Sustainable Energy for Smallholder Farmers (SEFFA) in Ethiopia, Kenya and Uganda

Baseline Study and Market Assessment

endev

Energising Change

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Abbreviations

ACC	Agriculture Commercialisation Clusters
ACDP	Agriculture Cluster Development Project
ATA	Ethiopian Agricultural Transformation Agency
CIP	International Potato Centre
COMTRADE	United Nations International Trade Statistics Database
CSA	Central Statistical Agency of Ethiopia
EAC	East African Community
EnDev	Energising Development Programme
Equity IRR	Equity Internal Rate of Return
ETB	Ethiopian Birr
EUR	Euro
FAO	Food & Agriculture Organization
FCDO	Foreign, Commonwealth and Development Organization
FGD	Focus Group Discussions
GDP	Gross Domestic Product
GHG	Green House Gases
GIZ	German International Cooperation Agency
Global GAP	Global Good Agriculture Practices
GoE	Government of Ethiopia
GoK	Government of Kenya
GoU	Government of Uganda
Ha	Hectares
IFC	International Finance Corporation
IFPRI	International Food Policy Research Institute
ILSSI	Innovation Lab for Small-Scale Irrigation
JKUAT	Jomo Kenyatta University of Agriculture & Technology
KEREA	Kenya Renewable Energy Association
KII	Key Informant Interviews
Ksh	Kenyan Shillings
M&E	Monitoring & Evaluation

MAIIF	Ministry of Agriculture, Animal Industry and Fisheries
MFI	Micro-Finance Institutions
MT	Metric Tonnes
NAADS	National Agriculture Advisory Services
NPV	Net Present Value
NU-TEC	Nothern Uganda: Transforming the Economy through Climate Smart Agribusiness
PAEGC	Powering Agriculture
PAYGo	Pay-As-You-GO
PUE	Productive Use of Energy
RVO	Netherlands Development Agency
SACCO	Savings & Credit Cooperative Organization
SEFFA	Sustainable Energy for Smallholder Farmers
SME	Small & Medium Enterprise
SNNP	Southern Nations, Nationalities and People's Region
SNV	Netherlands Development Organisation
ToC	Theory of Change
UGX	Ugandan Shillings
UHT-Milk	Ultra-High Temperature (Milk Processing)
USD	US Dollar
WHO	World Health Organization

Executive Summary

This report presents the findings of the Baseline Study and Market Assessment study commissioned by the Sustainable Energy for Smallholder Farmers in Ethiopia, Kenya and Uganda (SEFFA) project. The study aimed to inform the design of SEFFA by i) conducting a baseline survey of horticultural and dairy producers to provide a diagnostic of current production systems and energy needs, develop "Smallholder Data Portraits", and lay the foundation for measuring and tracking improvements in impact to which the project expects to contribute, ii) conducting a market assessment of PUE technology demand and supply in the target countries, iii) developing business cases for each country, iv) establishing key indicators to measure project performance. The technological focus has been on irrigation, cooling and drying technologies.

A preliminary assessment was conducted to prioritise geographic locations, beyond the regions (Amhara, SNNP, Oromia and Sidama in Ethiopia; Eastern, Rift Valley and Central Regions in Kenya; Central, Eastern, South-Western Regions in Uganda). The primary shortlisting of locations, in all three countries, was mainly based on indicators relating to the horticulture and dairy sectors. The approach to the final selection, however, depended on the level of maturity of the PUE sector in a given country, with Ethiopia representing a nascent market, Uganda – a market with some experience of PUE technology application, and Kenya – with the most advanced market of the target countries.

The research tools for this assignment have included a baseline survey of 570 horticultural and dairy producers in each country (conducted remotely in Kenya and Uganda and face-to-face in Ethiopia), key informant interviews with PUE companies, enabling environment stakeholders, processors, etc., focus group discussions with smallholder farmers, and validation workshops (conducted in person in Ethiopia and virtually in Kenya and Uganda).

Ethiopia

In **Ethiopia**, **value chain diagnostic analysis** demonstrated that both horticultural and dairy sectors are growing in size and improving their productivity, though affordability of fruit, vegetables and dairy products remains a significant issue for a significant share of the population. While there is some, limited degree of commercialisation in both value chains, low-input, small-scale production represents the overwhelming majority of the sectors. Common weaknesses include limited accessibility and/or affordability of quality inputs, lack of access to finance, storage and adequate extension support, high degree of dependence on informal markets and farmgate sales to traders with a much stronger bargaining position, limited value addition, and low-price premiums for high-quality produce in absence of stronger market linkages. The dairy sector is also influenced by the high number of Orthodox fasting days, when consumption of animal products is forbidden. Women have a more pronounced role to play in the dairy sector as caretakers and milkers of animals, though their engagement in both the dairy and horticulture value chains remains informal. Youth participation in the target value chains is not clearly defined but tends to be limited due to low levels of interest by the youth being employed in "traditional" production sectors, attractiveness of off-farm employment, more established cash crops and commercial activities.

In terms of the **PUE technology solutions currently in use in Ethiopia**, **solar powered irrigation** is by far the most prominent, and growing fast, reflecting the broad recognition within the horticultural sector, in particular, of the need for irrigation. However, the direct customer base of solar irrigation providers overwhelmingly consists of donors, government agencies, NGOs and similar institutions who purchase the solar pumps and then distribute them to the farmers at heavily subsidised prices. Despite its currently small size, the market is already quite diverse, with the range of products on offer reflecting the wide variety of terrain, water availability and water requirements among solar irrigation customers. **Cold storage** ownership remains very rare. Of the few producers in the target value chains who use cold storage, almost all use small electricity-powered fridges. The only non-electric solution currently in operation is a Zero Energy Cool Chamber currently being piloted by the ATA. The technology, imported from India, relies on cement bricks and translates into a cost of ETB 70-80k per farmer, and up to ETB 125k in Oromia, while interviewees have stated that the capacity of 1.5-3tons is insufficient. Solar cooling has been discarded by the programme as prohibitively expensive for the farmer, even against this background.

Processing remains rare in the horticulture value chain, while it is very widespread in the dairy sector. However, it is largely artisanal and relies on the use of firewood and manual labour, and is largely carried out to avoid food loss by extending product shelf life, rather than as a strategy to add value and earn a price premium. To date, no information is available on any solar-powered or other renewable energy-based processing solutions for dairy or horticulture – although solar milling and solar grinding equipment for cereals and coffee, respectively, are being explored as options by some of the companies currently supplying solar-powered irrigation pumps.

In terms of **gaps and constraints that limit expansion of PUE technologies,** the demand side suffers from low levels of awareness of technology, low confidence in technical support, limited ways to establish or guarantee quality and reliability, high upfront cost coupled with low access to finance. On the cost side, supply is constrained by a shortage of FOREX which creates difficulties for procurement, import regulations and tax regime (though this is undergoing revision), access to finance, limited domestic manufacturing/ assembly capacity, and disruption of supply chains by conflict. On the revenue side, suppliers struggle with high rates of inflation, competition from lower-priced, lower-quality inputs from China, reliance on government procurement and resulting inflexibility of pricing, and lack of standardisation by the regulatory agency.

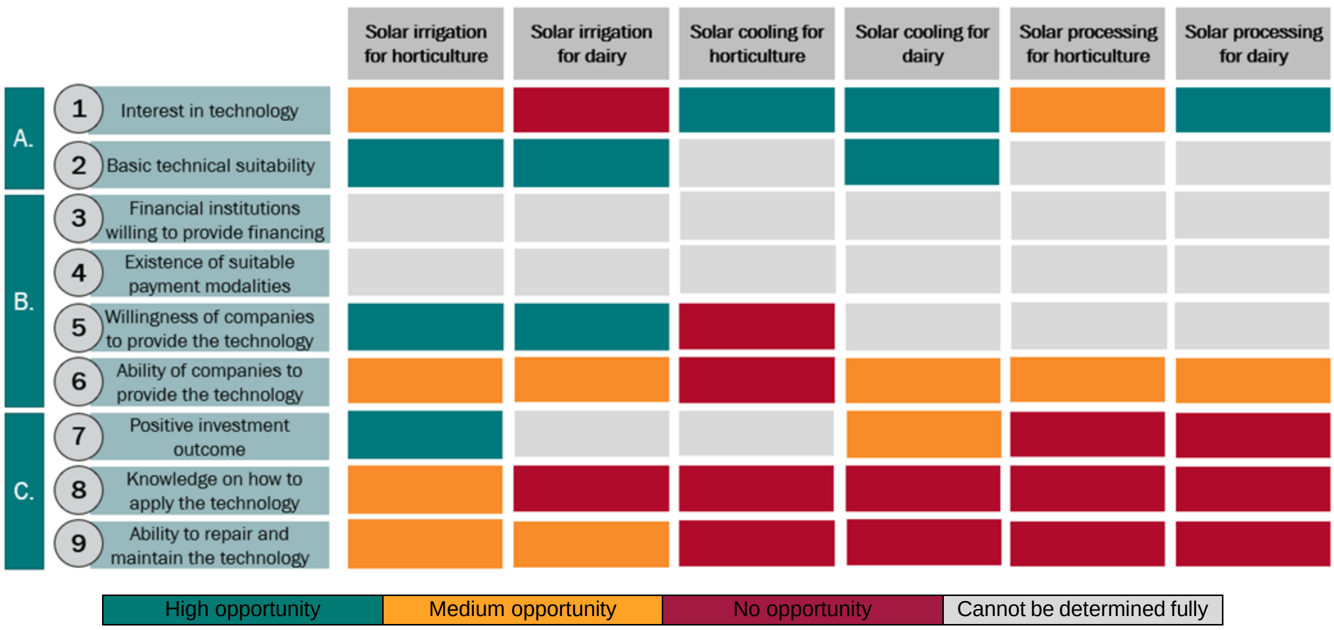
The strength of a business case depends on

i. farmer willingness to invest in technology, (which, in turn requires them to be aware of it, and for it to be technically feasible in the environment in which the farmers operate);

ii. farmers' ability to invest in technology, which requires the willingness and ability of PUE companies to supply it and financial service providers to offer suitable financial modalities; and

iii. farmer ability to derive benefits from the technology, as evidenced by a positive return on investment, knowledge on how to apply it, and ability to repair and maintain it.

Opportunities in the PUE sector can be summarised as follows:



This leads to the proposal to SEFFA to conduct commercial pilots for i) solar powered irrigation for horticulture (as the most established and high-potential PUE technology), ii) solar powered irrigation for forage production, and iii) cooling for dairy through a cooperative model, as well as a technical pilot of processing for chillies, based on indications of demand in the sector. The following table summarises the proposed plan of action for a ~EUR 2 million project, to be distributed across the two years of SEFFA implementation.

		Interest in technology	Financing solutions	Supplier interest	Ability to supply	Investment outcome	Training & maintenance
Commercial pilot	Solar powered irrigation for horticulture Solar powered irrigation for forage	1. Awareness raising campaign focused on demonstration centres, incl. training	2. Cost-sharing solutions and linkage to loans (incl. credit guarantee) 3. Trialling a leasing product	*Interventions not required – suppliers already operating in-country at a profit*	4. Working capital facility for PUE companies	5. Targeted support for farmers to select the right technology for their farm	6. Logistical assistance in finding workforce to be trained as maintenance workers
	Cooling for dairy	7. Identification of cooperatives	*Interventions not required – technology is new to Ethiopia and not yet commercially proven*	8. Procurement of solar/ biogas-powered coolers		9. Market Linkage support	10. Procurement of services for training
Technical pilot	Processing for chillies	11. Identification of solar grinding technology & interested processors		12. Procurement of solar grinding equipment		13. Technical trials of technology	

Kenya

In Kenya, **horticulture** production is estimated to be 8.5 million MT (as of 2019), having grown steadily at 3.36 percent each year since 2014. The value chain is predominantly characterised by smallholder farmers with 1-1.75 hectares of land, selling items to intermediaries, i.e., middle-men including brokers, aggregators, and transporters, who further transport items from farm gates to secondary and primary cities for sales to informal vendors and formal institutional buyers such as hotels, restaurants, and retailers. There are many registered aggregators and exporters that offer extension services to farmers and facilitate Global Good Agriculture Practice (GGAP) certifications for farmers; however, these are emerging trends and there are several constraints in the supply chain that need to be addressed to formalise the system. Some of these constraints include – (a) concentrated access to agriculture inputs to farmers in Central, Western, and southern parts of Eastern and Rift Valley regions in Kenya, (b) very limited efforts for establishing decentralised cold storage infrastructure at aggregation points; farmers practice 'same-day harvest and same-day sales' this leads to farmers as price takers and increases spoilage in the supply chain (c) commercial processing of fruits and vegetables is restricted to large investors.

On the other hand, farmers in the **dairy value chain** are grouped into co-operatives who manage supply chains, market, and sell milk to processors, gather revenue on behalf of farmers and repay them after having deducted their operations costs. As a result, farmers are not always price takers in the value chain but have some capacity to negotiate with the processors (usually medium to large companies). Most farmers supply milk twice a day (5-6 litres produced per day per cattle, of which ½-1 litre is retained for household consumption) which is transported in aluminium milk cans to aggregation centres. Most co-operatives have been supplied with cold storage by the local county governments that helps reduce spoilage. However, there are a couple of co-operatives (through our market research) with no cold storage infrastructure and having farmers to use jerry cans and other forms of transportation methods. Additionally, dairy farmers have invested in chaff cutters to feed their cattle, but often run into high operational costs due to fuel consumption.

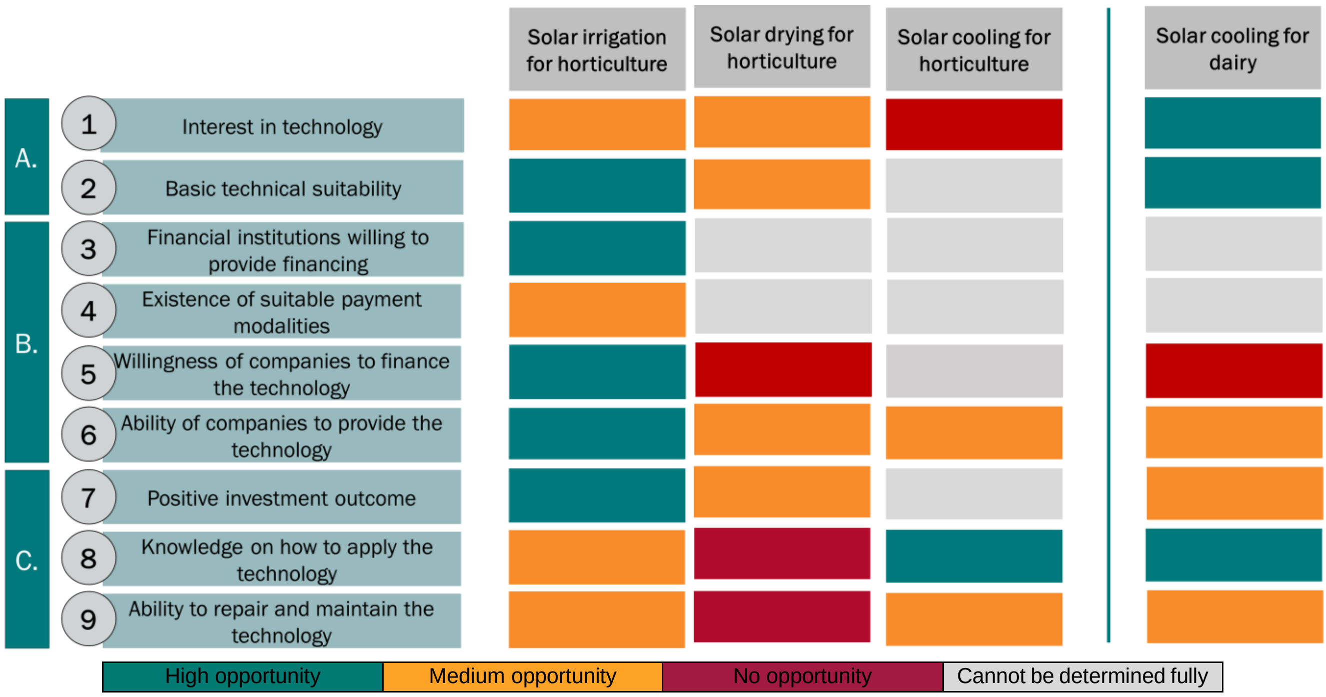
These **constraints offer opportunities to support farmers with relevant PUE technologies** in the two value chains to improve efficiency of production and reduce spoilage. These include:

1. Solar irrigation for horticulture production – 17 percent of the farmers (as per baseline survey) currently use diesel- or petrol-powered water pumps for irrigation. This helps farmers increase productivity but also leads to incurring high operational costs. There is opportunity for farmers to shift to solar-powered technology which would have a rather high initial investment but limited or no operations costs.
2. Renewable energy based drying horticulture technology – to reduce spoilage, a group of farmers can co-invest in renewable energy (mix of biomass and solar) horticulture drying facility to dry fruits and vegetables such as bananas, mangoes, kale, etc. However, the challenges around procuring and investing in such a technology is the initial investment cost, and market opportunities for farmers and co-operatives to sell processed items.
3. Hybrid cold storage for horticulture products – decentralized hybrid cold storage systems, powered by solar and non-renewable forms of energy are available in Kenya. Most of these systems are purchased

by large processors and exporters and attempts are being made to allow farmers and co-operatives to rent spaces using a user-fee model. However, the capacity to invest in such technologies directly by farmers and/or co-operatives does not exist (or is very limited).

4. Chaff cutters and water pumps for dairy farmers – Similar to diesel-or-petrol powered water pumps, chaff cutters used by farmers also consume fuel and lead to high operations costs. Dairy farmers also producing horticulture products, can benefit from solar panel installations and use the energy to operate chaff cutters (to process animal feed) and water pumps to produce animal feed, fruits, and vegetables. Investing in both solar-powered chaff cutter and water pump would increase capital costs for the farmer would have benefits in the long term by significantly reducing operations costs.
5. Solar powered cold chain for dairy farmers – The co-operatives have limited capacity to invest in cold chain infrastructure (transportation plus storage) that is powered through solar energy, especially when the current cold storage operating through grid-based power was provided to them by local county governments. The opportunity here lies in supporting the co-operatives with cold storage to shift from grid-based non-renewable energy supply to solar energy.

Similar to the approach applied in Ethiopia, we analysed the commercial and technical viability of these technologies from the point of view of the investor-user (farmer or a co-operative). The results are summarised below.



Potential quick wins for GIZ and SNV are to support (a) farmers that have already invested in diesel-or-petrol-powered water pump to shift to solar energy-based water pumps and (b) dairy co-operatives with cold storage to switch to solar energy.

Uganda

Uganda is currently the second largest producer of **fresh fruits and vegetables** in Sub-Saharan Africa after Nigeria. The country produces a diverse range of products – cassava, plantains, onions, tomatoes, explants, chillies, oranges, passion fruit, mangoes, spinach, avocadoes, papaya and among others. Between 2016 and 2020, the country also exported fruits and vegetables of USD 96 million per annum to EAC, EU, UK and Middle East.[1] Additionally, Uganda also has several dried fruit exporters exporting dried pineapples to Japan and other countries. The value chain is fragmented comprising of small-scale farmers who sell to transporters (on cycles and bikes) brining items to aggregation or collection centres, from where other intermediaries procure items. There are several challenges around access to seeds and other agriculture inputs.

Dairy sector accounts for 9 percent of the total agriculture GDP of Uganda, dominated by cow milk. The Central region of Uganda has the highest milk productivity (9.8 litres per cow per day). Most of the milk is locally consumed,

[1] International Trade Centre Database for Uganda – HS Code 07 and 08

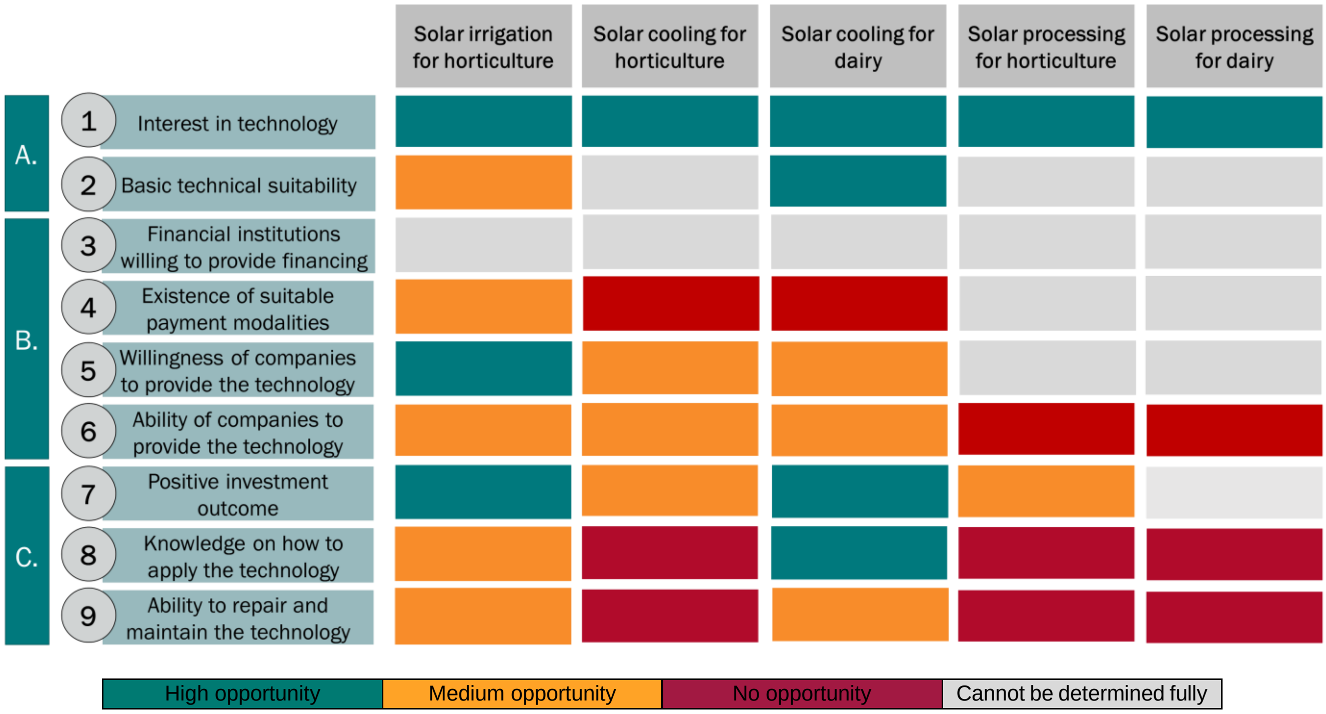
yet the supply does not meet demand. The country also imports milk and other dairy items. Large companies produce pasteurized milk, yoghurt, and cheese, while butter and ghee are also produced by households for self-consumption. The supply chain is structured very similar to that of Kenya where co-operatives support farmers in marketing and sales of milk. However, in Uganda, several farmers (in the districts surveyed for this report) also have large numbers of cows (at least 20 each farmer) and that provides opportunities for farm-level investments.

Farmers in both value chains have several **constraints in terms of use and application of technologies**. Farmers have invested in diesel-or-petrol powered water pumps which has affordable capital costs but high operations costs. There is limited awareness among farmers about PUE technologies and farmers are often discouraged by high capital costs. Additionally, consumer financing is difficult to obtain and pay-as-you-go (PAYG) companies have struggled with repayment rates. Loans from micro-finance institutions, commercial banks have interest rates ranging from 12 – 22 percent and often require collateral. On the supply side, companies are few dependent on imports of items and then assembling the same locally. This also leads to mismatch related to product design and features.

Opportunities for PUE technologies among horticulture and dairy farmers include:

1. Solar powered water pumps – to reduce costs as these are 22-56 percent cheaper than diesel pumps. There is potential to increase uptake of such a technology among farmers.
2. Solar powered cold storage for horticulture – demand is high among co-operatives and local SME processors of fruits (such as juice and dried fruit producers). However, given climatic conditions, having the cold storage entirely powered by solar energy would be challenging and therefore, co-operatives would require hybrid technologies. Additionally, maintaining and managing the system would be another constraint as these co-operatives are new to such infrastructure.
3. Cold storage for dairy – Such technologies are highly commercial for dairy farmers with at least 20-25 cows. Some of such farmers have already invested in such milk coolers (of 150 litres) but face high operations costs. However, the demand is niche as compared to demand for solar powered water pumps.
4. Milk processing – interest among dairy households is significantly high, but these are more for local consumption than for commercial processing. Investing in PUE technologies for processing small scale milk is feasible if the households invest in solar panel technologies to power various other appliances and technologies in the house.
5. Solar powered horticulture processing – there are a few companies (registered, with presence in Kampala) that are producing dried fruits and exporting these to foreign markets. The demand for such items locally is only among the urban areas (particularly consumers purchasing groceries at formal retail channels). There is interest among co-operatives to invest in such technology, but currently, there are no PUE horticulture drying technology suppliers in Uganda. The current exporters have imported technology from Australia. Furthermore, co-operatives require technical knowledge on application of the technology and also require an understanding of the market.

The exhibit below, summarises the opportunities for PUE technologies in Uganda.



