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Clean Energy for Productive Use in Post-Harvest Value Chains: An Integrated Literature Review with Field Work for the Kenya and Senegal Dairy Sectors

Energy Opportunities for Agriculture Systems and Food Security Project

Contract Number: AID-OAA-C-17-00112
Implemented by Green Powered Technology, LLC and ACDI/VOCA

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ACRONYMS

AFR/SD/EGEA	Bureau for Africa/Sustainable Development/Economic Growth, Environment and Agriculture
AEZ	Agro-Ecological Zones
AGRA	Alliance for Green Revolution in Africa
CAIT	Climate Analysis Indicators Tool
CCHP	Combined Cooling, Heat, and Power
CDCS	Country Development Cooperation Strategy
CDM	Clean Development Mechanism
CE	Clean Energy
CHP	Combined Heat and Power
CIP	Cleaning-in-Place
CLEER	Clean Energy Emission Reduction Tool
COMNACC	National Committee on Climate Change
COR	Contract Officer's Representative
EADD	East Africa Dairy Development (of Heifer International)
EE	Energy Efficiency
EU	European Union
FGDs	Focus Group Discussions
FMC	Farm Milk Coolers
FtF	Feed the Future
GFSS	Global Food Security Strategy
GHG	Greenhouse Gas
GoK	Government of Kenya
GPTech	Green Powered Technology, LLC
KIM	Kenya Investment Mechanism
LEDS	Low Emissions Development Strategies
M&E	Monitoring and Evaluation

ACRONYMS

MCC	Milk Collection Center
NAMA	Nationally Appropriate Mitigation Actions
OGE	Offgrid Electric
O&M	Operations and Maintenance
PA	Power Africa
PAg	Powering Agriculture
PH	Post-Harvest
PHL	Post-Harvest Loss
PV	Photovoltaic
PVR	Photo-voltaic refrigerator
QMS	Quality Management System
RE	Renewable Energy
ROI	Return on Investment
SMART	Sustainable Milk for Africa through Refrigeration Technology
SHS	Solar Home Systems
SSA	Sub-Saharan Africa
UNFCCC	United Nations Framework Convention on Climate Change
VC	Value Chain
U.S.	United States
VFD	Variable Frequency Drives
VSD	Variable Speed Drive
WHR	Waste Heat Recovery

Contents

1. INTRODUCTION

This Systematic Literature Review, Field Survey and Case Studies is a deliverable under the USAID Contract Number AID-OAA-C-17-00112, "Energy Opportunities for Agricultural Systems and Food Security Project (E4AS Project)," as implemented by Green Powered Technology, in partnership with ACDI/VOCA. The objective of the E4AS project is to expand and focus information related to how clean energy (CE) and energy efficiency (EE) could strengthen post-harvest (PH) value chains (VCs) and reduce loss in targeted countries in Sub-Saharan Africa (SSA), while also contributing to low emission development strategies (LEDS). The project is comprised of four Tasks:

- Task 1 – In-Depth Scoping
- Task 2 – Literature Review and Field Surveying
- Task 3 – Case Studies
- Task 4 – Guidance for USAID Programming and Policy

The following section presents the summary of the literature review as well as findings and recommendations from desk and field research in Kenya and Senegal, across the following areas:

1. **PH clean energy opportunities**: What are the key opportunities to increase RE and EE uptake within the farmgate-to-consumer segment of the relevant value chains?
2. **Integration into policy, partnerships, and planning:** How can these opportunities be integrated into policy, partnerships, and planning?
3. **Contributions to low emissions development goals:** What role can these opportunities for low-carbon energy use in the dairy value chain (VC) play in achieving a country's low emission development goals?

In alignment with the recommendations from the In-Depth Scoping Report, Task 2-3 focuses on the post-harvest segments of the **dairy VC**, across the target case study countries of Senegal and Kenya.

2. APPROACH TO LITERATURE REVIEW AND CASE STUDIES

This report represents information gathered from the team's initial literature review as well as fieldwork, undertaken in March and April 2018, in Senegal and Kenya. Fieldwork included interviews with various stakeholders in the dairy VC, relevant government officials, academics, NGOs, and energy vendors. The literature review process included the project team's review of available literature as well as stakeholder interviews and consultations, including several discussions with USAID missions in Sub-Saharan Africa (SSA) and USAID's Washington-based program staff. These included staff from USAID's Power Africa Program, Feed-the-Future Initiative, Powering Agriculture, and the Millennium Challenge Corporation (MCC), which is developing agriculture VC initiatives under its Compact with Senegal. The team identified and reviewed gender-focused studies and analyses, and integrated regional and international best practices on energy opportunities in the post-harvest (PH) agriculture VC that link rural food production and urban markets.

3. OVERVIEW OF DAIRY VALUE CHAIN

The following sections provide: (1) an overview of dairy VCs in Senegal and Kenya; (2) opportunities and constraints relative to PH clean energy opportunities; (3) and country-specific findings. Energy demands vary across the various segments of the dairy VC and differ among countries in SSA. On-farm energy intensity of milk production can vary substantially by type of production system and by agro-ecological zone (AEZ), where farm and production practices differ depending on the climate and soil type (e.g., arid, humid, and temperate environments).[i] **Figure 1** illustrates typical energy demands and inputs along the dairy VC, from on-farm energy use to the end-users (consumers, households).

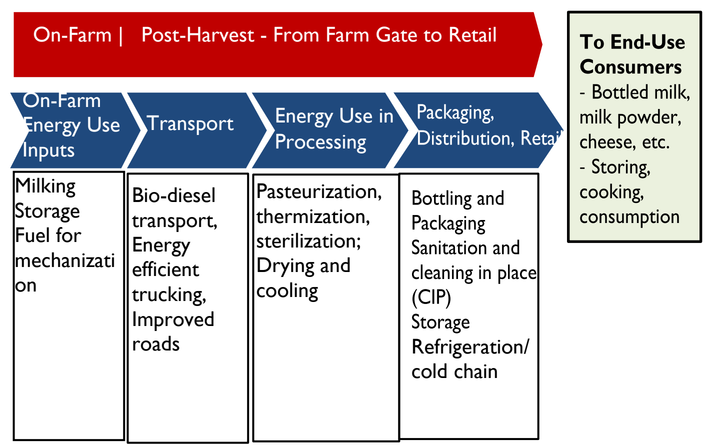

Figure 1: Dairy Value Chain – Summary of Energy Inputs

This study focuses on the post-farm gate segments of the dairy VC, including: (1) transport of raw milk from farm to dairy; (2) processing of raw milk into milk products; (3) production of packaging material; and (4) distribution of products from dairy to retail point. The following sub-sections will give a detailed overview of the dairy VCs in the selected Case Study countries of Senegal and Kenya.

3.1 SENEGAL

In Senegal, sources of the informal market vary, but the informal market makes up between 50-80% of milk sold and consumed in the country. Cow milk production in Senegal is marked by seasonality, with a scarcity of milk produced in the dry season (add months), when cattle are taken out in search of adequate food supply. During the rainy season, cows can produce almost twice as much milk as during the dry season, with sufficient food supply available.

The formal dairy chain consists of large milk processors. Milk powder is imported from the EU and reconstituted at processing plants in and around Dakar. There is one large domestic producer in the country, *La Laiterie du Berger*, which serves a niche market in Dakar by transporting milk from Richard Toll in refrigerated trucks. The informal dairy chain uses far less energy, and is less likely to be grid-connected, than the formal dairy processing facilities. Transportation in the informal market is rarely motorized and electricity connections are often too expensive for cold chain technologies.

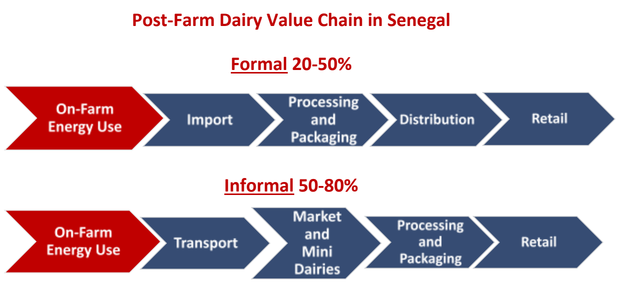

Figure 2 - Senegal's Formal and Informal Dairy Markets

Women are more likely to be involved early in the VC, particularly with caring for cows, and selling the milk to local markets. Many of the mini-dairies, where milk is processed and sold as fermented milk (or in the case of cold chain technology, also as fresh milk), are also women-owned and operated. In areas that have received significant donor support, energy investments and installations have tended to change the market, with men dominating the milk sector as additional revenues become available, thereby attracting their interest.

3.2 KENYA

In Kenya, the cattle and camel milk marketing occur through one of two channels, formal (approximately 20% of production) or informal (~80%), as illustrated in Error! Reference source not found.

The formal chain is distinguished from the informal chain by compliance with food safety, packaging, and business regulations. This requires substantial investment in quality testing at point of purchase and through the chain; cold chain and pasteurization/sterilization equipment and processes; labeling and packaging; and business overhead. This longer chain opens up opportunities for value addition but does lead to significant additional costs in production and increased prices for consumers relative to the informal chain. Milk prices fluctuate considerably, but currently range from 80—140KSH retail. Price to primary chiller/aggregators ranges from 28-35KSH/L, representing 25—35% of final retail price.[ii]

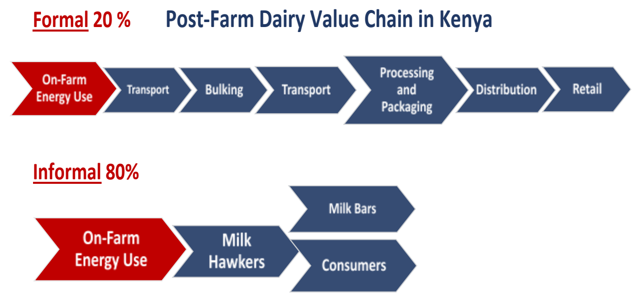

Figure 3: Kenya's Formal and Informal Dairy Markets

Kenya's informal dairy markets remain central to food security and consumption of most of Kenya's population, particularly the poor, women and children. According to 2016 data, about 5.2 billion liters was sold by unorganized, small-scale businesses in informal markets or consumed directly at home (over 80% share). Adulteration of milk through dilution with milk or addition of antibiotics or other stabilizers is common in the informal sector. Informal hawkers provide a fast, cash-based spot transaction without the rigorous quality requirements of formal milk channels for producers, but they have three distinct disadvantages as well:

- ***Price fluctuation and market predictability***: Prices offered by milk hawkers fluctuate more widely, and their lack of fixed costs allows them to enter and exit the milk market opportunistically. Informants reported prices paid from informal milk hawkers of 11—35KSH/L.
- ***Regulatory restrictions and enforcement***: The informal sector continues to face challenges such as milk hygiene, handling and safety. Many of the informal traders, including milk hawkers, are semi-literate and havd limited skills to conduct basic milk testing procedures for safety. Minimal investments in these sub-sectors have also limited their capacity to access better milk holding, transportation, and basic milk processing equipment.

  The government of Kenya (GoK) has recently begun to place restrictions, penalties on hawkers and other informal traders in addition to shutting down related informal trading activities, partly due to heighten concerns over hygiene standards. Its objective is to gradually crowd out the informal milk trade. This includes cracking down on camel milk transportation (via public buses) to the Eastleigh Estates market in Nairobi, for example. Similar actions have been taken with other common informal milk trade chains. The Kenya Dairy Board (KDB) recently banned the sale of raw milk in the informal sector, requiring all milk traders to conform to processing their produce before selling. However, access to these facilities and service prices are prohibitive for traders. In the effort to formalize the sector, there is need to cultivate more investments especially towards decentralizing processing plants, encouraging cottage industry and guiding traders to play part as key investors in processing. In the long run, these regulatory pressures are expected to increase.

4. PROJECT RESEARCH QUESTIONS

This section provides the team's summary information gathered from the literature review and fieldwork in Senegal and Kenya.

4.1 Research Question 1: What are the Key Opportunities to Increase RE And EE Uptake Within The Farmgate-to-Consumer Segment of the Relevant Value Chains?

The following section presents an overview of opportunities by country based on the available literature and fieldwork.

