28% of farmers in SunDanzer case 1 and 39% of farmers in SunDanzer case 2 sold their milk from home, with absolutely no transportation time. While these farmers sold a median of 2.25 L per day, one managed to sell as much as 25L without the help of a cooperative. Histograms of transportation times for all three cases are shown in *Graph 1*.



Graph 1: Histogram of milk transportation time by cases

4.3.2 A model of household milk consumption

A Variety of models were estimated, that explain milk consumption per person:

Milk consumption [Litres per person per day]	Model 1	Model 2	Model 3	Model 4
Milk production per day [L]	0.01*** (0.003)		0.01*** (0.003)	0.01*** (0.003)
1 / (Milk production per day [L])		-0.15* (0,05)		
Transportation time [min]			0.001 p=0.21 (0.001)	0.002 p=0.14 ()
Constant	0.19*** (0.02)	0.34*** (0.02)	0.17*** (0.03)	0 .15*** (0.03)
Fixed effects				
Household	yes		yes	yes
Dry Season	no		no	0.02 p=0.36 (0.02)
Summary Statistics				
N	169	155	145	145
Groups (households)	88	85	74	74
Adjusted R^2	0.812	0. 830	0.818	0. 818

*Standard errors are given in parentheses under coefficients. The individual coefficient is statistically significant at the *5%, **1% or ***0,1% level significance level using a two-sided test.*

Households do use a considerable amount of their milk production for self-consumption. The intercept of the linear models ranges between 0.15 L per person and 0.2 L per person. This matches the observation, that milk is widely consumed, even by those who do not currently produce it themselves. Model 1 shows that consumption per person rises with production, which is the main factor explaining milk consumption. Model 2 suggests that consumption only slightly increases when production is high and converges to 0.34 L per person per day. Model 3 and 4 also include transportation time to the selling point, which has a weak an insignificant effect on milk consumption. Availability of milk cooling, case, number of cows, housing score and education did not show significant effects on milk consumption.

4.3.3 Results of the discrete choice experiment

In the following, we present 3 models, that explain choice behaviour.

Choice	Model 1							Model 2						
	Coefficient				WTP			Coefficient				WTP		
	Mean	SD	CI		Mean	CI		Mean	SD	CI		Mean	CI	
Attributes														
Fee [KSh/L]	-2.59***	.87	-3.10;	-2.08				-2.12***	1.25	-2.63	-1.62			
Spoilage	-7.67***	-4.76	-11.07;	-4.28	-3.0	-3.9	-2.0	-4.5***	3.13	-6.7	-2.3	-2.1	-2.9	-1.4
Morning-cooled	11.14**	21.15	4.15	18.13	4.3	1.8	6.8	21.6***	.35	15.22	28.04	10.2	7.5	12.8
Evening-cooled	12.13***	9.07	6.55	17.72	4.7	3.0	6.4	19.9***	10.32	13.55	26.3	9.4	6.2	12.6
Attribute interactions														
Morning-cooled x spoilage								-1.07*	2.08	-1.9	-.24	-.5	-.9	-.1
Evening-cooled x spoilage								-1.97***	.08	-2.83	-1.1	-.9	-1.4	-.5
Summary Statistics														
N	2,604							2,604						
Log likelihood	-572.6							-543.2						
Wald chi2	134.6							98.27						
Prob > chi2	0.0000							.0000						

*The individual coefficients is statistically significant at the *5%, **1% or ***0.,01% significance level using a two-sided test. SD shows standard deviation; CI states 95% confidence intervals; CI for WTP were obtained using the delta method.*

Model 1 explains choice behaviour as a linear function of the attributes. Consumers are willing to pay 4.3 KSh per litre for morning-cooling, 4.7 KSh for evening cooling and 3 KSh for a spoilage decrease of 1 percentage point. These figures are surprisingly high, considering farmers demands to rise cooperative milk prices in all three cases. Also willingness to pay for spoilage reduction is far higher than the financial loss of that spoilage[15]. A reason for this overestimation could be that some farmers used a false heuristic claiming that paying 5 KSh more per litre or having 5% less spoilage were "economically the same"[16]. While the willingness to pay for spoilage reduction is probably overestimated, the model does show, that respondents did see an intrinsic value of cooling, irrespective of its ability to reduce spoilage.

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[15] Considering a farmer delivering 100L at a milk price of 50 KSh: the financial loss, if 1% of the milk spoils is 50 KSh. The willingness to pay for avoiding this loss is 300 KSh

[16] Again considering a farmer delivering 100L at a milk price of 50 KSh: the financial loss, if 1% of the milk spoils is 50. Paying 5 KSh per litre costs 500 KSh

Model 2 expands that idea, as it considers interaction effects between the attributes. Respondents were willing to pay 0.5 KSh for each percentage point that spoilage reduces due to morning-cooling and 0.9 KSh. WTP for spoilage reduction drops respectively.

Originally, it was also planned to include models showing the effect of socio-economic variables on choice behaviour. But the analysis so far could not provide models that could convincingly explain choice behaviour[17]. Therefor we do not present such models.

[17] No single variable significantly affected both WTP for morning and for evening cooling. Further we could not see a causal narrative with the variables that did prove significant in a rapid evaluation. To present a thorough model, more time and an in depth study would be needed.

5 DISCUSSION

We will now discuss reasons, why some solar coolers are in use, while others are not. Afterwards we will try and outlay how small scale solar milk cooling can be successfully implemented. Section 1 first looks into reasons that constrain the use of solar coolers, differentiating between reasons related to unsuited locations and those related to the implementation process. Lastly, it assesses why farmers in the Ice-maker case do use their cooler. In section 2, we will discuss how to implement a solar cooler in practice. While we focus on farmers organized in cooperatives in this study, implementation through traders or processors are also possible.

5.1 Reasons why some solar coolers are not used

In all three cases, at least one solar cooler was not used for milk cooling: In the Ice-maker case two solar coolers were used by farmers groups, but there was one solar cooler that was not in use in the currently unused processing plant. In the SunDanzer Cases only one cooler was used to cool milk, yet for the benefit of only one farmer. This is the consequence of both a misfit between the system and local conditions and the way the projects have been implemented.

5.1.1 Unsuited local conditions

Cooperatives function different in practise

All three projects used a cooperative structure to facilitate implementation. There are considerable differences between how these cooperatives work in theory and how they work in practise, which implementers did not seem to be aware of. The question why the solar coolers are not being used is connected to the question why farmers do not deliver to the cooperative. In SunDanzer case 1 we found that target farmers have never been part of the cooperative. Delivering to the cooperative is very unattractive for them, as they produce only little milk, that they can easily sell locally: The cooperative pays a lower price, and it has not organized for the milk to be picked up. Delivering to the distant cooperative would hence be more cumbersome than selling milk to neighbours or at the nearby market. These reasons do also apply to some farmers in the SunDanzer case 2, yet this cooperative does successfully run a collection centre. In SunDanzer case 2 the lack of farmers, who deliver milk, seems to be a problem tied to the locality of the solar coolers and thus an implementation problem.

Short value chains

In both SunDanzer cases the solar coolers are located in areas where dairy value chains are quite short. Often, farmers sell directly to customers, who come to the homestead to buy milk. As Omore et al. (1999) note this is typical among small-scale milk producers in rural areas and where production is low compared to the number of consumers. Both criteria apply to the locations of the solar coolers. In the household survey only 33% of farmers in SunDanzer case 1 states they market more than 2L per day – significantly less than in the Ice-maker case (65%) and in the SunDanzer case 2 (52%). 63% of farmers in SunDanzer case1 and 56% of farmers in SunDanzer case 2 exclusively marketed directly to consumers, whereas in the Ice-maker case only 4% did. Clearly in short value chains cooling is less needed as milk is naturally resistant to bacterial growth within the first couple of hours. It is possible to successfully handle uncooled milk, if basic hygiene rules are applied and transportation does not exceed 3 hours (Kurwijila, 2006b). Thus high bacterial contamination is usually found in outlets associated with a longer value chain (Omore et al., 2002). In the locations of the coolers in both SunDanzer cases morning and evening milk is not bulked or stored. Instead farmers either consume milk themselves or sell it directly to consumers[18]. Transportation time from the farm does hardly exceed 45min and milk is boiled before consumption. Farmers do not see a reason to deliver milk to a cooler at any stage of that process.

5.1.2 Difficulties during implementation

Poor understanding of local conditions

A key deficiency in the implementation of all three projects was a poor understanding of the challenges and constraints local farmers and cooperatives face. The cooperative of the Ice-maker case was suggested by the development agency as it was reported to have high spoilage rates. It was not considered that this spoilage was mainly caused by the repeated break down of cooling facilities at the buildings of the cooperative in the town centre. Instead development agents followed the argument of cooperative officials, who used milk spoilage as a pretext not to pay farmers, claiming the milk had already reached the cooperative spoilt. The projects in the SunDanzer cases were based on the idea of storing evening milk, that would otherwise get spoilt. When implementing the solar coolers, implementers failed to notice, that evening milk - as well as any milk - hardly spoils: In the Ice-maker case spoilage mainly happened in the rainy season. Only 5 (14%) farmers reported rejections, that added up to a monthly monetary loss of 1075 KSh (10.75 USD). In the SunDanzer cases, spoilage that mainly happened in the dry season, was reported by 3 farmers (9%) SunDanzer case 1 and 2 farmers (10%) in SunDanzer case 2 resulting in monthly monetary losses of 2925 KSh (29.25 USD) and 2176 KSh (21.76 USD) respectively. Yet in the SunDanzer cases these losses were dominated by two big farmers, who each lost 60L. The majority of farmers interviewed in the SunDanzer cases do not need evening storage: Milk that is not needed for home-consumption can be easily sold to neighbours. Even though the implementation agency considers the involved cooperatives as their local partners, agents hardly visit the cooperative. If they do, the visits resemble what has been termed “rural development tourism” (Chambers, 1979): Farmers explained that the short visits by urban based development agents before project implementation were limited to formal meetings or visits model to farmers. Yet according to Chambers (1979), development agents are unlikely to understand or even perceive the conditions of the rural poor if they mainly visit well-established projects receiving generous funds, mainly talk to the beneficiaries of these projects, and mainly communicate with local elites. In SunDanzer case 1 one farmer was only informed that a solar cooler would be installed at her place the day the cooler was delivered. It was the first time she heard about the project. This is an indication that there was little communication with ordinary people, when implementing the project.

Assuming a formal market structure

Instead of participatorily developing a project to address local needs, projects were based on theoretical considerations and the perceived characteristics of the formal milk market. Even though the three cooperatives were recognized legal entities, their operations fit most definitions for the informal market (see for example ILO, 1972; Roesel & Grace, 2014) as they mainly handle raw milk, as they possess limited cooling facilities and as quality standards are not enforced. The cooperatives in the Ice-maker case and in SunDanzer case 2 did possess pasteurizers. This equipment had been donated and was not in use either. Authors like Ngigi (2004), Grace (2007) and Omore (2001) have criticized

[18] In SunDanzer case 2 sometimes heavy rains impede transportation expanding the time during which milk needs to be stored. This scenario will be discussed later

policy makers and development agencies for focussing their support on the formal milk market. The informal milk market accounts for more than 80% of all milk marketed and raw milk provides income for 350,000 intermediaries along the milk value chain - 12% of the national agricultural workforce (S. Staal, 2004 in ; Grace et al., 2007). As consumers are unwilling to pay the price of processing and packaging, raw milk markets offer both higher prices to producers and lower prices to consumers (Thorpe et al., 2000). In all three cases the informal milk market was the main outlet for milk, as it offered better prices and was easily accessible. Even though, scholars have frequently emphasized the importance of informal markets for food security (see for example Bangasser, 2000; Omore et al., 2001; Roesel & Grace, 2014), implementers failed to acknowledge its existence and importance in the selected locations.