Given these opportunities, to increase uptake of such PUE technologies among dairy and horticulture producers and processors, GIZ and SNV need to support stakeholders with:

- Creating awareness
- Designing customised financial products for farmers to invest in solar powered water pumps
- Marketing efforts of PUE technologies
- Policy advocacy to reduce import barriers on import of PUE technology components

It should also be noted that this report contains a detailed section on the proposed Monitoring and Results Measurement Approach for the SEFFA project. The reader is invited to consult Section 6 for the appropriate detail.

Research team

This report is an outcome of a study conducted by the team at Triple Line Consulting (UK) – an international development consultancy specialising in private sector development and with offices in Ethiopia and Kenya. The study was co-financed by IKEA Foundation to assess potential for PUE technologies in Ethiopia, Kenya and Uganda among horticulture and dairy farmers and co-operatives.

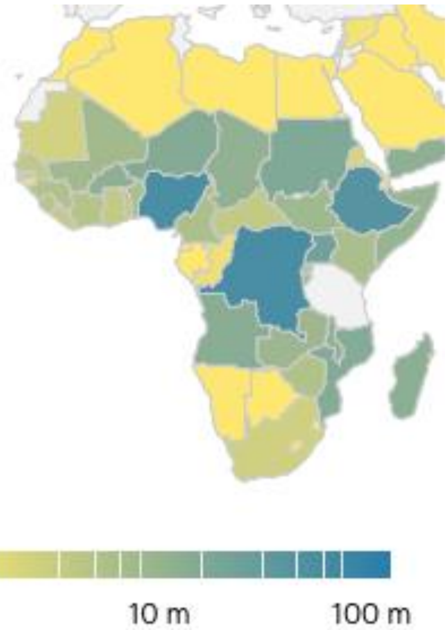
1. Introduction

The following report presents the findings of the baseline study and market assessment of Productive Use of Energy technologies in the horticultural and dairy value chains of Ethiopia, Kenya and Uganda. This section sets out the thematic background, introduces the Sustainable Energy for Smallholder Farmers (SEFFA) project for which this study was carried out, and outlines the objectives and the scope of the research.

1.1 Project Background

According to the International Energy Agency, the number of people without access to electricity in Africa dropped from almost 860 million in 2018 to 770 million in 2019[2], a record low. Nonetheless, the progress achieved is being reversed due to the Covid-19 pandemic: while the number of people without access to electricity had steadily declined since 2013, it is set to increase again in 2020. This will reverse progress achieved and push many countries farther away from achieving the goal of universal access to energy by 2030.

Figure 1: Number of people with no access to electricity



It is against this background that the IKEA Foundation is investing in renewable energy programmes across Africa and Asia through partners working on eradicating poverty through increased access to renewable-based energy solutions. The IKEA Foundation provided funding for Energising Development Programme (EnDev), a multi-donor energy access initiative managed by the Netherlands Enterprise Agency (RVO) and the German International Cooperation Agency (GIZ). Since 2005, EnDev has been working in developing countries to improve energy access for rural households, social infrastructure, and small enterprises.

The Sustainable Energy for Smallholder Farmers in Ethiopia, Kenya and Uganda (SEFFA) project was designed by leveraging close to 20 years of practical experience of the EnDev programme which identified lack of energy access as one of the critical development barriers in rural areas since it undermines agricultural productivity, exacerbates pre- and post-harvest loss, and makes it challenging to store and process produce.

Design and implementation of the SEFFA Program

The SEFFA project aims to **support scalable, innovative business cases using renewable energy services and technologies for irrigation, cooling and drying, as well as a renewable energy hub,** to improve production and livelihoods in the dairy and horticultural value chains across Ethiopia, Kenya and Uganda. The project puts particular emphasis to integrate the involvement of women and youth across the value chain and the agro-business eco-system. The project aims to improve rural livelihoods through the provision of practical and affordable PUE technologies across the value chain. Increased nutrition status, resilience to climate change and reduction in GHG emissions are envisaged to be attributed as a direct outcome from project implementation.

SEFFA is intended to be implemented from 2021 – 2023 over three distinct project phases – (i) inception, (ii) implementation, and (iii) finalization. The inception phase will (i) develop a longlist of innovative business cases for practical PUE technology/ies with the highest potential to improve livelihoods, increase resilience to climate change and contribute to reduction of GHG emissions amongst horticultural and dairy farmers and local businesses in Ethiopia, Kenya and Uganda and (ii) conduct a baseline study to lay the foundation to measure and track performance of the project during the second phase of project. **This has been the focus of the present study**.

[2] https://www.iea.org/reports/sdg7-data-and-projections/access-to-electricity

The second phase of the project - (ii) implementation, will pilot the innovative business cases identified in the first phase of the project. Practical mechanisms for smallholder farmers to access PUE systems and services to address the barriers and challenges identified will also be laid out. In parallel, capacity building and awareness creation activities amongst the smallholder farmers and agro-business eco system across the horticulture and dairy value chains will be conducted. Finally, the lessons learned will be captured to access finance to scale and replicate the project including informing other projects in the third phase of the project – (iii) finalization.

1.2 Scope and Objectives of the Study

This study aimed to inform the design of SEFFA by carrying out the following activities:

1. **Conduct a baseline survey of horticultural and dairy producers** to provide a diagnostic of current production systems and energy needs, develop “Smallholder Data Portraits”, and lay the foundation for measuring and tracking improvements in impact to which the project expects to contribute. The scope of the data collection included the following geographical areas:
    - Ethiopia - 4 regions (Amhara, Oromia, SNNPR & Sidama)
    - Kenya - 3 provinces (Central, Rift Valley (Central and Lower parts) and Eastern (Central and Lower parts)
    - Uganda - 3 regions (Southwestern, Eastern and Central)

Our approach towards selecting sub-locations within each country and the sampling strategy for surveying smallholder farmers in each has been provided in detail in the following section.

2. **Conduct a market assessment** to determine the renewable energy solutions with the greatest potential for improving livelihoods and nutritional requirements of farmers, increasing resilience to climate change and contributing to GHG emissions reduction among horticultural and dairy farmers and local businesses.
3. **Develop business cases** for each country such that these cases will be commercially viable and will deliver impact, in the area of sustainable irrigation, cooling and drying systems,
4. **Establish key indicators** to measure project performance during the piloting phase.

1.3 Structure of this report

This report is structured as follows:

- Section 2 provides a brief outline of the prioritisation and the data collection process that has served as the basis for this study;
- Section 3 presents the detailed market assessment findings for Ethiopia, Section 4 for Kenya and Section 5 for Uganda;
- Section 6 presents the results measurement framework, including the baseline indicators and proposed targets over the 3 years of project implementation.

It should be noted that smallholder farmer data portraits in PowerPoint, the bibliography, and the baseline survey datasets for all three countries are submitted separately and in addition to this report.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2. Prioritisation and data collection

A detailed methodology has been presented in the preceding reports, and Annex 1 provides the research framework for this assignment. The purpose of this section, however, is to clearly set out where and how the data that is used as the basis for the analysis in this report was collected.

2.1 Prioritisation of districts

In order to focus the research while providing a representative picture of horticultural and dairy value chain dynamics as well as PUE technology provision in each country, a preliminary assessment was conducted to prioritise geographic locations. As is demonstrated in the following subsections, the primary shortlisting of locations, in all three countries, was based on indicators relating to the horticulture and dairy sectors. The approach to the final selection, however, depended on the level of maturity of the PUE sector in a given country, with Ethiopia representing a nascent market, Uganda – a market with some experience of PUE technology application, and Kenya – the most advanced of the target countries.

2.1.1 Ethiopia

The prioritisation analysis in Ethiopia started with an examination of zone-level data on:

- Number of smallholders producing horticultural crops
- Cultivated area dedicated to horticulture
- Volume of annual horticultural production
- Number of cattle herders
- Number of dairy cows
- Number of breeding cows

Once the highest-potential zones were selected on this basis, target woredas in each zone were identified based on whether they were:

- Part of the Agricultural Commercialisation Cluster initiative of the Ethiopian Agricultural Transformation Agency;
- Priority woredas for SNV (for both horticulture and dairy);
- Priority woredas for GIZ (for both horticulture and dairy)

This led to the final selection presented below:

Table 1: Priority woredas for Ethiopia

Region	Zone	Woreda
Amhara	South Gondar	Fogera
	West Gojjam	Bahir Dar Zuria
		North Mecha
Oromia	East Shewa	Dugda
		Lume
	South-West Shewa	Woliso
Sidama	Sidama	Dale

		Shebedino
		Wondo Genet
SNNP	Guraghe	Mareko
		Meskan
	Hadiya	Lemo

2.1.2 Kenya

Likewise, in Kenya, we applied a similar approach, but included two steps. In the first step, we identified the following set of criteria against which we shortlisted counties for the baseline survey and market research:

For fruits and vegetables:

- Number of smallholders producing horticulture crops
- Cultivated area dedicated to horticulture
- Volume of annual production
- Presence of processors
- Availability of irrigation channels

For livestock:

- Number of cattle herders
- Number of dairy cows
- Number of breeding cows

In the second step, we validated the shortlisted counties through preliminary consultations with PUE companies. We assessed following factors to gauge interest from these companies in the shortlisted counties:

- Presence of PUE companies in the county to sell products such as water pumps and cold storage
- Marketing efforts and existing penetration of these companies among smallholder farmer groups
- Future expansion plans (geographically within Kenya and among horticulture and dairy farmers)

Based on this assessment, the shortlisted counties were –

Eastern Region	Rift Valley Region	Central Region
Machakos	Kajiado	Kirinyaga
Makueni		Muranga
Muranga		

2.1.3 Uganda

In Uganda, we analysed data against following criteria for each district –

1. Number of horticulture producers
2. Number of households with livestock
3. Number of cattle
4. Existence of a horticulture or dairy processor in the district or nearby (within 40 kilometres)

These factors supported the demand for PUE technologies, whereas we applied additional criteria such as existence of water source for irrigation, presence of PUE technology companies, prior or ongoing program experience of SNV and GIZ within the district to evaluate further feasibility of intervening in the district.

Based on this assessment, we prioritised following districts in Uganda –

1. Luwero, Central Region
2. Mpigi, Central Region
3. Mukono, Central Region
4. Iganga, Eastern Region

5. Soroti, Eastern Region
6. Isingiro, South West Region
7. Mbarara, South West Region
8. Kiruhura, South West Region

2.2 Baseline survey

A baseline survey of horticultural and dairy producers (570 in each country) was carried out in the target districts/counties in August 2021. The data obtained during this survey served both to develop the smallholder data portraits and to highlight the key trends for the market assessment analysis. The following tables provide the distribution of survey respondents by district and by value chain.

Table 2: Baseline Survey Respondents in Ethiopia

	Amhara	Oromia	Sidama	SNNP	Total
Horticulture	5	36	64	20	**125**
Dairy	31	16	0	11	**58**
Both	110	65	126	87	**388**
Total	**146**	**117**	**190**	**118**	**571**

Table 3: Baseline survey respondents in Kenya

	Kajiado	Kirinyaga	Machakos	Makueni	Meru	Muranga	Total
Horticulture	40	22	35	21	45	21	**184**
Dairy	58	29	84	68	84	67	**390**
Both		1	1	1	1	1	**5**
Total	**98**	**52**	**120**	**90**	**130**	**89**	**579**

Table 4: Baseline survey respondents in Uganda

	Central			Eastern		South West			Total
	Luwero	Mpigi	Mukono	Iganga	Soroti	Isingiro	Kiruhura	Mbarara	
Horticulture	31	20	47	60	28	1	2	2	**191**
Dairy	0	0	1	0	0	3	0	2	**6**
Both	45	24	53	31	23	75	52	79	**382**
Total	**76**	**44**	**101**	**91**	**51**	**79**	**54**	**83**	**579**

2.3 Key Informant Interviews and Focus Group Discussions

In addition to the baseline survey, primary data collection efforts also involved key informant interviews with key stakeholders in the sector, including producers, processors, PUE technology suppliers, government and donor projects, regulators, etc. A series of focus group discussions was held with smallholder farmers in both horticultural and dairy value chains to investigate in more detail the priorities, concerns, reasons for certain production and marketing decisions, intra-household nutrition patterns, attitudes towards PUE technologies, and similar topics. The tables below present the breakdown of interviewees and focus group discussions by type and by district/county in each country.

Table 4: Key Informant Interviews and Focus Group Discussions in Ethiopia

Region	Amhara	Oromia	Sidama	SNNP
# of Focus Group Discussions	5	7	4	7
# of Key Informant Interviews Facilitated	3 KIIs, Bank and Microfinance 3 KIIs, Livestock, Agriculture and Energy Offices 3 KIIs, Dairy and Horticulture Unions 2 KIIs, Energy Departments of Regional Offices 1 KII with Agribusiness 1 KII with an Animal feed provider 3 KIIs with solar technology distributors	2 KIIs with processors 2 KIIs with cooperatives 3 KIIs with Dairy and Horticulture Unions 5 KIIs with Agriculture, Animal and Fish resource offices 3 KIIs with Financial Service Providers 1 KII with Solar Panel distributor	3 KIIs with MFIs 3 KIIs with Horticulture/ Agriculture government offices 2 KIIs with Dairy offices 1 KII with solar equipment distributor 1 KII with animal feed provider	3 KIIs with Agriculture and Natural Resource Offices 3 KIIs with producer cooperatives 2 KIIs with Financial Service Providers 2 KIIs with regional representatives on Dairy and Horticulture 1 KII with Animal and Fish Development Office

Figure 2: Stakeholders consulted in Kenya

County	FGDs	KIIs
Kajiado	1 horticulture co-operative 2 dairy co-operatives	meetings with government officers
Kirinyaga	2 horticulture co-operatives 2 dairy co-operatives	
Machakos	1 horticulture co-operative 1 dairy co-operative	1 distributor
Makueni	1 horticulture co-operative 1 dairy co-operative	1 financier, 1 enabler, meetings with government officers
Meru	2 horticulture co-operatives 2 dairy co-operatives	1 financier, 1 enabler, meetings with government officers
Muranga	1 horticulture co-operative 1 dairy co-operative	1 enabler, meetings with government officers

Federal-level interviews / meetings:

1. Financiers – Equity Bank, Agriculture Finance Corporation, Musoni MFI, Faulu MFI, DigiFarm, Krep Fedha Services
2. PUE companies – Davis & Shirtliff, SunCulture, Savanah Circuit, Bio Afriq, Chloride Exide, Solar Gen, Grain Pro Bubble Dryer, DeKUT
3. Others – VegPro (Exporter), Kenya Renewable Energy Association (KEREA)

Figure 3: Stakeholders consulted in Uganda

Region	Central	Eastern	South West
# of Focus Group Discussions	3	2	3
Key Informant Interviews	3 KII with District Production Office KII with Ministry of Energy and Mineral Development KII with financial institution (Opportunity Bank) 2 KII with vegetable and fruits exporter and processor (**SULMA Foods**, RECO industries) KII with processing farmer group (**Bulan Tuklerewamu**) KII with donor programme (GIZ People's Energy Project, **SNV**) KII with solar energy provider (Tulima Solar)	2 KII with District Production Office 2 KII with water engineers KII with vegetable and fruits exporter and processor (**Soroti Fruit Factory**) KII with solar energy provider (David & Shirtliff) KII with USAID	3 KII with District Production Office (Isingiro, Kiruhura, Mbarara) KII with Dairy Development Authority (Mbarara) 3 KII with financial institutions (Centenary Bank, **EBO SACCO**, **Rushere SACCO**) KII with solar energy provider (Solar Now)
Meetings in Kampala	USAID, Dairy Development Authority, Pearl Dairies, Ministry of Agriculture		

2.4 Validation workshops

Lastly, validation workshops with c.50 key stakeholders were held in each country (in person in Ethiopia and virtually in Kenya and Uganda). These workshops presented the key findings of the research, asked participants to engage in identifying and prioritising key constraints, provided an opportunity for participants to ask questions and challenge the material, and offered a forum to share best practice for appropriate solutions. Annex 2 contains the list of participants at each workshop.

3. Ethiopia

3.1 Introduction to the target sectors

The following section provides an overview, including key statistics, of the production patterns, nutrition and consumption practices, the structure of the value chain, the differing roles for men and women, and the key constraints limiting productivity, market reach and farmer incomes.

3.1.1 Horticulture

In recognition of its beneficial impact on farmer incomes, nutrition and potential foreign exchange earnings, the **Ethiopian horticultural subsector has been growing in importance**, with both production and cultivated area increasing at a steady pace over the past 5 years (see figure 5 below). Moreover, given the fact that the growth of production has overtaken the growth of the cultivated area, it can be concluded that **productivity has been increasing**, as well – at least at the aggregate, national level. According to the latest statistics, the subsector currently represents ~ 23% of national crop production volume but only 5% of national cultivated area[3].

This is, at least partly, due to the **greater prominence of horticulture in national agricultural strategy and its implementation**; for instance, horticulture is one of the priority subsectors for one of the flagship government projects in the agricultural sector, the Agricultural Commercialisation Clusters. The ACCs adopt a market-driven, whole-of-value-chain approach to help smallholder farmers increase their productivity and improve their market linkages to achieve higher incomes. Within the horticulture ACC woredas, the priority commodities are tomato, onion, avocado, banana and mango. It should, however, be noted that **the many and varied agroclimatic zones and soil types allow for a considerable diversity of production**, with potatoes, sweet potatoes, taro, chillies, garlic lettuce, head cabbage, green peppers, beetroot, carrots, guava, lemons, oranges, papaya and pineapples also grown.

Lastly, the potential linkages between horticultural production and the growth of Integrated Agro-Industrial Parks (a key strategic focus) are frequently emphasised by policymakers and practitioners as a likely mutually reinforcing development path for Ethiopian agriculture which lends greater importance to the fruit and vegetable subsector.

Fresh fruit and vegetables are still relative luxuries for the average Ethiopian consumer, although demand is expected to grow as incomes rise and urbanisation continues. According to CSA, the percentage of nationwide horticultural production consumed by smallholder farmers at home ranges from 33% (e.g. lemons) to 79% (e.g. *gomen* cabbage), depending on the crop. Average marketable surplus (i.e. the proportion available to consumers outside of production areas) is c. 20-25%, with producers distinguishing between “market quality” and domestic consumption varieties. Overall, the consumption of fruit and vegetables is very low – according to the estimates of a 2018 study, only 1.5% of Ethiopians consume the WHO-recommended amount of 5 servings a day, although women have a slightly higher consumption rate (1.8%) than men (1.2%). An IFPRI study indicates that **affordability is a major factor** – the average Ethiopian household would have to allocate at least 11% of their income to meet the WHO-determined nutritional requirement for fruit and vegetable consumption, rising to 27% for the households in the poorest quintile.

[3] Agricultural Sample Surveys, Central Statistics Agency of Ethiopia

Figure 4: Key Statistics on the Ethiopian horticultural sector

Figure 5: Average daily consumption of fruit and vegetables

	Vegetables	Fruit
Rural	0.7 servings	0.4 servings
Urban	0.5 servings	0.3 servings

In terms of the **value chain structure**, the Ethiopian horticultural sector comprises small-scale actors, cooperatives, and a limited number of commercial businesses, as well as donor and government programs. The role of women differs depending on the value chain function, although the smaller, more informal components tend to be women-led. There are clearly identifiable and well-documented weaknesses at each stage of the value chain which, jointly, contribute to low productivity and suboptimal earnings for the smallholder farmers who make up the vast majority of national horticultural production. Table 6 below summarises the key features of horticultural value chains at national level.

Table 5: Key characteristics of horticultural value chains

Value Chain Function	withKey Players	Gender Roles	Key weaknesses
Input supply	• Research institutes and community-based seed multiplication • Private small-scale agri-input suppliers (including equipment providers) • Some donor programmes work to improve access to improved vegetable seeds, either through supporting agro-dealers (SNV) or through direct distribution (CARE, CRS)	**Men's responsibilities** typically include: • the use of diesel irrigation pumps • Purchase of seeds and other inputs • Ownership of agro-input businesses **Women's responsibilities** typically include the preparation of compost. Both men and women obtain water using traditional methods.	• Limited accessibility and high cost of improved horticulture seed and seedlings and prevalence of low-quality, uncertified and/or expired inputs. • Lack of preparedness on the farmers' part to invest in improved inputs due to limited perceived earning potential, lack of detailed knowledge, and lack of access to finance.

Production	• Mainly smallholder-led, as part of mixed cropping systems • Commercial production is limited – only 3% of national horticultural production comes from larger, commercial farms (CSA) • Cooperative membership is widespread. Examples of strong cooperatives and unions include Meki Batu (Oromia), Gamo Gofa (SNNP), Lante Cooperative (SNNP), etc.	**Men's responsibilities** typically include land preparation, weeding, and harvesting, with women playing a more minor role in those activities. **Women's responsibilities** typically include the watering of plants using traditional/ low-tech methods, as well as preparing food for the farm workers. Women also tend to be preferred as casual workers on commercial farms due to the perception that they take greater care with the sensitive produce	• There is little coordination in terms of which areas are planting which crops, and no commonly used agricultural calendar. This leads to surges in supply for a particular vegetable, followed by price crashes. • Due to a general lack of storage facilities, the crops are often left on the field for longer and only harvested once a buyer has been found – this, in itself, carries a risk of spoilage, as well as theft. • High incidence of **pests** and **disease**, with limited capacity to prevent those
Processing	• Processing of tomatoes and tropical fruit is dominated by commercial enterprises (e.g. Merti, Africa Juice, ET Fruit) • There are some small-scale businesses receiving donor support, e.g. Anjonus Banana Processing, Duwame Bakery, etc. • Small-scale co-op-centred initiatives (e.g. Agrobic) have not been successful	**Men** typically occupy senior positions in processing businesses. Both **men** and **women** are processing factory employees.	Past initiatives for on-farm and cooperative-based processing (e.g. tomato paste, jams, etc.) have faced prohibitive obstacles in terms of **access to suitable packaging** (which must be imported at significant cost) and **limited local markets**, willing to pay a premium for processed goods.
Aggregation	• Unions and cooperatives play an important role • However, this function is still dominated by farm-gate brokers who act as intermediaries	**Men** typically occupy senior positions in cooperatives and unions, as well as act as brokers and farmgate traders.	• Adequate transportation is rarely available at farmer level: most first-mile deliveries are made on a donkey cart. This limits marketing options. • Due to lack of storage and limited marketing opportunities, marketing is dominated by brokers who purchase produce at the farmgate, collude with each other, and push down prices. In addition, brokers use the poor road quality to justify driving prices down even further. • Alternatively, farmers can take their produce to the market themselves, but this typically involves staying in the market locality for longer than a day to be able to sell the entire volume – which is accompanied by additional expenses and perishability risks.
Marketing	• Wholesalers and small-scale retailers dominate domestic trade • Ethiopian Horticulture Producers Exporters Association promotes exports and provides advocacy and capacity building services for the sector.	**Women** are typically responsible for selling small quantities in retail markets. **Men** are typically responsible for large-scale sales to bigger markets/ wholesalers.	

			• Some supply chains have been interrupted by conflict (particularly in the Amhara region)

In addition to these core value chain actors, the horticultural sector also involves the presence of i) government programmes, such as the Agricultural Commercialisation Clusters initiative, ii) extension services from Woreda Agriculture and Natural Resource offices who are responsible for introducing new technologies and providing training and extension services, and iii) donor programming, such as SNV's HORTI-LIFE, FAO/ World Bank's Agricultural Growth Programme, and USAID/ MASHAV's Smallholder Horticulture Project.

Box 1: Prioritisation of horticultural value chain constraints: feedback from the validation workshop

Workshop participants noted many of the commonly known weaknesses in the horticultural subsector but paid particular attention to the lack of coordination and tailoring. Emphasis was placed on ensuring the agricultural calendar that is best suited to a particular area is adhered to, and that different water lifting technologies and technology packages are carefully matched to the contexts of particular farms. Participants also addressed cross-cutting concerns, such as access to finance, lack of standardisation of products, and the need for adequate road and water infrastructure, although recognised those as being less feasible to address. Constraints relating to farmers' abilities to earn higher revenue (through access to improved varieties, premium prices, value addition, etc) were discussed but were largely considered to not be the key limiting constraints.

The lessons for the SEFFA project from this exercise include the need to avoid "one size fits all" solutions and facilitate tailored approaches, but also the importance of emphasising the role market linkages for ensuring longer-term commercial sustainability of technology sales in a context where production-side constraints are seen as more important.

3.1.2 Dairy

Dairy production in Ethiopia is a significant and growing industry, encompassing milk derived from cows, goats and camels. While the relative significance of each animal follows geographical patterns and largely depends on the region, **cows are by far the most important animals for dairy production in the target regions** of Amhara, Oromia, SNNP and Sidama (see figure 6), jointly representing 86% of the national dairy cow population. Cow milk is, therefore, the logical focus of the analysis in this report, although goat milk is also considered, where relevant. At national level, of Ethiopia's 70-million cattle population, only 11% are dairy cattle, representing a decrease compared to 5 years ago. However, both the dairy cow population and the production of cow milk have been growing in recent years, and the faster growth of the latter indicates productivity improvements.

Small cattle holdings represent the majority, with **most households own between 1 and 4 cows**. The average number of cows per household is slightly lower in Sidama compared to the other target regions, although the difference is not significant. It is also important to note that cow ownership is widespread but not universal, with c.20-25% households reporting that they do not own any cows.