4.1.1 Senegal – Current Practices and Potential Opportunities

***Market Structure**:* The dairy market in Senegal exists in both informal and formal sectors, that follow largely urban/rural demarcations. The agro-pastoral livestock farming system accounts for approximately 61% of all milk production in Senegal. The formalized, intensive dairies in and around Dakar and Thiès account for the remainder of production. The market access for rural, agro-pastoral dairy production is largely decided by the proximity to local markets. Women are responsible for milking the cows, which produce 1-3 liters per day.[iii]

One large domestic processor is located in Richard Toll, La Laiterie du Berger ("Berger"). Berger collects milk from 800 farms in the northern part of Senegal, collecting the milk by motorcycle two times per day. The processing facility itself is fed by SENELEC electricity and an on-site generator, although plans are in place to install solar PV in an effort to save money and offset the expensive price of electricity. The milk is mostly sold in Dakar and is transported using refrigerated vehicles. Due to the cost of fuel required for the trip from Richard Toll, the price of milk that Berger sells is higher than competitors in Dakar, particularly the dairies that are located nearby and that create reconstituted milk from imported powder.

The project team found, during fieldwork, that the price for one liter of milk varied, depending on the market, from 250 CFA to 700 CFA. Lait caillé, which is typically sold in rural areas, is a type of fermented milk that is common, especially outside of large cities. The production of lait caillé in rural areas does not require improved energy resources. Fresh milk requires chilling and/or heat treatment and can garner higher income.

Other products that are developed with the use of improved electricity resources include: yogurt, cheese, butter, and butter oil. In some cases, the team noted that groups of 2-3 women would sell products such as fermented milk and butter oil along the side of the main road in rural areas. The products are sold in unmarked plastic bottles.

Outside of Dakar, the team found that much of the dairy market is informal and without cold chain, especially for transport. Transport is done typically by donkey cart or bicycle, with very few instances of motorized transport noted throughout the rural portion of the field study. Anecdotal evidence from the fieldwork indicates that most consumers are unaware of the differences between imported powdered milk and domestic milk, as the flavoring is similar.

***Government Interventions**:* The National Biogas Program has been working to institute biogas digesters on farms that are fed by cow manure and produce gas for cooking (or heating to treat milk). The first round of this project was found to be unsuccessful, so the government is now attempting to use the production of fertilizer to establish local markets and to create another income stream for farmers willing to use the biodigesters. While the government has been working to install these biodigester interventions, the team found in the field that even when they had been installed, people were unlikely to use them. Feeding the biodigester requires collecting cow manure. In addition to seeing the manure collection as unsanitary, it is difficult to collect, especially in the dry season when cows are out to pasture, looking for food.

The Ministry of Livestock and its Dairy division have been providing solar installations in an effort to assist dairies in improving their revenues, particularly with regard to the prohibitively high costs of electricity. The Ministry has also provided refrigerated transport motorcycles and trucks. In Kolda, the team found that some of the trucks distributed with government funding had since fallen into disrepair, and there was no mechanism in place for maintenance.

Energy Access & Utilization**:** The large-scale dairies in and around Dakar which produce milk largely from imported powder from the EU, have access to grid power that allows them to use electricity for processing. In rural parts of Senegal, only 28% of the population has access to electricity. Mini-dairies that exist across Senegal are either without electricity or have a SENELEC connection that is intermittently available and prohibitively expensive. Available solar technology solutions in the rural areas often have price points that make them inaccessible to rural farmers (ex: Bonergie, a company that sells German solar technology). The market for these improved solar products stays afloat, thanks to NGOs that purchase the technology on behalf of the end users.

There is a lack of consistency in the quality of solar products available, particularly with respect to inverters, batteries, and chargers. Solar home systems (SHS) are frequently sold with inverters that are oversized, which then waste a substantial portion of the system output, rendering the system inefficient. The team also witnessed solar installations in Kolda backed by non-functioning battery banks.

***Technology Innovations*:** The dairy sector does not currently appear to be engendering much innovation in energy technology; the rural sectors produce dairy that is largely used for home consumption and that excess milk is largely unavailable in the dry season. The Progrès Lait project in Senegal (translation: Milk Progress), has put together an innovative vision for projects that combine the development of solar minigrids (as a push for rural electrification takes hold) with milk collection and processing facilities. Despite the intention of the Progrès Lait project to increase incomes for women and improve the livelihoods of local farmers through milk-selling, the outcomes of the project have been quite different. The insert below provides more details.

Potential RE and EE Opportunities. Opportunities to increase RE and EE uptake in the dairy VC may include the following:

Innovative Refrigerated Transport: Solar-powered chillers, such as those seen in Kenya, can be fitted to a bicycle or donkey-cart. This would expand the distance that rural milk could travel in order to reach markets, expanding market access and allowing for farmers to increase incomes from milk production.

Solar Chilling without Batteries: One reason that solar refrigeration is prohibitively expensive in the rural areas is that the systems available are frequently state-of-the-art, European-manufactured systems that include full-battery back-up. Overnight storage of milk could be achieved through running solar panels during the day to chill the milk enough to keep cool overnight, and transport to markets the next day. This method would help to increase revenues from selling fresh milk, while keeping the costs of solar installations down.

Increased Rural Electricity Access through Minigrids: Rural electrification in villages through solar minigrids where cooling units might be placed would increase the refrigeration capacity in the supply chain. This assumes that the cost of electricity used to power such cooling units is low enough to be profitable.[iv] Whether electricity will be sufficiently inexpensive will depend upon the capital costs of the system and the structure of the tariffs.

Energy efficiency and energy audits: Grid-connected processing facilities also offer potential for efficiency improvements.[v] Berger indicated that an energy audit of the facility had already been undertaken and recommendations to improve EE at the facility are being integrated, but the audit itself was not shared with the team for likely proprietary reasons. Part of the outcome of the audit, however, will be the implementation of solar panels at the facility to save on electricity costs.

Tariffs on solar products: The government of Senegal currently charges import tariffs on solar energy products. This tax is largely passed through to end consumers, increasing the price of equipment. The USAID mission in Dakar has indicated that they have raised this issue with Senegalese government counterparts. With the increasing deployment of solar energy across Africa, the trend, as is the case in Kenya, is to reduce or eliminate import taxes instead. Unlike Senegal, Kenya's zero import duty and zero VAT policy for solar products is making solar energy more affordable. Nevertheless, the tariff context varies throughout the region, as there continues to be an over-reliance on imports for solar products in Sub-Saharan Africa.

Labeling of domestic products: A standardized labeling process for milk that is domestically produced (rather than re-constituted from imported powder) could help bolster the domestic dairy sector and help steer the market towards producing additional value to local milk producers.

Bundling of dairy cooperatives to access finance: The SEM Fund is working to bundle women's groups, in order to provide access to more affordable financing options.

Capacity Building: Field interviews indicated an ongoing interest and need for training and other capacity building on integrating RE and EE into the agriculture VC. In Senegal, for example, the team met with a group of women's agricultural cooperatives in Tambacounda. They were eager for training and capacity-building, particularly with respect to solar PV installation and maintenance. The establishment of a rural training program using pre-existing government training operations, such as a rural electrician certificate program, could help bridge the gap in technical capacity outside of cities.

Progrès Lait – Observations in Kolda: Mixed Success of Energy Interventions and Gender Inclusion

PROGRES-Lait is a high-profile, 4-year project (2015-2018) funded by the European Union and the Governments of Senegal and Mauritania for 6.9 million Euros or 4.556 billion FCFA. This project is led by Enda Energie, an international association member of the Enda Tiers Monde (TM) network comprising members across a number of SSA countries. Progrès Lait goal is to increase access to solar energy for productive activities and promote rural entrepreneurship, especially women's entrepreneurship. The project sought to establish up to 5 demonstration RE platforms in Senegal, combining solar minigrids with industrial milk processing equipment. Each of the five large platforms would be fed by five smaller collection stations. The smaller collection stations will have stand-alone solar refrigeration systems, rather than minigrids, which will serve only the five large platforms.

Technical Demonstration. The project team conducted a site visit to the pilot demonstration project in March 2018 near Kolda to better understand its approach, methodology, implementation progress, and current results and impacts. It was not a project evaluation site visit and views only represent early observations stemming from discussions and observations during the field visit. From an operational perspective, the team noted that the solar facility, inverters, chargers, and battery bank were operating and functioning properly. The electricity power had not been connected to the village households or businesses but was instead used to provide street lighting. The five smaller collection centers had not been electrified as originally planned, so the large platform acts as a collection center, which buys milk from farmers in the surrounding area who are able to travel 10-15 km by bicycle. The price offered to the farmers for their fresh milk is 250 CFA. The platform then sells the milk at 300 CFA to partner dairies. The team visited the **Le Fermier** Dairy, which sells milk, yogurt, and cheese. Le Fermier also purchases milk directly from the farmers, at 300 CFA. Farmers are not paid for each milk delivery, but instead receive payment from either the Progrès Lait platform or the participating dairies at the end of each month. The team noted that the farmers in this project are captive suppliers, selling fresh milk for the price of 250-300 CFA per liter. With better market access, the price for fresh milk could be closer to 500-600 CFA per liter.

Gender Integration? Despite being a key objective of the project, the team did not observe clear demonstration of gender inclusive approaches or activities on the project. The team's visit to the Enda Energie office in Kolda and its demonstration pilot project documented that men predominantly led and implemented the project at both locations, and there was little indication that the gender integration objectives were prioritized or realized. There were three women working at the platform, but management of the facility was undertaken by men. The farmers who sell the milk are also exclusively men, with the valorization of milk having the unintended effect of pushing women out of the more formalized market emerging around milk. The team noted that there was little interest in decision makers to invest in training women to manage the facility because the women "might get married and move to another village," as one interviewee indicated. The field observation on the project at this site did not seem in line with the broader reports of the various successes of the program nationally and the national and international exposure of the project. The project team understands that with its 4-year period ending, there will likely be a final report prepared by the Progrès Lait team or a formal evaluation of the program's achievements, challenges, and lessons learned that might shed further light on the project team's observations and preliminary findings.

4.1.2 Kenya: Practices and Opportunities

Market Structure: Kenya's dairy sector is in the midst of a structural shift towards formalization. While approximately 80% of dairies still sell through the informal market, we found evidence that government policy changes, changes in consumer demand, and business innovation are leading to formal sector expansion.

Government policy changes: The Kenyan government is increasingly focused on improving food safety, in part through dismantling informal market channels. For example, the camel milk sector is overwhelmingly informal, and camel milk is collected from various points in northern Kenya, bulked and chilled by traders, and sent (often via public bus) to the Eastleigh Estate market in Nairobi for sale. These public buses have no chilling capacity, and take widely varying times to reach Nairobi, making it a key spoilage and food-borne illness weak point in the supply chain. The government discourages this distribution method and has begun to penalize distributors, removing milk from buses and levying fines on drivers carrying milk. These actions align with a broader focus on improving food safety through formalizing the dairy value chain across Kenya.

Consumer demand: All dairy operations interviewed indicated that urban consumers across Kenya are increasingly interested in professionally branded dairy products, including fresh milk, lala (fermented milk), and yogurts.

Business Innovation: As competition in the dairy sector increases, businesses are looking for ways to cut costs and improve supply chain logistics. Technologies like the Maziwa Plus Cooling System, illustrated in **Figure 4** and

Figure 4. The Maziwa+ Cooling System uses solar energy to cools milk during transport.

discussed further below, leverage the expanded 2G and 3G wireless networks to build real-time supply chain logistics information for dairy operations, while also providing RE cold chain solutions for milk.

Energy Access & Utilization: Across the diverse geographies we visited of Nairobi, Eldoret, and Isiolo, all dairy processing facilities had varying degrees of access to grid-electricity from Kenya Power. However, they all cited several problems with existing energy supply.

Expense: Electricity constituted anywhere from 20-40% of interviewed small-scale dairy processors recurring costs. Two dairies interviewed cited these costs as a major factor limiting business growth, hiring, or diversification. One interviewed dairy noted that their electrical costs were so high, that it was unprofitable to run the large chiller they received free of charge through a grant, limiting their ability to add value to or hold milk during aggregation.

***Reliability*:** All interviewed dairies experienced regular power outages, ranging from 3-5+ times per week (depending on time of year—there are more frequent outages during the rainy season), lasting anywhere from minutes to a full day. Outage frequency was similar across geographies, from Nairobi to Isiolo, though more remote operations cited outages of longer duration. These outages increase operating costs by: (1) requiring the dairies to invest in backup power systems, primarily diesel generators and fuel; (2) increasing wear and tear on equipment through frequent stops and starts; and (3) causing outages that often lead to spills, jams, and other mishaps on the packing lines, leading to wasted product and labor time spent cleaning up.