Unsuited locations for solar coolers

When implementing a solar cooler, selecting the wrong location can wreck the entire project. In the Ice-maker case placing the ice-maker at the processing plant proofed to be inefficient because ice was not available during collection and no milk was handled in the building. This meant extra-work of commuting to the main dairy and handling the ice. The benefits, however, where perceived to be rather low, as milk was only cooled during the 20 min of transportation but not during the 2 hours of collection. As a result, the cooperative stopped this way of milk-cooling. In SunDanzer case 2 one system was placed on the top of a mountain. The rational of the project was to store evening milk, when heavy rains prevented those living on the mountain from delivering to the cooperative. The solar cooler was not installed in an established collection centre but a homestead, that was hard to access for cooperative and farmers alike. Picking up milk from the solar cooler would involve high transportation costs, that could have been avoided had the solar cooler been placed further down and closer to a main road.

Furthermore, during heavy rains the paths become so slippery that farmers living halfway up the mountain considered it impossible to climb to the top under such conditions. The site was chosen as the selection criteria for possible locations did discourage setting up the solar cooler close to the road. Going away from the main road was aimed to reach remote farmers, but it effectively precluded the existing collection centre. The second solar cooler was located in the valley. As the homestead was very close to the cooperative the benefit of bulking there is relatively low, considering the costs of recording and milk transportation. Evening storage is of little use, as milk can be delivered to the cooperative in the evening.

Insufficient communication

Comprehensible communication is key to a successful implementation process. Yet in all three cases there was uncertainty about the terms of the project. In SunDanzer case 1, the farmers living near the solar cooler stated they were uncertain about who was supposed to use the cooler. It was unclear whether non-members of the cooperative or people who were not enlisted as group members could use it. In SunDanzer case 2 farmers and officials still waited for the project to be officially launched and the terms of the project being explained even though the solar coolers had been installed 3 months before. The unresolved question who would bear the costs of a breakdown created insecurities for the caretakers. Also in both SunDanzer cases ordinary farmers had no means of communicating with the extension agents about deficiencies in the project, as their phone numbers were only known to the elite contact persons. In the Ice-maker case the cooperative stopped using one solar cooler after the technical trial was over. To them the way the cooler was used in the trial was cumbersome and produced only limited benefits. It is however unclear whether cooperative officials did have the authority to change the location or terms of use and whether they had the will or capacity to implement the cooler in a different setting.

5.1.3 Reasons why farmers groups in the Ice-maker case do use the coolers

While one of the solar coolers in the Ice-maker case was not used, the other two were. Not only did the two farmers groups use the solar coolers, they also put in considerable amounts of volunteer work to run the system. What motivates them? The implementation process was quite different in the Ice-maker case. Installation was done with the help of a foreign research team that then stayed for a month to conduct technical tests. The research team would explain procedures and rationales to all farmers in detail and its members were strikingly popular amongst the farmers. Farmers repeatedly claimed, they used the solar cooler or delivered to the cooperative because of the research team. Also, the project considerably improved the bargaining position of farmers towards cooperative officials, as it could no longer be claimed that milk got spoilt. Farmers from the first collection centre now demanded to be paid on the spot. The solar cooler helped them to create conditions that made it save to deliver to the cooperative, which in the Ice-maker case was a needed marketing structure as farmers generally produced more milk and had few reliable marketing alternatives.

5.2 Recommendations for the implementation of small-scale solar milk cooling systems

Implementing solar cooling is a considerable monetary investment, that needs to earn sufficient monetary benefits. While improvements of milk quality are well documented (Foster et al., 2017; Mrabet, 2016), there has been little work on monetary benefits.

5.2.1 Identifying Sources of monetary benefit

In theory monetary benefits could arise from reduced spoilage, a price premium for good milk hygiene or reduced labour costs all of which will be discussed below.

Spoilage reduction

Spoilage reduction has been the strongest argument for implementing milk cooling. Yet, there is little work about actual spoilage rates. Also, the causes of milk spoilage can be diverse and need to be evaluated in each given setting. It is obvious that the systems assessed are not a reasonable intervention when spoilage results from poor milk handling on the farm or within a cooperative. The systems have been designed for situations when milk collection and delivery cannot be organized to be completed before milk spoils or when milk needs to be stored e.g. overnight.

Low actual bacterial milk quality standards result in few milk being considered spoilt

In this study, we did not observe any milk being rejected due to spoilage. In fact, none of the cooperatives regularly used the alcohol gun test and few consumers state concerns about milk hygiene, usually smelliness. In the consumer survey only 6% of respondents stated they choose as certain supplier, because the milk is not smelly or curdled. There is low awareness about milk hygiene among consumers and cooperative staff alike. Likewise, related food safety regulations are not enforced. While scholars like Swai and Schoonman (2011) point out the health risks of bacterial contamination, others argue the risk is limited, because informally traded milk cannot be proven to certain diseases (Namanda, Kakai, & Otsyula, 2009) and because almost all milk is boiled before consumption (Arimi et al., 2005). Most consumers did not show food safety concerns, and few were willing to purchase pasteurized milk for a higher price. Instead they take the necessary food safety measures themselves: The consumer survey and the household survey both confirmed that milk is almost exclusively consumed in tea, with vegetables or as lala all of which comprise the killing of bacteria through boiling or a considerable decrease through fermentation. In a study by Arimi et al. (2005) all urban and 96% of rural consumers indicated, they boiled milk before consumption. As a result, health risks from bacterial pathogens are low. Through boiling consumers adapt their milk hygiene requirement to a standard (not curdled or separated) that can be achieved by local farmers and that they can assess themselves when buying milk. This method of dealing with information asymmetries between producers and consumers creates a situation in which traditional milk preservation methods like boiling or cold-water storage can be sufficient to ensure milk quality, especially if milk is eventually cooled at a cooperative or sold quickly.

Possibilities due to cooling during milk transport

There are, however, situations in which milk will be considered spoilt even when quality standards are low: If milk collection and transportation cannot be organized before milk spoils, the ice-maker can expand the timeframe of these activities. This can be especially valuable in rough terrain like in the SunDanzer Case 2 or in remote areas. Wayua (2011) describes a scenario of camel milk marketing in the Kulamawe-Isiolo milk chain in Isiolo County that involves several stages of bulking, 10km of transportation by donkey, 82km of transportation by lorry on rough roads and takes on average 7.5 hours until milk reaches the secondary market. At no time milk during this process milk is cooled and 43% of secondary milk traders reported to have problems with spoilage. Additionally, in rural areas cooling poses the possibility to sell more milk locally at consumer prices, instead of rushing into the city before milk gets spoilt. Some farmers in the Ice-maker case have used this opportunity to subvert the cooperative and sell their milk to consumers instead of delivering. The purpose of these activities was to receive a higher milk price. The small profit enabled them to pay the milk transporter and the recorder. The collection centre, where staff was payed, did not subvert the cooperative.

Possibilities due to evening storage

Another possibility is the storage of evening milk. When cooling evening milk, benefits can arise from more efficient utilization of evening milk or from increased production due to higher milking frequency. As in some cooperatives evening milk is not collected, some like Foster et al. (2017) have simply assumed, that the value of uncollected evening milk is zero. This neglects the different ways milk can be utilized, when not sold to a cooperative. In this study respondents would use evening milk for self-consumption, sell it to neighbours or traders or even store milk overnight with conventional methods. These uses of evening milk were continued, even where solar milk cooling was available and in use. This indicates that famers choose these ways to use their milk for reasons other than lack of milk preservation. If the farmers unwastefully use evening milk, it cannot be assumed, that cooling and thus marketing opportunities are strong incentives to improve milking frequencies. In fact, 74% of farmers in the Ice-maker case 88% in SunDanzer case 1 and 95% in SunDanzer case 2 already did milk in the evening. When implementing solar coolers, the actual potential of evening storage must be assessed critically. This also includes assessing the investment of a solar cooler against the cost of organizing a second milk collection per day.

Price premium for quality milk

Some have proposed that cooling could be profitable, if buyers were willing to pay a price premium for cooled milk. In Western Kenya around 85% of milk is dealt with in the informal sector, while only 9% is sold to processors (Muriuki, 2011), where no price premium can be achieved. In the consumer survey, respondents also showed a preference for affordable raw milk over the more expensive processed milk. Some retailers do, however, pay a price premium. For example KCC pays a premium of 1 KSh per litre (REEP, 2017). Yet, this firstly does not remotely cover the investment costs of a solar cooler and secondly the premium is payed irrespective of when milk was first cooled. If milk does get cooled down where it gets delivered to, e.g. at a cooperative, there is no additional monetary benefit from having it cooled even before.

Reduced labour

Besides creating direct monetary benefits cooling can help to reduce labour. Using the milk cans with the ice compartment within the cooperative spared the staff the task of milk-boiling, which takes about 2 hours. In situations where labour is scarce, this can provide additional benefit. In the research cases, however, labour cost for boiling did not play a significant role as staff was either volunteering, under-payed or able to multi-task fulfilling other duties while boiling. If other cooling facilities already exist in a cooperative, this potential cannot be fulfilled. Solar coolers can also spare cooperatives to pick up evening milk. When milk is picked up only once per day, instead of twice, the labour and fuel of the transporter can be saved. This might be especially relevant, if milk collection is situated very far.

At the same time using and maintaining the system involves a considerable amount of labour. Both the Ice-maker and the SunDanzer system need to be wiped once a week. In the ice-maker case further labour involves fetching water, cleaning the cans and ice-containers and making ice. These tasks were all done by volunteers without remuneration.

Characteristics of regions where monetary benefits are likely to materialize

While price premiums and reduced labour costs can be a source of further benefits, our results suggest that they alone cannot recover the cost of a system. Successful implementation is thus unlikely where no spoilage of milk occurs.

From these considerations successful implementation is more likely where

1. there is a surplus of milk and farmers have limited options to market their milk,
2. transportation cannot be organized in a way that effectively prevents spoilage, especially where milk collection takes place are very far from selling or
3. there are real incentives to improve milk quality e.g. where milk quality standards are enforced or where milk is consumed raw.

Yet, not all places within a region that fulfils the above criteria can benefit from small-scale solar milk cooling. Careful attention needs to be taken to assess the local conditions and potentials. What are the main reasons for milk spoilage? What alternative options are available to address these issues? Judging whether solar milk cooling does provide sufficient economic benefit in a given situation does require comprehensive and detailed knowledge of local circumstances. This could be achieved either through more regular and inclusive field visits and a shift in approach away from a top-down approach that searches the people that fit to the project. Local communities (not elite contact persons) should be empowered to decide what projects they want to implement.