According to CSA, the **% of nationwide dairy production consumed by smallholder farmers at home ranges from ~50% for milk to 75% for processed goods.** Milk that isn't sold is consumed at home – although it is less fresh and requires further processing to extend the shelf life. Dairy production enables over 80% of farmers to add milk to their diets – although, given the lack of storage, this is limited to the milking seasons. However, this balance between sale and domestic consumption at farmer level leaves a relatively low proportion for sale to those who do not have their own livestock holding – which (along with low productivity) helps to explain why, across Ethiopia, the **average consumption of milk is at 19 litres per person per year,** compared to the African average of c.40 litres.

As in the case of fresh fruit and vegetables, incomes have a significant effect on consumption levels, with dairy consumption of the richest household quintile estimated to be five times that of the poorest. Nonetheless, the benefits of milk and dairy products, particularly for children, the infirm and the elderly, are widely known. As such, while the whole family is typically able to drink milk, children tend to be given dairy products first (or, in some communities, after the father of the household). Moreover, annual quantities per adult equivalent have increased by 31% between 2005 and 2016, and the 2015 Livestock Master Plan forecasts a supply shortfall of 29% relative to demand by 2027. This growing demand and the gradual, early-stage developments of modern dairy chains are some of the factors credited with driving increases in production and productivity in the country.[4]

Figure 6: Key statistics on the Ethiopian dairy sector

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[4] https://onlinelibrary.wiley.com/doi/full/10.1111/agec.12641

An important feature of the dairy subsector is the set of **religious restrictions that influence dairy consumption**. For instance, Orthodox Christians (who represent 83% of the population in Amhara, 30% in Oromia, and 20% of SNNP and Sidama, according to the latest census), abstain from animal products ("fast") on Wednesdays and Fridays, as well as during several major fasts (Abiy Tsom, Nenewe, Hidar, Filseta), lasting from two weeks to two months. However, children and the infirm are typically exempt from these restrictions.

In terms of the **value chain structure,** there is a considerable difference between modern, commercial dairy value chains and the much more widespread smallholder dairy production, and the sector's weaknesses, from input supply to marketing, can largely be explained by the difference in access to resources and premium markets. The dairy sector overall has clearly delineated roles for women – arguably, to a greater extent than other agricultural subsectors. Table 7 presents the overview by value chain function, with elements predominantly relating to commercial dairy production indicated in italics.

Table 6: Key characteristics of dairy value chains

Value Chain Function	Key Players	Gender Roles	Key weaknesses
Input supply	• Private-sector fodder suppliers • Donor initiatives (e.g. SNV, USAID/ Feed the Future supplying animal forage seed) • *Equipment & machinery suppliers* • *Artificial insemination providers* • *Veterinary services*	**Men's responsibilities** are typically limited to purchasing the feed. **Women's responsibilities** are more extensive and include mixing the feed, cleaning and feeding the animals, as well as looking after the young	• High-quality fodder is very expensive and has a direct effect on the quality of milk • Shortage of surface water, requiring long journeys • Shortage, high price and limited quality of veterinary services and vaccines
Production	• Smallholder farmers produce 87-97% of the national volume of milk • At smallholder level, most households milk twice a	Dairy production is overwhelmingly seen as the responsibility of the **women** in the household, strongly tied to cultural norms.	• Lack of availability/ affordability of improved/ hybrid breeds with better productivity

Value Chain Function	Key Players	Gender Roles	Key weaknesses
	day – the "morning milk" is sold, and the "evening milk" is kept for household consumption • *The (limited number of) commercial producers with > 25 cows are concentrated in the vicinity of Addis Ababa*	Example quote from focus group discussions: "It is not comfortable for men to obtain or process the milk like women do". **Men's responsibilities** are typically limited to the purchase of improved breeds which are expected to offer higher milk yields.	• Lack of storage limits the marketing window for milk • Lack of targeted support from extension workers and other government bodies for private dairy producers • Poor animal husbandry practices, resulting from high input costs and lack of training
Processing	• Artisanal processing involves churning milk to create butter, cheese and yoghurt • *Commercial processing is undertaken by c. 25 enterprises, 4 of which supply 75% of all pasteurised dairy products.*	At household level, **women** are typically responsible for undertaking artisanal processing using traditional methods. *Senior positions in formal processing companies are typically occupied by* ***men.***	• Limited number and capacity of formal processors • Poor linkages from producers to agro-processors • Shortage and affordability of machinery for domestic processing • Low profitability of processed milk for artisanal producers
Aggregation	• 119 Dairy farmer unions with membership ranging from 50-300 members (approx.) • Cooperatives play an important role in aggregation for their members • However, farmgate collectors remain very common	**Women's responsibilities** typically involve delivering the milk to the cooperative collection centres. Brokers who purchase produce at the farmgate tend to be **men**	• Marketing is dominated by brokers who purchase produce at the farmgate and tend to offer low prices • Shortage of appropriate packaging, transportation and storage to minimise quality loss and spoilage during aggregation • Lack of business orientation at dairy cooperatives
Marketing	• Local retail trade is primarily focused on "traditional" churned milk. Pasteurised milk is primarily an urban product. • ~70% of production passes through informal channels • *Supermarkets and formal retail are the main marketing channels in urban areas*	**Men** are typically responsible for delivering the milk directly to the market after the morning and evening milking, as well as for the sale of dairy animals on the market. **Women** typically take on the sale of milk and traditionally processed dairy products in small, local markets. As interviewees in the sector have emphasised, "the woman has no obligation to tell her husband about the minor income from small sales which can cover household expenses like salt and oil."	• **Peaks and troughs in demand** due to the pattern of Ethiopian Orthodox fasting seasons • The premium that consumers are willing to pay for quality is **not commensurate with the extra price of inputs** to achieve that quality

Box 2: Prioritisation of dairy value chain constraints: feedback from the validation workshop

The workshop participants identified a broad range of constraints across the dairy value chains, notably consigning to the “low impact/ high feasibility” category most issues where efficient use of PUE technology might provide viable solutions. This included lack of hygiene management (for which biogas-fuelled pasteurisation could be an appropriate response), lack of processing, and lack of cold storage. However, while the high potential for irrigation technology was recognised, the biggest constraints identified by the stakeholders attending the workshop overwhelmingly related to production and productivity – inefficient mixing of feed, lack of hydroponic systems for fodder production, lack of quality control of feed mixes, etc. The attendants also expressed a certain degree of pessimism about poor market linkages, noting that the prevalence of informal markets had a high impact on the sector but was difficult to address.

The conclusions for the SEFFA project resemble the lessons learned from the discussions on the horticultural value chains. PUE technologies clearly have the potential to contribute to the solution to some of the broadly acknowledged weaknesses in the dairy sector but, just as in the case of horticulture, it is important to address the market linkage aspect in order to ensure longer-term commercial sustainability of technology sales in a context where production-side constraints are seen as more important.

3.1.3 The role of youth in the horticultural and dairy sectors

Youth participation in horticultural and dairy value chains is not clearly defined; however, some common trends have been identified by interviewees. Interest in smallholder horticultural and/or dairy production, or any elements of production that can be considered “traditional” (e.g. at-home dairy processing) appears to be limited, with youths drawn more towards off-farm employment, more established cash crops, more commercial activities, etc. The interest, therefore, lies more in activities such as ox fattening and livestock breeding, rather than dairy production. Some initiatives to organise youth workers in an association to process milk are reported to have failed because of this. For those who are interested in the target sectors, despite these prevailing attitudes, the major obstacle to participation is lack of access to finance – particularly given the frequent requirement for collateral, the most common form of which is land ownership.

In terms of the **suitability of the youth to functions within the value chains**, since the (generalised) common characteristic of rural youth is better physical fitness and strength, the activities most commonly cited by interviewees as being undertaken by youth in the sector are farm labour, pesticide application, and loading and unloading of produce at collection points and marketplaces. However, the generally higher education rates present additional opportunities for youth to take over more business-orientated and management-related functions.

Existing entry points for interventions to support youth include youth-specific associations, particularly in the horticulture sector, where the youth feel a greater sense of ownership over decision-making, crop management, marketing, etc.

3.2 PUE technology solutions currently in use in Ethiopia

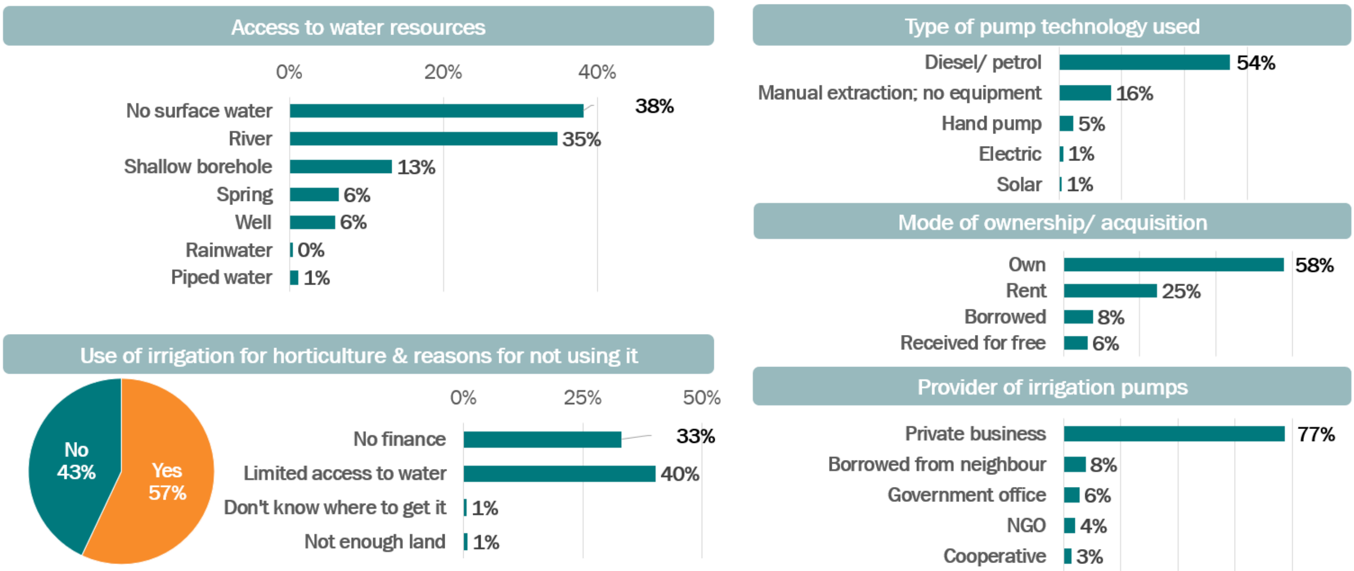
The following section takes each of the prioritised PUE technologies – irrigation, cooling and processing – in turn and outlines the current patterns of use, the prevailing practices where PUE technologies are not available or not in use, and the structure of PUE technology supply.

3.2.1 Solar-powered irrigation

While the solar irrigation sector is in the early stages of its development, there is ample evidence that horticultural producers, in particular, recognise the importance of irrigation and are willing to invest in it. As figure 7 demonstrates, the findings from the baseline survey indicate that, despite the significant proportion of farmers who do not have ready access to water, the majority (57%) of horticultural producers make the effort to irrigate their crops. In contrast, only 3% of dairy producers reported the use of irrigation pumps to water their animals – 2% using solar pumps and 1% using a diesel pumps. Overall, diesel/ petrol pumps are, by far, the most common (responsible for 54% of the 57% of farmers using irrigation), and outright purchases from private business are the most popular form of use. The reported price for diesel pumps ranges from c. ETB 12,000 to ETB 25,000, depending on capacity and accessories, although prices have been rising in recent years due to inflation. Government offices and NGOs still play a role in facilitating access to irrigation (especially when it comes to solar irrigation, as will be discussed in more detail below), and contribute to the distribution of free water pumps, but that role is relatively minor.

The supply of solar irrigation pumps is largely driven by the public sector; however, private firms are increasingly attracted to the business. The importers are usually based in Addis Ababa and include companies such as ACME, Adams, Davies and Shirtliff, Emu general PLC, Fosera, Key engineering, Lydetco PLC, Mathy, Solar Development PLC, Solar Village, Solar Women, and Suntransfer. Distributors include local branches and representations of importer companies and wholesaler sellers of a range of agricultural inputs (which can include irrigation pumps), although the vast majority of solar pumps are acquired by donors, NGOs and government offices and distributed to farmers participating in particular programmes, most often for a heavily subsidised price. In addition, the public sector actors also play an important role in notifying the farmers when the pumps are available and the benefits of using them. Cash at the point of purchase (to the company) is, therefore, the only payment mechanism that is currently used for solar pumps.

Figure 7: Key findings on irrigation use among smallholder farmers



The example products and services provided by existing solar pump suppliers, as outlined in table 7 below demonstrate three key trends in the market for solar irrigation equipment in Ethiopia:

1. The **current demand for solar pumps is very low** – of the selected companies, the highest annual sales are reported by Solar Village, which have only reached 361 units;
2. Nonetheless, **demand is growing rapidly** – all the companies consulted reported exponential growth in units sold over the past 3-5 years;
3. Despite the limited scale, **the market is already quite diverse**, with irrigation pumps with different water extraction capacity, different combinations of accessories, and different support packages available at different price points. This reflects the wide variety of terrain, water availability and water requirements among solar irrigation customers.

It should, however, be noted that there is no direct correlation in the examples given between extraction capacity, cost, and land size suitability – all these metrics have been provided by the companies based on their experience on the ground, and conceal substantial differentiation in crops produced by the customers, landscape, gradient, accessory packages, etc. It is therefore difficult to generalise about the suitability or adequate cost of given irrigation solutions across smallholder contexts in the target regions.

Table 7: Example solar pump product offerings

	ACME Engineering & Trading PLC	Solar Village Ethiopia	YASART Engineering PLC	Davis & Shirtliff
Current solar irrigation offering	• Small-scale pump, suitable for <1.5ha, 1-3 litres/sec, @ ETB 420,000 • Medium-scale pump, suitable for 1.5-5ha, 15 litres/sec, @ < ETB 1.2M • Larger pumps, suitable for > 5ha, 15-17 litres/sec, @ < ETB 1.2M	• Small-scale pumps, suitable for <2.5ha. • Capacity varies: • 8 litres/sec (300W + battery, light, charger), @ ETB 72,000 • 8 litres/sec (600W, no accessories), @ ETB 68,000 • 3 litres/sec (160W, portable, with batteries), @ ETB 70,000	• Small-scale solar irrigation, shallow well or surface water • Suitable for <1ha, 8 litres/sec, @ ETB 140,000 • Suitable for <2ha, 16 litres/sec, @ ETB 230,000	• Small-scale, <5.5kW, a 4kW pump @ ETB 950,000 • Medium-scale, 5.5 – 18kW, a 11kW pump @ ETB 1.7m (~75% of sales) • Large-scale, >18kW
Sales	Started this year, 14 units sold (mainly small-scale irrigation)	361 units this year, 443 units since the company was founded in 2018	80 units this year, up from 80 units over the past 4 years	23 units this year, 90 units over the past 4 years
Other products offered	Potable water irrigation pumps, wastewater treatment pumps, large-scale irrigation systems, generators, transformers, etc. The company is about to add solar processing (grain milling) to its range.	n/a	The company is currently trialling solar crop processing for cereals.	Small-scale coffee processing machinery, solar pumps for off-farm activities
Clients	• Government organisations (Regional Water and Irrigation Bureaus) • NGOs (NRC, COOPI, Norwegian Church Aid) • Direct sales to end customers are not common – donors/ gov't act as intermediaries	• Farmers with less than 2.5 ha, producing cash crops • Government organisations (regional bureaus, research centres, primarily in Amhara and Oromia) • NGOs (e.g. CARE, ICRC, IRC) • ATA (regional and federal offices)	• Government Organisations (regional Water and Energy Bureaus) • Research Centres (e.g. Harbu) • ATA • NGOs and donors (Catholic Relief, World Vision, USAID) • Direct sales to end users are rare	• Government Organisations (regional Water and Energy offices) • NGOs (Farm Africa, REST, CARE, German Agro Action) • Almost no products are sold to farmers directly
Service Offering	• After-sales service • Installation • Maintenance • Repairs	• Remote monitoring • Back-up advisory service • 5 youth associations at woreda level have been trained in operational and maintenance service provision	• Operations manual in Amharic, Oromifa and Tigrinya • After-sales service • Installation • Maintenance • Repairs	• Price includes transport in the radius of 500km, panel, pump, and installation • Maintenance and repairs service also provided

		• Operations manual in Amharic		
Sourcing	Nastec (Italy)	• Sunculture (Kenya) • Planning to start in-country assembly in the near future	• Europe • Turkey (pumps) • China (solar panels) • India (cables)	• Kenya (quick orders) • Panels from China • Pumps from Italy (Pedrollo) or Denmark (Grundfos)
Quality issues	None reported	• None reported – SV requires technically appropriate boreholes before equipment is sold	• Occasionally, there are issues with components/ control panels, but these are usually quickly repaired and resolved	• No issues noted
Key obstacles to expansion	• Access to FOREX • Ability to build up stock	• Access to FOREX • Training the youth at the local/ woreda level • Inefficiency of drilling	• Access to FOREX • Regulatory complexity (in terms of import taxation procedures)	• Access to FOREX • Selling price is fixed by the government • Regulatory obstacles

3.2.2 Cold Storage

Responses from the household survey indicate that cold storage ownership remains very rare – only 2% of dairy producers reported using cold storage, and all of those who did used it for storing milk. None of the horticultural producers interviewed or surveyed mentioned having access to cold storage.

The users identified through the survey use electricity-powered fridges (with only one respondent mentioning a diesel-based system), own them outright, and are generally (66%) satisfied with the functionality, if not with the insufficient size, or with its cost. The cost cited ranges from ETB 1,200 to ETB 15,000, largely dependent on the capacity. Electric-powered milk coolers with a greater capacity of 500 litres, which are better suited for commercial livestock farmers or cooperatives, are currently available on the market for c. ETB 45,000.

The only non-electric solution currently in operation is a Zero Energy Cool Chamber currently being piloted by the ATA. The technology, imported from India, relies on cement bricks and translates into a cost of ETB 70-80k per farmer, and up to ETB 125k in Oromia, while interviewees have stated that the capacity of 1.5-3tons is insufficient. Solar cooling has been discarded by the programme as prohibitively expensive for the farmer, even against this background.

In line with these findings, no companies supplying renewable-energy-powered coolers have been identified in the course of this study.

3.2.3 Processing

A substantial number (34%) of **dairy farmers** who responded to the household survey claimed to process their milk – this tallies with the broader findings from the focus groups and interviews that draw attention to the lack of cold storage, limited shelf life (~4 hours) of fresh milk, and the need to preserve it in the form of butter or yoghurt to avoid waste. Butter was the most popular form of processing, produced by 21% of respondents, with 7% mentioning cheese production. However, all respondents, without exception, referred to a manual churning method, with firewood frequently burned to boil the milk, and accelerate the fermentation process.

Electricity-powered butter extractors (ETB 27,000) and cream separators (ETB 22,000) are available on the market – however, demand is limited, and none of the farmers consulted said they had access to these technologies or considered them affordable.

No reference has been made in interviews, focus groups or survey responses to horticultural producers (farmers or cooperatives) having or seeking access to processing technology. Small-scale businesses engaged in processing to make chilli paste, banana flour, banana-based baby food, sweet potato flour, etc. tend to rely on electricity from the grid. Previous experiences with cooperative-based horticultural processing faced substantial obstacles because of thin local markets for processed goods and expensive imports of packaging.

To date, no information is available on any solar-powered or other renewable energy-based processing solutions for dairy or horticulture – although solar milling and solar grinding equipment for cereals and coffee, respectively, are being explored as options by some of the companies currently supplying solar-powered irrigation pumps.

3.3 Gaps and constraints that limit expansion of PUE technologies

The following section presents the findings from interviews with PUE sector stakeholders, including companies, federal and regional government ministries and regulators, and potential users of the relevant technologies. The constraints to PUE technology expansion are addressed from both the demand and the supply side.

3.3.1 Demand side

While farmers are, in general terms, aware of the potential benefits of irrigation, cooling and processing, demand for PUE technologies is constrained by both the willingness and the ability to pay. Specifically:

Willingness to pay	• ***Awareness of technology***. There is increasing awareness of solar irrigation pumps (in particular) through media and from observing other farmers. However, awareness of other forms of renewable energy technology (e.g. coolers, processing machines) is limited, with no clear perceived advantage to using solar-based tech, as opposed to diesel-run coolers, for instance. Nonetheless, there is evidence from interviews that once farmers become aware of how a technology works and what benefits it brings, demand goes up. • ***Confidence in technical support***. Farmers require training and tech support to make the most out of the products on offer. While PUE companies offer maintenance support, there is limited availability of skilled manpower at woreda level/ technicians for maintenance and repairs. • ***Quality and reliability.*** Farmers find it difficult to identify trustworthy suppliers and products (although technology supplied through the Unions is usually trusted). Often, the temptation is to use cheaper products which break more easily. While some PUE technology companies do provide 1 or 2-year warranties, the practice is not universal
Ability to pay	• ***Upfront cost***. As Table 8 demonstrates, the cost of most solar pumps is at least 3 times (and, more often, up to 10 times) that of a diesel pump. In addition, most solar pumps require the drilling of wells – this is physically demanding work, the cost is reported to have gone up in recent years, and averages at ETB 5,000. The problem of affordability is, of course, exacerbated by the limited productivity and poor market linkages for both horticulture and dairy producers, as outlined in Section 3.1. • ***Access to finance.*** Access to loans is limited: horticulture is considered a high-risk sector and loan amounts are either insufficient for PUE technology or require group lending, which many farmers are not interested in. Table 9 below provides some illustrative examples. In addition, many farmers are highly risk-averse when it comes to interest rates. In Muslim communities (e.g. in Oromia) this is compounded by religious considerations.

Table 8: Example service offerings of financial institutions operating in the target regions

	Commercial Bank of Ethiopia (CBE)	Amhara Credit and Saving Institution (ACSI)	Oromia Credit and Saving Share Company (OCSSC)
Loan size	(e.g.) ETB 2 million	(max) ETB 75,000	Loans provided in cycles, ETB 30,000 max
Loan terms	11-16%	18%	17% interest rate + 3% service (1 year)
Target customers	Mainly SMEs, farmers with > 2ha	Smallholder farmers	Agricultural sector
Qualification for loans	Collateral, guarantee letter from gov't, financial plan, 30% of project cost covered	Group loans only (no collateral) Land ownership	Collateral, group loans, mandatory savings at OCSSC as guarantee, business plan
Concessionality	n/a	Reduced penalties for loan cancellation	Declining interest rates
Horticulture/ Dairy/ PUE track record	Little experience so far	Loans for solar lights: ACSI pays the full price to the supplier, signs warranty agreements, etc., and the loan recipients repay over time. Good repayment rates.	Loans for solar lights (EverBright) but bad experiences due to poor quality. Repayment rates very high
Interest in PUE	Open to the possibility	Open to the possibility	Open to the possibility

3.3.2 Supply side

While the supply of PUE technologies (namely, solar irrigation pumps) has been growing, a number of core challenges, relating to both the costs of doing business and the revenue potential, present obstacles to further expansion. Specifically, these include:

Cost	• ***Shortage of FOREX***. Highlighted by every PUE company as a constraint, difficulties in accessing sufficient quantities of foreign exchange in a timely manner mean higher costs and greater delays in importing materials, including the higher transactional cost resulting from the bureaucratic burden. In theory, goods related to the agricultural sector may have priority access to FOREX, however, in practice, this isn't always the case. The added uncertainty makes some suppliers hesitant to work with Ethiopian businesses. • ***Import regulations and tax.*** There is a lack of clear and consistent regulation at customs: imports are tax-free if the direct customers are smallholder farmers – but not if the product is sold to traders/ distributors; Dismantled solar products are not considered as solar devices and may be subject to tax; Importing assembled products facilitates negotiation with the customs office but increases purchasing and transport cost and removes the option to shop around for components across different countries. The Government of Ethiopia has recently launched a task force for tax review to streamline import regulations – PUE equipment that was not specified in the old tax book is specified in the new one, and imports are now tax exempt. However, the general awareness of regulation and the changes applied seems to be limited within the PUE sector and continues to cause confusion. • ***Access to finance.*** Lack of a suitable working capital facility means that PUE companies have a limited ability to maintain stocks and thus respond to peaks in customer demand in a timely manner.

	• ***Limited domestic manufacturing/ assembly capacity.*** The need for FOREX and complications regarding import regulations could be sidestepped if there was greater in-country assembly capacity. Some PUE technology companies are already planning to develop this function. • ***Conflict (especially around the Amhara region)*****.** Multiple interviewees have noted that restrictions on movement have disrupted supply chains, both for the distribution of inputs and equipment and for marketing agricultural produce.
Revenue	• ***Inflation***. High inflation rates affect affordability of equipment – for instance, ACME basic solar irrigation pump now costs ETB 420k, compared to ETB 250k a year ago. Solar Village prices increased from ETB 40k to 70k. • ***Competition.*** Competition with lower-priced, lower-quality imports from China at farmer level. • ***Reliance on government procurement***. The selling price is fixed by the government, and it is difficult to adjust it in a timely manner based on market conditions. Frequently, the cheapest solution is selected from the list of tenders, regardless of quality or effectiveness • ***No standardisation by the regulatory agency.*** The Ethiopian Standards Authority has developed standards and testing procedures for diesel pumps and is currently intending to develop the same for solar pumps. VeraSol (quality assurance body for solar technology) has developed a testing method for solar pumps, which ESA now has access to. However, the standard still has to be developed – for this, technical support and some funding is required.