In addition to grid electricity, one dairy operation had already adopted solar PV as its primary electricity source. This 10,000 L/day capacity dairy was paying on average $4,000 USD/month for electricity and was frustrated by the frequent outages and high cost. This dairy purchased a 100 kW PV array and inverters for approximately $100,000 USD, leading to a 75% drop in monthly electric bills from Kenya Power. At $3,000/month savings, this system has a payback period of less than three years.

All dairies that were visited used oil, diesel, electric, or wood boilers as the primary heat source for pasteurization and other hot water needs.

Technology Innovations: There are a variety of technology initiative and innovative programs that seek to improve production in the dairy sector throughout Kenya, funded by donor organizations, the private sector, universities, the government, international NGOs and local community-based organizations. Opportunities exist to leverage partnerships with these innovation initiatives to scale up, commercialize, or otherwise apply lessons learned from them.

Innovation in Action: Savanna Circuits Maziwa+ milk cooling system

Savanna Circuits Ltd, a technology start-up incubated in Strathmore University's iBiz incubator program, specializes in developing appropriate-scale technology for agribusinesses. They have developed a cluster of solar PV-chilled milk storage and transportation devices. The Maziwa+ system is a scalable milk transport system that can attach to the back of a motorbike (100L capacity), donkey (40L capacity), or single aluminum milking can (10L) that uses a small integrated PV panel to chill a cold plate in the tanks. This system can chill ambient temperature milk to 4 degrees centigrade within three hours. In addition, the motorbike system has an integrated digital scale and cellular-enabled logistics interface. Once milk is added, it tells the buying agent and farmer the precise volume, and can send an SMS with the volume, pickup time, and location to the seller and the central dairy collector, increasing supply chain transparency.

This system has two potential positive impacts on milk procurement:

- First, as the milk arrives at the dairy pre-chilled, it reduces total energy demand from the chilling units at intake.
- Second, as it can chill while milk is in transport, it significantly expands the potential catchment area that milk buyers could source from, increasing competition for milk at the producer level.

Several start-up companies, including Savanna Circuits (discussed under 'Opportunities' below), which designed and is commercializing a solar-powered mobile milk collection system and cooler with automated milk quality checker and SMS notification, are investing in RE technology development to help improve transportation and chilling logistics within the dairy industry.

The USAID/GIZ-led "Powering Agriculture: An Energy Grand Challenge for Development" program supports the development and deployment of clean energy innovations and has a regional office in Nairobi. Powering Agriculture's East Africa regional hub is based in Nairobi. Its innovation grants are 3-year grants and range from $500,000 USD - $1.5million USD. Of the current 24 Grand Challenge awards, 10 are in East Africa and six of those are for projects in Kenya, which are ongoing.

Within the dairy sector, Challenge Grants have included one to *SunDanzer,* which developed a small-scale portable cooling system tailored for use in the Kenyan dairy market. The system comprises a photo-voltaic refrigerator (PVR) that uses solar energy to cool a chest refrigerator. This uses phase-change materials—

substances which are capable of storing and releasing large amounts of energy—as energy storage. SunDanzer also developed milk can blankets to retain the cold temperature as farmers transport the milk to the collection site.

Another Challenge Grant was awarded to the University of Holenheim, which developed a milk cooling solution based on a commercially available DC Refrigerator, with a modified control unit to make it works as a smart solar freezer by adjusting its working-operation to the availability of solar energy. The freezer has a volume of 166 liter and is capable of producing approximately 8-13 kg ice per day. One system includes 25 reusable ice tins of 2-kg capacity and two 30-liter isolated milk cans (prototypes) with removable ice compartment (**Figure 5**).

Figure 5. Powering Agriculture Grant Award for Solar Milk Cooling System

To cool down 30 liters of milk from 36°C to 15°C in one of the supplied milk cans, the systems requires 6 kg of ice and roughly 80 minutes of time. USAID's *Photovoltaics for Sustainable Milk for Africa through Refrigeration Technology (PV-SMART)* project is a creative concept of providing on-farm solar milk refrigeration for off-grid dairy farmers in Kenya. It uses a modified off the shelf direct-drive photovoltaic refrigerator (PVR) technology, coupled with innovative cooling and energy storage approaches to chill evening milk on the farm for later transport the next morning to dairy collection centers. The battery-free PVR unit is designed to work optimally in locations with at least 4 average peak sun-hours per day.

Farmers can receive a premium price for providing higher quality, refrigerated evening milk to dairy processors that would otherwise spoil. Dairy processors can also charge a premium for better quality and tasting dairy products from better quality milk that is maintained chilled from farm to factory. These solar farm milk coolers (FMC) are the first of their kind in the world, using thermal ice storage in lieu of electrochemical batteries and operating directly on DC power from a PV module powering a variable speed DC compressor.[vi]

Organizations such as *Save the Food* have been helping Kenyan dairy farmers implement a system called *ISAAC Solar Icemakers* to drastically extend the amount of time farmers have to get their dairy products to market. The icemakers use the sun's heat to drive a chemical reaction that separates a liquid refrigerant from a solid absorbent. The solid absorbent stays in the solar collector, while the liquid refrigerant is driven away and stored in a separate component called the evaporator. This movement happens without valves or pumps or any mechanical components—simply through natural convection. Since most of the 650,000 small-scale dairy farmers in Kenya are without electricity, the solar icemakers could particularly useful. They make up to 50 kg of ice on a sunny day, which can chill up to 100 kg of milk. This can supply up to 30 farmers with sufficient ice for chilling.[vii]

While many of these innovations show promise, very few have demonstrated significant adoption velocity that would indicate they are moving towards adoption at scale. Interviews with VC actors identified that high cost and limited access to finance were key barriers to adoption. Grid electricity and incumbent technologies like diesel generators or wood boilers have intrinsically spread out cost structures—capital investment for the systems occur upfront, but fuel costs are spread across the lifetime of use. RE storage technologies are expensive and require up front purchase. Informal quotes for RE systems sufficient to chill 1,000 L/day found that adding storage would more than double system costs, reinforcing the need for financing as a core element of any RE scaling approach. Currently, there are limited commercial options for financing that wouldn't require collateral equal or greater than the value of the loan.

RE and EE Opportunities. Opportunities in Kenya to increase adoption of RE and EE in the dairy sector:

Government infrastructure investments: The government of Kenya (GoK) also encourages investment in cold chain infrastructure by marketing cooperatives and private investors through incentives such as tax exemptions on the necessary imported equipment. East Africa Dairy Development, EADD, encouraged the construction of a milk chilling plant that would be the main component of a dairy "hub."[viii]

Infrastructure improvements. Many feeder roads have been inadequately maintained and are in poor condition, which impacts the efficiency of milk collection. Improvements to road building and maintenance could offset time of travel and fuel use. Additionally, support infrastructure such as electricity and potable water is also lacking in many milk-producing areas.[ix] Improvement in infrastructure could reduce spoilage.

Innovation and diffusion of new technologies: There is strong potential for adapting current dairy VC equipment to utilize the portability and cost competitiveness of renewable energy. Supporting local innovation in these areas through innovation and start-up accelerators, aligning appropriate financing for each phase of innovation and business growth, and building platforms for collaboration among industry innovators will be key. In Kenya, for example, there are a number of business incubators and accelerators, including some university-based incubators such as the C4DLab, a Startup Incubation Hub at the University of Nairobi, and organizations such as the Nairobi Incubator Lab.

Support scaling of EE practices: In particular, waste-heat recovery for pasteurization was adopted by several dairies that the team visited, but this approach was unknown to several small- to medium-scale dairies as well. This practice recovers waste heat from the chilling process and utilizes it to reduce energy requirements for pasteurization. The potential impact on energy use is significant, representing up to a 70% reduction in total energy required for heating, and requires minimal additional materials (pumps, piping, and heat exchangers), representing the best return-on-investment (RoI) of any of the opportunities identified. Development practitioners and government agencies can work to make these systems required or at minimum standard offerings through dairy engineering and equipment suppliers.

Leverage private and impact capital to fill financing gap: Kenya currently has a financing gap for renewable systems. Most equipment suppliers and engineering and installation firms do not have embedded financing capacities, but we found that the upfront cost structure of the technologies presents a major barrier to adoption. Commercial banks are still not aggressively pursuing RE system financing, but there is definite appetite from private capital providers if deals for financing would meet a minimum scale.

Potential Firm Level Effects. At the facility or enterprise level, potential effects include:

Reduced operating costs and energy access risk exposure: Once RE systems are installed, payback periods based on current Kenya Power pricing suggest that they would provide energy cost savings in the long run. Recurring cost savings would depend on the type and structure of financing (if any) used to purchase the RE system. As important as cost, however, is the reduced risk these systems would provide users, as they would no longer have to contend with sporadic grid blackouts.

Reduced costs may spur additional investment and jobs: When interviewed dairies were asked what they would do if they were able to reduce their energy costs, 60% stated that they would increase wages and/or hire more staff. 20% said they would retain the revenue as profits and the other 20% said they would expand operations with more or larger equipment.

Potential for informal MSMEs to be further marginalized: As RE is adopted, it will enable medium-scale enterprises with greater technical, financial, and operational capacity to expand further beyond the grid than they are currently able, increasing local competition with informal traders in new geographies. While there is significant potential for this market investment and disruption to be beneficial for all VC actors in the long-run, the short-term effects will most likely be to drive micro and small-scale informal traders out of business. This was a concern cited in an interview with Tarakal, a small women's association of camel milk traders in Isiolo. They stated that increased demand for milk from their suppliers by new dairy processors in Isiolo was reducing the volumes of milk available for them to purchase and sell through informal channels in Nairobi.

Given the Government of Kenya's (GoK) long-term focus on phasing out informal trade in the dairy sector, and the basic fact that these larger volume firms are proving more competitive on price with smaller traders, the solution is not to artificially prop up informal trade, but instead to help firms like Tarakal identify emerging market niches (whether selling directly to the new processors, or developing their own value addition services, such as camel ice cream, an initiative supported through USAID/Kenya's Regal-AG activity).

4.1.3 What Are the Market and Social System Preconditions Required for These Opportunities to be Adopted?

The literature on technology adoption highlights the need for multiple social, economic, and technical support dynamics to be in place to drive adoption of new upgrades. E.M Rogers' seminal Diffusion of Innovation Theory (DOI) highlights five factors that influence adoption.

Rogers' five factors that influence adoption of an innovation (LaMorte, 2016):

1. **Relative Advantage**: The degree to which an innovation is seen as better than the idea, program, or product it replaces.
2. **Compatibility**: How consistent the innovation is with the values, experiences, and needs of the potential adopters.
3. **Complexity**: How difficult the innovation is to understand and/or use.
4. **Triability**: The extent to which the innovation can be tested or experimented with before a commitment is made.
5. **Observability**: The extent to which the innovation provides tangible results.

The project team applied these five factors to potential RE and EE practices and technologies below in Table 1.

Table 1 – Five Adoption Factors as they Apply to this Exercise

Opportunity	Relative Advantage	Compatibility	Complexity	Triability	Observability
Improved EE practices	Medium	High	Low	High	Low
Improved RE practices	High	High	Medium	High	High
Improved gender mainstreaming	Medium	Low	High	Medium	Medium

A review of literature related to the return on investment (ROI) for EE and RE technologies applicable to the dairy industry, and especially for new and emerging technologies was conducted. Information on applicable existing and emerging technologies was identified in the literature focused on the dairy industries in Europe, the U.S. and Australia, but none specifically on the dairy industries in any African countries. Some information on typical implementation costs, potential energy savings, simple payback time was identified for dairy processors in Australia which is applicable to similar processing facilities in African Countries ("Saving Energy in the Dairy Processing Industry", Energy Saving Fact Sheet, Australian Industry Group, www.aigroup.com.au). For new technologies, for example, cost and ROI affect relative advantage (the extent to which new technology ROI exceeds the incumbent technology), and triability. The triability parameter highlights the value of leasing options for new technologies, as they lower the up-front and long-term cost of experimentation in the new technology.