Both, the Ice-maker and the SunDanzer system are planned to be commercialized. It is assumed that if farmers have to pay for a solar cooler themselves, they would ensure it generates the necessary benefits to pay back the costs. While commercialization can enhance self-selection mechanisms, it brings its own problems, like setting up a marketing infrastructure, fixed costs of business administration and providing spare parts.

5.2.2 Finding the right location for a solar cooler

As seen finding the right location for a cooler is a crucial point when implementing a solar cooler. An installation site needs to fit the technical requirements of the solar cooler, it needs to be suited to realise the potential of the cooler, and it needs to be conveniently accessible for farmers and cooperatives. The process of selecting these sites must be designed to consider the above criteria and avoid elite capture.

General requirements

The main technical requirements of the systems are the availability of sun, and for the Ice-maker the availability of water. As explained above to realise the potential of the coolers the Ice-maker should be placed, where spoilage occurs due to long transportation or insufficient preservation of evening milk. The SunDanzer system is suited, when there is a need to store evening milk.

Convenient locations

The location of the solar cooler on the mountain in SunDanzer case 2 can be used to illustrate what is considered a (un)convenient location. It has been outlined before that this place is not easily accessible, neither for the cooperative, nor for the farmers. These are obvious reasons, why the cooperative is not running a collection centre near the homestead. Whenever a cooler shall be placed at a location, that has not before served as a collection centre, one should enquire why there is no collection centre. Only if lack of cooling is a main reason the location should be considered. It has been reported that cooperatives were not willing to set up collection centres in remote off-grid locations (REEP, 2017).

Installation in homesteads

Nevertheless, in all three cases some systems have been installed in homesteads, mainly to address the treat of theft. Yet this option has two downsides: Firstly, it might impede disproportionate burdens on the caretakers. In the SunDanzer case 2 the caretaker family of the solar cooler on the mountain, did not only have to remove the door to fit in the cooler and to expand the house, they also feared to be made responsible in case the system would break down. Secondly, a system placed in a homestead can be susceptible for elite capture. If these considerations exclude homesteads, theft must be prevented by other means. Hiring a watchman is a simple but costly solution. Risk can be reduced considerably, when the panel is installed on a roof and at a place surrounded by homesteads where people are around at night time.

Finding suited locations does not only require detailed knowledge about the reasons of milk spoilage and the characteristics of possible sites. It usually also involves trade-offs and thus value judgements, for example between accessibility and security. The decision-making process should thus be organized in a way that enables all local dairy farmers, including women, elderly and the poor, to participate and that confines elite capture.

5.3 Avoiding negative side-effects

Effects on household milk consumption

It is recommended to also consider effects on the wider community. As milk is highly perishable, farmers are forced to sell before it spoils. This leads to a low shadow price of milk and thus access to milk as a protein source to all the neighbourhood (Koepke & Baten, 2008). In the studied region milk prices are very stable, not even changing between the seasons. Small-scale systems, like the ones studied should hence not impact prices and access. Another concern is, that the selling of evening milk decreases household milk consumption. While we could not find evidence for this claim, Foster et al. (2017) have reported reduction of home-consumption and direct sales of evening milk due to the implementation of a SunDanzer solar cooler. To enhance local availability of milk, the location of the solar cooler can be used as a selling point, during milk collection.

Fair allocation of rights and responsibilities

To avoid conflict, it should be determined clearly who has which user and decision-making rights and who is responsible for tasks and for the proper functioning of a solar cooler. It needs to be clear, who can use the solar cooler and for what purpose. Day to day tasks like ice making, cleaning of equipment etc. need to be assigned and depending on the structure of the user group also remunerated. In unexpected events like breakdowns there needs to be clarity, who is responsible for organizing measures and who is responsible for bearing the costs. Lastly, it must be clear, who has the authority to make operational and strategic decisions. Operational decisions involve the amount of ice to use this day or what to do if more milk is delivered than the capacity of the system. Strategic decisions include the change of system location or turning a collection centre into a sales outlet.

6 CONCLUSION

Small-scale milk cooling has the potential to ensure food safety and reduce spoilage for smallholder farmers. Solar based systems further address the challenges of remoteness, vulnerability to energy markets and the need for climate-friendly technologies. In principle, small-scale solar cooling systems can help to generate additional income for smallholder farmers and increase their livelihoods.

Yet, the study cases show, that implementation must be planned carefully for these potentials to materialize: When implementers lack in depth knowledge about the formal and informal milk market of an area, there is a risk, that non-optimal project regions are chosen. Once a project area is chosen, selecting the wrong location is essential to the success of the project. Lastly, lack of transparent and consistent communication can create disincentives to use the solar cooler.

We thus recommend implementers to conduct a comprehensive assessment of the potential benefits a system can have in a specific region. While a price premium for cooled milk or a reduction of labour costs can bring economic benefits, our study suggests that it is unlikely to recover the costs without a reduction of milk spoilage. Therefore, we recommend, to focus the assessment on actual spoilage rates and their causes. We further recommend to base this assessment on the local understanding of milk spoilage, that might differ from official definitions. Generally, spoilage during transport is more likely in remote areas with long value chains. If a project shall be based on evening storage, the current milking frequency and current use of evening milk can reveal, whether evening storage is needed.

A site where a solar cooler is installed needs to not only fulfil the technical requirements of the system. It must also be conveniently accessible for farmers and cooperative milk transporters and it should enable a cost effective mechanism to prevent theft. When implementing a solar cooler there must be a fair and transparent allocation of user and decision-making rights as well as responsibilities for tasks and for the well-functioning of the cooler. Lastly, we recommend to monitor follow-up projects to ensure that negative side-effects can be prevented.

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ANNEX

7.1 Random Walk Sampling

Flat areas SunDanzer case 1

Creating the random walk

The random walk directions was created using two dice, one with the numbers 1-6, another one with letters including L and R, which would signify left and right. When the dice were rolled, 3 and R would stand for the 3rd household on the right, 1 and L for the 1st on the left. If neither L nor R showed, the dice were rolled again.

The random walk

The interviewer starts at a solar cooler. Then she*he interviews:

- The 6th house on the right
- the 4th house on the right
- the 6th house on the left
- the 5th house on the right
- the 6th household on the right
- the 3rd household on the right
- then the procedure was restarted from the top

additional rules

- If households did not own cows, they were not interviewed.
- If the interviewer reached a crossing, a coin was tossed (heads=left; tails=right)

Mountainous areas in SunDanzer case 2

As households in SunDanzer case 2 were rather scattered and quite hard to reach, the random walk was adapted: Each household next to the path, that owned cattle was interviewed; if a crossing was reached, a coin was tossed.

7.2 Questionnaire household survey

1 Background information

1. **Household number** ________________________
2. **Interviewer** ____________________________
3. **Date of interview** _________________________

4. **Respondent's name** _________________________
5. **Location** ________________________________

Milk Cooling available □ yes □ no

Place of interview
□ home of respondent
□ Collection Centre
□ cooperative headquarters
□ other: _______________________

1 household Roster

Please indicate the following for all household members, who live in the household, including elderly and children.
For polygamous households, list all members, who are related to the same wife. If the respondent is the household head list all related to the first wife.

ID	Household member	Connection to household head	Gender	Year of Birth	Age	Marital status	Major occupation	Minor occupation	Years of formal schooling KCPE	KCSE	Uni
Code	**2_name**	**2_connection**	**2_gender**	**2_birth**	**2_age**	**2_mstatus**	**2_mainoccupation**	**2_minoroccupation**	**2_yrseduc**		
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
12											
	name	1=household head 2=spouse 3=Son 4Daughter 5=Parent 6=Father/mother in law 7=Brother 8=Sister 9=Grandparent 10=Other related person 11=Unrelated person	1=male 2=female			1=Never married/ single 2=Monogamously married 3=Polygamously married 4=Separated 5=Widowed -9=Other Specify	0=None 1= Farming 2=Casual labour 3=Salaried employment (civil servant etc) 4=Student/school -9= Other (Specify)______	0=None 1= Farming 2=Casual labour 3=Salaried employment (civil servant etc) 4=Student/school -9= Other (Specify)______	Class level	Class level	years

If you employ laborers for dairy, please indicate their names and daily wage ____

3 Socio-economic position

Do you have access to the following?

□ Electricity (grid)
□ solar power
□ None

What means of transport does the household own?
□ Bicycle
□ Motorbike
□ Car
□ Truck
□ Tractor
□ Animal Cart
□ Other, Specify
□ None

How many minutes does it take you to get to…
…a tarmac road during the dry season? ___________________ *(by ____________)*
…a market during the dry season? ___________________ *(by ____________)*
…a public school during the dry season? _________________ *(by ____________)*
…a tarmac road during the wet season? ___________________ *(by ____________)*
…a market during the wet season? ___________________ *(by ____________)*
…a public school during the wet season? _________________ *(by ____________)*

What kind of house do you have?

Walls
□ mud
□ iron sheet
□ wood
□ plastered
□ bricks
□ stones
□ other specify ___________________

Roof
□ grass
□ iron sheet
□ tiles
□ other (specify) ___________________

Floor
□ earth
□ cement
□ wood
□ tiles
□ other specify ___________________

Source of water
□ pipe
□ spring, river
□ well / borehole
□ catchment from roof
□ other specify ___________________

4 Plot Roster

How many acres of land do you own?

Use: Homestead /home garden: _____ acres; Crops: _____ acres; Pasture _____ acres ; Rented out _____ acres; Forest _____ acres; Others, namely________ _____ acres

Please provide the following information for all your plots last year.

ID	Plot size	ownership	distance to house	crop	yield of last year	
					no	units
Code	**4_size**	**4_owner**	**4_distance**	**4_crop**	**4_yno**	**4_yunit**
	acres	1=Own 2=Rented 3=Lease 4=Communal 77=other	min	1=Maize 2=Rice 3=Sorghum 4=Millet 5=Cassava 6=beans 7=Vegetables 8=napier grass 9=other fodder 10=other 11=sweet potatoes 12=bananas 13=groundnuts		**Write down units used**

5 Livestock kept

Please indicate the number of adult animals owned by the household

Cattle_________ Sheep_________ Goats_________ Chickens _________ Pigs _________ Others____

For dairy cattle, please provide details for each animal individually considering the last year.