3.4 Analysis of opportunity

In order to prove the business case for a given PUE technology, it must be demonstrated that a number of key conditions are met, namely:

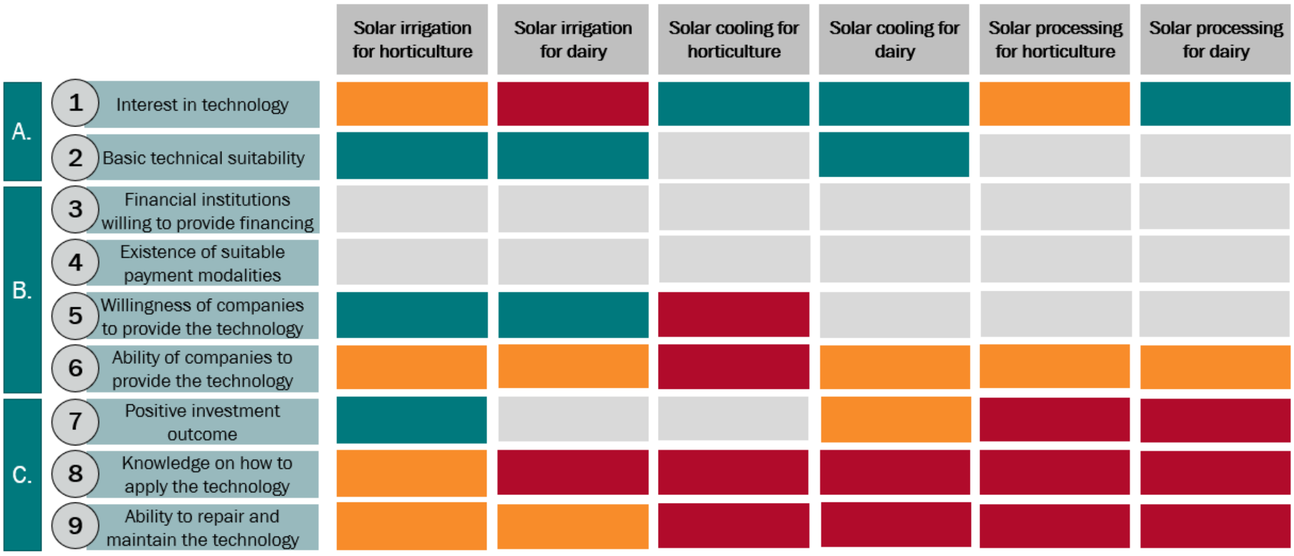
A. That farmers are willing to invest in the technology (which, in turn requires them to be aware of it, and for it to be technically feasible in the environment in which the farmers operate));

B. That farmers are able to invest in the technology (which requires the will and ability of private companies to provide the technology, the willingness of financial institutions to provide financing, and the existence of suitable financial modalities);

C. That farmers are able to derive benefits from the technology, as evidenced by i) a positive return on investment (driven by higher volumes sold, higher prices obtained and/or a reduction in cost as a result of using the technology), ii) knowledge on how to apply the technology, and ii) the ability to repair and maintain the technology, and thus ensuring it is used throughout its productive life.

Assessing the three types of technology under consideration (irrigation, cooling and processing) for both horticulture and dairy against the criteria listed above leads to the summary in Figure 9 below. The following subsections provide the evidence for this assessment for each technology/ value chain combination in turn.

Figure 8: Summary of opportunities in the PUE technology sector

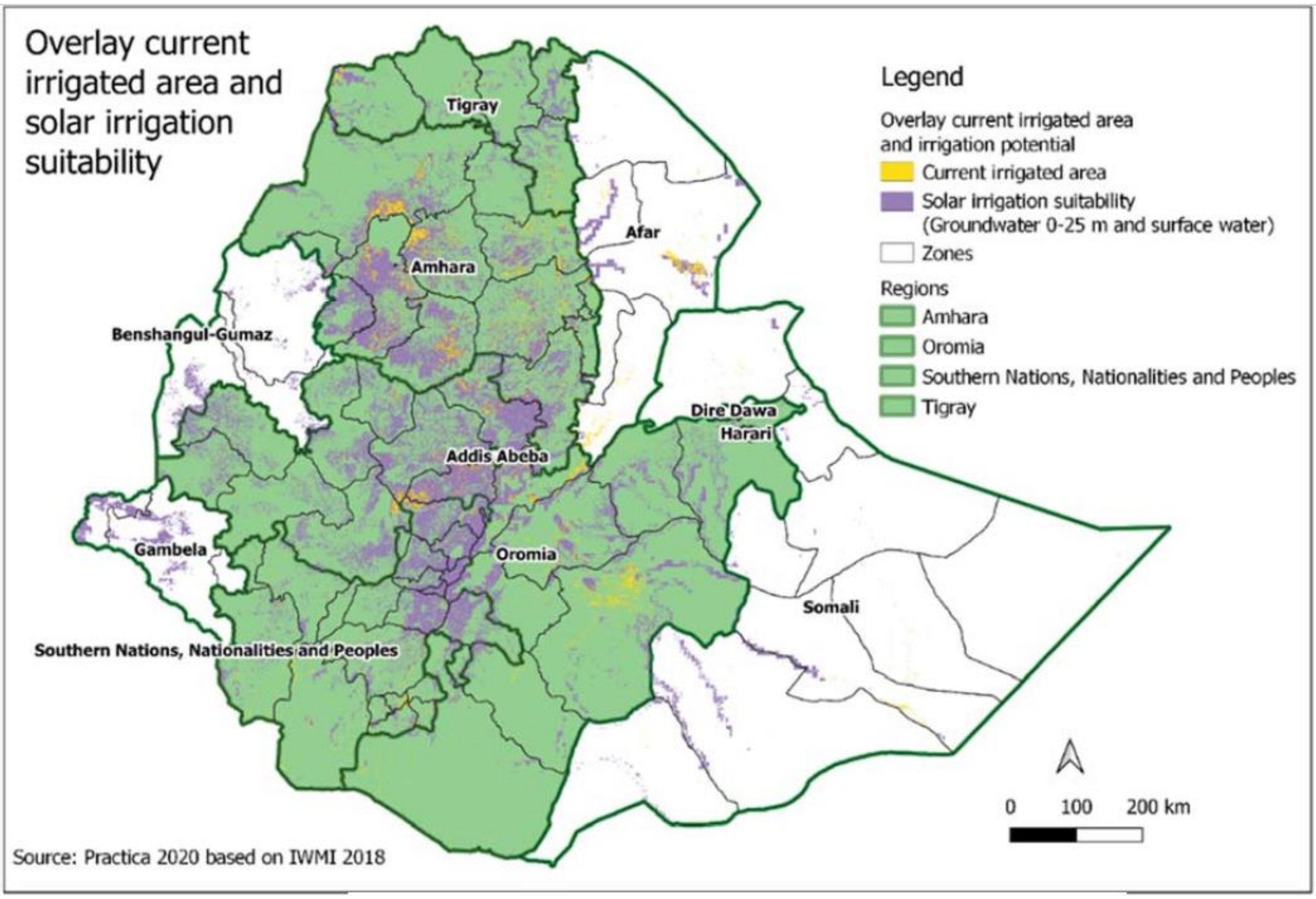


3.4.1 Solar irrigation for horticulture

Interest in technology. Multiple interviewees among PUE enablers indicated that awareness of solar pumps remains low. However, farmers are highly aware of the benefits of irrigation, and 57% of household survey respondents indicated they already irrigate their horticultural crops. In addition, multiple FGD participants and interviewees who already use diesel pumps cited cost of diesel as a concern, indicating that an alternative technology that reduces the operating cost by foregoing the need for diesel would be of interest.

Basic technical feasibility. There is some degree of debate over the exact extent and distribution of areas within Ethiopia that are suitable for solar irrigation. However, it is clear that there is considerable potential that, to date, remains underutilised. Figure 10 provides an indication of the extent of this underutilised potential. The high number of donors, NGO and government programmes currently engaged in promoting irrigation does not significantly limit the potential scope of intervention, according to interviewees in the sector. According to a government irrigation expert, "*I do not think there is a risk of overlap and repetition in smallholder irrigation activities – little has been done so far, there is a lot of space for many to engage.*"

Figure 9: Current irrigated area vs. solar irrigation suitability



Financial institutions willing to provide financing & existence of suitable payment modalities. As has been discussed in previous sections, full payments for solar pumps at the moment of purchase are, currently, the only payment modality in practice. However, this is only possible for the richest farmers, or for the donors who purchase the equipment on behalf of the smallholders. In order to expand the provision of PUE technologies and ensure the sustainability of this subsector over time, other payment modalities that allow for more direct smallholder involvement must be considered. Table 9 outlines the 4 main options, based on experiences from other countries. Credit products present the most immediately viable solution, based on the financial sector's familiarity with them. However, lease-to-own offers a number of advantages from the point of view of the farmer and could be trialled.

Table 9: Financing options for PUE technologies

	Purchase on credit	Lease-to-own	PAYGO	Outgrower scheme
Description	Loans from Banks, MFIs or SACCOs	Farmer makes regular payments and is transferred ownership of the asset after full repayment	Farmer pays for use; supplier retains ownership and responsibility for maintenance	Nucleus agribusiness provides equipment to farmers on a loan basis, which is then deducted from sales
Key considerations	Many financial institutions require 10-40% of savings deposits of loan amount	• No requirements for group financing or collateral	• ICT system linked to a usage meter	There are no functioning out grower schemes for horticulture or

	and/or will not lend the full cost of equipment. However, most financial institutions consulted stated that they are open to providing loans for PUE technologies, assuming they meet the standard lending criteria. The appetite for group loans is limited among farmers (and there are logistical constraints for irrigation).	• No significant upfront cost required • Long repayment horizon for supplier • GoE, with support from the IFC, has recently improved the enabling environment for leasing, and some initiatives are starting up	• Suppliers willing to invest in storage, maintenance and management, have a longer repayment horizon	dairy in Ethiopia at the moment, which means that this is not a viable option
Experience in Ethiopia	Credit for agricultural equipment is well established, if not for PUE technologies specifically	A new company, Ethio Lease, is interested in social impact projects and invites donors to collaborate	Box 3 provides the summary of a recent GIZ study on the potential for PAYGO	n/a
Potential for piloting	Yes - options for overcoming constraints include: guarantee funds, cost-sharing, negotiating with MFIs to improve lending terms	Yes – clear advantages to farmers and partnership with Ethio Lease worth exploring	No – recent GIZ study suggests it's not currently commercially viable for PUE technologies	n/a

Box 3: Scoping Study: Enabling Environment for PAYGO for Energy Access in Ethiopia - Summary of findings

The market potential for PAYGO in Ethiopia is substantial, with 56% of households reporting willingness to pay for electricity supply technologies. To date, an estimated 8,000 of standalone off-grid units have been sold with a PAYGO plan (primarily household lighting and charging solutions), with PAYGO providers including local start-ups, social enterprises, NGOs and MFIs. In the majority of cases, MFIs partner with PAYGO companies, provide them with access to their networks, provide consumer finance or support in the vetting or collection process.

However, the subsector faces a number of key hindrances, namely i) limited access to finance, including credit lines to cover the gap between asset financing and end-user receivables for PAYGO companies, ii) need to organise demand to enable timely pay-offs, iii) improvable policy and enabling environment to allow foreign companies to invest in PAYGO schemes, full PAYGO regulation and tax regime, etc., iv) weak stakeholder engagement and ability to compensate for low mobile money penetration and weak GSM coverage through agent-based networks.

Willingness of the companies to provide the technology. All PUE companies interviewed have seen increasing sales of solar pumps over the last few years and report that the product lines are profitable. In addition, previous studies have indicated that 53.5% and 46.2% of PUE companies currently engaged in the distribution of solar pumps consider the products, respectively, extremely important and somewhat important for their companies' growth. The market potential – arguably, one of the key determinants of the companies' level of interest in the technology – has been estimated using several approaches, all of which indicate an upward trend in demand:

- Projecting from current growth rates of solar pumps, demand will reach 940 units per year by 2025;
- Assuming replacement of all diesel pumps, demand for solar pumps is estimated at 150k units;
- Applying the historical growth rate of diesel pumps to solar, demand will reach c. 0.5 million by 2025;

- 17m units would be required to reach the full solar irrigation potential.

Ability of the companies to provide the technology. As has been discussed in Section 0, constraints to expanding supply include FOREX limitations, import regulations (recently eased), access to finance, and lack of recognition/ differentiation of quality.

Positive investment outcome for the farmer. The following analysis considered two different scenarios – i) a farmer obtaining a loan for a solar irrigation pump against the baseline of no irrigation equipment, and ii) a farmer obtaining a loan for a solar irrigation pump to replace an existing diesel irrigation pump.

In the first scenario, the major benefit is the increased volume of production due to the higher irrigated yield, and thus higher revenues, while the major costs are associated with digging a borehole, acquiring the new pump and repaying the debt. In the second scenario, there is no difference in revenue because of the simplifying assumption that both types of pump are capable of extracting the same amount of water, that this water is used to irrigate the crops in an equally efficient manner, and that there is, therefore, no difference in yield. However, on the cost side, the replacement of a diesel pump with a solar pump represents a considerable decrease in operating costs, since the use of a solar pump removes the need to purchase increasingly expensive diesel fuel.

The cost-benefit analysis was carried out with two objectives in mind: i) obtaining key financial metrics (NPV and IRR) in a scenario where no donor support is provided, and ii) considering scenarios where donor support is used to subsidise the initial cost of purchasing the solar pump, to negotiate with the financial service provider for a lower interest rate, or to negotiate for a longer loan term.

Another important consideration is the size of the negative cashflow – while it is expected that it will take a number of years for the farmer to breakeven, negative cashflows are not easy to sustain for smallholder farmers with limited alternative income-earning opportunities and savings. Some measure of negative cash flow absorption is provided by other farming activities (since horticulture is assumed to only take up 31% of the farm), although it may be instructive to cap that at, for instance, ETB 20,000 – 25,000 since that is the average cost for a diesel pump which a substantial number of surveyed farmers have evidently been able to afford. Therefore, the peak negative farmer cash flow is another key metric.

Table 12 provides the overview of the results of cost-benefit analysis, assuming no donor support, with beneficial outcomes highlighted in green and infeasible outcomes highlighted in red.

Table 10: Key assumptions of the cost-benefit analysis for investing in solar-powered irrigation for horticulture

Metric	Value	Rationale
Average farm size	1.1 ha	Baseline survey
% of farm dedicated to horticulture	31%	Baseline survey
Crops under consideration	Onion Cabbage Avocado	• Most farmers produce 3 different crops (survey) • The 3 crops represent three different types of horticultural plants: root crop, leafy greens, tree crop) • The 3 crops are some of the most widely grown in the target regions (survey) Yield figures with and without mechanised irrigation and prices taken from baseline survey
Inflation	16%	Although inflation in 2020 reached 20%, there are reasons to believe that this is an exceptionally high rate. The average over the past 15 years is closer to 16%.
Interest rate	18%	Based on interviews with financial service providers
Loan term	3 years	Based on interviews with financial service providers
Farmer Cost of Equity/ discount rate	20%	Conservative estimate to account for high risk aversion & high interest rates

Price of diesel per litre	ETB 80	Average value given by interviewees (higher than could be expected because of general shortages and the fact that farmers in remote areas have to rely on black market brokers to obtain diesel, with correspondingly inflated prices)
Cost of digging a borehole	ETB 5,000	Interviews in Fogera, cross-checks with secondary literature
Annual maintenance cost of solar pumps	3% of purchase cost	While this might be lower depending on the exact type of technology and the type of accessories that are included in the package, 3% is a reasonable conservative assumption in an early-stage sector, based on similar studies.

Table 11: Results of the Cost-Benefit Analysis for solar irrigation for horticulture

As is evident from the results summary, the outlook for investing in solar irrigation is looking broadly positive, particularly for the scenario where solar pumps replace diesel pumps, reflecting the considerable and worsening cost burden of diesel. There is, of course, notable differences between different packages and types of equipment, with the following broad conclusions emerging:

	ACME	Solar Village	Yasart	
Specifications	• Suitable for <1.5ha • 1-3 litres/ second • Includes accessories	• Suitable for <2.5ha • 0.5- 1 litres/ second • Doesn't include accessories	• Suitable for <1ha • 0.5- 1 litres/ second • Includes accessories	• Suitable for <2ha • 1-2 litres/ second • Includes accessories
Upfront cost	ETB 420,000	ETB 72,000	ETB 140,000	ETB 230,000
No irrigation vs. solar irrigation	NPV: **- ETB 245,000** IRR: **-2%** Peak negative cash flow: **- ETB 185,000**	NPV: **ETB 126,750** IRR: **63.3%** Peak negative cash flow: **- ETB 15,919**	NPV: **ETB 52,279** IRR: **28.7%** Peak negative cash flow: **- ETB 49,089**	NPV: **- ETB 46,286** IRR: **14.6%** Peak negative cash flow: **- ETB 92,991**
Diesel vs. solar irrigation	NPV: **- ETB 161,281** IRR: **9%** Peak negative cash flow: **- ETB 176,129**	NPV: **ETB 219,835** IRR: **158%** Peak negative cash flow: **- ETB 6,375**	NPV: **ETB 145,364** IRR: **44%** Peak negative cash flow: **- ETB 39,545**	NPV: **ETB 46,800** IRR: **25%** Peak negative cash flow: **- ETB 83,447**

- **Solar Village pumps** are the cheapest on offer, and clearly demonstrate positive investment outcomes. The key hurdle to overcome in this case would be the initial upfront cost and the willingness of the financial institutions to lend that amount. This could be addressed with either i) an upfront grant subsidy from the donors, or ii) negotiated deal or guarantee that allows financial institutions to feel more confident in lending the full amount.
- **Yasart pumps** show good potential – particularly the smaller/ cheaper solution which would, in any case, be more suitable to the "average farmer" who serves as the basis for this model and is assumed to irrigate circa 0.34ha of horticultural crops. However, the main concern would be the prohibitively negative cash flows the farmer would have to sustain for the duration of the loan term. This could be mitigated by lower interest rates and/or a longer repayment period. The concerns about the ability of farmers to deal with high upfront costs, outlined above, also apply here.
- **ACME pumps** do not seem to be financially feasible without a considerable degree of donor support – NPV, IRR and cash flow metrics all indicate substantial difficulties for the average farmer under consideration.

Table 12 presents a summary of all the above options for donor support and the level of said support that would be required for farmers to achieve breakeven NPV and manage their cashflow. Since the upfront cost and the resulting NPV is the most immediate constraint, it is addressed first, with interest rate and loan term variations considered in addition to the upfront subsidy.

Table 12: Effect of donor support on the financial feasibility of solar irrigation pumps

		ACME	Solar Village	Yasart	
	Purchase cost	ETB 420,000	ETB 72,000	ETB 140,000	ETB 230,000
No irrigation vs. solar irrigation	Upfront subsidy required for breakeven	81% of purchase cost	n/a – NPV already positive	n/a – NPV already positive	27% of purchase cost
	Interest rate & loan term required for manageable cashflow	• 0% interest rate and 3-year loan term, OR • 18% interest rate and 10-year loan term	n/a - cashflow already manageable	• 5% interest rate and 5-year loan term, OR • 10% interest rate and 7-year loan term, OR • 15% interest rate and 10-year loan term	• 0% interest rate and 6-year loan term, OR • 8% interest rate and 10-year loan term
Solar irrigation vs. diesel irrigation	Upfront subsidy required for breakeven	51% of purchase cost	n/a – NPV already positive	n/a – NPV already positive	n/a – NPV already positive
	Interest rate & loan term required for manageable cashflow	• 7% interest rate and 10-year loan term, OR • 5% interest rate and 8-year loan term	n/a - cashflow already manageable	• 2% interest rate and 3-year loan term, OR • 18% interest rate and 6-year loan term	• 0% interest rate and 6-year loan term, OR • 8% interest rate and 10-year loan term

The key takeaways from this analysis are as follows:

- The validity of the positive investment outcomes depends on the farmer irrigating their crops in the most efficient manner to achieve the expected boost in yield;
- For the benefits of using irrigation to be fully realised, farmers must be able to sell the excess production they obtain. This requires well established market linkages – which is not always a solid assumption to make;
- Replacing diesel pumps with solar provides the most positive investment case across the technology types – which suggest that targeting diesel pump owners first might provide a quick win for SEFFA;
- However – there is a clear need for a combination of financial support tools to not only enable the initial investment but also ensure that the repayment schedule is affordable to the farmers.

Ability to repair and maintain the technology. PUE companies interviewed offer maintenance services as part of the package deal but noted that the availability of skilled technicians at woreda level is a significant constraint.

Knowledge of how to apply the technology. According to previous studies, lack of technical expertise at farmer and at organisation level is one of the biggest constraints to the growth of the solar pump market that is cited by government institutions. For instance, there is evidence that farmers who are accustomed to traditional irrigation methods often have doubts whether the water that is being slowly delivered and applied through drip systems is sufficient to meet the requirements of their plants[5]. In addition, lack of expertise/ knowledge at implementer level

[5] IWMI study

(e.g. the ability to recommend the correct equipment and operating instructions for a given farm size/ crop combination) is a persistent problem.

3.4.2 Solar irrigation for dairy

Interest in technology. While limited fodder availability is widely recognised as one of the biggest constraints within the sector, **none of the interviewees or FGD participants interviewed noted any interest in access to irrigation equipment for fodder production**, or identified it as a priority. Most farmers surveyed only have 1-3 cows and c. 1.1ha of land – this, arguably, does not justify dedicating a significant share of cultivated area to fodder production.

Basic technical feasibility. A study carried out by Feed the Future's Innovation Lab for Small-Scale Irrigation (ILSSI) established that 20% of all land in Ethiopia is suitable for fodder production, with Abbay, Omo-Ghibe and Rift Valley basins (i.e. SEFFA target regions) suitable for production of Napier grass, oats, vetch, etc.Groundwater availability has already been outlined under irrigation for horticulture.

Willingness and ability of the companies to provide the technology. The findings for solar pump supply for horticultural producers apply here as well.

Positive investment outcome for the farmer. Cultivation of fodder can provide a viable alternative to increasingly expensive factory-produced concentrated mixed feed. However, to date, experiences with commercial production of fodder in Ethiopia have been very limited. Fodder production can involve the production of seeds (c. 2 months) for sale to livestock producers who have land to cultivate the fodder, or the production of green fodder (c. 3 months) for own use or for sale. Currently, there is a more established market for seed than for green fodder – however, there have been some start-up initiatives to support both types of production. SNV's BRIDGE project has been working to link farmers willing to produce fodder seed with agro-input dealers who would be able to distribute it and subsidising the purchase cost of fodder seed.

A pilot initiative by Feed the Future/ ILSSI indicates that fodder production could be highly profitable for farmers (see Box 4 below). However, these results represent a small-scale experiment, and no comparative analysis on the profitability or seed and green fodder production has yet been carried out. Thus, while there is certainly potential in this subsector, there is a need for further investigation of commercial feasibility.

Box 4: ILSSI pilot on irrigated fodder production

Pilot design. The pilot was carried out in Amhara and SNNP, including the woredas of Bahir Dar Zuria and Lemo (i.e. target woredas for this study). The pilot primarily targeted farmers with experience of irrigated khat or ch'at production – given the high degree of profitability of the crop, the case for diverting production, at least partially, to fodder had to be very convincing. 17 participating farmers allocated circa 0.01ha each to produce both annual and perennial forage, including oat-vetch, Napier, Desho, Brachiaria, Desmodium, and pigeon pea, using mixed irrigation technologies. Additional activities included strengthening farmer cooperatives, supporting gender and climate resilience aspects, and training the farmers.

Key results. Fodder production was shown to be highly profitable (ETB 150,000 – ETB 200,000/ ha). A crop such as napier grass could be harvested 6-9 times per year in a 12-month period, representing a valuable method for maintaining cashflow between main harvests. **Use of solar powered irrigation was shown to triple forage yield and milk yield per cow, and double net profits.**

Secondary effects. Membership of participating cooperatives has tripled due to interest in irrigated fodder production and improved marketing opportunities. Farmers have taken the initiative to establish fodder seed multiplication groups.

Limitations. Limited access to forage seeds and planting materials, limited access to extension services, limited access to markets.

Knowledge on how to apply and maintain the technology. The findings for solar pump supply for horticultural producers apply here as well.

3.4.3 Cold storage for horticulture

Interest in technology. Despite the fact that the baseline survey did not indicate that post-harvest loss rates at farm level are particularly high, stakeholders across regions and value chains indicated that cold storage for horticulture is a priority for the subsector.

Basic technical feasibility. This has not yet been proven in Ethiopia – however, given the feasibility of solar-powered irrigation, it is likely that solar-powered cooling is also possible, at least to some extent.

Willingness and ability of the companies to provide the technology. It should be emphasised that this type of technology is not currently available in Ethiopia, with the exception of the Zero Energy Cool Chambers being currently piloted by the ATA (see Section 5.2.2). The possibility of the promotion and distribution of this technology therefore depends on the ability of companies operating in the broader region (or beyond) to expand into Ethiopia and the suitability of their product for the Ethiopian context.