There is a substantial literature on farm-level technology adoption dynamics in the target countries for dairy, but limited information on dynamics post-farmgate. There was a deeper literature relevant to energy technology adoption for energy technologies. The project team identified six necessary economic and social pre-conditions for RE and EE adoption in the dairy VC in target research countries:

Clear advantage over incumbent practices. Studies of RE adoption in SSA have found that new technologies must demonstrate clear advantages over incumbent technologies—simply matching their performance is not sufficient.[x]. As one respondent put it: "these [dairy processors] are busy every day, and to change their electricity source would be a lot of work they don't have time for."[xi] At the same time, incumbent technologies' advantages are often more perceived than real. In Kenya, and Senegal, access, reliability, and cost of electricity (both on- and off-grid) were cited as key challenges for the dairy VC.[xii,xiii,xiv] In 2012, researchers found that in Kenya, the lifetime cost of energy from renewable off-grid sources is lower than from diesel generators.[xv]

Supportive policy environment. Policy regimes can be critical in enabling RE and EE implementation. An enabling environment for RE may include: carbon pricing, subsidies for new power plants, feed-in-tariffs, low import taxes, and others. For off-grid, household, or enterprise level solutions, policy can play a supporting role in reducing early adopter risk. In Senegal, solar panels and other electrical equipment are currently listed as Category 1 for imports, which includes a 5% import duty, a 1% statistical charge, and a 1% community solidarity tax.[xvi]

Supporting ecosystem of supply chains and human capital. A key component of legacy technologies' advantages is the existence of strong supporting ecosystem of repair technicians, and a ready market of new and used parts and equipment. The emergence of a depth of suppliers and supporting services a key marker of market maturity. For RE technology adoption to endure, it should be paired with a concurrent development of local service providers with the skillsets to maintain those technologies, and ready access to spare parts.[xvii,xviii]

In Kenya, for renewable energy, Strathmore University's Energy Research Centre is focused on strengthening the solar energy ecosystem through training service technicians and by working with the standards board to set quality standards for solar products (solar lamps, panels, etc.) as well as running rigorous testing for these products for certification. Quality control is critical to maintain momentum in technology adoption, particularly for RE technologies coming from a wide range of origins. The Centre's staff noted that they have found a wide range of counterfeit and low-quality products that do not perform as advertised.

These sub-standard products have contributed to a generally negative reputation of renewables in the country, therefore a robust testing and standards service will be essential to restoring and maintaining the reputation of RE systems.

In Senegal, there is a similar problem regarding low-quality and poorly designed systems and products. This is particularly problematic in rural areas, where there is a dearth of electricians with sufficient technological know-how to diagnose and repair solar PV systems.

Growth of a middle class. Empirically, this ecosystem will be much slower to develop for post-farmgate enterprises without a parallel growth in household level RE adoption. As HH solar networks expand, enterprises can piggyback on the mass market for support services to expand spare parts supply networks and build a critical mass of support technicians. Many researchers have found the existence of an 'energy ladder', showing that as income and education levels rise, consumers graduate to increasingly efficient energy sources.[xix]

Commodity end-market growth. Several studies reviewed found that end market growth for target commodities is an essential element to stimulate investment upchain, including in energy technologies.[xx] In Kenya, milk consumption is growing 3.5% per year.[xxi] Senegal's dairy sector has seen increased FDI, including investment from Danone, Grameen Credit Agricole, and Phitrust Partners in a domestic dairy firm.[xxii]

Appropriate Financing. While total lifetime costs for RE technologies are increasingly comparable or lower than legacy technologies, renewables' cost structures are a unique barrier to adoption without external financing. Most renewable technologies require substantial upfront investment beyond the reach of most emerging market SMEs. Cost intensive opportunities require embedded or third-party asset financing that: (1) does not include prohibitive collateral or interest rates, ideally using the purchased asset(s) themselves as collateral; and (2) has repayment timelines and structures aligned to household or business cashflow lifecycles.[xxiii]

4.1.4 What are Anticipated Gendered Effects of These Opportunities?

The literature suggests many possible positive and negative effects on women's livelihoods from new technologies. Depending on the context, increasing adoption of RE or EE practices and technologies could improve women's incomes or displace them, or have other seemingly contradictory effects. This range of possible outcomes highlights the need for VC upgrade strategies to thoroughly understand existing social and economic dynamics before intervention, and to develop strategies to maximize positive and pre-empt negative outcomes.

Anticipated Positive Effects: Technology upgrades that expand the cold chain or enable better quality control to have demonstrated potential positive benefits for women and men in the dairy VCs studied.

Increased income: Powering Agriculture (2017) noted that biogas-powered evaporative coolers at the farm level reduced milk spoilage, increasing volumes sold and revenue. These increased incomes allowed female farmers to "pay for private education for their children, have greater access to medical care for their families, and have a sense of empowerment from having their own source of income separate from their husbands."[xxiv] The same study found that solar-powered cold storage had increased income for three female dairy farmers. Since they were able to chill their evening milk, it reduced the rejection rate at the milk collection center.[xxv] The same study also found that farmers were able to use the solar units to charge neighbors for cell phone charging, earning upwards of $1/day for this service. One of the farmers used this income to pay for transport for her daughters to go to school.

Income diversification through multiple uses of a technology such as this builds resiliency into women's income, making escapes from poverty more sustained.[xxvi] Additionally, several studies have found that electric light is cheaper than kerosene or candles, reducing household costs where these are common forms of lighting.[xxvii]

Technology upgrades beyond the farm level have also led to positive income effects for female producers. Standalone milk dispensers/vending machines in Kenya (popularly milk 'ATMs') require consistent power supply, but their self-contained, portable nature makes them well-suited to on- or off-grid solutions, particularly standalone solar units. Katothya (2017) found that farmers in Kiambu, Kenya, retained a greater share of the total end price for the milk from milk dispenser channels than any other marketing channels, although the reasons for this were not presented.

Reduced time burden: Across both study countries, women spent significant time at the household or enterprise level gathering firewood as a heat fuel, either for home cooking or to boil milk for a commercial dairy.[xxviii] Electrification can also automate several household tasks previously burdening women's time. In South Africa, electrification reduced this time burden through mechanizing household chores, allowing women to pursue microenterprises or employment away from home[xxix]

Expand long-term employment and business growth prospects: Rural electrification can have significant impacts on women's employment prospects. First, improved access to electricity extends the potential work day at rural enterprises, improving productivity and increasing demand for rural labor. It can be a critical resource to help in extending the work day for precision handwork (e.g., handicrafts, sewing, or other activities), and reducing women's time burdens (see above).[xxx] Second, for rural SMEs, expanded electrification spurs hiring. In Senegal, 24% of SMEs and 15% of large enterprises, including dairy VC actors, reported that intermittent power outages reduced their hiring.[xxxi]

Improved Household Health: Any opportunities to displace wood fire as a heat source (either at the household, or at local dairy enterprises) will likely lead to significant improvements in household health.[xxxii] A study in western Kenya found reductions in kitchen air pollution when households switched to cleaner cooking fuels.[xxxiii] These environmental pollution effects obtain at the village level as well. Exhaust from diesel generators "contains more than 40 toxic air contaminants, including many…cancer-causing substances. Up to 70% of cancer risk attributable to inhalation of toxic air pollutants in the [US] arise from diesel exhaust."[xxxiv] Switching to clean off-grid solutions would vastly improve health of workers and neighbors of MCCs and dairy processors.

Improved Nutrition: Expanding cold chain access, pasteurization, and other energy uptake in the dairy VC will decrease spoilage and occurrences of food-borne illnesses. This decrease in loss will increase the supply of milk, which is a valuable nutritional source.

Negative: RE and EE opportunities require significant capital investment, so their availability is most likely limited to formal actors with established credit histories and the ability to access finance. Particularly as technologies are deployed through formal sectors, there are two major possible negative effects of RE and EE opportunities for women:

Dispossess women's control over dairy products and income as markets formalize: Across both target countries, women's representation in VC governance decreases both as chains formalize, and at higher levels of aggregation and processing.

In Senegal, smallholder dairying is primarily a woman's occupation.[xxxv] However, the proportion of women benefiting from the sale of milk decreases as the level of market orientation increases, in-line with other studies that have shown a shift in benefits from women to men as household livestock enterprises in developing countries commercialize.[xxxvi] Fisher, Warner, and Masters (2000) found that zero-grazing adoption in rural Senegal improved milk production and profits for the predominantly female-headed dairy operations.[xxxvii] Over time, however, this very increase in profits led to takeover by men (though the authors note that overall HH welfare did still improve, as men shared benefits with their families). The fieldwork in Senegal found that as RE opportunities increase the potential value of milk, that the women who sell the milk to dairies (whether they are women-owned or not) tend to be displaced from the market by their husbands. In Kenya, the FAO found that as the dairy supply chain formalized, value capture shifted from producers to processors.[xxxviii]

In Kenya, Katothya (2017) found a traditional gender division in milk income that is common to many countries in Africa: morning milk is taken to formalized milk collection centers (MCCs), sold for cash, and the income is controlled by men. Evening milk, because it comes too late in the day to be taken to MCCs, is controlled by women, sold or bartered locally, or consumed by the household. In instances where the cold chain has been extended to the household, the technology disrupted this gendered division of control, allowing evening milk to be chilled and stored overnight and transported as part of the male-controlled morning milk to the MCCs.[xxxix]

Amplify competitive challenges for women-owned enterprises: In both case study countries, women entrepreneurs and heads of household were found to have weaker business information networks, and consequently weaker access to financing, information, and markets and opportunities.[xl,xli,xlii] If new RE and EE technologies and practices generate competitive advantages for early adopters, it could adversely affect women-owned enterprises with less access to these technologies. Historically, innovation has targeted and benefited established lead firms and producers, which tend to be led by men, marginalizing smaller and less formal firms, which includes the majority of women-owned enterprises.[xliii]

Senegal Findings: Gender in the Dairy VC

Production: Women manage the cows and milk production. The men will take the cows out for grazing, sometimes even going over the border into Mauritania during the dry season. In the areas visited by the team, milking and overseeing the cows was considered to be women's work.

Processing: Mini-dairy operations tend to be woman-owned and operated, although there is a clear correlation between the size of the dairies and the potential for male takeover. Particularly in Kolda and Tambacounda, which have been the sites of the highest level of donor intervention, the dairy operations have tended to fall more into male hands. At La Laiterie du Berger in Richard Toll, (the only large, mechanized, domestic dairy processing facility), the operation was almost entirely managed by men. While Berger does employ a handful of women, none of them are in leadership positions.

Transport: Transportation of milk and dairy, where milk is transported by bicycles and donkey-carts in rural areas for mini-dairies, or trucks for larger facilities, are predominantly conducted by men in Senegal.

Retail/marketing: Retail positions in the dairy sector are typically occupied by women. In some cases, for example, retail operations comprise simply a group of women selling dairy products along the highway.

Gender Impacts: The project team conducted site visits to mini-dairy processing facilities near Louga, Tambacounda, and Kolda. Of the mini-dairies visited, three were women-owned, and 2 were male-owned. In Louga, the woman-owned dairy had solar refrigeration capabilities, but the machinery was in disrepair. The village was located approximately 20 km away from a main road, and travel by walking or donkey-cart means they are far away from anyone who might be able to fix the device. They had seen benefits from the solar refrigeration, because it was able to offset the cost of the SENELEC connection. Another woman-owned dairy outside Tambacounda had a similarly positive outcome. An NGO had donated a solar refrigerator to the group, which saved enough money off-setting SENELEC electricity that they were able to afford a second refrigerator. With the increased income generated from the business, the women can also use extra money to send their children to school. A third woman-owned dairy business, in Kolda, found that the SENELEC costs (which are collected every two months) halved with the installation of solar panels to run the refrigeration.

While impacts to incomes for dairies that are woman-owned are potentially positive, the opposite is true for women who sell milk to dairy processors for extra income. In multiple cases, it was found that processing capabilities have increased the value of milk, and that women were displaced in the market. In Kolda, milk that is sold to the markets (particularly those that have been created in the wake of donor funding) is done so by men, who bring the milk to the Progrès Lait dairy platform or to the participating dairies by bicycle. When interviewed, the male farmers said that they keep the income and do not pass it on to their wives, but that they use it for household necessities. Other anecdotal evidence from women in the sector gave the impression that the women had lost control over an important source of income, and that in some cases the men used additional money to take a second wife. A veterinarian in Kolda gave anecdotal evidence that when he visits sick cows, the women are still expected to pay the bill, even if the husband incurs the revenue from milk-selling.