ID	Animal category	owner	obtaining	Person responsible for taking care	breed	Household members involved in breeding decisions	Date of calving	Liters of Milk produced daily during months of the year												Illnesses last year	treatment cost of illness last year	Interval of Tick control	Interval of deworming	Vaccinations	Price of Vaccinations
								1	2	3	4	5	6	7	8	9	10	11	12						
Code	**5_category**	**5_owner**	**5_got**	**5_respons**	**5_breed**	**5_decisions**	**5_calv**													**5_no_ill**	**5_cost_ill**				
	1=Dry Cow 2=Lactating cow 3=Heifer 4=Calves 5=Bull 6=Steer 7=♂ weaner 8=♀ weaner	1=household head 2=spouse 3=Son 4Daughter 5=Parent 6=Father/mother in law 7=Brother 8=Sister 9=Grandparent 10=Other related person 11=Unrelated person	1=bought, also write price in Shillings 2=donation (NGO) 3=gift 4=dowry 5=own calv -9=other	1=household head 2=spouse 3=Son 4Daughter 5=Parent 6=Father/ mother in law 7=Brother 8=Sister 9=Grandparent 10=Other related person 11=Unrelated person 12=hired labour	1=Pure Exotic 2=Ashar 3=Zebu 4=other	1=household head 2=spouse 3=Son 4=Daughter 5=Parent 6=Father/mother in law 7=Brother 8=Sister 9=Grandparent 10=Other related person 11=Unrelated person														1=mastitis 2=Foot and Mouth 3=East coast fever 4=Black water	Shillings	1=weekly 2=fortnight 3=month 4=two months 5=half yearly 6=yearly 7=3 months -9=other			

Please indicate the price of: tick control method used______ Shillings, Deworming________Shillings

Which household members where involved, when it was decided to sell cattle last time? ____

Which household members where involved, when it was decided to buy cattle last time? ____
Do you have access to veterinary service? □ yes □ no

6 Production System/ Feeding

How do you keep your cattle??

Dry Season
□ herding
□ tethering
□ mixed: stall feeding + herding
□ Cut and Carry / zero grazing
□ Other

Wet Season
□ herding
□ tethering
□ mixed: stall feeding + herding
□ Cut and Carry / zero grazing
□ Other

If two systems are used, provide the names of the cows

For herding and tethering:
How long are the cattle herded/tethered each day? ____________________________________ Which family members are responsible? ______________________________________
How long does herding/tethering take in the wet season ___________________________ and in the dry season?

For stall feeding and Cut and Carry:
What are the main feeds you use? (including dairy meal)

	dry					wet				
ID	Type of feed used	Quantity used	source	Price per unit	No of units	Type of feed used	Quantity used	source	Price per unit	No of units
Code	7_d_type	7_d_quant	7_d_source	7_d_price	7_d_unit	7_w_type	7_w_quant	7_w_source	7_w_price	7_w_unit
	1=grass 2=fodder crops 3=crop residue 4=processed feed 5=other		1=own 2=bought 3=swapped,__ 4=other,___	Shillings		1=grass 2=fodder crops 3=crop residue 4=processed feed 5=other		1=own 2=bought 3=swapped,_ 4=other,___	Shillings	

Which family member is responsible for the feeding?

How long does feeding take in the wet season
____
and in the dry season?

Do you preserve fodder for the dry season?
□ yes
□ no

if yes, how?

Do you use:
□ salt
□ minerals
□ none

7 Water Supply/ Treatment

How are cattle watered in the dry season and the wet season?

Dry Season	**Wet Season**
□ Animals go to water	□ Animals go to water
□ Water is provided	□ Water is provided
□ both	□ both

If source is different from household consumption, please check

□ pipe	□ pipe
□ spring, river	□ spring, river
□ well / borehole	□ well / borehole
□ catchment from roof	□ catchment from roof
□ other specify ___________________	□ other specify ___________________

When can cattle drink water?

Dry Season	**Wet Season**
□ Always available	□ Always available
□ Once a day	□ Once a day
□ ______ times a day	□ ______ times a day
□ Other __________________	□ Other __________________

How long did you have to go to fetch water for cattle and provide it each day?

Dry Season	**Wet Season**
□ _____min	□ _____min

Which household members go to fetch water?

Please indicate the water quality in dry season and wet season.

Dry Season	**Wet Season**
□ Good/ clear	□ Good/ clear
□ Muddy	□ Muddy
□ Salty	□ Salty
□ Smelly	□ Smelly
□ Other	□ Other

8 Milking, Marketing and Use

Which family members milk the cows? ____

Please explain, what steps you undertake when milking the cows.

□ get warm water	□ make sure place is clean	□ pre-milking
□ wear overall	□ wash utter	□ test for mastitis
□ wear milking gloves	□ massage the utter	□ use milking salve

What type of container do you use to transport the milk?

□ aluminuim can □ mazzi can □ plastic can (bought) □ plastic can, formerly used for ___________ □ plastic bucket □ other________

How many liters milk was produced yesterday and how where they used? | **How much milk did you produce during the dry season and how was that used?**

	Morning	Evening	Morning	evening
Total output				
Self-consumption (family)				
Self-consumption (calves)				
Donations				
Direct sales				
Delivery to collection center				
Delivery to cooperative				
Sale to informal milk traders				
Hotels/Restaurants				
Other, namely:				

Which household member sells milk to neighbors or traders? ________________________________

What is milk used for in the household

Id	**Dry Season**			**Wet Season**		
	Use	**Liters**	**Household Category**	**Use**	**Liters**	**Household Category**
Code	**8_d_use**	**8_d_litres**	**8_d_category**	**8_w_use**	**8_w_litres**	**8_w_category**
	1=tea 2=vegetables 3=fresh 4=lala 90=Other		1=household head 2=spouse 3=Son/Daughter 4=Parent 5=Father/mother in law 6=Brother/Sister 7=Grandparent 8=Other related person 9=Unrelated Person 10=All	1=tea 2=vegetables 3=fresh 90=Other		1=household head 2=spouse 3=Son/Daughter 4=Parent 5=Father/mother in law 6=Brother/Sister 7=Grandparent 8=Other related person 9=Unrelated person 10=All

For both marketing ways, please indicate:

	Cooperative / collection centre		Informal traders	
	Rainy season	Dry season	Rainy season	Dry season
Price received [Shillings/Litre]				
Mode of payment				
Time of payment (daily, weekly, monthly)				
Household member who gets the money				
Distance to selling point (km)				
Time needed for milk transportation				
Household member transporting the milk				
How often was milk rejected per month?				
How many liters of were rejected per month?				

What did you do with the rejected milk? ____

What share of the yearly household income comes from dairy (%)? __________________________

Why do you choose to deliver to the cooperative/collection centre?

____

____

____

____

How satisfied are you with the cooperative? □ very satisfied □ satisfied □ neutral □ dissatisfied □ very dissatisfied

Why do you choose to deliver to informal traders?

How satisfied are you with the traders/middlemen? □ very satisfied □ satisfied □ neutral □ dissatisfied □ very dissatisfied

If you deliver to others, please also state reasons

9 Challenges

What are the 3 biggest challenges in keeping cattle for you?
(check the named boxes)

Animal production
□ Lack of grazing land
□ Lack of feed in dry season
□ Lack of water in dry season
□ Incidence of drought

economic
□ rejection of milk by buyers
□ low milk production
□ low milk price
□ overproduction
□ time constraints
□ Livestock theft
□ Lack of extension services

Animal health
□ Low fertility of animals
□ Miscarriage
□ Parasites and predators
□ Diseases
□ failed insamination
□ price of animal health services

□ Others ________________
□ Others ________________

Is there anything you want to add?

10 Choice Experiment

	a)	b)	c)
E			
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Shortened Questionnaire

General information

Household number ______________ Respondent's name ________________________
Interviewer ______________________ Location_______________________________
Date of interview __________________ GPS ____________________________________
Milk Cooling available □ yes □ no
Place of interview □ home of respondent □ Collection Centre □ other: ______________________

Personal information

Age______ **Relationship to household head** ___________ **Main occupation** ____________
Gender __ **Years of education** _____ **Minor occupation** ____________

Family members

name	Relation to household head	gender	age	Main Occupation	Minor occupation

What kind of house do you have?

Walls
□ mud
□ iron sheet
□ wood
□ plastered
□ bricks
□ stones
□ other specify
____
_

Roof
□ grass
□ iron sheet
□ tiles
□ other (specify)
____

Floor
□ earth
□ cement
□ wood
□ tiles
□ other specify
____

Source of water
□ pipe
□ spring, river
□ well / borehole
□ catchment from roof
□ other specify
____

What share of the yearly household income comes from dairy (%)? ______________________

Livestock Roster

ID	Animal category	breed	Date of calving	Liters of Milk produced daily during months of the year											
				1	2	3	4	5	6	7	8	9	10	11	12
	1=Dry Cow 2=Lactating cow 3=Heifer 4=Calves 5=Bull 6=Steer 7=♂ weaner 8=♀ weaner	1=Pure Exotic 2=Ashar 3=Zebu 4=other													

Who is the owner of the cows? ________________________

What type of container do you use to transport the milk?
□ aluminuim can □ mazzi can □ plastic can (bought) □ plastic can, formerly used for ___________ □ plastic bucket □ other________

Which household member receives the money, when milk is sold? _________________________

In the dry season:
How often was milk rejected per month? _____________
How many litres of milk were rejected per month? __________

In the wet season:
How often was milk rejected per month? _____________
How many litres of milk were rejected per month? __________

Choice experiment

E	A	B	C
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

How long does it take you to get to….

a tarmac road during the dry season? __________________ (by ____________)

a tarmac road during the wet season? __________________ (by ____________)

a market during the dry season? __________________ (by ____________)

a market during the wet season? __________________ (by ____________)

a public school during the dry season? ________________ (by ____________)

public school during the wet season? ________________ (by ____________)

Plot Roster

How many acres of land do you own?

Homestead /home garden: _____ acres; Crops: _____ acres; Pasture _____ acres ;

Rented out _____ acres; Forest _____ acres; Others, namely________ _____ acres

Please provide the following information for maize, beans and napier last year.

ID	Plot size	ownership		Yield
Code	**4_size**	**4_owner**	**4_crop**	**4_yield**
	acres	1=Own 2=Rented	1=Maize 6=Beans 8=Napier	

Production System & Feeding

How do you keep your cattle??