Table 13: Effect of donor support on the financial feasibility of solar irrigation pumps

	Solar Freeze	EcoFrost (EcoZen)	Inspira Farms	Tan 30
Country				
Technical specifications	Mobile solar-powered cold room	Micro solar-powered storage, 6MT capacity, integrated IT monitoring system	Cold storage & packhouses, minimum 30m2, compliant with export standards	Thermal battery-powered mini storage boxes/ units, requires cooling in a freezer before use
Cost per unit	USD 0.50 per day per crate of produce for rent, est. USD 6k per unit	USD 18k per unit	Unknown	USD 67 for 50l capacity
Business model	Micro-franchise – supporting village women to own and rent out units as micro-entrepreneurs	Purchase, lease and rental, community model	Orientated towards export crops, launched pay-per-use model in Kenya	Direct purchase
Commercial sustainability	TBD, pilot stage – 3,000 farmers reached by August 2020, aiming for 30k by 2030	150 cold rooms sold to farmers in India to date. New technology in the country, subsidised by gov't	Series B financing round completed in 2020	TBD – start-up phase

The above overview demonstrates that the companies developing products suitable for Ethiopia's smallholder farmers (e.g. Solar Freeze) are at very early stages of their development and are primarily focused on growing within the local markets. The only company reported to have a footprint in Ethiopia (InspiraFarms) offers sophisticated solutions that are primarily orientated towards high-value export produce with established buyer relationships and are unlikely to be financially viable for the vast majority of horticultural cooperatives in Ethiopia, let alone individual farmers.

Positive investment outcome for the farmer. Assuming a pay-per use model, and the effect on reduced PHL ***and*** higher prices due to the ability to delay sales until market prices improve, farmers may be prepared to pay ***up to ETB 25k per year for cold storage*** (based on extra revenue). However – this is **entirely dependent on market linkages** and the extent of peaks and troughs of market prices.

Knowledge on how to apply and maintain the technology. Since the technology is completely new to the country, this knowledge and capacity are non-existent.

3.4.4 Cold storage for dairy

Interest in technology. There is a **high degree of interest** in this technology; it has been highlighted by multiple stakeholders as the priority form of equipment for the sector, although FGD participants and interviewees were not aware of the possibility of solar-powered cooling specifically.

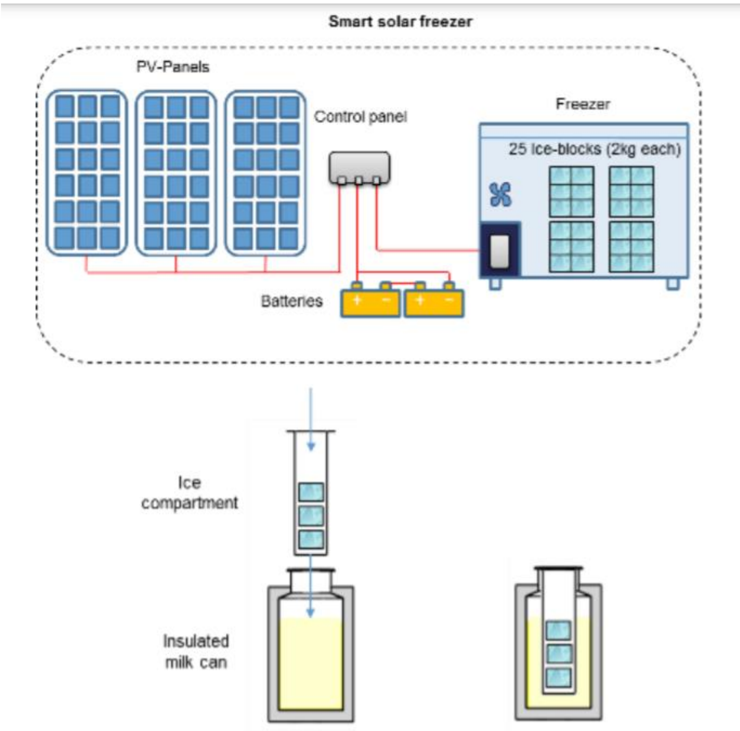
However, there is also a **high degree of misunderstanding** about the benefits of cooling: the reason stated by most respondents for being interested in cooling technologies is to store milk over the fasting periods – given the duration of most fasting periods (over two weeks), this is not a viable solution.

Basic technical feasibility. Two studies have been conducted to demonstrate the technical feasibility of milk coolers. One was carried out in Kenya, under agroclimatic conditions similar to large areas of Ethiopia[6], which involved a solar-powered freezer producing ice blocks which can be inserted into milk cans via integrated ice compartments and preserve milk quality for 6-16 hours, depending on the volume of ice produced. This is illustrated in the figure overleaf.

The second trial was carried out by the Netherlands branch of Paul Mueller, a private food processing company, in Ethiopia. This was in partnership with SimGas, a biogas provider, and involved developing an off-grid biogas-powered milk cooling system for small dairy farms. The innovation was recognised by an OpenIDEO Agriculture Innovation Award in 2016.

Willingness and ability of the companies to provide the technology. There are, to date, no commercial providers of solar- or biogas-powered milk cooling technology. Despite the successful technical pilot, the Mueller solar or biogas equipment has not yet been developed as a commercial product on the market. Among the problems cited has been the ease of doing business in Ethiopia and the problems associated with FOREX[7].

Figure 10: Example solution for solar-powered milk cooling



Source: Salvatierra Rojas et al (2018)

[6] Salvatierra Rojas et al (2018): "Improving milk value chains through solar milk cooling", Working Paper 172, ZEF Centre for Development Research, University of Bonn
[7] https://www.wur.nl/en/project/Milk-cooled-by-solar-power.htm

Positive investment outcome for the farmer. The investment case for solar cooling for dairy rests on four key assumptions which jointly guarantee that applying cold storage would increase the amount of milk available for sale and would lead to higher revenues for the dairy farmers. The evidence for these four assumptions is mixed. Specifically, it must be proven that:

- **Post-harvest loss is a significant problem:** based on Focus Group Discussions, this does not seem to be universally true, with a majority of respondents reporting that all leftover milk is processed traditionally or consumed directly by the family.
- **All extra produce is sold rather than consumed**: this is inconclusive – most interviewees report that some extra production is both consumed and some is sold, with no reliable data on what that breakdown might look like in practice.
- **Most spoilage occurs after the evening milking due to the lack of marketing opportunities:** most respondents indicated that evening milk is consumed by the family.
- **There is a price premium for high-quality milk:** locally, premiums are very low (~ETB 4) – however, at markets in Addis, demand is high and premium is ~ETB 10.

Nonetheless, it is worthwhile considering the investment case based on the above assumptions holding, and the base figures presented in table 14 below. The analysis takes the example of the 30-litre milk cooling unit the technical feasibility of which was tested by the ZEF study. Given the capacity, this type of equipment is more appropriate for a cooperative rather than for individual farmers.

Table 14: Key assumptions of the cost-benefit analysis for investing in solar-powered cooling for dairy

Metric	Value	Rationale
Average number of cows per farmer	2	Baseline survey
Average number of litres produced per day	6	Baseline survey
Baseline post-harvest loss	40%	National statistics
Post-harvest loss with cold storage	20%	Interviews with sector experts & cold storage providers
Number of milking days per year	150 days	Literature review
Baseline marketable surplus	30%	Key informant interviews
Marketable surplus with cold storage	35%	Conservative assumption
CapEx of 30-litre milk cooling unit	USD 2,245	ZEF milk cooling study
OpEx of 30-litre milk cooling unit	USD 1,680/year	ZEF milk cooling study

Assuming a system whereby cooperative members share the costs of investing in cold storage between themselves, and that this technology enables cooperatives to access Addis markets, **this investment can produce positive outcomes – albeit highly sensitive to post-harvest loss, premium price and marketable surplus assumptions.** The breakeven number of cooperative members for whom this investment would be worthwhile is 45.

Furthermore, it is worth investigating what the investment outcomes would look like for farmers investing both in solar-powered irrigation for their horticultural crops and in dairy cooperative-owned solar coolers – since the vast majority of farmers interviewed in the course of the baseline survey reported practicing both horticultural and dairy production.

For simplification, this analysis only considers the scenario whereby farmers with diesel pumps decide to make the switch to solar, as well as co-investing in a cooperative solar cooler. The expected benefits are therefore:

- Reduced costs of horticultural production;
- Higher marketable surplus of milk;
- Higher prices for milk

As table 15 demonstrates, co-investment in milk coolers, in addition to solar pumps, does have a positive effect on the investment outcomes for farmers, with the beneficial effect increasing with the number of farmers in the dairy cooperative. However, it is also evident that co-investment in milk coolers does not radically alter the overall outcome, and that investment in solar pumps is the substantially more financially significant component.

A final consideration is the fact that there are currently electric milk coolers available from agricultural equipment distributors in Ethiopia, with a capacity of c. 500 litres, at a cost of ETB 45,000 (USD 1,277) – i.e. half that of a solar-powered cooler with a lower capacity. While the reliability of such a cooler could be questioned, given the frequent interruptions in power supply in rural areas, the price and capacity difference should be noted.

Knowledge on how to apply and maintain the technology. While the use of technology is not necessarily complicated, it still requires detailed instructions and technical support from the equipment supplier. In absence of a commercial provider, this knowledge cannot be transferred or maintained.

Table 15: Cost-Benefit Analysis for replacing diesel pumps with solar and co-investing in solar milk coolers

	ACME	Solar Village	Yasart	
Upfront cost of solar pump	ETB 420,000	ETB 72,000	ETB 140,000	ETB 230,000
Upfront contribution to solar cooler cost	ETB 2,305	ETB 2,305	ETB 2,305	ETB 2,305
Diesel vs. solar irrigation + solar cooler – **45 cooperative members**	NPV: **- ETB 162,172** IRR: **9%** Peak negative cash flow: **- ETB 177,086**	NPV: **ETB 218,944** IRR: **142%** Peak negative cash flow: **- ETB 7,332**	NPV: **ETB 144,473** IRR: **43%** Peak negative cash flow: **- ETB 40,502**	NPV: **ETB 45,909** IRR: **25%** Peak negative cash flow: **- ETB 84,404**
Diesel vs. solar irrigation + solar cooler – **90 cooperative members**	NPV: **- ETB 151,544** IRR: **10%** Peak negative cash flow: **- ETB 175,564**	NPV: **ETB 229,572** IRR: **174%** Peak negative cash flow: **- ETB 5,809**	NPV: **ETB 155,101** IRR: **45%** Peak negative cash flow: **- ETB 38,980**	NPV: **ETB 56,536** IRR: **26%** Peak negative cash flow: **- ETB 82,882**

3.4.5 Processing for horticulture

Interest in technology. Low – not a single farmer or cooperative interviewee mentioned interest in this type of technology. Most managers of current small-scale processing initiatives do not see the rationale for replacing their machinery with solar-powered technology. The only interested party has been a kochkocha producer whose grinding machine suffers from interruptions in electricity supply.

Basic technical feasibility. Unproven – there is little evidence of renewable-energy processing technology at the moment.

Willingness and ability of the companies to provide the technology. No private-sector companies are currently providing this type of technology.

Positive investment outcome for the farmer. There is **little market demand domestically** for most processed goods, which tend to be seen as luxury products (tomato paste, juices), or are completely new to the market (e.g. green banana flour) and require substantial promotion, strengthened market linkages, or export channels to justify additional expenditure on improved technology. **The exception is chilli processing (e.g. kochkocha).** This can be considered the single biggest constraint to the promotion of renewable-energy processing for horticulture in Ethiopia.

On the cost side, **packaging is a significant and costly constraint**, with most forms of packaging having to be imported from abroad.

Knowledge on how to apply and maintain the technology. Since the technology would be completely new to the country, this knowledge/ capacity is non-existent.

3.4.6 Processing for dairy

Interest in technology. **High** – dairy processing equipment at household level (cream separators, milk churners, etc.) has been highlighted by multiple groups as a priority for the sector. This is mainly due to the fact that current processing is physically demanding and labour intensive, and can take the women of the household c. 4 hours to complete.

Basic technical feasibility. **Unproven** – there is little evidence of renewable-energy processing technology at the moment.

Willingness and ability of the companies to provide the technology. No private-sector companies are currently providing this type of technology.

Positive investment outcome for the farmer. **Low:** Average price for butter is approx. ETB 360/ kg. Assuming a conversion rate of 16 litres of milk per kg of butter, this translates into ~ ETB 22/ litre of milk (rising to ETB 30/l during holidays), compared to the average market price of ETB 20-24 / litre of raw milk. There is thus **almost no price premium for domestically processed goods.** This reflects the fact that processing is undertaken more to preserve the produce, rather than to earn a substantial market premium.

However, mechanising the processing would have a significant effect on freeing up the time and energy of the women in the household to perform other tasks, which would have a strong social impact, if not a clear financial benefit.

Another consideration is that electricity-powered churners and cream separators are available on the market at approx. ETB 24,000 – a moderate price, compared to the likely elevated cost of an appliance equipped with solar panels.

Knowledge on how to apply and maintain the technology. None.

3.5 Recommended plan of action for SEFFA

The comparative analysis of business cases for PUE technology in horticultural and dairy sectors in Ethiopia leads to a recommended plan of action that prioritises the most promising technology applications and provides different forms of support depending on the stage of market development. This section outlines i) the components of this recommended plan of action, ii) the indicative budget and timelines, and iii) an analysis of where implementation should be focused.

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3.5.1 Recommended intervention package

We propose a 4-part intervention package that builds on the momentum in the solar irrigation subsector and undertakes commercial and technical piloting for some cooling and processing technologies. The components of this intervention package are intended to systematically address every element of a successful business case, as follows:

		Interest in technology	Financing solutions	Supplier interest	Ability to supply	Investment outcome	Training & maintenance
Commercial pilot	Solar powered irrigation for horticulture Solar powered irrigation for forage	1. Awareness raising campaign focused on demonstration centres, incl. training	2. Cost-sharing solutions and linkage to loans (incl. credit guarantee) 3. Trialling a leasing product	*Interventions not required – suppliers already operating in-country at a profit*	4. Working capital facility for PUE companies	5. Targeted support for farmers to select the right technology for their farm	6. Logistical assistance in finding workforce to be trained as maintenance workers
Commercial pilot	Cooling for dairy	7. Identification of cooperatives	*Interventions not required – technology is new to Ethiopia and not yet commercially proven*	8. Procurement of solar/ biogas-powered coolers		9. Market Linkage support	10. Procurement of services for training
Technical pilot	Processing for chillies	11. Identification of solar grinding technology & interested processors		12. Procurement of solar grinding equipment		13. Technical trials of technology	

3.5.2 Indicative budget and timelines

Total proposed budget amounts to EUR 2 million, to be distributed across the 2 years of SEFFA implementation.

Package	Activity	Timeline	Estimated cost
Commercial feasibility of solar-powered irrigation	1. Awareness-raising campaign	Q1 Year 1 – Q4 Year 2	EUR 150,000
	2. Cost-sharing/ subsidising the initial purchase of solar pumps and negotiating with financial institutions to guarantee larger loan amounts for farmers	Q1 Year 1 – Q4 Year 2	EUR 200,000-EUR 500,000 (depending on technology selected)
	3. Leasing pilot	Q1 Year 2 – Q4 Year 2	EUR 100,000 guarantee facility
	4. Working capital facility for PUE companies (credit line with CBE, for example)	Q1 Year 1 – Q4 Year 2	EUR 500,000
	5. Targeted support for farmers to select the right technology (setting up Advice Bureau)	Q1 Year 1 – Q4 Year 2	EUR 250,000
	6. Logistical assistance in finding staff to be trained by PUE companies for maintenance work	Q1 Year 1 – Q4 Year 1	EUR 100,000
Commercial feasibility of solar-powered dairy cooling	7. Identification of suitable dairy cooperatives	Q1 Year 1	EUR 50,000
	8. Procurement of solar milk coolers (x2)	Q1 – Q3 Year 1	EUR 10,000
	9. Market linkage support to dairy cooperatives	Q2 Year 1 – Q2 Year 2	EUR 100,000
	10. Procurement of services for training	Q2 Year 1	EUR 50,000
Technical feasibility of horticultural processing	11. Identification of solar grinding technology	Q1 Year 1	EUR 50,000
	12. Procurement of technology (x2)	Q2 Year 1 – Q4 Year 1	EUR 100,000
	13. Technical trials of technology	Q1 Year 2	EUR 100,000

3.5.3 Selection of implementation woredas

From the initial shortlist of woredas that formed the basis for this study, different woredas offer high implementation potential for different types of technology. The table below outlines the key criteria to be considered when prioritising locations for the implementation of each component of the intervention package, while

	Solar-powered irrigation for horticulture	Solar-powered irrigation for forage	Cooling for dairy	Processing for chillies
Factors to be considered	• Incomes earned from horticultural production (proxy for market access) • Prevalence of diesel pumps • Reliance on manual irrigation	Given the high degree of dependence on the ILSSI pilot for driving the business case, project implementation woredas are the only viable option	• Presence of dairy cooperatives (no data at woreda level) • Incomes earned from dairy production	Volume of chillies production
Best suited woredas	Bahir Dar Zuria (Amhara) Dugda (Oromia) Meskan (SNNP)	Bahir Dar Zuria (Amhara) Lemo (SNNP)	Bahir Dar Zuria, North Mecha (Amhara) Wondo Genet (Sidama)	Bahir Dar Zuria, North Mecha, Fogera (Amhara) Woliso (Oromia)

Figure 11: Woreda comparisons against key metrics provides the key evidence for drawing the comparison.

Table 16: Prioritisation of woredas for implementation

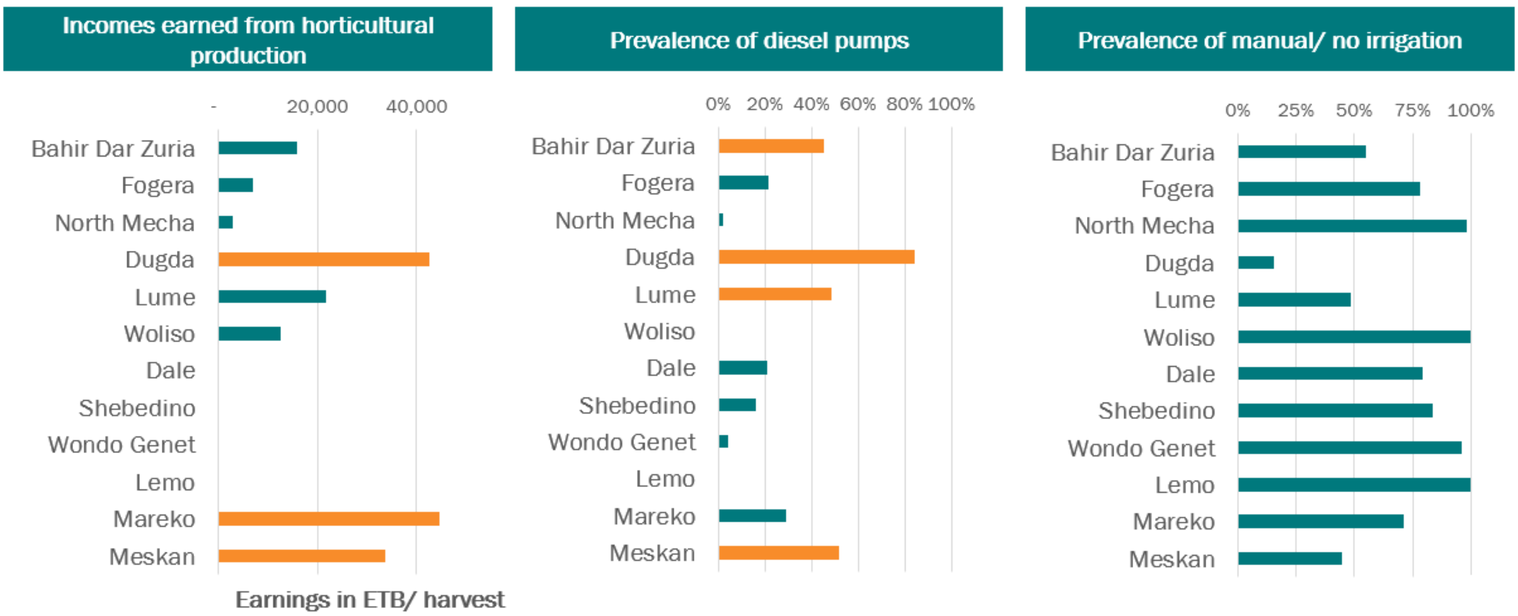
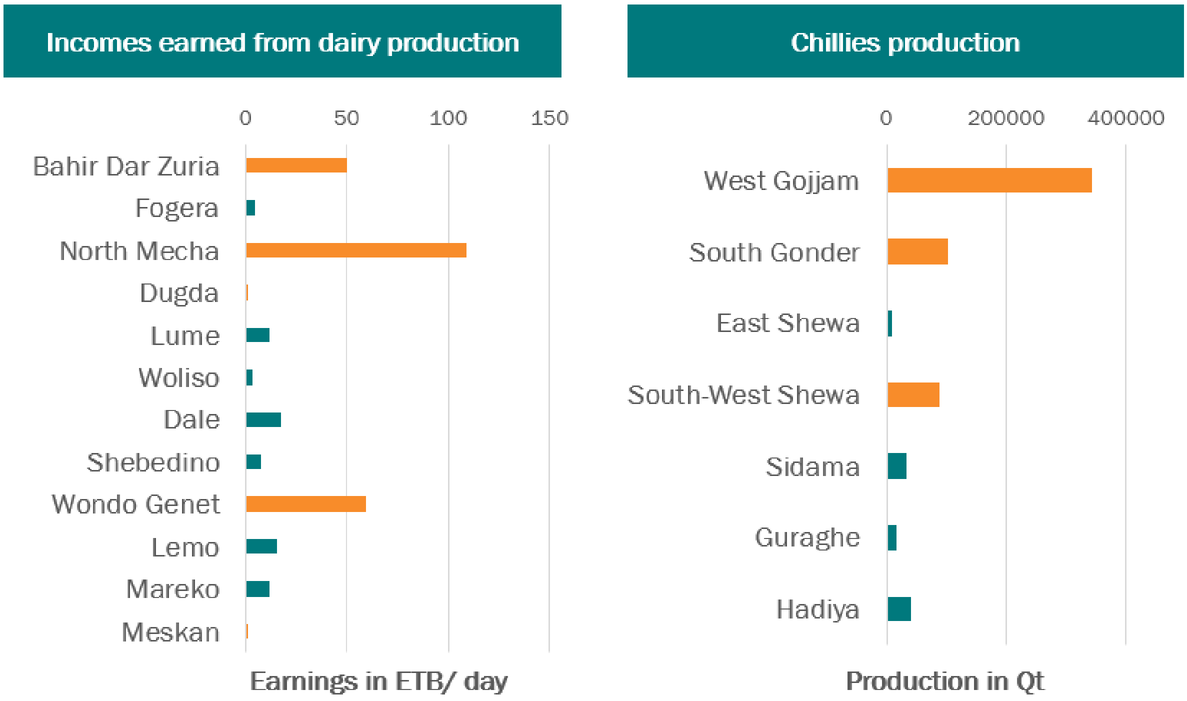


Figure 11: Woreda comparisons against key metrics



Based on the above analysis, Bahir Dar Zuria (Amhara), North Mecha (Amhara), Meskan (SNNP), Dugda (Oromia) and Wondo Genet (Sidama) would provide a good combination of woredas for implementing the support package. However, **it is critically important to align woreda selection with existing and planned GIZ/ SNV projects and with government counterparts.** The shortlist presented in this section is, therefore, only a suggestion, to be validated with partners.

4. Kenya

4.1 Introduction to the target sectors

The following section provides an overview of the two value chains or sectors, including key statistics of the production patterns, nutrition and consumption practices, the structure of the value chain, the differing roles for men and women, and the key constraints limiting productivity, market reach and farmer incomes.

Agriculture is the backbone of the Kenyan economy, comprising of 35.2% of the Gross Domestic Product (GDP) in 2020 and valued at $34.7B. The sector has grown at 11.94% per annum since 2011, of which horticulture and dairy have remained key contributors.[8]

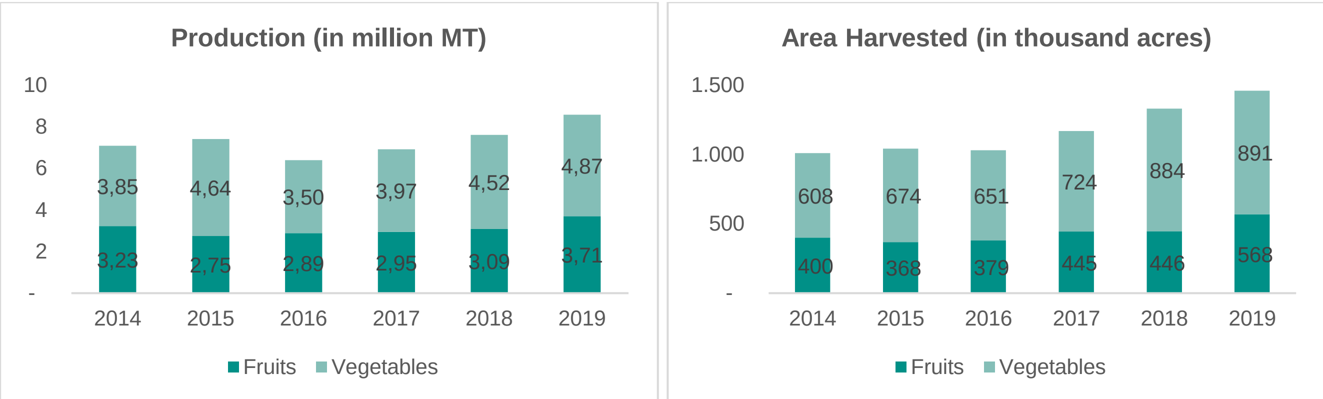
4.1.1 Horticulture

Production, consumption and exports

Horticulture sector in Kenya is composed of five sub-sectors – vegetables, fruits, flowers, nuts, and medicinal and aromatic plants. The sector is among the leading foreign exchange earners and contributes significantly to farmer livelihoods and employment to a range of actors such as traders, transporters, informal vendors, formal retailers, wholesalers, logistics companies and processors. Vegetables and fruits account for at least 75 percent[9] of the total horticulture sector. The design and implementation of SEFFA program will focus on Kenya's fruits and vegetables sub-sectors, and therefore the analysis presented in this report includes the same.