Kenya Findings: Gender in the Dairy VC

Production: General findings are that men typically own cattle and women manage cows and milk production. Ownership of milk revenue varied by location, but women on average own 20% fewer cattle than men.[xliv] Camel milk seemed wholly-owned by women producers.

Processing**:** The majority of dairy operations are owned or led by men, with a handful of high profile exceptions, such as the Maasai Women's Dairy and the Elenerai Cooperative Women's Society. As employees, women at processing plants dominate packaging, retail, marketing, and cleaning positions.

Transport**:** Transportation is consistently a male occupation, from primary transport via motorbike to larger scale bulk transport by tanker truck.

Retail/marketing**:** Retail positions at milk bars/kiosks are predominantly occupied by women.

Gender Impacts**:** In Kenya, the only women-owned business interviewed by the Field team was at risk of marginalization through more formalized competitors (described above). At the same time, the research team's limited interaction with women at the producer level found only positive impacts from the entry of more formal buyers. The research team only interviewed one women's producer association, that sold camel milk to buyers in Isiolo. This group had previously sold through an informal women's cooperative linked to the Eastleigh informal market in Nairobi but is now selling directly to processors in Isiolo town. They reported a price premium from formal buyers, reinforcing the fact that changes to market structure can have positive and negative effects on women at different points in the chain. Effects on female employees seem consistently positive: A majority of interviewed dairy operations reported that cost savings from RE or EE adoption would be reinvested in staff through increased wages. At the dairy level, most women are engaged in cleaning, packaging retail products, and marketing.

4.1.5 What are Key Economic and Regulatory Constraints to EE And RE Solutions? What are the Policy Recommendations to Address These Constraints?

Depending on the market structure and regulatory framework, barriers vary in each country. There are common financial and regulatory constraints, which will be outlined here briefly. Then the regulatory environment will be discussed for both countries in further detail.

Financial Constraints. Lack of up-front capital remains a key constraint to introducing energy solutions. Even in the case where, for example, a solar PV installation at a dairy processing facility could offset the cost of on-grid electricity in the long term, the initial installation costs are sometimes prohibitive and thus a disincentive. Similarly, implementing some energy efficient measures for process improvements can also result in long-term cost savings but may require process changes and equipment upgrades or replacement that may also be cost prohibitive. While some EE improvements require up-front investment, others instead are based on minor, low-cost process improvements. These types of EE implementations are constrained less by lack of financial capital, and instead by a lack of technical know-how or sufficient manpower.

Regulatory Constraints. Regulatory constraints may be unfavorable import policies regarding EE and RE equipment, policies that do not favor RE or EE, or policies that support fossil fuel generation at the expense of RE. Additionally, high tariffs on imports of RE and EE may increase the cost burden of those technologies.

Senegal Constraints

The team identified the following constraints to the implementation of EE and RE in the dairy VC.

***Foreign Competition**:* In Senegal, one major financial constraint is related to the market share of powdered milk coming from the European Union (EU). Powdered milk imported from the EU is taxed at 5%, with 25,000 tons imported each year, constituting 90% of Senegalese milk consumption in the *formalized* markets.

The only large-scale domestic producer, Berger, noted that the costs of milk collection are high, and it is difficult to compete with the imported powdered milk.[xlv] Berger also faces higher transport costs than the imported dairies that are located in or around Dakar. With the difficulty to compete from a price perspective, additional costs in energy infrastructure may be difficult to finance.

Lack of access to affordable products: Solar systems offer an opportunity to increase revenues for small dairies across Senegal; however, the products on sale are capital intensive and require a heavy up-front investment that make them difficult to access.

***Access to finance**:* In the field, the team observed small women-run dairies that had increased their revenues as a result of access to solar products such as solar refrigeration. However, in the absence of grant funding for purchase, access to financing is lacking. Microlending institutions exist, but charge interest rates of about 27%.

***Market access**:* Energy interventions offer an opportunity for rural farmers to produce improved products from cow's milk, such as yogurt and cheese. However, selling these products requires access to markets in more urban areas where demand for these products is greatest. A lack of motorized transport options limits the demand for improved dairy products in rural areas.

***Lack of rural electricians**:* One major complaint across small dairies was that there are not many local electricians available to service solar systems when they break down. This is especially problematic when solar has been provided as a donation, and the responsibility for maintenance falls on the beneficiary.

***Social Constraints**:* One major impediment to biogas production in small dairies is a perception around using manure as fuel. While the National Biogas Program, at the national government level, is working to install biogas digesters, it will be difficult for this program to see success without 1) researching and piloting additional fuel sources, and 2) providing training and capacity-building activities to promote uptake. This will be required for biogas chilling technology as well.

Kenya's Market

The Kenyan dairy market produces about 5 billion liters of milk annually. Milk is considered important nutritionally for its protein content.[xlvi] One impediment to implementing EE measures in pumping infrastructure in the literature in Kenya is a lack of measurement controls. Without appropriate measuring equipment, it is difficult to quantify the level of efficiency, and therefore difficult to determine appropriate improvements (or to measure their success). While many EE improvements may be relatively simple and widely available, the lack of technical capacity and poor organizational structures may hinder implementation of efficiency measures, such as for pumping infrastructure. [xlvii]

The current return on investment (ROI) for cold chain in Kenya is estimated to take eight to ten years, far longer than the three-year ROI that is expected by most foreign direct investors. High startup costs, lengthy bureaucratic delays and confusing rules and regulations combined with numerous legal and illegal fees throughout the business process make entering the market a daunting task, especially for a capital-intensive industry such as cold chain.[xlviii]

Policy Recommendations

Senegal. One regulatory barrier is the tariff on solar imports, as mentioned above. Removing or decreasing these tariffs could help to decrease the up-front cost of solar products. The quality and consistency of solar products (especially inverters, chargers, batteries) is variable. Regulatory efforts overseeing the quality of imports could actively improve the uptake of technologies if they are more likely to work as promised.

A labeling scheme for domestic milk sold could help orient the markets towards domestic supplies of milk. This would require monitoring and verification, because even the rural mini-dairies are forced to resort to powdered milk in the dry season when supply runs out.

An additional policy recommendation is to have government support or regulation of a rural electrician certification for solar maintenance. At present, when solar installations break-down in the rural areas, there is very little knowledge about how to fix it, nor are spare parts available. This was a common theme during the fieldwork in Senegal.

Kenya. The policy and regulatory framework for RE and EE in Kenya, including low emissions development strategies, has been developed and continue to evolve with support from the donor community over the years and expansion of government commitments. The project team met with the Kenya Ministry of Energy (MOE) during the trip to Kenya, namely the Deputy Director of the Renewable Energy Department, and discussed the MOE's priorities and plans on EE and EE integration. Renewable energy is one of the four technical Directorates of the MOE, with a broad objective to promote the development and use of energy technologies, from renewable sources: biomass, (biodiesel, bioethanol), solar, wind, tidal waves, small hydropower, biogas and municipal waste.

The RE Department has three program offices: (1) Bioenergy, (2) Alternative Energy, and (3) Energy Efficiency (the latter group is where the climate change mitigation and LEDS programs are located). Kenya recently developed a dairy sector NAMA to track GHG emissions and reductions efforts in the sector, but that is still nascent in terms of accurate sector data and processes to capture information on GHG reductions. On EE, Kenya recently issued mandatory, legally binding Minimum Energy Performance (MEP) Standards, targeting four electrical appliances (ACs, industrial motors, commercial display refrigerators and incandescent bulbs) and since 2015, the Energy Regulatory Commission (ERC) has required consumers of more than 180,000 units of electricity per year to carry out audits every three years.

For dairy processing centers and larger facilities, the energy audits will help identify high energy consumption systems and processes and recommend areas for investments in improvement measure. During the team's visit to the Githunguri Dairy Cooperative outside of Nairobi, the team was presented with the results of the energy audit of the facilities, with details on energy costs, energy consumption rates, and recommendations for improved efficiencies. The audit were done via an outside energy audit firm, working in coordination with engineers at the facility. These regulatory requirements are providing additional incentives and opportunities for some of these larger facilities to improve their efficiency, reduce emissions, and improve energy cost savings.

Bottlenecks in Reaching Urban Markets

In both Senegal and Kenya, it was found that the major impediment to reaching urban markets is the cost of transportation. Many of the small dairy producers in Senegal do not have access to motorized transport, limiting the distance that can be reasonably traveled (even with refrigeration capabilities). Domestic dairy producers, necessarily based outside Dakar, must incur the costs of transportation that will force an increase in the retail price vis-à-vis the Dakar-based powdered milk processing facilities.

4.1.6 How Will Solutions Differ in On-Grid and Off-Grid Scenarios?

Senegal. Senegal has an overall electricity access rate of 55%. In rural Senegal, however, access is only 28%.[xlix] In 2014, Senegal produced 3,729 GWh of electricity, 84% from fuel oil, and 9% from hydropower. The remaining generation came from natural gas, biofuels, and other sources. The retail tariff of electricity in Senegal is reported by the World Bank to be $0.213 per kWh.[l] The Senegalese government has a goal of 60% electrification by 2017 and universal electrification by 2025.[li]

The Senegal power infrastructure consists of one main grid, and a few smaller, independent regional grids that are not interconnected with the main grid. The main grid is served by a 90kV national transmission line, as well as an international 250 kV transmission line that connects to the Manantali hydropower plant in Mali.[lii] Some of the hydropower consumed in Senegal is imported from Mali through this transmission line. The fuel oil power plants that produce most of the electricity in Senegal are being pushed past their intended lifespan; this aging infrastructure helps to contribute to power outages across the country. Additionally, a huge dependence on imported fuel makes the country's power sector vulnerable to oil price fluctuations.[liii]

Electricity from SENELEC costs ~$0.213 per kWh. Due to the high cost of electricity, coupled with intermittency due to black and brown-outs, there are not major differences in the types of RE implementations in both grid-connected and off-grid dairy processing facilities. On-grid implementations in Senegal will offset the cost of paying $0.213 per kWh. Off-grid implementations will be focused in rural areas, where connection rates are only 28%. The one exception is the case of electrification through mini-grids which will target solely off-grid towns and villages.

The Government has developed a concessionary approach to private sector electricity generation in off-grid areas, through the establishment of large-scale concession schemes that divide the country into 10 Priority Rural Electrification Programs. In recognizing that large-scale grid extension will not meet the needs of remote off-grid communities, the Government has allowed for smaller off-grid projects in the form of mini grids, SHS, and other decentralized solutions. These initiatives are termed Local Rural Electrification Initiatives (ERILs), which may be implemented by private companies, NGOs, and community groups.[liv]

There is potential to combine this off-grid electrification approach, particularly town-sized minigrids, with an approach that improves the ability to store dairy products, through cold chain and refrigeration. Senegal has also previously implemented large off-grid RE installations for processing, including a Clean Development Mechanism (CDM) project in which a cogeneration plant powers a large sugar factory.[lv] In a country that has regional grid connections rather than one overarching national grid, the idea of agricultural "hubs" has the potential to focus on regional agriculture products, including dairy. Senegal is also seeing major changes to the power mix on the horizon, including a push for solar generation to feed the national grid. The team visited a near complete 20 MW solar plant in the north of the country and learned that seven other such plants are due to come online in the coming years.

Kenya. As of 2016, total installed capacity in Kenya was 2.6 GW, and the country had an electrification rate of 56%. In 2015, Kenya produced 12.956 TWh of electricity: 26.9% from oil, 34.4% from hydropower, and 38.7% from non-hydro renewables (geothermal, wind, solar).[lvi] The Ministry of Energy's "Vision 2030" targets an installed capacity of 19 GW by 2030; RE sources are expected to play a vital role in this expansion.[lvii] The Kenyan electricity grid faces frequent outages and blackouts and will need to be upgraded to fully implement variable generation resources. Delays to wind and solar projects in the country are partially due to the state of the transmission and distribution system.[lviii] Kenya is currently in the process of updating the grid, with a USD 63.45 million investment underway. This large transmission project focuses on five rural areas, which will connect an additional 35,460 households to the grid.[lix]

4.1.7 Where in the VC will EE and RE Solutions Have the Greatest Impact on Post-Harvest Loss?

Senegal. The fieldwork portion of this sub-question has yielded results that do not align with some of the literature review findings. For example, in Senegal, the magnitude of PHL in the dairy sector can be mitigated in a variety of ways. If milk begins to sour in transit, it is often converted into *lait caillé,* thereby reusing it as an alternative to fresh milk, thus decreasing the volume that may be discarded. Multiple government programs have focused on increasing the milk output of cows (e.g., by interbreeding with cows from Brazil or Mauritania), in an effort to increase the local milk output to meet demand. Much of the current demand is met with powdered milk because insufficient milk production occurs locally. At the mini-dairies visited, less than 5% of milk was lost due to spoilage or tampering (such as cutting with water), while Berger said they have virtually eliminated spoilage by testing milk on site and working with the farmers to provide higher quality raw milk.