Dry Season

- □ herding
- □ tethering
- □ mixed: stall feeding + herding
- □ Cut and Carry / zero grazing
- □ Other

Wet Season

- □ herding
- □ tethering
- □ mixed: stall feeding + herding
- □ Cut and Carry / zero grazing
- □ Other

If two systems are used, provide the names of the cows

Which household member is responsible for feeding?_______________

How long doies it take you to feed your cattle? Dry.______;Wet:______

	dry				
ID	**Type of feed used**	**Quantity used**	**source**	**Price per unit**	**No of units**
Code	**7_d_type**	**7_d_quant**	**7_d_source**	**7_d_price**	**7_d_unit**
	1=grass 2=fodder crops 3=crop residue 4=processed feed 5=other		1=own 2=bought 3=swapped,__ 4=other,___	Shillings	

	wet				
ID	**Type of feed used**	**Quantity used**	**source**	**Price per unit**	**No of units**
Code	**7_d_type**	**7_d_quant**	**7_d_source**	**7_d_price**	**7_d_unit**
	1=grass 2=fodder crops 3=crop residue 4=processed feed 5=other		1=own 2=bought 3=swapped,__ 4=other,___	Shillings	

Milking & Milk Marketing

Which household member usually dies the milking?___________

	Morning	**Evening**	**Morning**	**evening**
	Yesterday		**Dry Season**	
Total output				
Self-consumption (family)				
Self-consumption (calves)				
Donations				
Direct sales				
Delivery to collection center				
Delivery to cooperative				
Sale to informal milk traders				
Hotels/Restaurants				
Other, namely:				

Reasons for selling to this place

____

____

____

____

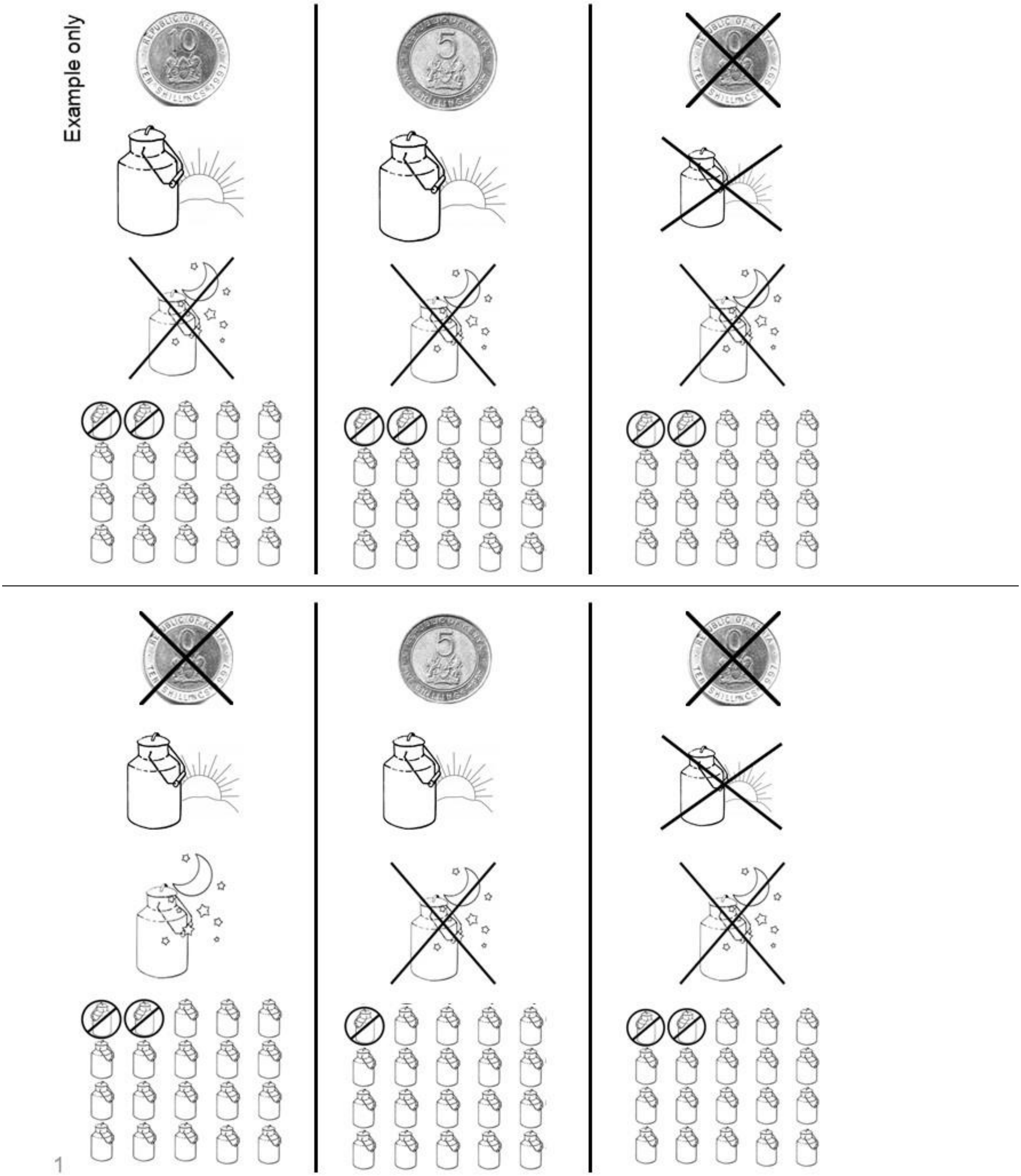
____

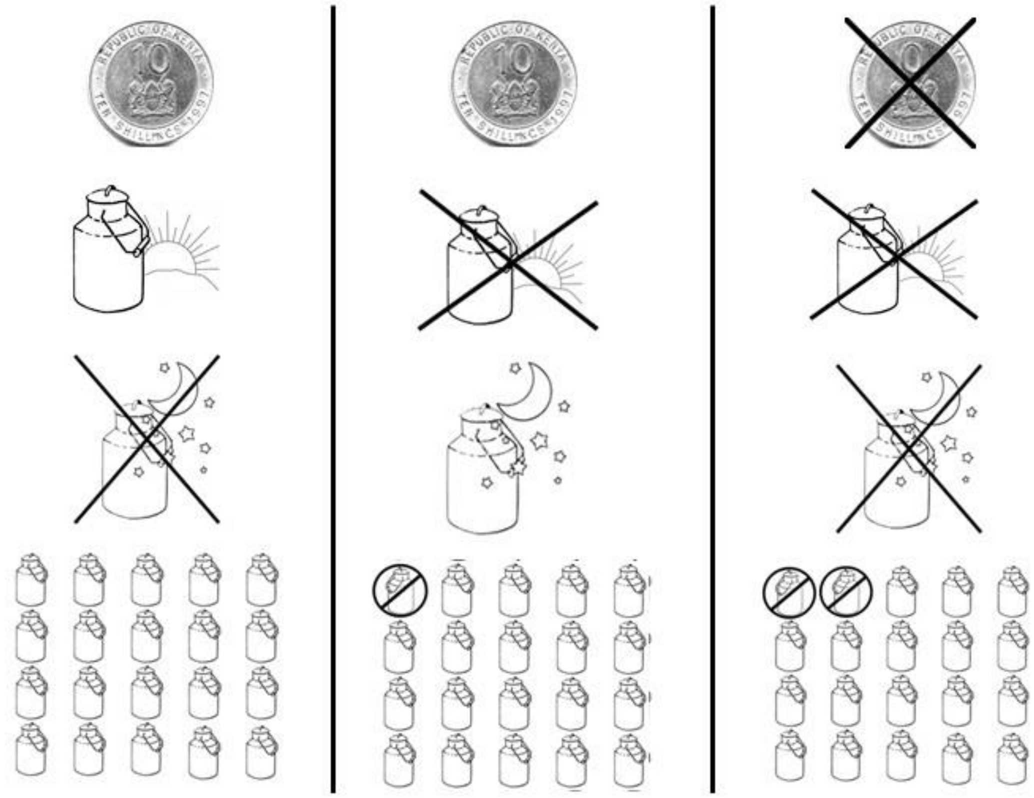
Costumer		
	Rainy season	**Dry season**
Price received [Shillings/Litre]		
Mode of payment		
Time of payment (daily, weekly, monthly)		
Household member who gets the money		
Distance to selling point (km)		
Time needed for milk transportation		
Household member transporting the milk		

How satisfied are you with the cooperative?

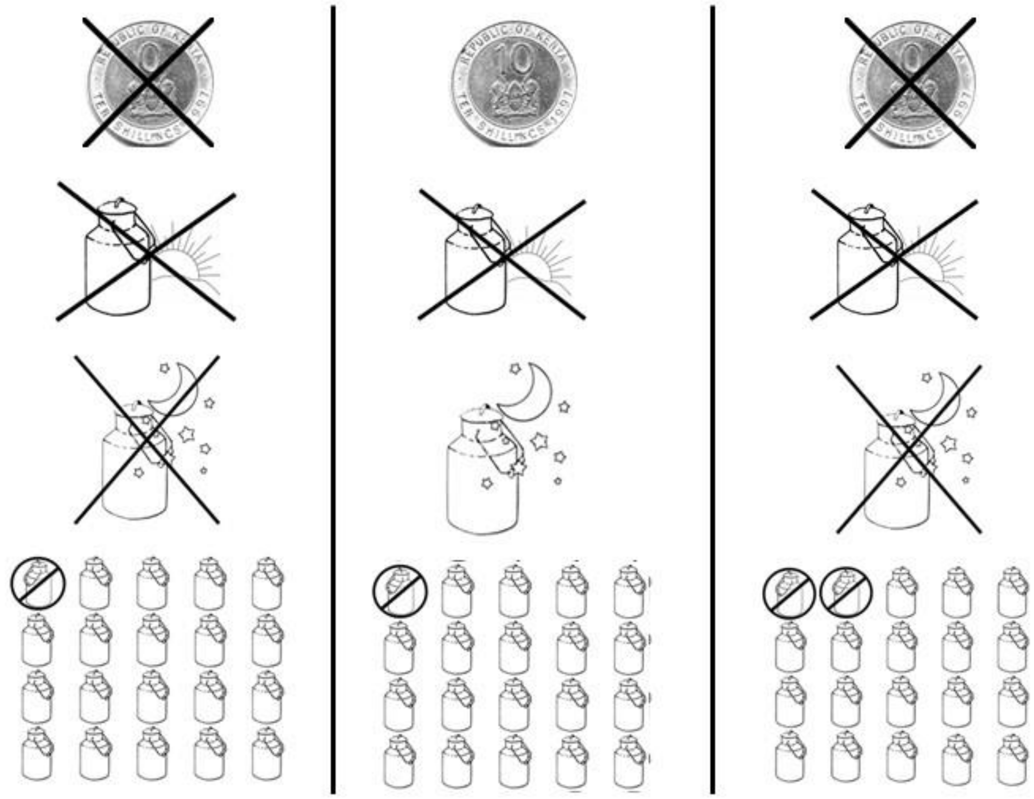
□ very satisfied □ satisfied □ neutral □ dissatisfied □ very dissatisfied