According to Food & Agriculture Organization (FAO), around 8.5 million metric tonnes (MT) of fruits and vegetables were produced in Kenya in 2019. This grew from ~7 million MT in 2014 at 3.26 percent per annum. Fruit production, comprised of 45 percent of the total volume in 2014, but this has marginally reduced to 43 percent in 2019 with the largest drop in 2015, in which in terms of absolute volumes as well as relative composition of fruit production reduced in Kenya. In terms of area of land, a total of 1.46 million acres was harvested in 2019 for fruits and vegetable production, with the latter harvested on nearly 62 percent of the total.

Figure 12: Fruit and vegetable production and area of land harvested in Kenya

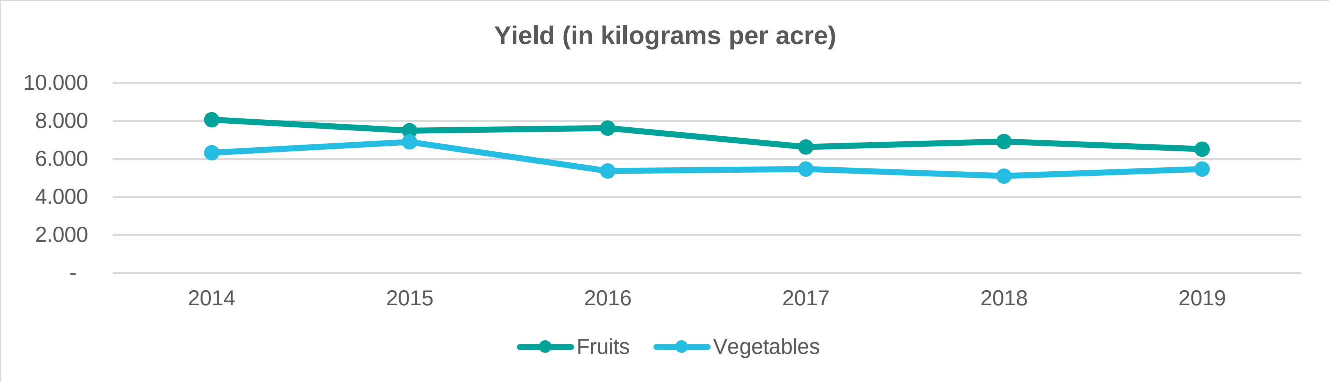


Source: Food & Agriculture Organization (FAO) Statistics for Kenya (2015-2019)

While overall production volumes and area of land harvested has increased, the productivity of fruits and vegetables in terms of kilograms per acre has reduced from 7,019 in 2014 to 5,880 in 2019. Much of this is attributed to two trends, each having a positive and negative impact on overall productivity – (1) increased diversification of production to include other items such as cauliflower, cabbages, cucumber, garlic, spinach and Asian vegetables, has improved farming methods, access to variety seeds, and hence volumes and yield of these items; (2) climate change and over-production of conventional items, specifically tropical fruits such as passion fruit, mangoes, avocadoes, bananas and watermelons, their yields have fallen significantly.

Figure 13: Fruit and vegetable productivity in Kenya

[8] World Bank Data – Agriculture, Forestry and Fisheries Value Added (in % of GDP and in US$ current value) for Kenya (2011, 2020)
[9] Research Solutions Africa (2015), A Report on a Desk Study of Fresh Vegetables Market in Kenya



Source: Food & Agriculture Organization (FAO) Statistics for Kenya (2015-2019)

The table below summarises top fruits and vegetables produced in Kenya. While production is being diversified to produce a variety of new fruits and vegetables, bananas, potatoes, sweet potatoes, mangoes, and cabbages continue to the largest produced items.

Table 17: Top fruits and vegetables produced in Kenya

Average Fruit Production (2014-19) in MT			Average Vegetable Production (2014-19) in MT		
Avocados	225,804	7.34%	Cabbages and other brassicas	755,575	17.57%
Bananas	1,428,569	46.43%	Carrots and turnips	198,225	4.61%
Lemons and limes	19,291	0.63%	Cauliflowers and broccoli	4,506	0.10%
Mangoes, mangosteens, guavas	718,554	23.35%	Chillies and peppers, green	2,314	0.05%
Oranges	81,228	2.64%	Cucumbers and gherkins	3,832	0.09%
Papayas	126,296	4.10%	Garlic	2,029	0.05%
Pineapples	290,764	9.45%	Okra	7,167	0.17%
Strawberries	750	0.02%	Onions, dry	45,621	1.06%
Watermelons	185,707	6.04%	Plantains and others	32,892	0.76%
Total	**3,076,963**		Potatoes	1,737,925	40.41%
			Spinach	125,312	2.91%
			Sweet potatoes	892,750	20.76%
			Tomatoes	492,366	11.45%
			Total	**4,300,514**	

> 20%	5%-20%	<5%

Source: Food & Agriculture Organization (FAO) Statistics for Kenya (2015-2019)

Most of the fruits and vegetables are produced in southern parts of Eastern and Rift Valley provinces, Central province and the Coastal province of Kenya; specific counties include – Muranga, Thika, Makueni, Embu, Meru, Nyeri, Bungoma, Nakuru, Naivasha, Kilifi and Kwale. As per the baseline survey among 579 smallholder farmers, carried out as part of this study, each farmer produces 2,500 to 4,000 kilograms of fruits and vegetables on their farmland each year. This production is in addition to maize, beans, coffee, tea and other such items produced by the farmers on a land with average area of 1-1.75 hectares (~2.47 to 4.32 acres of land). Around 40-50 percent of this land is used for horticulture crop production for 2-3 times in a year. While 95 percent of these horticulture volumes are sold commercially by smallholder farmers, the remainder is consumed by the farmer-households. On average, as per the survey, each household consumes 7 kilograms of fruits and vegetables per week.

According to the Enhanced Food Balance Sheet of Kenya (2014-18) – a study conducted by Kenya National Bureau of Statistics, per capita calorie intake per day among Kenyans have increased from 2206 calories in 2014 to 2235 calories in 2018. Of this, over the same period, contribution of fruits and vegetables to calorie intake per day has remained constant at 87-88 percent. However, the study indicates changes in fruit and vegetable dietary patterns – households are consuming proportionately less volumes of bananas, potatoes, cassava and such staple items and are increasingly adding carrots, cabbages, tomatoes, onions, spinach to their daily diet. This is further validated by the smallholder farmer baseline survey presented in the data portrait.

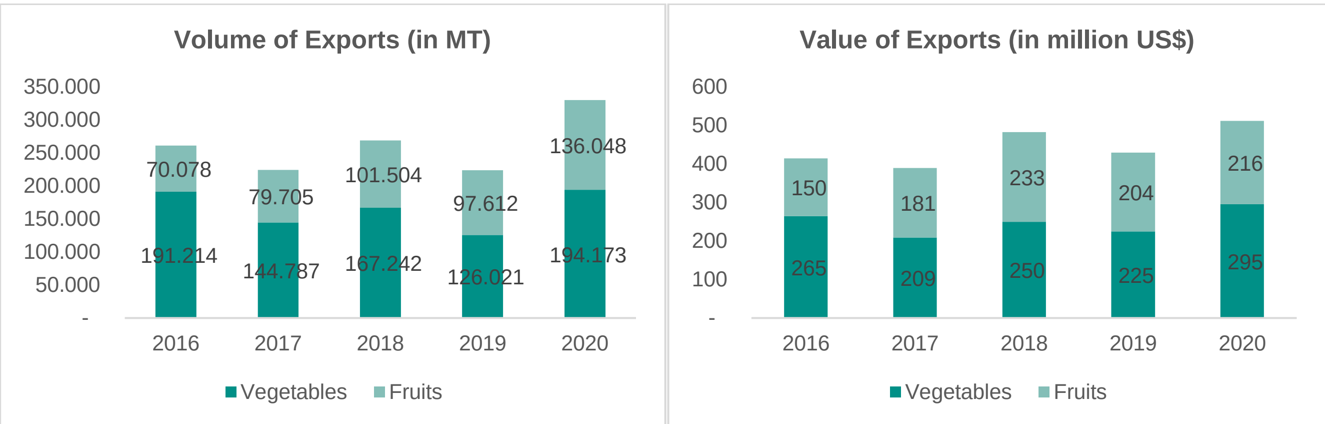
Additionally, consumption of value-added items in Kenya is also increasing, particularly among urban and semi-urban areas. These items include – fresh fruit juices and smoothies, fruit yoghurts, banana and potato chips, dried fruits such as bananas, mangoes, pineapples, and jackfruit. These trends are the drivers behind structural changes in the horticulture value chain – i.e., diversified consumption of fruits and vegetables and consumption of processed items; and more importantly increasing investments in the industry to improve quality along the value chain and supply chain and to produce value-added items. More on this will be discussed in forthcoming section.

The quality of production has increased in the last decade – the Kenya Agriculture & Livestock Research Organization (KALRO) has sourced and developed several locally-bred varieties of seeds / seedlings. The organization has collaborated with International Potato Centre (CIP) and World Vegetable Centre (WVC) to produce sweet potato and African green leafy vegetable seed varieties[10]. These efforts have been combined with those from Kenya Plant Health Inspectorate Service (KEPHIS) and those from international organizations such as Kenya Markets Trust and the US Agency for International Development (USAID) under the Feed the Future Program) to improve -among others- access to agriculture inputs such as seeds, fertilizers, tissue culture for bananas through agriculture – stockist supply network and to improve inspection services to improve quality.[11]

Farmers are more aware of the quality of agriculture inputs available, have a strong network with stockists (that offer convenient delivery and payment methods such as use of M-Pesa) and can differentiate counterfeit seeds. Moreover, the practice of out-grower models and contract farming is also becoming popular in Kenya.[12] According to our focus group discussions with smallholder farmers in Muranga, Makueni and Kajiado, exporting companies are closely working with farmers to offer extension services and support them in seeking Global Good Agriculture Practice (Global GAP) certifications.

Fruit and vegetable exports have grown at 4.79 percent per annum between 2016 and 2020. Fruit exports have grown at 14 percent each year from 70,000 MT in 2016 to 136,000 MT in 2020, whereas vegetable exports have grown barely at 0.31 percent – i.e., remained stagnant at 191,000 MT during the same period. In terms of value, fruit exports grew at 7.62 percent from 2016 to 2020, valued at $216 million in the last year, and vegetable exports grew at 2.21 percent during the same period, valued at $295 million in 2020. As a result of differences in growth rates of volume and value of exports, the unit prices of fruits have fallen from ~2,138 US$ per MT in 2016 to 1,590 US$ per MT in 2020[13].

Figure 14: Fruit and vegetable exports by Kenya



[10] (2018) Technical Report: Planting Materials for Value Chain Crops, Prepared by Agri-Experience for RTI International – Kenya Crops and Dairy Market Systems Activity (KCDMS), Feed the Future funded by USAID

[11] Match Maker Associates (2017), *Mapping of Production of Fruits & Vegetables in Kenya,* Study commissioned by the Embassy of the Kingdom of the Netherlands

[12] Alulu Joseph, David Jakinda Otieno and Willis Oluoch-Kosura (2019), Drivers of Transformations in Smallholder Indigenous Vegetable Value Chains and Contract Farming Evolution in Western Kenya, Paper prepared for oral presentation at the 6th international conference of African agricultural economists held at Abuja, Nigeria

[13] Analysis based on International Trade Centre data

Source: Kenya's exports of HS Code 07 and 08, International Trade Centre Statistics (2016 – 2020)

The tables below summarise top fruit and vegetable exports by Kenya, on average from 2016 to 2020 in US$. These include – mangoes, pineapples, avocadoes, leguminous vegetables, potatoes, carrots, cabbages, etc. These are formal exports from Kenya, exported to EU and Middle East. The country also exports informally to its neighbours (Uganda, Tanzania, Somalia) through its cross borders. The informal market is dominated by small-scale traders and women vendors who export daily 0.5-2 MT to households living on other side of the border. Kenya also imports small volumes of fruits and vegetables, particularly, tomatoes, pineapples and citrus fruits from Uganda, grapes and strawberries from South Africa, mushrooms from Rwanda.

Table 18: Kenya's key fruit and vegetable exports

Top Fruits Exported by Kenya (average 2016 -2020)	Value (in US$)
Dates, figs, pineapples, avocados, guavas, mangoes and mangosteens, fresh or dried	117,548,400
Other nuts, fresh or dried, whether or not shelled or peeled (excluding coconuts, Brazil nuts ...	71,460,600
Fresh strawberries, raspberries, blackberries, back, white or red currants, gooseberries and ...	3,614,600
Coconuts, Brazil nuts and cashew nuts, fresh or dried, whether or not shelled or peeled	2,572,000
Citrus fruit, fresh or dried	884,600
Other fruits	681.400
Total	**196,761,600**
Top Vegetables Exported by Kenya (average 2016 -2020)	**Value (in US$)**
Other vegetables, fresh or chilled (excluding potatoes, tomatoes, alliaceous vegetables)	66,156,200
Dried leguminous vegetables, shelled, whether or not skinned or split	48,160,000
Vegetables, uncooked or cooked by steaming or boiling in water, frozen	49,059,600
Leguminous vegetables, shelled or unshelled, fresh or chilled	70,190,400
Potatoes, fresh or chilled	2,448,800
Carrots, turnips, salad beetroot, salsify, celeriac, radishes, and similar edible roots, fresh	2,825,000
Cabbages, cauliflowers, kohlrabi, kale and similar edible brassicas, fresh or chilled	3,291,200
Onions, shallots, garlic, leeks and other alliaceous vegetables, fresh or chilled	5,882,200
Dried vegetables, whole, cut, sliced, broken or in powder, but not further prepared	311,200
Tomatoes, fresh or chilled	125,600
Cucumbers and gherkins, fresh or chilled	47,200
Roots and tubers of manioc, arrowroot, sweet potatoes and similar	52,800
Vegetables provisionally preserved, e.g. by sulphur dioxide gas, in brine, in sulphur water	243,800
Lettuce, fresh or chilled	20,600
Total	**248,814,600**

Source: Kenya's exports of HS Code 07 and 08 at 6-digit, International Trade Centre Statistics (2016 – 2020)

Structure of the value chain and key challenges

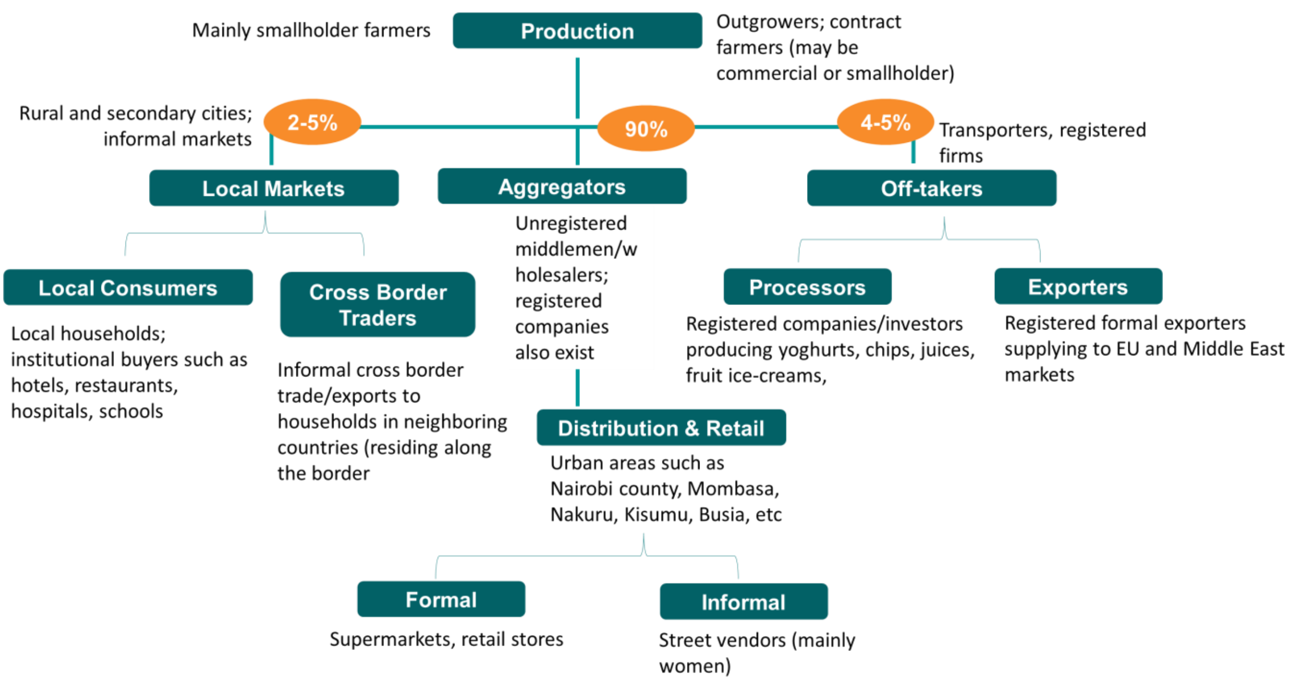
The structure of Kenya's horticulture value chain is complex and fragmented comprising of many middlemen and traders. Smallholder farmers producing fruits and vegetables are at the apex. These farmers are largely grouped in co-operatives that help them market their products and provide access to aggregators and off-takers. About 2-3 percent (mostly less than 5 percent) gets self-consumed by farmer households, while remainder is sold commercially through three different channels:

1. A large proportion is sold to brokers or aggregators (the middlemen in the supply chain) who arrange for transportation and then further supply to informal and formal retail markets in large and secondary cities of Kenya. The informal retail channel includes street vendors, dominated by women, whereas formal channels include supply to (a) hotels, restaurants, and cafeterias (HORECA) and (b) supermarkets, retail

stores – which is the fastest growing distribution segment. While most of these aggregators and brokers are informal or grouped into transport co-operatives, there are a few emerging formal aggregators (acting as wholesalers). These formal registered aggregators have invested in their fleet of trucks, banana ripening centres and storage infrastructure in cities. The farmers harvest the same day when aggregator or broker is available to procure. These sales mainly happen in the early morning hours (2-3 AM) and vehicles of different types (ranging from small vans, mini trucks of 8MT capacity to large trucks of 30 MT capacity) visit farm gates to aggregate and transport all fruits and vegetables. Farmers have limited or no storage facility and therefore to avoid spoilage they practice same day harvest – same day sales. Transportation during early morning hours ensure that the temperatures are low, and fruits and vegetables would remain protected from the heat. Farmers are price-takers – the prices are determined by the aggregators or brokers based on supply volumes.

2. Some farmers (including both smallholder and commercial farmers) supply to processors and exporters – these are registered companies that offer extension services and agriculture knowledge to farmers to produce items that meet the required quality. The supply chain in this channel is different and more sophisticated, as quality is prioritised from farm to fork. Most of these export to EU markets and Middle East countries, mainly UK, Germany, France, and UAE. The standards in both these markets are different and therefore most exporters supply to the wholesalers in the EU and UK (as standards are more stringent) whereas exporters supplying to UAE work directly with retailers and supermarkets. Kenya also has a fast-growing fruit processing industry – several companies in industrial areas of Nairobi and along Mombasa produce packaged fruit juices, fruit yoghurts, packaged frozen and canned vegetables and fruits, a variety of chips made from potatoes, bananas, cassava, and fruit ice-creams. These by-products of processed items are for the local consumers in Nairobi and other secondary cities, as supplied via formal retail channels, while small volumes are also exported to rest of the countries in East Africa.
3. The third channel is where the remainder of the volumes of fruits and vegetables are sold by farmers to local intermediaries within their counties. These intermediaries sell in the local market and supply to local institutional buyers such as schools, hospitals, restaurants, hotels, etc. The exhibit below provides an overview of these three supply channels.

Figure 15: Structure of Kenya's horticulture sector



Source: Stakeholder consultations

Despite the evolving structure of Kenya's horticulture industry, particularly with increase in formalisation of supply chains, there continue to be several challenges:

Production –

- Farmers are price-takers and not price-setters. This does not give farmers a bargaining power in negotiating prices. The key reasons for such a practice are – (1) lack of cold storage does not allow farmers and co-operatives to hold back a portion of the production volume and sell these when the supplies are limited or when there are opportunities to increase prices. As a result, the co-operative structure remains very ineffective for horticulture farmers; (2) several middlemen are involved in the supply chain who do not offer direct market access to the farmers. As a result, farmers remain unaware of the actual prices in the end-consumer market and the margins are earned by the middlemen.
- Several farmers around the country lack technical agriculture expertise– these farmers produce tubers and roots (potatoes, sweet potatoes, cassava, etc) and less of other diversified fruits and vegetables. These farmers also have limited market access opportunities.
- Prices of agriculture inputs (seeds, fertilizers and other chemicals) increased, specifically during Covid-19 times); farmers around Nairobi County increasingly realise excessive competition from nearby counties and therefore earn low margins.

On-Site Storage & Transportation -

- No on-site storage at farmer level and co-operatives have limited investment capacity. Kenyan farmers and aggregators practice 'same day harvest – same day pick up' – and therefore this does not incentivise the farmers and co-operatives to invest in or rent cold storage infrastructure. Farmers are more concerned about daily cash-earnings and getting rid of the produce before it spoils.
- Transportation from farms to processing sites or export collection centres or further distribution is via a range of vehicles (bikes, motor vehicles, trucks of all sizes – 8 – 12 – 20 MT) and there is no standardization.
- Limited or poor infrastructure at local county-level markets which increases spoilage.

Processing -

- Processing is carried out by large players / investors in Nairobi with small scale production at county level (mainly juice production and drying). Fruits are also supplied as raw materials to yoghurt industry, but such practices do not exist in semi-urban and rural areas. Contract manufacturing for drying fruits is increasing, mainly for export products. Small-scale industries such as potato chips processing is growing but these industries have limited marketing capacity.
- Constraints for small scale industries to scale up businesses include - competition from large players; access to finance and technology; lack of cold storage to store fruit and vegetable inventories and therefore cannot take advantage of price fluctuations.

Distribution and Sales –

- As high as 40-50 percent of fruits and vegetables are spoilt in the supply chain from farm gate to retail in Kenya. This is mainly due to lack of cold chain infrastructure and high proportion of informal retail which lets street vendors sell items for up to a week in the sun (with no shade) – products such as bananas, tomatoes which ripen quickly get spoilt easily.
- Due to demand uncertainty in terms of volumes (while demand overall is increasing), retailers and aggregators prefer 'same day harvest – same day sales' model. Cold storage and management of fruits and vegetables in retail stores is limited or negligible – application of sprinklers to keep green leafy vegetables in the stores fresh and lasting for up to 1 week, does not exist.
- Spoilage in informal retail sales is significantly high. Upcoming models such as Twiga[14] connects farmers with informal retailers and uses storage infrastructure and banana ripening centres – such models have increased reliability of supply and transportation and cut down middlemen which results in lower prices to consumers and better margins for farmers.

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[14] Case Study 3: Twiga Foods – Improved market access for farmers and a reliable supply for vendors, START-UPS AND MOBILE IN EMERGING MARKETS: INSIGHTS FROM THE GSMA ECOSYSTEM ACCELERATOR

Role of women and youth

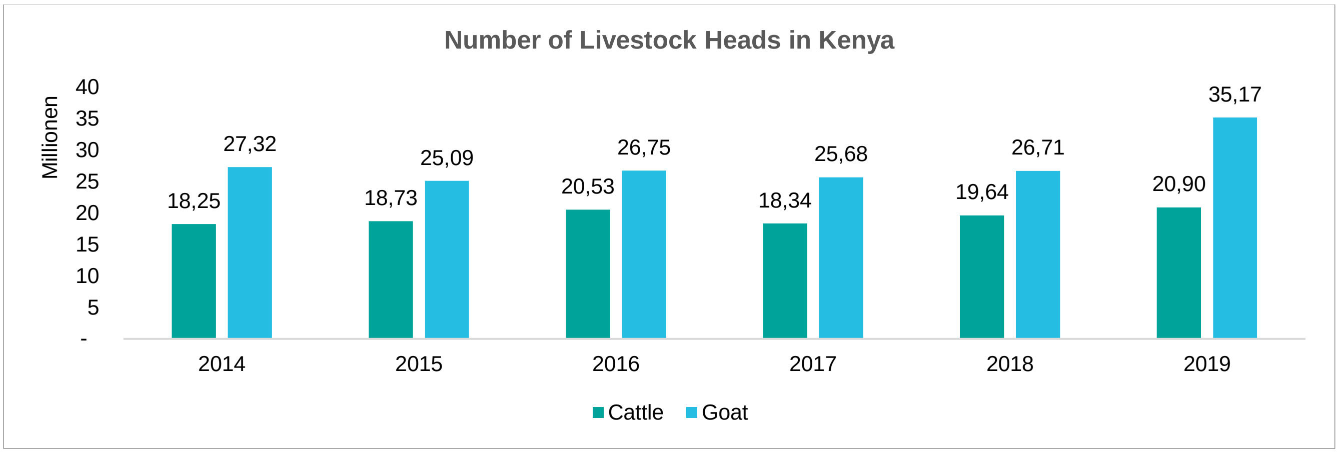
Men have the primary role of pumping water through advanced irrigation methods, purchasing agriculture inputs, transporting fruits and vegetables (if using vehicles and not on foot) and selling bulk volumes to brokers and middlemen. Women, on the other hand, restrict themselves to on-site farming activities such as land preparation, pumping water from a shallow well, harvesting, cleaning and sorting fruits and vegetables, selling items in the local market and small-scale household level processing such as sun-drying mangoes or bananas. Among the youth, both men and women are interested in progressing towards being commercial farmers to produce high quality fruits and vegetables, investing in green houses, exporting items and investing in technologies such as juice production and drying. There is significant interest among these groups to learn new agriculture practices – several of them attend seminars and workshops held by donors, Jomo Kenyatta University and KALRO. The youth are also interested in distribution and retail, particularly, establishing retail shops to sell agriculture inputs and fruits and vegetables (a grocery store).