Kenya. In Kenya, post-harvest loss estimates in the secondary literature range from 10—40% for cattle milk, but field research only revealed post-harvest losses of 5% or less, most of these accounted for through cow health problems (e.g. mastitis) and not temperature-related spoilage. The Kenyan cattle milk VC has developed two adaptation mechanisms to minimize losses:

- ***Fermented products***: consistent with long-standing dairy consuming cultures around the world, Kenyans consume a range of fermented milk (maziwa lala), yogurts, and cheeses. While these are traditional products, as the value chain has modernized, dairies have developed modern, pasteurized versions of these products. Fresh milk at risk of spoilage can be channeled into a fermented product line.
- ***Constrain supplier geography***: Stakeholders at the dairies visited indicated that they limited their sourcing to geographies where they could access milk and where they could meet within the post-milking interval of 2-3 hours before the milk sours. This strategy severely limited the supply volumes dairies could secure, and particularly during the dry season, led to supply shortages in zones with grazing as a key feed strategy.

4.2 <u>Research Question 2:</u> How Can These Opportunities Be Integrated into Policy, Partnerships, and Planning?

The technical, social, gender, market, regulatory, and institutional post-harvest energy opportunities identified through the literature review, stakeholder consultations and field visits should be integrated into respective local and national policies, leverage partnerships with ongoing or planned programs and initiatives, and be key parts of sector planning efforts to have sustained impacts on the low carbon development goals of each country.

Policy Integration Opportunities

At the policy levels, both Senegal and Kenya have relatively robust policies on energy, agriculture and rural development, food security, dairy sub-sector development, low emissions development strategies (LEDS), climate adaptation and mitigation issues, all of which represent potential opportunities to integrate relevant findings and recommendations from this study. This is particularly relevant to the post-farm gate focus of this project, where there is often a dearth of information and specific policies that address EE and RE opportunities along this segment of the dairy VC. Energy consumption data along the post-harvest segments of the VC in the dairy sector (e.g., at milk processing centers) is often lacking and thus opportunities to quantify GHG emissions from storage, transportation, and processing activities as well as data from potential energy savings and GHG reductions may be able to be integrated to inform future policy development or to help illustrate policy impacts related to the sector.

Relative to institutional roles, policies that have impacts on the dairy industry are often diverse and crosscutting, involving a variety of ministries and include direct measures such as breeding and animal health, as well as indirect measures, such as rural infrastructure, tax policy, energy policies, climate change mitigation policies, and decentralization or other governance policy.[lx] Coordination entities such as national dairy boards (e.g., Senegalese Dairy Board, Kenya Dairy Board,) provide opportunities to collect information and potentially contribute to shaping sector policy formulation. An understanding of key public, community, and private stakeholders, including institutions leading other sectors such as energy and transportation, is important to further integrate energy opportunities into the policy framework. Illustrative policy options for Senegal and Kenya include:

- Net metering: Net metering is a billing mechanism that credits solar energy system owners for the electricity they add to the grid. Net metering policies vary but can serve as to catalyze private investment in renewable energy. It would build system resilience through incentivizing distributed storage and increase total supply of renewable energy. Neither Senegal nor Kenya has net metering policies.
- Waste Heat Recovery (WHR): Develop policy, regulatory and technical guidelines and incentives to promote WHR for processing lines of new dairy and other value chains, adapting best engineering practices and other available technical information resources.
- Subsidies: Provide guarantees, subsidized debt interest, or tax incentives to adopting RE to displace existing wood or diesel boilers.
- Bundling of Projects to Access Finance: Integrate VC development with private capital financial development projects: Most private capital focuses on investment sizes greater than $1M USD, but most SME RE investments are smaller than this. RE service providers could bundle 10-12 solar PV install opportunities at similar operations, for example, and sell to private capital to fund as a single deal. A finance development project such as USAID's Kenya Investment Mechanism (KIM) could support this approach through matchmaking RE service providers with financial partners. The SEM Fund in Senegal has been bundling multiple women's dairies to access finance but working directly with the RE providers to access private capital could streamline this system. Market system development activities, like USAID/Kenya's Crops & Dairy and Livestock Market Systems, could help build the pipeline of customer SMEs in their value chains.

Partnership Opportunities

Government and Donor-Funded Partners. During the literature review, the project team identified a variety of recent, ongoing, and planned programs that may represent opportunities for leveraging, partnerships, and coordination. These include agriculture sector (and dairy sub-sector), clean energy, gender and social integration, climate change, food security, and related projects funded by various USAID program and Missions, the Millennium Challenge Corporation (MCC), Millennium Challenge Account (MCA) entities, IFAD, UN Environment Program (UNEP), UNDP, GEF, GIZ, AfDB and respective governments. Program implementers include international NGOs and contractors such as Land O'Lakes International, SNV, Practical Action, Energy4Impact, and local organizations and companies.

This E4AS Project's themes and focal areas have potential synergies with various USG initiatives in the region, such as Power Africa (PA), Feed the Future (FtF), Powering Agriculture (PAg) and its Energy Grand Challenge, and energy and agriculture programs under the MCC's Compacts in Ghana, Niger, Senegal, Burkina Faso, and Benin. Power Africa has an extensive list of public and private sector partners throughout the SSA region, representing potential partnerships for opportunities identified under the E4AS project.

The Powering Agriculture's *Energy Grand Challenge* initiative, the *Scaling Off-Grid Energy Grand Challenge* (partners include Power Africa, USAID's Global Development Lab, the U.K. Department for International Development (DFID), U.K.'s Energy Africa campaign, and the Shell Foundation), and DFID's OpenIdeo Agricultural Innovation Challenge Fund have supported international and local implementers to further innovative programs that bridge energy and agricultural development, including the dairy VC.

USAID also has major initiatives in the region that have supported national strategies and built capacity of public and private sector stakeholders in the dairy industry, including in post-harvest VC segments. Land O'Lakes International implemented USAID's *Kenya Dairy Sector Competitiveness Program (KDSCP)*, worked to eliminate inefficiencies, and lower production and processing costs throughout the dairy VC, while ensuring that Kenyan milk meets domestic and international quality standards. KDSCP built capacity of youth and women and applied agricultural best practice and empowering many women to increase their incomes and to take leadership positions in their farms or in cooperatives.[lxi]

Potential Private Sector Partners. In Senegal, the team identified potential private sector actors who could be encouraged to participate in the energy/agricultural sector through donor-funded projects. Below is a list of solar panel providers in Senegal. Working directly with these providers to expand access to rural areas, perhaps through the provision of less expensive technology models, could be a fruitful partnership. Additionally, bundling projects for solar energy, working with groups such as the SEM Fund (with women's cooperatives), could allow for access to cheaper financing. At present, most of the companies listed in Table 2 below do not provide alternative financing options, which limits the type of customer that can access such products.

Table 2. Illustrative List of Solar panel Providers

Name	Country of Origin	Products	Financing Plans (Y/N)
African Energy	U.S.	solar, minigrid, back-up power	N
Oolu	Senegal	solar products	Y
Solar Energy Senegal	Senegal	grid-scale and small-scale solar, solar lamps, solar refrigeration, solar chargers, solar pumping	N
Top Energie Solaire	Senegal	solar panels, batteries, lightbulbs	N
NRJ Solaire	Senegal	solar home systems, batteries, water heaters, solar refrigeration, solar pumping	N
SATECH SARL (Division of SMA)	Senegal / Germany	solar home systems, batteries, solar pumping	N
Saloum Energie	Senegal	solar panels, solar lighting, batteries, charge controllers	N
Bonergie	Senegal	solar home systems, batteries, water heaters, solar refrigeration, solar pumping	Y

Planning Integration Opportunities

Along with potential for policy integration and partnerships with program implementers, donors, and project sponsors, finding and recommendations from the E4AS project may be used and contribute to planning efforts by USAID, government agencies, dairy processors and other stakeholders to inform their planning efforts for future activities.

For USAID Missions, information and recommendations on energy opportunities in the agriculture chain can support ongoing efforts to update the Country Development Cooperation Strategies (CDCS) and to inform current programming efforts, particularly in the energy and agriculture sectors, under them. USAID/Senegal's Development Objective (DO) #1 – "Increased inclusive economic growth" includes Intermediate Results (IRs) related to inclusive agriculture sector growth, private sector investment and trade, community and systems resilience, and nutrition.

In Kenya's CDCS, DO #3 – "Inclusive, market-driven, environmentally sustainable economic growth," key IRs related to climate change/green growth economic development, increased food security and resilience, and improved private sector investment. Energy and agriculture sectors expect to continue to be priorities in these countries. Both missions also promote gender-sensitive approach to development.

In addition to supporting USAID's planning efforts the E4AS study may contribute to informing some of the planning efforts of other donors working in the agriculture and energy sectors, including the Compact programs under MCC and MCA entities in Senegal and other SSA countries as well as AfDB, DFID, and the World Bank. During the field visits, the team met with USAID missions, donor organizations, and implementing partners to identify potential areas of collaboration, partnerships, and entry points for future initiatives that address the nexus between energy and food security.

4.2.1 How Can These Policy and Programming Approaches Maintain Gender Equity?

A key assumption for policy development is that behavior change/technology adoption pathways will be different for women than men, and structure accordingly. In contexts where women have culturally tenuous control over even their 'own' businesses, they will often deploy tactics to shield their resources from husbands or other male family members.[lxii] This will often lead female entrepreneurs to resist changes that would grow their enterprise to a point that it risks male takeover. Addressing differences in technology adoption:

- Conduct gender analysis and incorporate data as part of activity design to better identify challenges and opportunities related to women's ability to afford the proposed technology (and access to finance); access to information and known outcomes; accessibility of services; price and profit margins (as well as control over income); and socio-cultural norms relevant to the technology's design, dissemination, and use.
- Monitor and assess gender differences in adoption rates at the individual farmer level—not just the household level—to understand both male and female farmer perspectives on the intervention.
- Target information not only to women who are de jure household heads, but also to women in male-headed households and de facto women-headed households who are isolated from agriculture information channels.
- Women tend to value face-to-face interaction with those providing information on new technology. Women-specific farmer groups and farmer field schools provide opportunities for face-to-face interaction in venues and formats that are comfortable for women. Women value formats that are interactive, encourage questions, and discuss details on how to use new products and services. Where men tend to dominate mixed gender meetings, women-only training is preferred. Increasing the number of women trainers

and extension agents can also improve information flow to women.

Addressing Male Takeover Risks:

- Promote activities that increase women's independent, legal ownership of assets, including special programs for female-headed households
- Strengthen women's voice in household decision-making over expenditure and assets.
- Promote women's access and control over income.
- Develop the capacity of rural producer organizations to represent women's interests in the market.
- Ensure that physical infrastructure, such as processing and storage facilities, means of product transportation, information and communication technologies (ICTs), and the facilities at retail and wholesale markets meet women's needs.
- Address challenges and constraints within the enabling environment, promoting women's understanding of relevant laws and policies, contracts, service providers, and work with institutions to address women's needs.

4.2.2 How Can the Findings from this Study be Used Across Other Countries and VCs?

Technical solutions, social and gender integration, and market dynamics are specific to the context for each of the targeted case study countries. There are a number of EE and RE technical solutions along the post-harvest dairy VC that can be extrapolated or adapted to other VCs as well as in other countries and regions (e.g., cold chain EE improvements, transportation options, RE technology integration, and others discussed in this report that are applicable across various contexts). Similarly, on gender mainstreaming issues, there are interventions and approaches that will have relevance in other VCs and countries in SSA.

4.3 Research Question 3: What role can low-carbon energy use Opportunities in the dairy VC play in achieving a country's low emission development goals?