7.3 Choice Sets

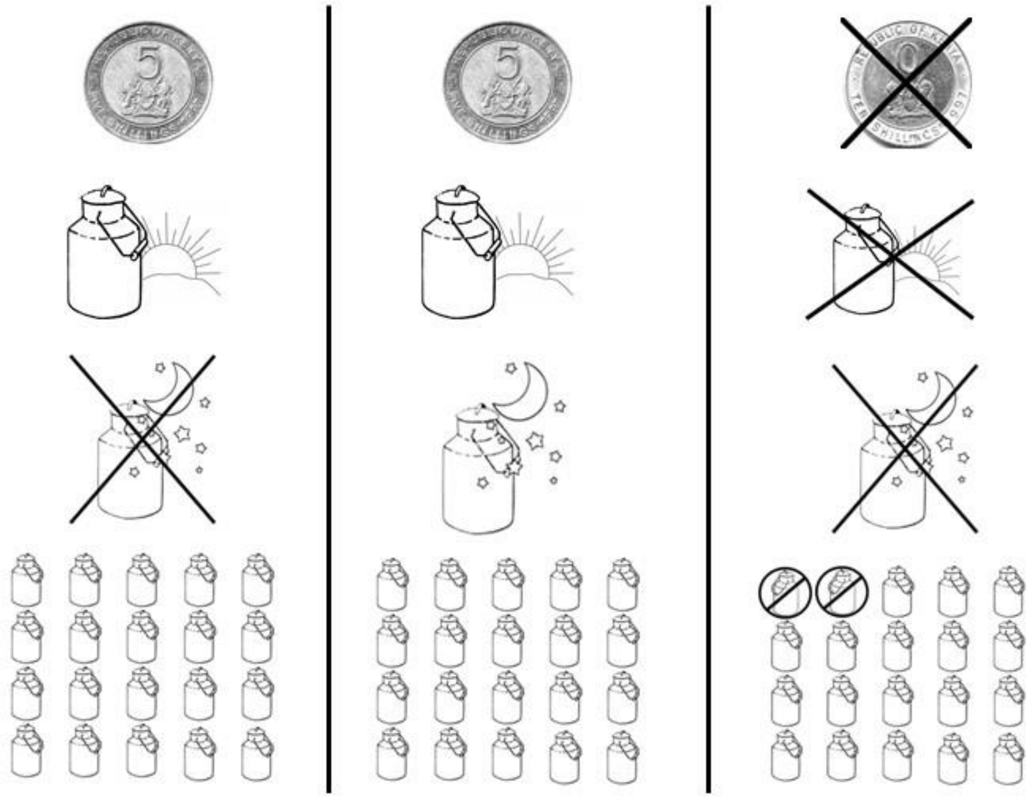



REPUBLIC OF KENYA
10
TEN SHILLINGS 1997

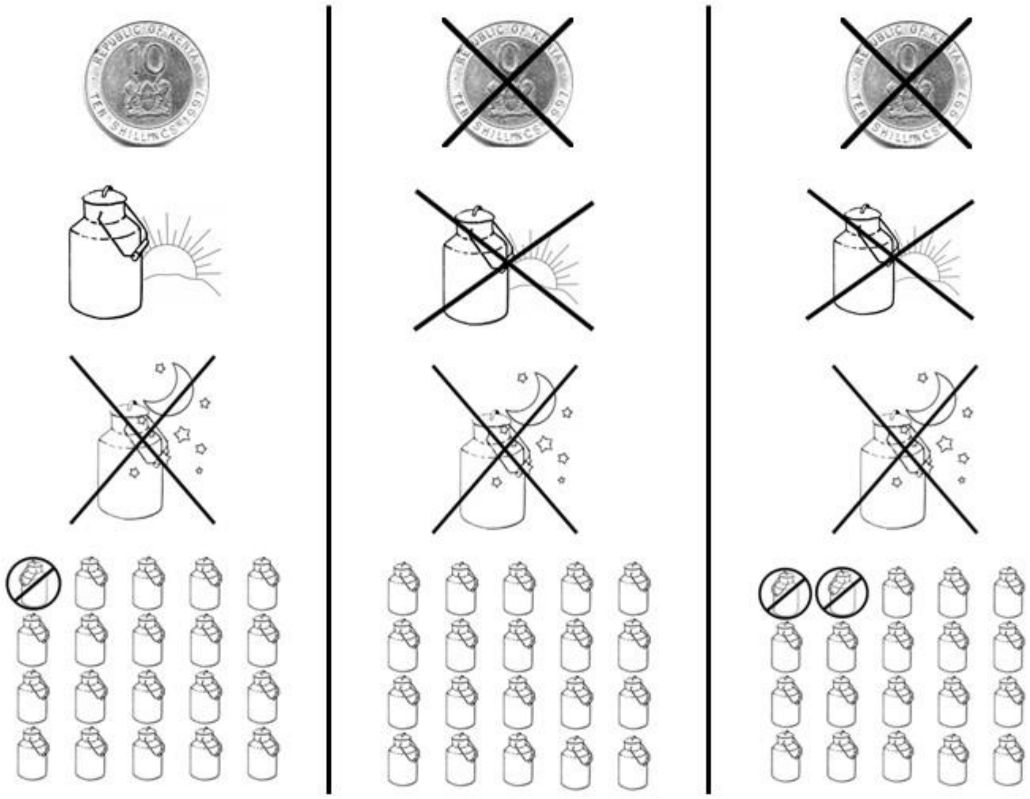
2


REPUBLIC OF KENYA
10
TEN SHILLINGS 1997

3



4



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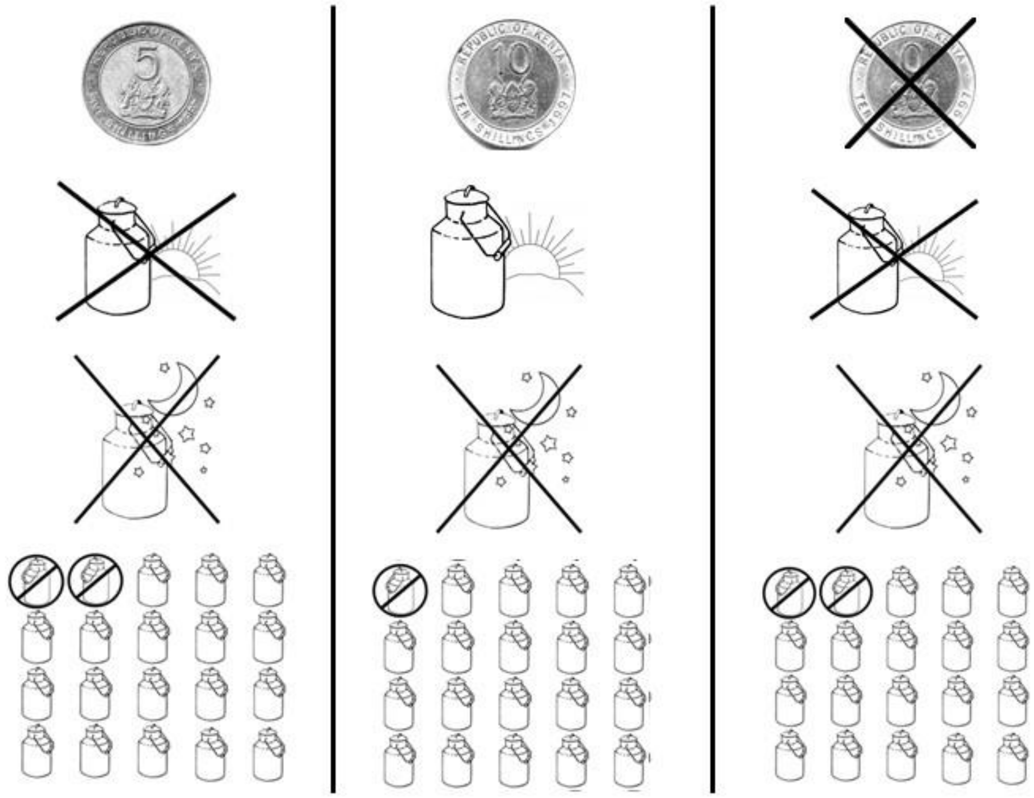

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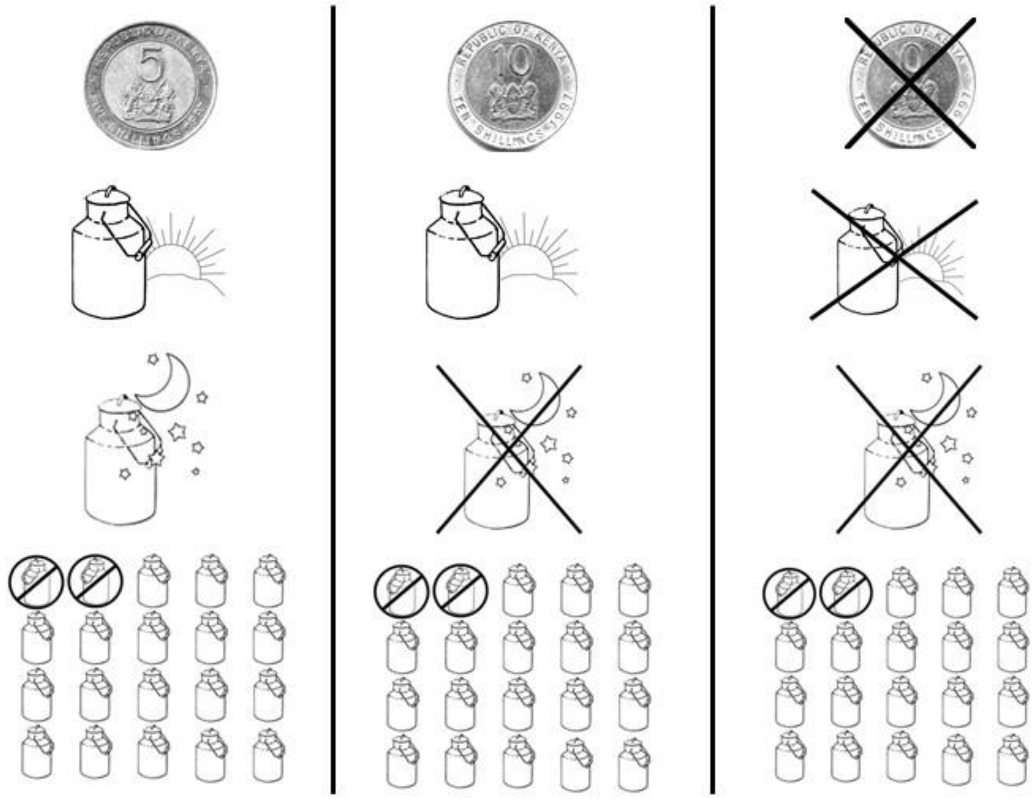
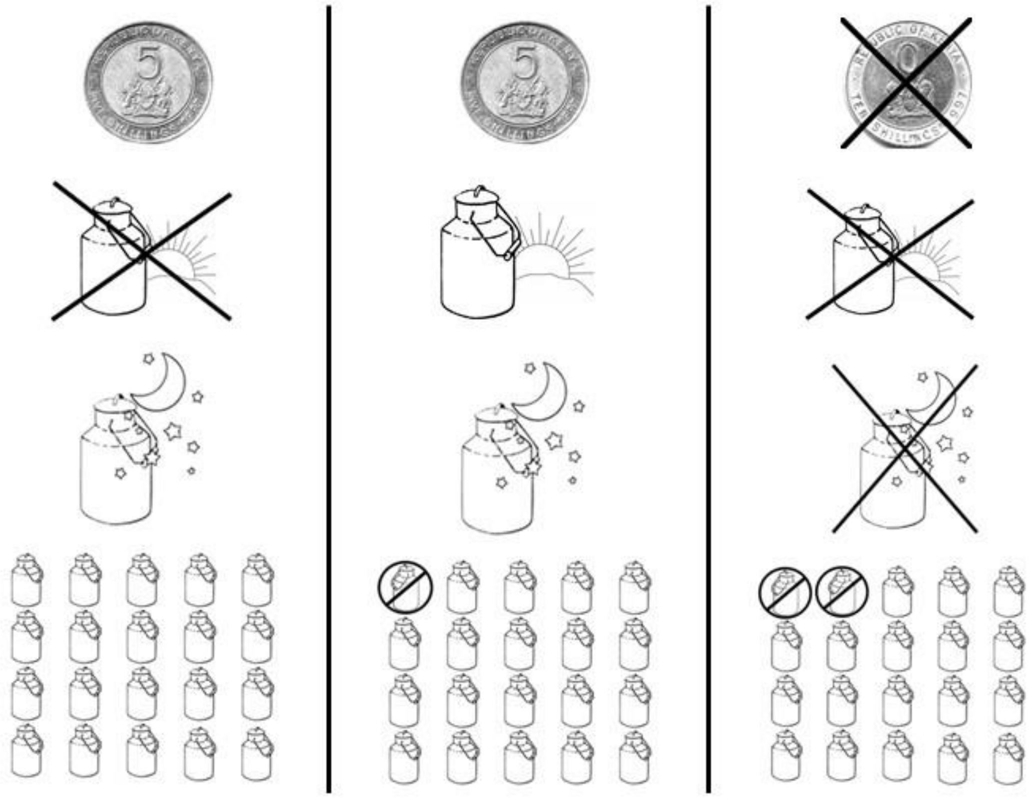