4.1.2 Dairy

Production and consumption

Kenya has ~55 million goat and cattle livestock, of which there are 35 million goats and remainder cattle. Number of heads of goats have increased at 4 percent per annum since 2014, whereas that of cattle has increased by 2 percent. However, nearly 90-95 percent of fresh milk produced in the country is from cows: ~3 billion litres per annum which has been growing at the same rate as the number of cattle.[15] Counties in Rift Valley and Eastern provinces have the largest number of cattle; these include – Uasin Gishu, Kericho, Machakos, Meru and Embu[16]. The distribution of livestock is driven by increased migration of households from densely populated high rainfall areas and vulnerable zones with climate variations to medium rainfall areas, which allow smallholder farmers to open pastures for feeding cattle.

Figure 16: Number of livestock heads in Kenya

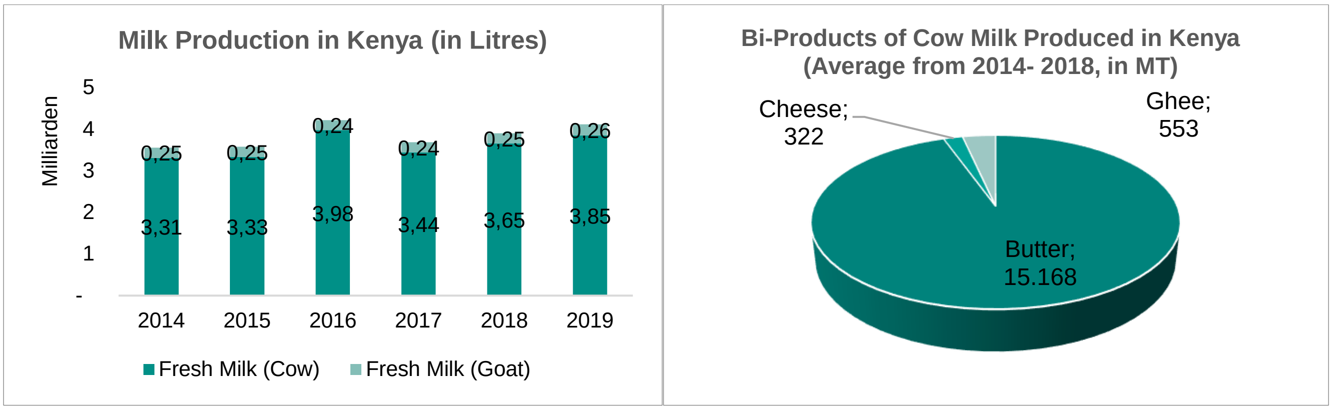


Source: Number of Livestock (by type) in Kenya (2014-2019), Food & Agriculture Organization Statistics

According to data available for 2016, per capita milk consumption in Kenya is estimated to be 110 litres.[17] According to the National Dairy Master Plan (2010), this consumption is expected to increase to 220 litres by 2030 due to envisaged better incomes which will drive investments in milk processing. This would, therefore, translate to production requirement of 12.76 billion litres by 2030 from level of 4 billion litres in 2010.. There is substantial need to improve the breeds of the cattle, to improve productivity levels from current 5 litres of milk per day per cattle, invest in inspection and health services of cattle and cold chain. It is also expected that a certain proportion of this demand would also be met through plant-based milk and its biproducts, particularly, use of soy and almond milk.

[15] FAO Statistics for Kenya (2014-19)
[16] (2014) USAID KAVES Dairy Value Chain Analysis
[17] Denise Recheis (2017), Dairy Value Chains in Kenya and Potential Entry Points for Clean Energy Solutions, REEP Project, INVESTA FAO

Figure 17: Milk and its biproduct production in Kenya



Source: Volumes of milk, ghee, butter and cheese produced in Kenya (2014-2019), Food & Agriculture Organization Statistics

One of the key concerns prohibiting increased productivity of milk is the feeding patterns in Kenya. Feeding constitutes a large proportion of the costs of milk production in market-oriented dairy farming in Kenya. Generally, dairy animals are underfed, with most smallholder farmers feeding dairy cattle on natural forage, cultivated fodder, and crop by-products. The feed/forage used by farmers includes maize, dried poultry waste, hay silages, homemade rations of locally available grains and other ingredients (sometimes even fruits and vegetables) and grazing. Cow milk in Kenya is also used to produce a variety of byproducts such as 15,000 MT of butter annually, followed by ghee and cheese. This is mainly produced by registered companies, more of which is discussed below.

Structure of the value chain and key challenges

Kenya 's dairy sector is dominated by small-holder farmers who constitute 70% of total production. Large cattle sheds or farmers with multiple cows is limited. A few farmers also have goats and camels, though cattle are mainly considered as an asset for milk production. According to the baseline survey conducted for this study, smallholder farmers have 2-3 cows, and each produces 8-10 litres of milk – each cow is milked twice (very rare, thrice as well) in the day – one in the morning and second in late afternoon. The farmers are grouped into dairy co-operatives that support farmers in aggregating milk and marketing to large scale dairy companies. Compared to horticulture value chain, farmers in dairy value chains are not always price takers. While the farmers are aware of the prices at which milk is sold to large milk processing companies, the price is negotiated between the company and the co-operative.

The dairy co-operatives supply to milk processing companies such as New Kenya Cooperative Creameries and Brookside Dairies that hold 60% of the processing capacity (pasteurization and packaging), and to other local institutional buyers such as county-specific milk processing co-operatives or to schools, hospitals, restaurants, etc. The co-operative earns a margin on transportation and sales of milk on behalf of farmers and then uses these savings to invest in milk cans, vehicles and even cooling facilities.

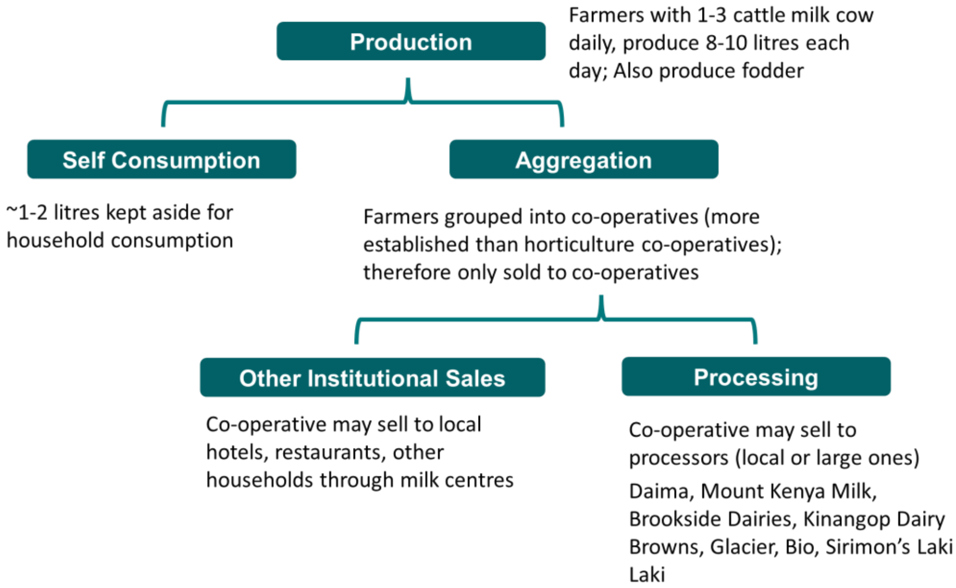
Some of the milk is also supplied to companies producing biproducts such as cheese, yoghurt, butter and ice-creams – the number of such companies have increased in the last decade in Kenya and supply these items to urban consumers. Most of the value addition to milk is through formal channels, while informal production is limited. Households in Kenya also do not produce as much of butter or ghee or yoghurt – such practices are limited. Household consumption of milk is mainly limited to feeding milk to infants (in the age group of 0-5 years), young children (5-12 years), using milk in tea and fermenting milk to eat with *ugali.*

However, there continue to remain several challenges in the dairy industry of Kenya -

- Limited infrastructure such as cow sheds, safety and standards for animal husbandry (inspection requirements) and cold chain infrastructure from farm to market. Most of the cold chain infrastructure is from collection centres to milk processing units of large companies.
- Distribution is heavily driven by co-operatives, giving some bargaining power to farmers based on volume and margins.
- Fodder options are limited, and spoilt food is also fed to animals which affects health.
- On farm milk losses due to spoilage. According to a 2014 FAO Study, national milk losses were 7.3 percent

- Increase in milk product imports (such as milk, cream, curd, yoghurt) which is ~22,000 – 30,000 MT per annum

Figure 18: Structure of dairy value chain in Kenya



Source: Stakeholder consultations

Role of women and youth

Similar to horticulture value chain, in the dairy value chain of Kenya, men are more involved in activities requiring physical labor and interactions with other stakeholders in the supply chain. Men are engaged in irrigation of fodder, purchasing/sales of livestock, taking animals for health inspection, transporting milk to collection centers, coordinating with the co-operative on prices and volumes of sale and revenue generated. On the other hand, women are involved in taking care of animals, feeding fodder and water, bathing animals, delivering milk to neighbors or at a small-scale to local markets, filling up milk cans, and processing milk at household-level.

The youth, particularly men, participate in milk aggregation and transport service for co-operatives and are interested in investing in high-quality cattle breeds, establishing cow sheds and resting centers, exploring milk production from other livestock, such as goats and from plants such as soybeans and establishing such businesses, producing yoghurts and ice-creams for rural and semi-urban populations of Kenya. Despite these interests, there are obstacles such as limited technical knowledge and access to finance.

4.2 PUE technologies currently in use in Kenya

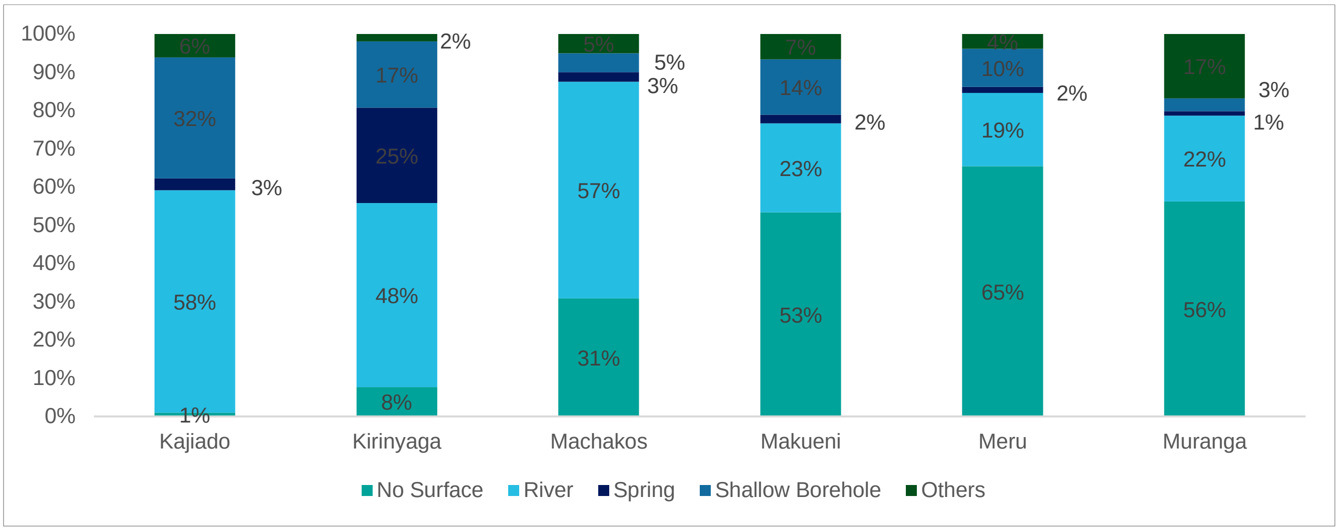
In this section, we present our findings from baseline survey and market research to capture current practices of technologies (PUE and non-PUE) among smallholder farmers of dairy and horticulture value chain, illustrate existing supply of such technologies and highlight key challenges.

4.2.1 Solar irrigation for horticulture production

According to the baseline survey, at least 30 percent of the farmers in Muranga, Meru, Makueni and Machakos have limited access to surface water[18]. The farmers rely on rain for irrigation of their crops. Farmers in Kajiado rely on water from Athi River basin to irrigate their land. Some of the farmers also use shallow boreholes to access water. Likewise, in Kirinyaga, farmers access water from Thiba River, while around 40% also use spring water and shallow boreholes. In Meru and Muranga counties, farmers experience extreme weather conditions, and therefore, have limited surface water resources; farmers rely on rainwater during the monsoons, while others use drip irrigation.

[18] Surface water refers to lakes, ponds and other forms, apart from rivers and spring water

Figure 19: Access to surface water sources among smallholder farmers

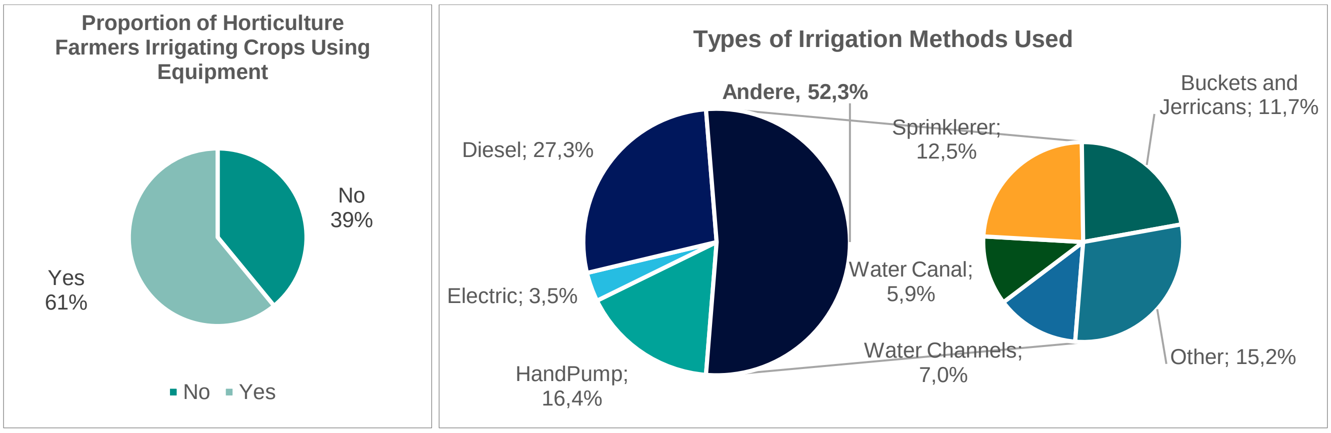


Source: Baseline survey; N= 574

Given various resources of water, as per the survey, 61% of the farmers (~350 farmers) use irrigation equipment to farm their lands. 27% of these farmers (95 farmers) use diesel or petrol powered water pumps, 17% use hand pumps (60 farmers) and around 50% of these (175 farmers) use other methods such as sprinklers, buckets and jerry cans and direct sourcing from water canals using hose pipes. These findings resonate with the findings from focus group discussions, where at least 80 percent of the farmers in Kirinyaga and Machakos counties indicated use of petrol- or diesel-powered water pumps during dry or non-monsoon seasons.

The cost of purchasing such a diesel or petrol powered water pump is 40,000 to 50,000 Kenyan Shillings (Ksh) – this allows farmers to pump up to 15,000 – 20,000 liters of water per hour for a 1-acre land. However, these farmers indicated that the cost of operating such a water pump is very high, as farmers need to spend at least 1,000 Ksh per week to buy fuel.

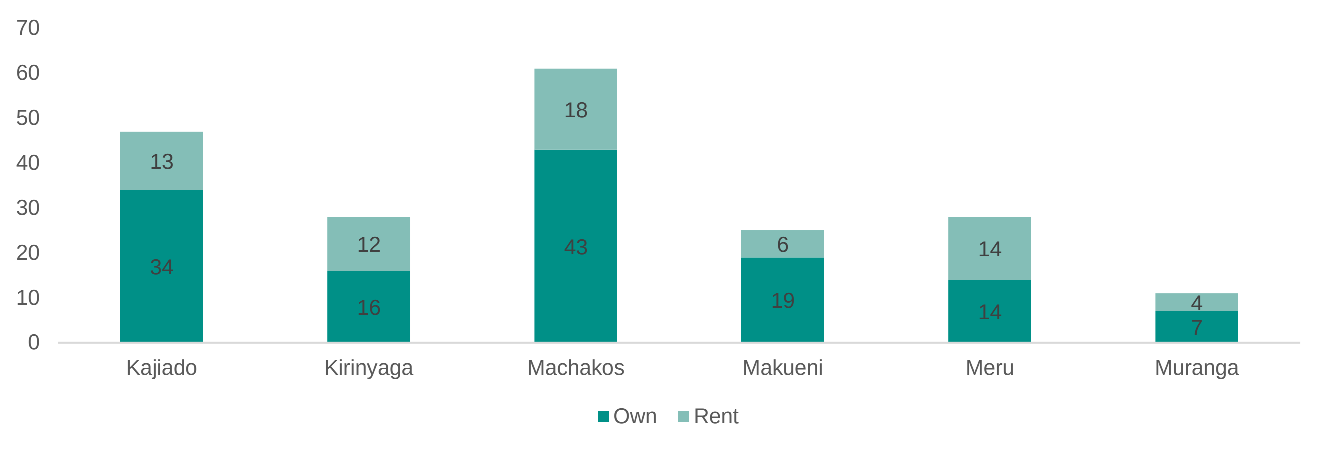
Figure 20: Irrigation practices among smallholder farmers in Kenya



Source: Baseline survey; N=574 for figure on the left; N=350 for figure on the right

Most of the farmers using some form of irrigation equipment, specifically diesel-or-petrol-powered water pumps of sprinklers, own the equipment. However, others using jerry cans or buckets or handpumps either borrow or rent such equipment from neighbors.

Figure 21: Number of farmers who own or rent irrigation equipment



Source: Baseline Survey; N=165

Application of solar powered irrigation systems or solar powered water pumps is almost negligible or limited to a handful of farmers in each of the counties. According to our consultations with these farmers, they indicated lack of awareness of such as technology as the key reason. Some of the farmers were aware of such equipment offered and sold by companies such as Davis & Shirtliff and Sunculture – these farmers have either attended demonstration sessions organized by the companies or have come across the products in agriculture stockiest stores in Meru Town and Embu. However, these farmers indicate that the cost of investment in solar-powered technologies is very high and mentioned that they are aware that such equipment costs as high as 100,000 Ksh. When probed further, these farmers were not aware of the capacity and usages of such technology, and neither were aware of the low or absolutely zero operations costs.

We interacted with several existing suppliers and distributors of PUE technologies in Kenya, specifically those offering component-based systems such as solar panels and batteries for households that want to switch to low-cost energy solutions and supplying items such as water heaters and water pumps that can be powered through solar energy. These companies indicated that there are two types of water pumps available for smallholder farmers – (1) which is 100 percent powered through solar energy and (2) which can be powered through hybrid sources of energy. The latter solution is offered to Kenyan customers as it meets their requirements during the monsoon seasons when access to sunlight is limited. However, these companies have been able make limited traction among smallholder farmers; their key customers are large scale farmers who are exporting. These farmers realize the benefits of switching from diesel-powered water pumps to solar powered water pumps by significantly reducing operations costs. Additionally, the solar powered direct drive equipment (including the panels and batteries) lasts for at least 10 years, and it is unlikely for a farmer to face any significant maintenance costs. These companies have targeted several counties in Rift Valley, Central, Eastern and Coastal Provinces of Kenya and have invested in marketing opportunities and awareness creation. Despite these efforts since 2018, each company is selling around 30-100 equipment per month, mainly to medium and large-scale farmers producing maize, beans and horticulture crops meant for exports. The table below summarizes the product offer of these companies for solar-powered water irrigation.

Table 19: Solar-powered water pump product offering by Kenyan distributors and suppliers

Current Products in the Market	1. Solar powered water pumps ideal for smallholder farmers with up to 1 acre of land 2. Hybrid water pumps – (a) electric plus solar powered ideal for medium sized to commercial farmers; (b) drip irrigation with solar powered water pump for smallholder farmers
Features of the Products (capacity, etc)	1. Solar powered water pumps for smallholder farmers can pump 1,100 to 2,500 litres of water per hour; this is more applicable for farmers with shallow borewells. Options are available to source water from 30 metres to 70 metres depth 2. Hybrid option of electric plus solar powered water pump can pump 20,000 litres of water per hour

Current Customers	1. Farmers producing horticulture crops (mainly for exports) 2. Companies with water pumps <50,000 Ksh have been able to penetrate into counties with longer dry seasons 3. Dairy co-operatives, small scale milk processors interested in sourcing solar energy to reduce costs
Cost of the Products & Financing Options	1. 45,000 Ksh – 110,000 Ksh for 100% solar powered water pumps; cost includes solar panels, batteries and other accessories 2. 400,000 Ksh – 600,000 Ksh for hybrid water pumps (solar plus other non-renewable forms of energy)
Target Markets	1. Rift Valley with more potential in Uasin Gishu and Kajiado 2. Central – Kirinyaga 3. Eastern – Machakos and Makueni 4. Coastal regions
Other Services Offered by PUE Companies	• Several companies have offices in various counties of Kenya • 3-year warranty service • A few companies have financing options
Challenges for Increased Penetration in the Market	• Awareness among farmers and willingness to shift from diesel to solar powered irrigation technologies • Weather conditions (must be dry / at least warm for most of the year) and access to source of water • Affordability due to high upfront cost of investment

Source: Stakeholder consultations

4.2.2 Drying horticulture products

Drying of horticulture products in Kenya, is an emerging opportunity for farmers, SMEs and large companies: mangoes, bananas, pineapples, jackfruit, berries are dried (i.e., dehydrated to remove water content), packaged and sold to consumers in Nairobi and other urban markets in Kenya. A few companies also export these products, but the volumes are low. For a smallholder farmer, drying fruits and vegetables offers an attractive opportunity to reduce spoilage, especially during monsoon season and when supply volumes are high such that price offered is very low. Sun-drying of bananas and mangoes is the most common practice among households in Kenya. This indicates that there is certainly demand for select dried fruits. However, for a smallholder farmer to invest in a drying technology that offers scalability and quality, requires him/her to invest in a technology that costs at least 30,000 Ksh.

Local entrepreneurs in Kenya (including those through partnerships with Jomo Kenyatta University of Agriculture and Technology (JKUAT)) have developed customised horticulture drying technologies – these technologies can range from a capacity of drying 50 kilograms of one fruit or one vegetable per session to as high as 500 kilograms. Only one item can be dried at a time, as each fruit or vegetable has a different level of water content, and a session may take from as low as 2-4 hours to as high as 16 hours to dry the items. This requires significant amount of energy and therefore these entrepreneurs have developed solutions for investors to use renewable forms of energy – such as combination of biomass and solar. As a result, apart from the initial capital investment, the investor would only incur costs of buying manure (which is very low – 10 Ksh per kilogram).

The companies have made strides in the market and have sold such technologies to co-operatives and SMEs in various parts of Kenya. According to them, smallholder farmer may not have the capacity to invest in it unless –

(a) The farmer is interested in establishing a business for drying fruits and vegetables – this requires packaging and labelling of products, managing quality and a strong understanding of markets; i.e., price structure, consumer base and marketing channels. Such technology may be more attractive to young farmers investing in green houses and producing a variety of fruits and vegetables and is entrepreneurial and has risk-taking capacity.

(b) Or the farmer rents out the technology to other farmers and generates income

Alternately, a group of farmers (even through a co-operative) may invest in such as technology. The table below presents key insights from our interactions with horticulture drying technology suppliers in Kenya.