The EE and RE opportunities for the PH dairy VC (from farm-gate to retail and consumers) identified earlier will result in reduction in greenhouse gas (GHG) emissions and will be able to contribute to the respective country's goals for LEDS, particularly for the dairy sector. In the dairy sector, GHG emissions from the farmgate to the retail/consumers typically stem from the following:[lxiii]

- ***Transport of milk from farm to dairies***. GHG emissions from transport in the post–farm chain relates to the transportation of raw milk from the farm to a processing point, and to the transportation of products from the processing point to the retail point. Emissions relate to both energy use and the leakage of refrigerants. Emissions may be estimated by obtaining information on the total distance, transportation mode, emissions per unit of distance travelled and emissions per time unit (cooling system). Transport emissions may be estimated for milk, cream, cheese, butter and milk powder. It is important to distinguish between motorized and non-motorized transport. In Senegal, the lack of motorized transport means that the transport sector does not make up a meaningful portion of GHG emissions in the domestic milk sector.
- ***Processing of raw milk into milk products such as cooled milk, yoghurt, cheese, butter, and milk powder.*** Emissions at the processing stage mostly come from energy consumption, particularly electricity generated from fossil fuels. Processes such as pasteurization, refrigeration and cold chain, and heating to create products, all require inputs of either electricity or gas (in the case of heating). If grid electricity is used, the GHG emissions are based on the generation mix (e.g., fossil fuels are a much higher percentage of GHG emissions from grid electricity than RE sources).
- ***Production of packaging material***. Producing packaging uses energy and creates GHG emissions. GHG emissions may be obtained by combining average energy use for packaging per kilogram of product and emissions factors per unit of energy used.
- ***Transport/distribution of processed products to the retail point***. This transportation segment from processing to retail can often be a greater contributor of GHG emissions (and fuel costs) than the farm-to-dairy segment, particularly for larger facilities, where distribution via large, refrigerated trucks often travel across the parts of the country to reach retailers and consumers.

Kenya has developed a Nationally Appropriate Mitigation Action (NAMA) for the dairy sector, with technical assistance support from donor organizations and the private sector. It has national development strategies supportive of climate resilient investments in the sector, within the framework of national strategies such as Vision 2030, the National Climate Change Action Plan, the National Dairy Master Plan, and the Climate-Smart Agriculture Framework Policy.

In Senegal, the agriculture sector contributes 37% of total GHG emissions, second only to the energy sector at 49% (2013). According to the World Banks' 2016 Intended Nationally Determined Contributions (INDC) report for Senegal, the country has an existing Low Emissions Development Strategy (LEDS) in place or under development, but no NAMAs or National Adaptation Plan of Action (NAPA). Any energy savings under the dairy VC (particularly in the instances of replacing grid electricity with solar or renewable generation) will contribute generally to the country's LEDS, as will the current push to add renewable energy onto the grid. Due to the under-developed nature of the dairy VC in Senegal, as the markets formalize, energy intensity of the VC will likely increase. The Senegalese dairy industry has the potential to increase its carbon pollution in the coming decades. However, at this early stage, RE interventions have the potential to prevent this.

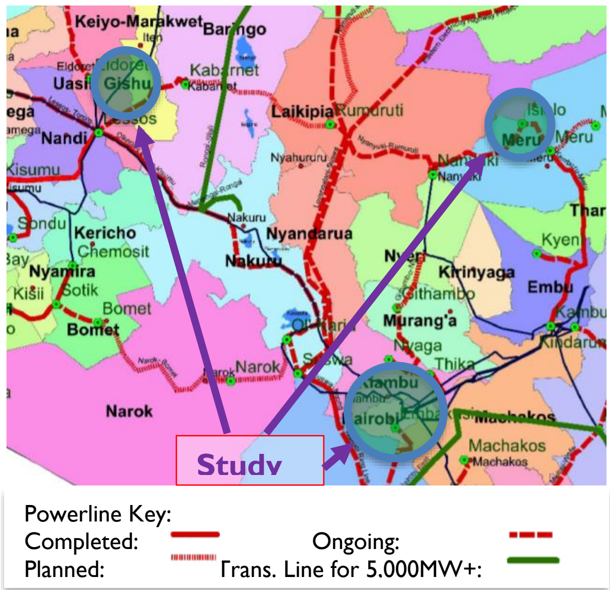

Figure 6. All interviewed dairies had grid access but were also located close to trunk lines. (Map source: KETRACO)

4.3.1 What is the Potential for Off-Setting Fossil Fuel Consumption in On-Grid and Off-Grid Areas?

In **Senegal**, the on-grid potential for off-setting fossil fuel consumption is high, due to the carbon intensity of electricity produced for the national grid. Berger has planned to install solar energy to this end. In off-grid areas, the dairy VC does not use significant amounts of energy, and milk is generally sold fermented. Electrification through solar lighting can offset the use of fossil-fuel powered lamps, but the potential here for offsetting fossil fuel use is low. In rural areas, the use of motorized transportation is rare. In the production of domestic dairy products, motorized transport is only a major factor for Berger, with other mini-dairies focusing mostly on animal or human-powered transport to reach local markets. As the sector develops, motorized transport may become more common.

In Senegal, fossil fuels constitute 84% of the power generation mix. The fossil fuel combustion emission factor for in Senegal is 42.62 TJ/kt, according to the IPCC.[lxiv] Senegal has been promoting biofuels, as demonstrated in its 2010 Law 2010-22 Regulating the Biofuels Industry, where the Law aims to develop the biofuels sector, establishing norms and conditions for the production and exploitation of biofuels in the national territory as well as for international co-operation. More broadly, the law aims to contribute to environmental protection and increase the value of forest and agricultural resources.

In **Kenya,** fossil fuels (fuel oil) constitute 27% of the power generation mix. The fossil fuel combustion emission factor for in Kenya is 42.08 TJ/kt, according to the IPCC.[lxv] All dairies and dairy processing firms interviewed had grid connections, unsurprising given their locations in proximity to the main grid trunk lines (see **Figure 6**). While all dairies were connected to the grid, they all cited frequent outages (3-5 times per week) and high cost as challenges with the grid.

Transport and Fuel Use. In Senegal, transport was largely fuel-less outside of Dakar. The major exception to this was Berger, which uses refrigerated trucking to get its product to market in Dakar (and even as far as The Gambia). Transport is a major barrier to market access, with many farmers only able to access milk collection centers or markets within 10-15 km of their farms. This is due to both a lack of motorized transport and a lack of cold store transportation options. In Kenya, transportation was not cited as a key challenge by respondents, though there are limited cold storage transportation options. The lack of cold storage in transport is a limiting constraint on milk trade, as processors can typically only buy from farmers within a 3-hour catchment.

On-Site Generation

In Senegal, the team visited several mini-dairies that had some kind of solar PV installation where equipment had been provided by an NGO or donor-funded organization. One small woman-owned dairy outside of Tambacounda had two solar refrigerators. The first had been provided by an NGO, and the second had been purchased by the cooperative after the first refrigerator helped the cooperative to increase its revenues. In Kenya, the team visited three dairies incorporating RE offsets of two types:

- *Solar PV*: One 10-15,000L/day facility had installed 100kW of solar PV capacity to offset grid electricity for $100,000USD. This reduced their average monthly energy bill from $4,000 to $1,000, resulting in a payback period of 33.3 months.
- *Solar thermal*: Two dairies had installed solar thermal to offset heating costs for their Clean-In-Place (CIP) systems, but not for other water heating needs, as solar thermal would not consistently reach high enough temperature for pasteurization and sterilization processes.

4.3.2 Where Along the VC Will EE Have the Greatest Impact on Energy Savings?

In Senegal, dairy farming, collection, and even processing by mini-dairies requires little energy input. The greatest impact on energy savings will occur at the large-scale facilities. Our interviews at Berger led to information about an energy audit process that was underway. Energy auditing at Berger and the processing facilities in Dakar and Thiès will provide the main options for efficiency improvements and savings. In Kenya, Waste Heat Recovery for pasteurization and sterilization showed significant return on investment at the dairies. Milk processing requires substantial energy to cool milk as it is received (32℃→4℃), then heat that milk for pasteurization/sterilization (4℃→173℃), then cool it again (173℃→4℃) for further processing and packaging. A case study utilized an energy audit data to model EE through waste heat recovery and found it would reduce energy use by 19% for a large scale (200,000 L/day) dairy.[lxvi]

4.3.3 How Will Planning and Implementation of Energy Programs Align with and Contribute to Low-Carbon Growth Strategies?

Both Kenya and Senegal continue to prioritize its national and international commitment to work towards a low-carbon economy, having developed a variety of regulations, institutions, and programs to establish low emissions development strategies (LEDS) and nationally appropriate mitigation actions (NAMAs). In Kenya's case, the country has developed a NAMA specifically for the dairy sector. Capacity and expertise to develop sound GHG emissions inventories and mechanisms to quantify emissions reductions from initiatives continue to evolve in these countries, with Kenya's progressing ahead of Senegal (particularly having established some sector-level NAMAs with international support). The Case Study visits to Kenya and Senegal improved understanding of the institutional arrangements in the country and opportunities to help align energy opportunities in the dairy sector with government programs and plans.

Senegal. As of 2016, Senegal reported in its INDCs that the country has a LEDS, but no NAMAs or NAPAs in place. Senegal has nevertheless has placed priority in climate change issues at the national level since 2011, when the foundation of the National Committee on Climate Change (COMNACC) contributed to creating a central platform for cooperation on climate change. One of the key roles of the Committee is following the activities developed at the UNFCCC, thus reinforcing the link between global and national climate politics. [lxvii]

The project team located general GHG emissions data about Senegal, where the agriculture sector and the energy sector in the country contribute the majority of GHG emissions, the actual country LEDS for Senegal has not been located during this literature review, nor was there data available on specific dairy VC GHG emissions. The government reported in the INDCs a number of ongoing national RE and EE initiatives. The field team made requests to the requisite government agencies in Dakar, but specific GHG data for the dairy VC was not made available at the time of the project. Based on the field research, processing appears to be the largest energy input in the sector.

Kenya. Energy efficiency and RE integration measures into the dairy VC will result in reduction of GHG emissions in the sector in Kenya and will contribute to the country's sector GHG reductions goal. Kenya has developed a nationally appropriate mitigation action (NAMA) for its dairy sector that is expected to reach 227,000 dairy producers and yield an additional 6.6 billion liters of milk p.a. while reducing GHG emissions by 8.8 Mt CO2 eq. The MOE's Department of RE leads the national level climate change mitigation and LEDS efforts, with the EE Office of the Department. Energy opportunities identified via E4AS will coordinate with the Department and the Kenya Dairy Board (KDB) on low carbon alignment issues with the GoK.

Kenya has received a significant amount of donor assistance to help it implement its NAMA and further develop its methodology for GHG inventory calculations. For example, as of early 2018, Kenya, still relies on the use of simple methods (commonly referred to as Tier 1) for estimating livestock emissions in their GHG inventories and this is unable to capture and report on the mitigation associated with the NAMA. While Tier 1 requires the least resources, it is unable to reflect a country's unique circumstances or trends over time other than changes in total animal numbers. More advanced methods (Tier 2 and 3) require more detailed data that capture specifics of production systems in countries. They also reflect changes in emissions that result from improvements in the productivity and efficiency and enable policy makers to target and design efforts for GHG mitigation. Kenya's growing capacity to prepare sector GHG inventory, which will form the basis to measure its performance in achieving its sector reduction targets.

ANNEX I – SENEGAL FIELD WORK, METHODOLOGY AND TRIP NOTES.

The GPTech/ACDI VOCA team's visit to Senegal sought to achieve the following objectives:

1. Collect information regarding the dairy VC, and major stakeholders, including any current energy projects underway (private sector, government, NGO, etc.)
2. Collect information about gender in the dairy value chain: where are women active, what are the constraints
3. Collect information regarding post-harvest loss in the dairy VC
4. Estimate energy use throughout the value chain (differences between yogurt, milk, milk powder, cheese, etc.), which areas of the value chain use the most energy (transport, processing, storage, etc.)
5. Identify current energy practices already in place in the value chain, assess/document performance/effectiveness where possible
6. Identify potential energy implementations that would reduce fossil fuel consumption and PHL
7. Identify and meet with renewable energy solution vendors

The trip included travel to Dakar and site visits to a variety of dairy facilities and VC stakeholders in Louga, Saint-Louis, Richard Toll, Kolda, and Tambacounda, as illustrated in the map below. The team had prepared key

Figure 7. Map of Trip Site Visits in Senegal

research questions and gathered information from government stakeholders, farmers, collection centers, processors, academics, international donor organizations, and local non-governmental organizations (NGOs). A list of the stakeholders interviewed is included below.