7



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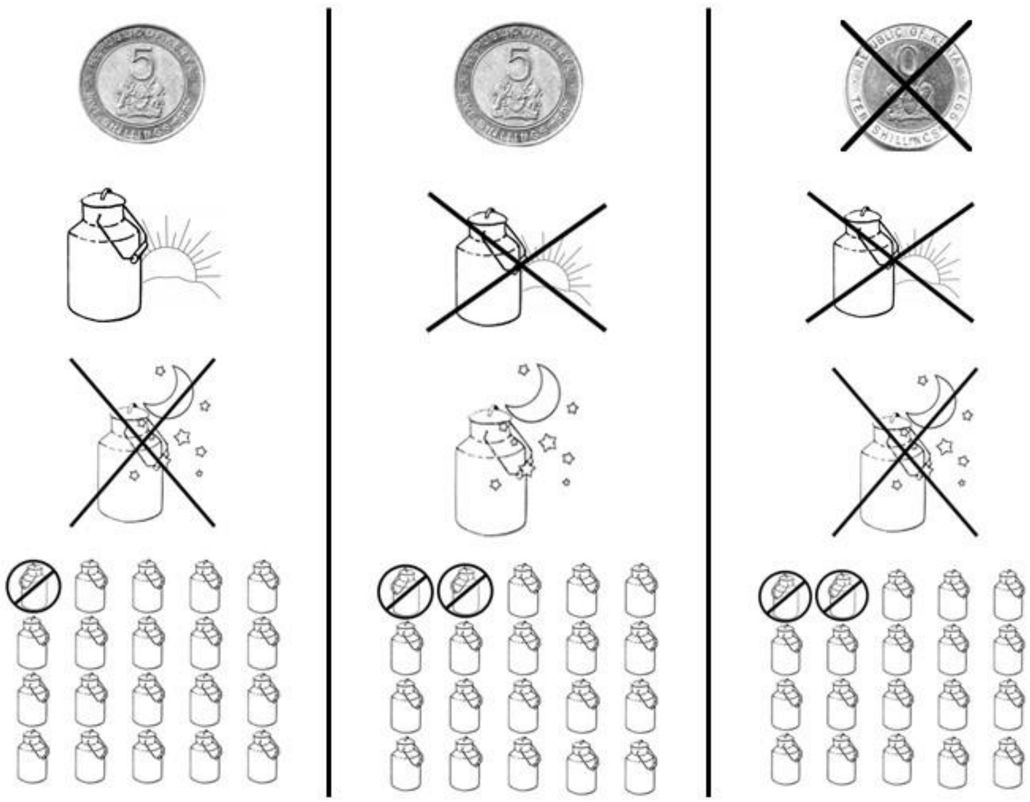
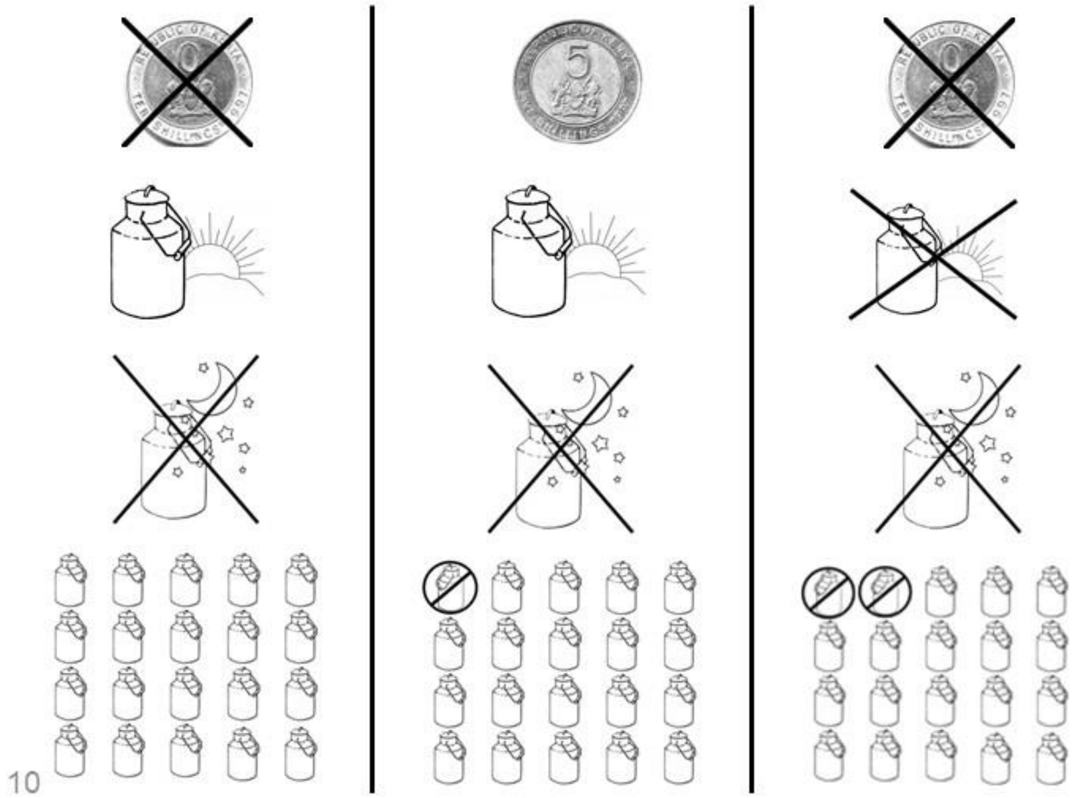


9



7.4 Consumer survey

Lead questions

- What price do you pay per litre of milk?
- Which days of the week, do you buy milk?
- How much milk do you buy each day?
- How is that milk consumed?
- At what time of the day, is milk purchased?
- What is good milk for you? (What are quality parameters?)
- Where do you buy the milk?
- Why do you choose this seller?

Additionally the type of consumer (household, hotel, school,…) is noted down for each interview.

7.5 Calculation of indicators

7.5.1 Housing quality score

In developing countries socio-economic position can be described by household assets and housing characteristics. As housing is generally the key component of most people's wealth in both industrial and developing countries, housing characteristics measure main material aspects of socio-economic position. At the same time, they are comparatively easy to measure (Galobardes, 2006). As these indicators may be specific to the temporal and geographical context, the 2009 Kenya Population and Housing Census (2009, Chapter 5) was used as a guide to construct a housing quality score based on wall material, floor material and the water source of the household. Since there were 3 items, the top consolidated score was 3, the lowest score was 12.

Score	Walls	Floor	water
1	(6) Stone (5) bricks	(4) Tiles	(1) Pipe into dwelling
2	(3) Wood (-9) Cement (4) Plastered	(2) Cement	
3	(1) Mud	(3) Wood	(4) Catchment from Roof (3) Well /Borehole
4	(2) Iron Sheet	(1) Earth	(2) Spring /River

Items and their respective scores used to create a consolidated housing quality score

7.5.2 Dependency ratio

Dependency ratio is defined as

$$\frac{persons\ younger\ than\ 14\ and\ older\ than\ 65}{persons\ aged\ between\ 15\ and\ 64} \times 100$$

To avoid dividing by zero, 0.1 was added to the numerator and the denominator.

7.6 Stata output

7.6.1 Comparison of means

Example for t-tests

(non-overlap of confidence intervals were used as an equivalent to t-tests, as they produce equivalent results)

Housing quality score

```
. mean housing_score, over(case)

Mean estimation                  Number of obs    =          88

            1: case = 1
            2: case = 2
            3: case = 3
```

Over	Mean	Std. Err.	[95% Conf.	Interval]
housing_score				
1	8.171429	.4047734	7.366898	8.97596
2	9.21875	.2233108	8.774896	9.662604
3	9.380952	.3271536	8.730699	10.03121

Production system

```
. tabulate sdry_dairy case
```

	case			
sdry_dairy	1	2	3	Total
1	0	3	2	5
1.2	0	1	1	2
2	1	3	5	9
3	4	6	1	11
4	27	3	2	32
5	1	13	9	23
6	2	3	1	6
Total	35	32	21	88

Example for proportion test

```
mean few_sales if( not_milking ==0), over(case)

Mean estimation                  Number of obs   =         78

            1: case = 1
            2: case = 2
            3: case = 3

--------------------------------------------------------------
        Over |       Mean   Std. Err.     [95% Conf. Interval]
-------------+------------------------------------------------
few_sales    |
           1 |   .3548387   .0873553      .1808922    .5287852
           2 |   .7692308    .084265      .6014377    .9370238
           3 |   .4761905   .1116766       .253814    .6985669
--------------------------------------------------------------

. ***tests
. prtest few_sales if( not_milking==0 & case3==0) , by(case1)

Two-sample test of proportions                     0: Number of obs =       26
                                                   1: Number of obs =       31
------------------------------------------------------------------------------
       Group |       Mean   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
           0 |   .7692308   .0826286                      .6072816    .9311799
           1 |   .3548387   .0859347                      .1864097    .5232677
-------------+----------------------------------------------------------------
        diff |   .4143921   .1192152                      .1807345    .6480496
             |  under Ho:   .1324532     3.13   0.002
------------------------------------------------------------------------------
        diff = prop(0) - prop(1)                                  z =   3.1286
    Ho: diff = 0

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(Z < z) = 0.9991         Pr(|Z| > |z|) = 0.0018          Pr(Z > z) = 0.0009

. prtest few_sales if( not_milking==0 &   case2==0) , by(case1)

Two-sample test of proportions                     0: Number of obs =       21
                                                   1: Number of obs =       31
------------------------------------------------------------------------------
       Group |       Mean   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
           0 |   .4761905   .1089852                      .2625835    .6897975
           1 |   .3548387   .0859347                      .1864097    .5232677
-------------+----------------------------------------------------------------
        diff |   .1213518   .1387896                     -.1506708    .3933743
             |  under Ho:    .138675     0.88   0.382
------------------------------------------------------------------------------
        diff = prop(0) - prop(1)                                  z =   0.8751
    Ho: diff = 0

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(Z < z) = 0.8092         Pr(|Z| > |z|) = 0.3815          Pr(Z > z) = 0.1908
```

```
. prtest few_sales if( not_milking==0 &   case1==0) , by(case3)

Two-sample test of proportions                    0: Number of obs =       26
                                                  1: Number of obs =       21
------------------------------------------------------------------------------
       Group |       Mean   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
           0 |   .7692308   .0826286                      .6072816    .9311799
           1 |   .4761905   .1089852                      .2625835    .6897975
-------------+----------------------------------------------------------------
        diff |   .2930403   .1367672                      .0249816     .561099
             |  under Ho:   .1409743     2.08   0.038
------------------------------------------------------------------------------
        diff = prop(0) - prop(1)                                  z =   2.0787
    Ho: diff = 0

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(Z < z) = 0.9812         Pr(|Z| > |z|) = 0.0376          Pr(Z > z) = 0.0188
```

Household milk consumption

```
. xtset household d_season
       panel variable:  household (strongly balanced)
        time variable:  d_season, 0 to 1
                delta:  1 unit

.
. *model 1
. xtreg cons_pp totaloutput, fe vce(cluster household)

Fixed-effects (within) regression               Number of obs      =       169
Group variable: household                       Number of groups   =        88

R-sq:                                           Obs per group:
     within  = 0.2160                                         min =          1
     between = 0.2085                                         avg =        1.9
     overall = 0.2059                                         max =          2

                                                F(1,87)            =     22.61
corr(u_i, Xb)  = 0.1857                         Prob > F           =    0.0000

                             (Std. Err. adjusted for 88 clusters in household)
------------------------------------------------------------------------------
             |               Robust
     cons_pp |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
 totaloutput |   .0137717    .002896     4.76   0.000     .0080156    .0195279
       _cons |   .1922304   .0161155    11.93   0.000     .1601991    .2242617
-------------+----------------------------------------------------------------
     sigma_u |   .2094502
     sigma_e |  .10756638
         rho |  .79129611   (fraction of variance due to u_i)
------------------------------------------------------------------------------

. scalar adj_R2_1 = 1 - (e(rss)/ (e(N) - e(df_r) - e(df_b) - 1))/(e(tss)/(e(N) - 1))

. display  adj_R2_1
.81200717
```

```
. *model 2
. generate by_output =1/totaloutput
(21 missing values generated)

. xtreg cons_pp by_output, fe vce(cluster household)

Fixed-effects (within) regression               Number of obs      =       155
Group variable: household                       Number of groups   =        85

R-sq:                                           Obs per group:
     within  = 0.1263                                         min =          1
     between = 0.1146                                         avg =        1.8
     overall = 0.1036                                         max =          2

                                                F(1,84)            =      7.47
corr(u_i, Xb)  = 0.1613                         Prob > F           =    0.0076

                             (Std. Err. adjusted for 85 clusters in household)
------------------------------------------------------------------------------
             |               Robust
     cons_pp |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   by_output |  -.1503026   .0549815    -2.73   0.008    -.2596394   -.0409658
       _cons |   .3370466   .0170408    19.78   0.000     .3031591    .3709342
-------------+----------------------------------------------------------------
     sigma_u |   .2184159
     sigma_e |  .10150109
         rho |   .8223956   (fraction of variance due to u_i)
------------------------------------------------------------------------------

. scalar adj_R2_1 = 1 - (e(rss)/ (e(N) - e(df_r) - e(df_b) - 1))/(e(tss)/(e(N) - 1))

. display  adj_R2_1
.82951213
. *model 3
. xtreg cons_pp t_transport totaloutput, fe vce(cluster household)

Fixed-effects (within) regression               Number of obs      =       145
Group variable: household                       Number of groups   =        74

R-sq:                                           Obs per group:
     within  = 0.2243                                         min =          1
     between = 0.1316                                         avg =        2.0
     overall = 0.1432                                         max =          2

                                                F(2,73)            =     10.14
corr(u_i, Xb)  = 0.0777                         Prob > F           =    0.0001

                             (Std. Err. adjusted for 74 clusters in household)
------------------------------------------------------------------------------
             |               Robust
     cons_pp |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
 t_transport |   .0013423   .0010575     1.27   0.208    -.0007654    .0034499
 totaloutput |   .0133752   .0030344     4.41   0.000     .0073277    .0194227
       _cons |   .1653242   .0326143     5.07   0.000      .100324    .2303244
-------------+----------------------------------------------------------------
     sigma_u |  .22803151
     sigma_e |  .11092534
         rho |   .8086486   (fraction of variance due to u_i)
------------------------------------------------------------------------------

. scalar adj_R2_5 = 1 - (e(rss)/ (e(N) - e(df_r) - e(df_b) - 1))/(e(tss)/(e(N) - 1))

. display  adj_R2_5
.81799781
```

```
. *model 4
. xtreg cons_pp d_season t_transport totaloutput, fe vce(cluster household)

Fixed-effects (within) regression               Number of obs     =        145
Group variable: household                       Number of groups  =         74

R-sq:                                           Obs per group:
     within  = 0.2349                                         min =          1
     between = 0.1171                                         avg =        2.0
     overall = 0.1312                                         max =          2

                                                F(3,73)           =       8.81
corr(u_i, Xb)  = 0.0539                         Prob > F          =     0.0000

                            (Std. Err. adjusted for 74 clusters in household)
------------------------------------------------------------------------------
             |               Robust
     cons_pp |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    d_season |   .0183761   .0200002     0.92   0.361    -.0214842    .0582365
 t_transport |    .001537    .001031     1.49   0.140    -.0005177    .0035916
 totaloutput |   .0128522   .0032612     3.94   0.000     .0063527    .0193517
       _cons |   .1546666   .0311526     4.96   0.000     .0925796    .2167536
-------------+----------------------------------------------------------------
     sigma_u |  .22951151
     sigma_e |  .11097655
         rho |  .81050094   (fraction of variance due to u_i)
------------------------------------------------------------------------------

. scalar adj_R2_4 = 1 - (e(rss)/ (e(N) - e(df_r) - e(df_b) - 1))/(e(tss)/(e(N) - 1))

. display  adj_R2_4
.81782971
```

Discrete Choice experiment

Model 1

```
global randvars "morning_cooled evening_cooled spoilt"

. mixlogitwtp y, rand($randvars) group( gid ) price( minus_fee) id(household) nrep(200)

Iteration 0:   log likelihood = -625.78264  (not concave)
Iteration 1:   log likelihood = -602.44609  (not concave)
Iteration 2:   log likelihood = -590.32756  (not concave)
Iteration 3:   log likelihood = -586.06646  (not concave)
Iteration 4:   log likelihood = -577.99261  (not concave)
Iteration 5:   log likelihood = -575.67242
Iteration 6:   log likelihood = -572.87194
Iteration 7:   log likelihood = -572.64848
Iteration 8:   log likelihood = -572.64585
Iteration 9:   log likelihood = -572.64585


Mixed logit model in WTP space                  Number of obs     =      2,604
                                                Wald chi2(4)      =     134.62
Log likelihood = -572.64585                     Prob > chi2       =     0.0000

--------------------------------------------------------------------------------
             y |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
---------------+----------------------------------------------------------------
Mean           |
morning_cooled |   11.14177   3.567258     3.12   0.002     4.150075    18.13347
evening_cooled |   12.13272   2.850837     4.26   0.000     6.545182    17.72026
        spoilt |  -7.672923   1.732911    -4.43   0.000    -11.06937    -4.27648
     minus_fee |  -2.590314   .2586339   -10.02   0.000    -3.097227   -2.083401
---------------+----------------------------------------------------------------
SD             |
morning_cooled |  -21.15242   4.946938    -4.28   0.000    -30.84824    -11.4566
evening_cooled |  -9.071747   2.891194    -3.14   0.002    -14.73838   -3.405111
        spoilt |  -4.755081   1.131136    -4.20   0.000    -6.972067   -2.538095
     minus_fee |    .872478   .2038511     4.28   0.000     .4729371    1.272019
--------------------------------------------------------------------------------
The sign of the estimated standard deviations is irrelevant: interpret them as
being positive



. wtp minus_fee morning_cooled evening_cooled spoilt

     morning_cooled  evening_cooled          spoilt
wtp       4.3013208       4.6838798      -2.9621592
 ll        1.835874       2.9629398      -3.8823486
 ul       6.7667676       6.4048198      -2.0419698
```

Model 2

```
. global randvars " morning_cooled evening_cooled spoilt Morning_spoilt
evening_spoilt"

. mixlogitwtp y, rand($randvars) group( gid ) price( minus_fee) id(household)
nrep(200) difficult

Iteration 0:   log likelihood = -611.59446  (not concave)
Iteration 1:   log likelihood = -588.50003  (not concave)
Iteration 2:   log likelihood = -571.75992  (not concave)
Iteration 3:   log likelihood = -554.52162  (not concave)
Iteration 4:   log likelihood = -553.23855  (not concave)
Iteration 5:   log likelihood = -553.22757  (not concave)
Iteration 6:   log likelihood = -551.61246  (not concave)
Iteration 7:   log likelihood = -546.67594  (not concave)
Iteration 8:   log likelihood = -545.17249
Iteration 9:   log likelihood =  -544.2796  (not concave)
Iteration 10:  log likelihood = -543.50451
Iteration 11:  log likelihood = -543.38584
Iteration 12:  log likelihood = -543.23753
Iteration 13:  log likelihood =  -543.2246
Iteration 14:  log likelihood = -543.22455
Iteration 15:  log likelihood = -543.22455

Mixed logit model in WTP space                  Number of obs     =      2,604
                                                Wald chi2(6)      =      98.27
Log likelihood = -543.22455                     Prob > chi2       =     0.0000

------------------------------------------------------------------------------
             y |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
---------------+--------------------------------------------------------------
Mean           |
morning_cooled |   21.62534   3.270526     6.61   0.000     15.21523    28.03545
evening_cooled |   19.92709    3.25299     6.13   0.000     13.55135    26.30283
        spoilt |  -4.501372   1.123546    -4.01   0.000     -6.70348   -2.299263
Morning_spoilt |  -1.073357   .4229752    -2.54   0.011    -1.902374   -.2443413
evening_spoilt |   -1.96532   .4405814    -4.46   0.000    -2.828844   -1.101797
     minus_fee |  -2.123763   .2584845    -8.22   0.000    -2.630383   -1.617142
---------------+--------------------------------------------------------------
SD             |
morning_cooled |  -.3492905   1.609672    -0.22   0.828    -3.504189    2.805608
evening_cooled |  -10.31749   2.475429    -4.17   0.000    -15.16924   -5.465737
        spoilt |  -3.134383   .7349777    -4.26   0.000    -4.574913   -1.693854
Morning_spoilt |   2.085185   .5367882     3.88   0.000       1.0331    3.137271
evening_spoilt |  -.0835944   .1551708    -0.54   0.590    -.3877235    .2205348
     minus_fee |   1.253014   .2354815     5.32   0.000      .791479    1.714549
------------------------------------------------------------------------------
The sign of the estimated standard deviations is irrelevant: interpret them as
being positive

. wtp minus_fee morning_cooled evening_cooled spoilt spoilt Morning_spoilt
evening_spoilt

     morning_cooled  evening_cooled         spoilt         spoilt  Morning_spoilt  evening_spoilt
wtp       10.182561       9.3829185     -2.1195268     -2.1195268      -.50540369      -.92539548
 ll       7.4880961       6.1807365     -2.8859098     -2.8859098      -.90068087      -1.3608598
 ul       12.877025       12.585101     -1.3531437     -1.3531437      -.11012652      -.48993116
```