Methodology

The GPTech/ACDI VOCA team combined meetings in Dakar with key agencies within the GoS, such as ASER, Ministry of Livestock and Dairy Industries, and ANER to better understand the policy level priorities, plans, and initiatives such as the National Biogas Program, a program to distribute 10,000 biogas chillers in rural areas.

The team sought to maintain relative consistency among the variety of individual interviews, focus group discussions and tours of facilities during site visits. Some interviews were impromptu and unscheduled, such as

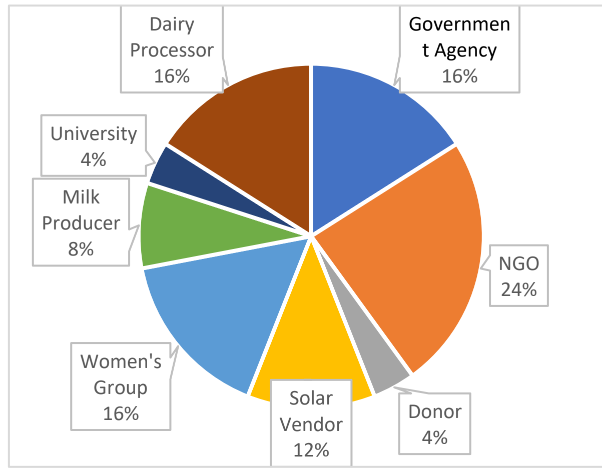

Figure 6. Stakeholder Composition Visited by the Team in Senegal

stopping at roadside dairy retailers, local businesses and other organizations along the way to various scheduled site visits. Interviews outside of Dakar, in particular, were generally conducted in French, but it some cases in local languages that required translation (e.g. Wolof, Pulaar).

Stakeholders Interview/Site Visit List

Over the 2-week period of the trip, the GPTech/ACDI VOCA team conducted about 25 meetings and site visits across Senegal – from Dakar to the northern regions of Richard Toll and St. Louis to southern regions of Tambacounda and Kolda. In Dakar, the team met with national governmental agencies such as ASER, ANER, and the Ministry of Livestock and Dairy Industries, in addition to donor agencies and implementers such as the UNDP and representatives of the Millennium Challenge Corporation. The team also visited Senegalese NGO implementers such as SEM Fund and Enda Energie at their offices in Dakar, obtaining information about programs on gender integration and micro-finance in the energy sector (SEM Fund) and ongoing regional renewable energy initiatives from a leading local NGO in Enda Energie, where lessons learned were documented from some of their projects. Outside of Dakar, the team conducted site visits at several dairy processing facilities, dairy producers, NGO implementers, solar energy facilities, women-owned enterprises, and other local governmental and private stakeholders.

Dairy Value Chain Stakeholder/Sit Visits List

The following table provides a list of the key stakeholders interviewed and sites visited during the GPTech Team's Case Study visit to Senegal in March 2018.

Name	Location	Category	Notes
National Biogas Program	Dakar	Government Agency	Overview of biogas program and future programming. The NBP estimate that the total potential for bio-fertilizer production is 500,000 tons annually. Of that 500,000 200,000 would be used by the farmers who produce the fertilizer, while the remaining 300,000 tons would be sold on the market. Less than 10% of crops are grown using fertilizer, so the existence of this market would help increase crop yields. They plan to install 2,000 biodigesters each year over a period of 10 years (20,000 total).
SEM Fund	Dakar	NGO	Bundling of women's groups for better access to financing. SEM Fund has a databases of 2,000 women's groups, covering 12 regions. 2 more regions are being added. It has experience in the dairy sector, working with Energia and Energy4 Impact. Its key interests are productive use of energy and entrepreneurial opportunities for women in the agriculture sector, where they help make market linkages with manufacturers, vendors, and others…and work to improve women's bargaining power in the market, including working with small businesses on microcredit/microfinance schemes
ANER (National Agency of Renewable Energy)	Dakar	Government Agency	Met with ANER, whose mission is to promote the use of renewable energies. Discussed constraints in the dairy VC, energy access, and the Progres Lait project
Ministry of Livestock and Animal Production	Dakar	Government Agency	Met with head of Ministry and the Head of Dairy to discuss project and ask about government interventions and statistics. The Ministry has been carrying out solar projects since 2009, indicating that most dairies would go bankrupt due to high costs of electricity. Milk processing and conservation needs a constant cooling chain and most small dairies would not afford it), hence, the Ministry had distributed solar fridges. The Ministry have also encouraged local solar energy private companies to look at opportunities regarding solar powered farms. The Ministry has also equipped some SMEs and women's groups by providing them motorcycles (tricycles) with a refrigerated case. The units that produce more than 500 l/day were equipped with refrigerated vans.
UNDP	Dakar	Donor	Facilitating work of a multi-stakeholder Sustainable Energy for All (SE4All) platform on renewable energy, mostly emphasizing solar energy.
USAID Mission Dakar	Dakar	USG	Met with USAID Power Africa team and provided exit briefing to Mission staff at the end of the 2-week visit, where USAID placed high emphasis on improving energy for productive use and engagement of private sector.
M. Abdoulaye Touré – Solar Vendor	Mekhle	Vendor	Overview of available products and uses – viewed mini-dairy under construction
Innovent/Kima Afrique – Solar Farm	Louga	Vendor	Overview of 20 MW solar park – construction nearly complete, will be sold onto SENELEC grid
DIRFEL Thiargny	Thiargny	Processor	Women's cooperative, some solar refrigeration/freezing, grid connection available but not used. Lait caillé – 20 L per day, sold at 225-250 CFA
Ferme de Keur Momar Sarr	Louga	Farm	20 L production (rainy season), hybrid cows Senegal/Brazil no energy use, transport by horse
Gaston Berger University - Centre d'impulsion pour la Valorisation de l'élevage	Saint-Louis	University	Develop local techniques to add value to milk to increase revenue for local producers; demonstration of processes.
La Laiterie du Berger	Richard Toll	Processor	Largest domestic dairy – 100 employees, uses grid + back-up

Name	Location	Category	Notes
			generator (considering solar), refrigerated trucks for transport, generator is for grid black-outs. Main issue is not energy, but scarcity of milk supply and difficulty of collection
Enda Energie (Progrès Lait)	Saint-Louis	NGO	Overview of the Progrès Lait program, selling fresh milk, minigrid, solar refrigeration, platforms and demonstration projects, carbon financing
Enda Energie	Dakar	NGO	Project ends 2019, main barriers: climate, expensive technologies, lack of technical expertise, lack of marketing strategy for the fresh milk
Le Fermier	Kolda	Processor	Mr. Fall runs the dairy, purchasing milk brought by farmers for 300 CFA. Part of Progrès Lait. He has a cheese room and makes cheese and yogurt, has a solar installation that powers the dairy, cut the SENELEC bill by 66%. 150 L/day dry season, 300 L/day rainy season. Employees – 3 women 3 men Sells fresh milk for 450 CFA/L, Yogurt for 1000 CFA/L, and cheese 5500/kg
Mr. Diaga Ball	Kolda	Farmer	Farmer selling milk to Le Fermier – arrived by bicycle. Has 17 cows, 5 for milking. 7 km, no electricity in village
Progrès Lait Platform	Diambanouta	Processor	11 Kwp, 300 to 500 V, electricity to the dairy storage, mosque, school, and street lighting. Storage capacity 600 L. Supply – 150 L/day dry season, 430 L/day rainy season. Four female employees and four male employees. In talks to ASER to expand to sell electricity to households
Bilaame Pul Debbo	Kolda	Processor	Woman-owned, 300 L/day capacity, part of Progrès Lait. Fresh milk – 500 CFA/L, yogurt 1200 CFA/L, cheese 7500/kg, fermented 1000 CFA/L, use motorcycles for delivery of product
Enda Energie Bureau Progrès Lait de Kolda	Kolda	NGO	Background of site selection, members are expected to pay 15,000 CFA fee. Challenges: platform not profitable,
Handoube et Dagnal	Kolda / Tambacounda	Women's Organization	Group of cooperatives, totaling 300 women. Mostly agriculture, some dairy. Processing machine, but no electricity, so cannot use it. Tried to sell solar projects with NGOs, but too expensive and no one wanted to purchase them
GIE Kawral - Sinthiou Malem	Tambacounda	Processor	Small women's cooperative, dairy. 2 solar refrigerators, grid power (except on Saturdays). First solar refrigerator allowed savings to purchase the 2nd. Fermented milk: 1250 CFA/L. heating with charcoal
La Lumière - OXFAM	Tambacounda	NGO	Network Village and Savings Loans Associations. Constraints to dairy VC: animal feed, climate, local projects buying for 300 CFA when farmers should be able to get 500 CFA / L in local market
Bonergie	Tambacounda	Solar Vendor	Solar Vendor, solar home systems, refrigeration, pumping. Made in Germany. Partners with Energy4 Impact program by GVEP; sometimes provide payment options by partnering with NGOs/women's groups
Federation of 11 Women's Groups, organized by Nouvelle Dynamique	Tambacounda	Women's Organization	Mostly in agriculture, some women in dairy. Desire for capacity-building activities, particularly with respect to solar installation/management.
GRET	Dakar	NGO	Gender-focused projects in dairy (not energy, gender and nutrition)
ASER	Dakar	Government Agency	Rural Electrification Agency, involvement with Progrès Lait, overview of rural electrification strategy (ERIL), concessionaires,
World Vision	Dakar	NGO	PAPLAIT project, focused on adequate feed and stables for cows, to increase milk production

ANNEX II - KENYA FIELD WORK, METHODOLOGY AND TRIP NOTES

The Kenya Study trip sought out three different dairy sector contexts to understand energy opportunities and constraints at different scales. Given time and resource constraints, we were unable to visit all regions relevant to the dairy sector (including western Kenya). That said, secondary literature and stakeholder interviews suggest that the size, business model, and marketing approach of the various dairy sector enterprises we interviewed are consistent with those in other parts of the country. The team interviewed a mix of dairy aggregators and processors in the camel and cattle milk value chains as well as implementing partners, donor initiatives, the Ministry of Energy, and other value chain supporting actors. Dairy processors represented a wide range of scale, sophistication, geography, and function in the value chain.

Figure 8. At Tawakal Farmers' Cooperative, Kenya

Methodology

We deployed a semi-structured approach to each interview, using guiding questions but remaining flexible to probe further. This method allowed us to maintain some consistency between interviews while following interesting findings with follow-up.

Dairy VC Actor Interview List

Name	Location	Volume	Notes
Classic Foods (Isiolo)	Isiolo	10-15,000L/day	Camel & Cow Milk dairy processor, creating fresh milk, lala, yogurts
Classic Foods (Nairobi)	Nairobi	10-15,000L/day	Cow milk processor creating fresh milk, lala, yogurts
Tarakwat (Eldoret)		1,000L/day	Cow milk; currently only chilling and bulking milk for larger processors
Githunguri Cooperative	Nairobi	215,000L/day	Cow milk; Fully vertically integrated cooperative, with 20,000+ members; has conducted energy efficiency audit of processes
Women's camel milk supplier association	Isiolo	Suppliers (not processors)	Women's camel milk supplier association.
Tarakal	Isiolo	500L/day	Informal camel milk trader & aggregator.

Other VC Stakeholder Interview List

Name	Location
USAID Power Africa	Nairobi
USAID/Kenya Feed the Future	Nairobi
SolarGen	Nairobi
SNV/Kenya	Nairobi
Strathmore University Energy Research Centre (SERC)	Nairobi
Savanna Circuits, Ltd.	Nairobi
USAID/Kenya Livestock Market Systems & Regal AG Activities	Nairobi
USAID/Kenya Crops and Dairy Market Systems Activity	Nairobi
Moi's Bridge University Livestock Research Group	Eldoret
GIZ/Powering Agriculture East Africa Hub	Nairobi
Kenya Ministry of Energy/Department of Renewable Energy	Nairobi
Hivos/Energia	Nairobi
SIDAI and Inspira Farm	Nairobi

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