Table 20: Horticulture drying product offering in Kenya

Current Products in the Market	Drying technologies for fruits and vegetables with capacity ranging from 50 kgs to 500 kgs per session; each session of drying may last from 6 to 10 hours depending on the water content in the fruit / vegetable
Current Customers	Farmers, co-operatives and SMEs in Central, Eastern and Coastal counties of Kenya *Such technology is new to the market, recent sales – 40-60 units per year*
Cost of the Products & Financing Options	30,000 – 500,000 Ksh depending on capacity No financing options available directly from the supplier
Target Markets	All horticulture producing locations in Kenya, specifically those that are rain fed and where volumes of spoilage are significant. Drying technology provides an alternative source of revenue
Other Services Offered by PUE Companies	• 3-year warranty • Installation and maintenance services; training included in the cost
Challenges for Increased Penetration in the Market	• Market for dried fruits and vegetables • Capacity of farmers, co-operatives and SMEs to package, label and market their products • Competition from imported dried fruits in urban areas (such as dried berries, apricots, etc) makes it challenging for small-scale processors to penetrate the market

Source: Stakeholder consultations

4.2.3 Cold storage for horticulture products

The previous section discussed about the extent of spoilage in the horticulture supply chain, particularly from aggregation to retail distribution and those farmers are price takers in the system. According to consultations with farmers and the baseline survey, the level of spoilage at the farm gate is low – around 2-3 percent per harvest. While additionally, some fruits and vegetables may have lost their shape and appearance, farmers believe these are not spoilt as long as these are free from diseases and fit for consumption. However, farmers still see benefits in a cold storage infrastructure at the collection center – the storage helps farmers to retain some of the volumes harvested and sell these a week or two later when the supply has reduced, and prices increase. This would also allow farmers to control or negotiate for better prices as they would have greater control on the volumes they can sell.

In Kenya, decentralized hybrid cold storage systems, powered by solar and other non-renewable forms of energy are available. Most of these cold storage systems are purchased by large scale processors and exporters, but attempts are being made to make these available to farmers and co-operatives using a user-fee or a rental-fee model.

The table below captures the current product offering – our consultations with such suppliers indicated that horticulture co-operatives or a group of farmers can invest in such storage infrastructure. Additionally, solar refrigerators are available for households to store daily perishable items such as fruits, vegetables, meat, milk and other dairy products. Such as system is more convenient for households that can invest in solar panels and use solar energy to power all electronic systems (including televisions) in the houses.

Table 21: Horticulture cold storage product offering in Kenya

Current Products in the Market	1. Solar refrigerators – *more suitable for household level storage of perishable items* 2. Rental cold storage for small and medium farmers – *hybrid models (solar and other sources of energy); being piloted in Kenya*
Features of the Products (capacity, etc)	1. Solar refrigerators - <10-15 kgs 2. Mobile cold storage – 10 – 1,000 pallets (assume 1-1.5 MT per pallet)
Current Customers	1. Refrigerators purchased by urban and semi-urban households using solar energy for household appliances 2. Rental cold storage is being piloted; limited evidence on success
Cost of the Products & Financing Options	1. Refrigerators – 200,000 – 250,000 Ksh 2. Depends on capacity; if used as a rental model, then the company decides the user fee (20-50 Ksh per Kg per day)

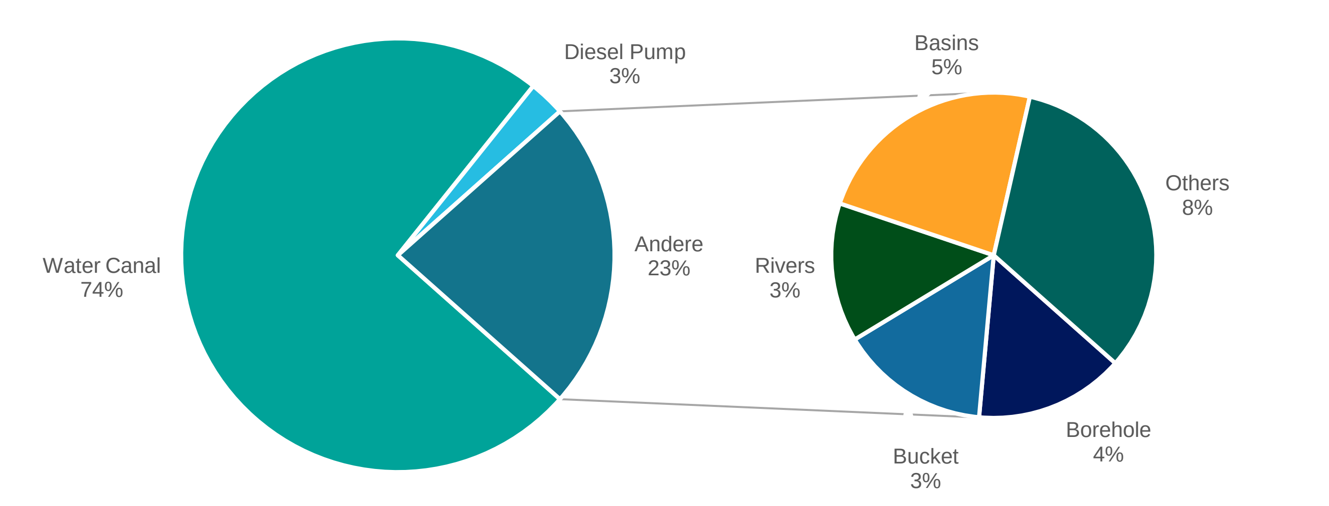
Challenges for Increased Penetration in the Market	• Same day harvest – same day sales practice; more importantly both farmers and retailers must see benefits from cold storage • Farmers reluctant to use cold storage as they require immediate cash • Cold storage for fruits and vegetables must be temperature controlled with compartmentalised differential temperatures to serve different types of items • Unstructured supply chains between farmers and retailers; farmers rely on traders/middlemen

Source: Stakeholder consultations

4.2.4 Chaff cutters and water pumps for dairy farmers

Several dairy farmers in Kirinyaga and Makueni have invested in chaff cutters to cut and process animal feed. The initial cost of investing in such an equipment is around 30,000 to 40,000 Ksh with a monthly operational cost of 100-200 Ksh per litre for purchasing fuel. The chaff cutter consumes around 1 to 1.5 liters of petrol per hour. In addition, farmers involved in both horticulture and dairy have invested in water pumps to irrigate land used for producing maize, beans, fruits, vegetables and animal feed. These farmers have access to shallow wells and pump water to also provide drinking water to cattle and bath them on a weekly basis. There is an opportunity for such farmers to shift to solar-powered technologies to reduce operations costs.

Figure 22: Methods for watering animals by dairy farmers in Kenya



Source: Baseline Survey; N=189

4.2.5 Cold storage for dairy farmers

As per our consultations with dairy farmers, spoilage of milk at the farms is very minimal – as low as 2 percent. Usually, the farmers immediately offer any unsold milk to neighbors or use it for self-consumption. Milk from farms is transported using milk cans to collection centers – either the farmers arrange for transportation, or the co-operative arranges for collection of milk from the farmers. However, a few co-operatives and their members do not have sufficient milk cans and therefore, they use jerry cans to transport milk. Select co-operatives have invested in a cold storage at the collection center or have been provided one by the county government. For example, a co-operative in Kirinyaga has a 9,000-liter cold storage for milk. The co-operative retains 1.8 Ksh per liter of milk sold for operations (such as hiring of motorbike riders to collect milk and consumption of energy). The co-operative incurs a cost of 250,000 Ksh per month to power the cold storage; this also includes the cost of running the generator. Milk is collected twice a day (mornings and late afternoons) from the farmers and sold within 4-5 hours of collecting. As a result, the co-operative needs to ensure that the cold storage continues to operate for at least 14 -16 hours in a day, assuming 100 percent of the milk gets sold each day. Similarly, in Muranga, the co-operative has a 5,000-liter milk cold storage facility supplied by the County Government. It relies on grid-based power supply and incurs a cost of 60,000 Ksh per month; additionally the co-operative may consume up to 4,000 liters of fuel per month due to erratic power outages.

There is opportunity for the co-operative to shift to solar-powered cold storage technology and further invest in cold transportation (together referred to as cold chain). There are suppliers in Kenya offering such technology, including mounting potable chillers on motorbikes or *tuk tuks.* However, the cost of investment is very high and a co-operative that has received grant-based support from county governments or donors and is financial unstable, may not be the target investor. Such an investment requires a financially strong co-operative with multiple dairy farmers as members (in thousands) and with a guaranteed market such as that from large milk processing companies in Kenya. The table below summarizes the dairy cold chain product offering.

Table 22: Dairy cold chain product offering

Current Products in the Market	1. Portable solar-powered chillers (which includes power back up); can be mounted on motorbikes and *tuk-tuks* – useful for collection and transportation of milk 2. Solar powered cold storage
Features of the Products (capacity, etc)	1. Portable chillers – 100 – 1,000 litres 2. Cold storage for milk – 120 – 240 litres Note: Cold storage of 5,000 – 7,000 litres also available; these were originally powered through non-renewable sources of energy and then co-operatives have recently shifted to use of solar energy to reduce cost
Current Customers	1. Milk / dairy co-operatives to invest in collection and aggregation of milk 2. Large dairy farmers (with at 20+ cows)
Cost of the Products & Financing Options	1. Potable chillers – 150,000 Ksh to 1,600,000 Ksh 2. Cold storage of milk – 200,000 Ksh to 300,000 Ksh
Other Services Offered by PUE Companies	• Training • Warranty – up to 3 years • Installation, repair and maintenance services
Challenges for Increased Penetration in the Market	• Weather conditions – 100% solar powered technologies do not work in monsoons. Therefore, need for hybrid sources of energy • High capital investment cost; not suitable for individual farmers • Milk transportation and storage requires reliable energy supply as the cold chain must not be interrupted and therefore grid-based solutions are usually more preferred

4.3 Gaps and constraints that limit expansion of PUE technologies

There are significant challenges hindering increase in uptake of PUE technologies among horticulture and dairy farmers in Kenya. While Kenyan farmers are more exposed to technological solutions such as diesel-powered water pumps, chaff cutters and milk cold storage, there are factors that prohibit these farmers from adopting more cost-effective solutions.

Lack of awareness

Some farmers are aware of such technologies given their frequent visits to stockists and hardware shops, but generally there is very limited awareness on what these technologies look like and how these function. As a result, helping the farmers realise of the benefits, particularly around costs, from investing in PUE technologies remains critical.

Financing options

High initial cost of installation (these cost 100,000 KES as against petrol-based water pumps that cost 40,000 KES). Farmers who are members of SACCOs can borrow loans but need to repay each month. This does not align with revenues from horticulture harvest cycle (once in 3-month earnings for farmers, or sometimes twice a year). The other commercial banks such as Equity Bank, Kenya Commercial Bank and among others offer loans but require a collateral. Also, such banks prefer offering loans to formal registered agriculture businesses. The micro-finance institutions, on the other hand, offer loans at a very high rate (as high as 20%).

However, the PUE technology companies have explored the option of offering financing plans to farmers. Most companies require farmers to pay an upfront deposit of 20% of the investment cost and pay the remainder in monthly instalment of 30-36 months. While this option may seem attractive, PUE companies have not been successful in conducting a thorough due diligence of farmer businesses and tracking their payments. These companies also attempted to partner with financial institutions that can conduct due diligence on their behalf, monitor loans and collect payments. However, this has not seen any success in Kenya. The table below summarises the various financing options offered by different institutions.

Table 23: Various financing options offered by financial institutions

	SACCOs	Micro-Finance Institutes	Development Banks	Commercial Banks	Financing through PUE Companies
Target customers	Farmers, co-operatives, government employees, individual entrepreneurs		Farmers, co-operatives, exporters, processors, wholesale lending to MFIs and SACCOs	Commercial farmers, SMEs, established processing units	*Depends on technology*
Size of loans	100,000 Ksh (~1,000 USD)	50,000 – 3,000,000 Ksh		Any size	As per cost of the equipment (100% can be financed)
Features of the financial products	Payable within 12-36 months	Payable within 12-36 months; 20% interest rate (securitized loans)	Payable within 12-36 months; 10% interest rate	2-5 years	20% usually as immediate deposit, remainder financed; to be repaid within 30-36 months
Pre-requisites	Member of the SACCO Loan pegged up to 3 times the deposit made by the member of SACCO	Equipment purchased is considered as a collateral; additional collateral required equivalent to size of loan; due diligence of borrower's business and income	Collateral + insurance	Collateral + insurance	Evidence of income / sources of revenue/ stability of business
Challenges	Farmers unable to pay on a monthly basis, as incomes depend on harvest seasons, weather conditions	Lack of collateral for security; poor capacity among farmers to finance assets (PUE technologies considered as an asset)	Small land parcels where breakeven within the loan repayment period is doubtful	Informal nature of business among farmers, hence do not lend them usually unless registered (commercial farmers)	PUE companies have limited capacity for due diligence Attempts to partner with financing institutions have not seen much success

Source: Stakeholder consultations

Market uncertainty

While it may seem attractive for farmers to invest in value-addition technologies such as drying of fruits and vegetables, their capacity to gauge demand from the market for such processed items and develop this opportunity into a small-scale business is limited. Moreover, dried fruits or yoghurts or butter are items mainly consumed by institutional buyers such as hotels, restaurants or by high income households in urban areas. Therefore, the market for such products in rural areas, where smallholder farmers are mainly based is limited.

Weather conditions and access to water sources

Another concern among farmers is the weather condition – most of the counties identified in this study are well fed by rains, except for northern parts of Meru, eastern parts of Muranga that experience more dry weather. As a result, for nearly 3-6 months in a year, the solar panels may remain ineffective unless farmers also invest in energy capture equipment. The energy capture equipment allows farmers to generate and store as much of solar energy during the hot season. Additionally, investment in water pumps requires farmers to access water within a short radius. This may not be feasible for all farmers, especially those who depend on use of jerry cans and buckets for fetching water.

4.4 Analysis of opportunities

In order to prove a business case for a PUE technology, a number of conditions have to be met, including willingness to invest, ability to invest, and ability to derive benefits. In this section, we have developed a set of criteria in these three buckets to evaluate the potential for PUE technology market in Kenya. For each opportunity, we have presented an analysis on (a) technical feasibility and (b) commercial viability from the point of view of the farmers.

Figure 23: Criteria to assess potential for PUE technologies in Kenya

A. Farmer willingness to invest in technology	B. Farmer ability to invest in technology	C. Ability to derive benefits from the technology
Awareness of technology	Financial institutions willing to provide financing	Any of the following, leading to a positive investment outcome: • Higher volumes sold • Higher prices obtained • Reduction in cost
Basic technical suitability (e.g. water availability)	Existence of suitable payment modalities	Knowledge on how to apply the technology
	Commercial viability of the products (from investor's perspective)	Ability to repair and maintain the technology

Solar irrigation for horticulture farmers

There are several technical challenges that affect demand for solar powered water pumps. These have been discussed in previous sections, but to summarize here, these include – (a) monsoon season; (b) limited capacity of solar water pumps to pump several ten-thousands of liters of water – hybrid water pumps generate 1.5X more than 100 percent solar powered pumps; (c) access to water resources within the surrounding location (around 70-80 meters in radius).

We also evaluated the commercial viability of investing in such technology under following scenarios –

1. An individual farmer with no existing investment in mechanized irrigation would then purchase a solar powered water pump

For such a farmer, an investment of 110,000 Ksh of water pump would improve the productivity / yield and generate around 8% return over a period of 12 years. This rate of return is much lower than farmer's cost of equity, assumed to be 20%

2. An individual farmer with a diesel-powered water pump shifts to solar-powered water pump

Here, a farmer invests in solar powered water pumps to reduce operational costs (i.e., for cost savings), but uses such as technology during dry periods. However, there is a difference in the productivity / yield of horticulture volumes that can be produced per acre when using solar powered water pump versus a diesel- or petrol-powered water pump. This is due to differences in the amount of water each pump can generate – the former can pump 5,000 to 10,000 liters per hour whereas the latter can pump as high as 25,000 liters per hour. Therefore, for farmers to use solar powered technology, would require them to invest in another low-cost irrigation option such as drip irrigation to keep the yield close to that from using diesel- or petrol-powered water pump.

The exhibit below provides an overview of the assumptions and the financial outcomes of a typical individual farmer in Kenya, who invests in only a solar-powered water pump. Such a farmer would earn returns as high as 85 percent but would need to incur negative cash-flows in the first 3 years which is the repayment period. This implies, the farmer needs to service the debt in the short term to generate high profit margins in the long term.

Figure 24: Assumptions and business case for an individual farmer investing in a solar water pump

Metric	Assumptions
Average farm size	2.46 acres
% of farm for horticulture production	1.25 acres (50.8%)
Top crops produced	Bananas, tomatoes, French beans Others – avocadoes, carrots, cabbages, potatoes
% of sales	95% of production post 4% losses at farm gate
Inflation	6.92%
Interest Rate	12%
Cost of Equity	20%
Loan Term	3 years

Business Case	
Capital Investment	110,000 Ksh
Equity NPV	1,664,316
Equity IRR	84.69%
Cash Flows	Negative for first 3 years – 16,000 to 23,000 Ksh per annum

Source: Consultant's analysis

3. A group of 4 farmers co-invest in a solar-powered water pump

On the other hand, if a group of four farmers co-invest in a solar water pump, given their case situation is no mechanized irrigation, then such as farmer may earn returns as high as 85 percent with a small negative cash flow in the first 3 years. However, such a business proposition requires technical assessment, as solar panels can only be installed in a fixed location which could be equidistant from each farmer. The solar water pump is mobile, but each farmer must have access to water sources to pump water. This business case is more theoretical and has not been put into practice yet in Kenya.

Solar drying technology for horticulture farmers

In this, we have applied a very simple business case for an individual farmer to invest in a small 22,500 Ksh worth drying facility to dry bananas 2-3 times a year. The average return on investment is estimated to be 18 percent but the farmer would incur negative cash flows of 6,000 to 7,000 Ksh per annum in the first 3 years.

Additionally, as discussed before, investment in drying technology poses market and revenue risk to the farmers. Mitigation strategies include –

(a) Renting out the technology to other farmers using a user-fee or a rental model; this would allow maximum utilization of the technology
(b) A group of farmers co-invest in the drying facility to reduce financial risk

Figure 25: Business case for investing in a drying technology by an individual farmer

Metric	Assumptions
Average farm size	2.46 acres
% of farm for horticulture production	1.25 acres (50.8%)
Crop processed	Bananas (411 Kgs produced annually)
% of crop processed	20%
Conversion rate	Weight of bananas = 85% post drying
Capacity of the technology	50 Kgs per session
Capacity utilized	2 sessions per year
Inflation	6.92%
Interest Rate	12%
Cost of Equity	20%
Loan Term	3 years

Business Case	
Capital Investment	22,500 Ksh
Equity IRR	18%
Cash Flows	Negative for first 3 years – 6,000 to 7,000 Ksh per annum
Risks	Market risk Underutilization of capacity

Source: Consultant's analysis

Solar cooling for milk co-operatives

In the last case, we have evaluated the possibility for a dairy co-operative to invest in a cold chain infrastructure (portable chillers mounted on bikes and cold storage) worth 8.4 million Ksh. The return on investment is 17% which is close to the cost of equity. However, the co-operative will need to incur significant negative cashflows of 2-2.5 million Ksh for initial three years. Therefore, it would be impossible for the co-operative to service this debt, especially when these co-operatives only earn a small margin (1.5-3 Ksh per liter of milk sold per day) and have limited capacity to invest. Our findings show that the co-operatives that currently have a cold storage, did not self-invest in this, but were given these facilities as a grant by county governments.

Figure 26: Business case for a dairy co-operative to invest in cold chain infrastructure

Metric	Assumptions
Sales per co-operative	12,000 liters per day
Co-operative's sales price	47 Ksh per liter
Co-operative's margin	4 Ksh per liter
Number of days per year for milk sales	320 days
Avg monthly cost if cold storage powered through diesel	250,000 Ksh
Inflation	6.92%
Interest Rate	12%
Cost of Equity	20%
Loan Term	3 years

Business Case	
Capital Investment	8,408,000 Ksh
Equity IRR	17%
Cash Flows	Negative for first 3 years – 2-2.5M Ksh per annum

Source: Consultants' analysis

Based on this analysis, we can draw following conclusions, for PUE technology market opportunities in Kenya:

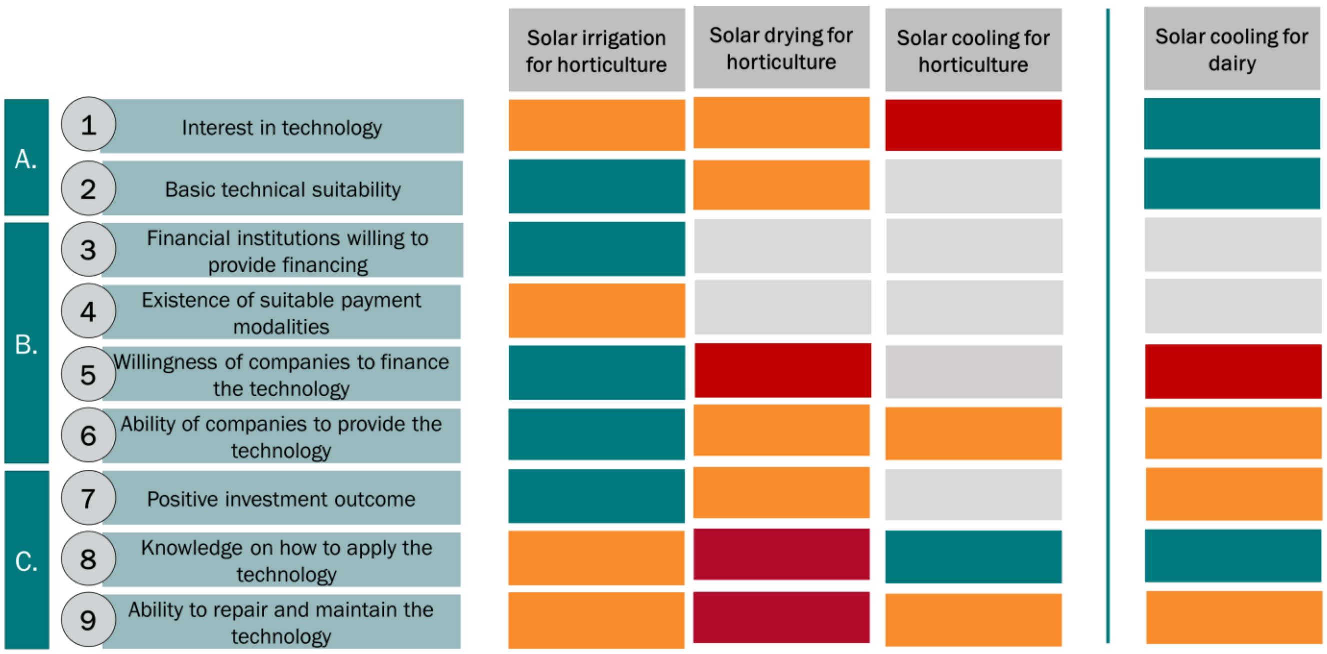
(a) There is a strong case for GIZ and SNV to target farmers who are currently using diesel-or-petrol-powered water pumps. These farmers are already used to mechanized irrigation and would benefit from saving significant operational expenses (purchase of fuel). However, for these farmers, it is essential to create awareness, and more importantly make them financially literate on their choices of water pumps. Additionally, the target farmers can invest in solar energy retention equipment that allows these farmers to continue farming during monsoons at a much cheaper rate.

(b) The second opportunity lies in supporting horticulture or a group of farmers to invest in drying technologies to reduce spoilage, add value and gain incomes from selling dried fruits and vegetables. However, here GIZ and SNV must ensure the farmers or group of farmers or co-operative investing in such as technology has an entrepreneurial mind-set, understands the market dynamics for dried fruits and has capacity in establishing the business.

(c) Lastly, the opportunity among cold storage infrastructure for dairy co-operatives lies in supporting existing co-operatives with a cold storage to shift to solar-powered methods (i.e., change source of energy) but not invest in a new technology. Individual farmers using chaff cutters can invest in solar energy production equipment for their household and use the same for multiple requirements – irrigation of crops and fodder, pumping water for animals, operating chaff cutters, using water heaters and televisions at home.

The figure below summarizes these opportunities against the criteria defined above. #

Figure 27: Summary of PUE technology opportunities in Kenya



Source: Consultants' analysis

High opportunity	Medium opportunity	No opportunity	Cannot be determined fully

4.5 Recommendations & Intervention Package

To increase uptake of PUE technologies among smallholder farmers in horticulture and dairy value chains of Kenya, we recommend the following as the way for GIZ and SNV. We have categorized these into (a) quick wins where there is immediate opportunity to create awareness among farmers already using diesel-powered water pumps to upgrade to solar pumps and among dairy co-operatives that have already been supported with cold storage infrastructure; (b) intermediate or gradual wins where persistent effort needs to be applied to change the mindset of the farmers and design customized financing solutions for them to adopt technologies; (c) pilot programs where GIZ and SNV can identify 1-2 financially stable co-operatives to support them in investing in dairy cold chain infrastructure or horticulture drying technology using solar or hybrid power.

Each of the above recommendations require customized sets of interventions ranging from creating increased awareness among smallholder farmers, making farmers realize of the long-term cost benefits of investing in PUE technologies, hand-holding co-operatives and identifying a few with substantial financial capacity to procure and invest in such technologies, offering results-based-financing to PUE companies or distributors to increase their marketing efforts and sales to smallholder farmers and lastly, working along with financial service providers, specifically, designing financing packages offered by these providers through collaborations with PUE companies.

Table 24: Intervention design for increased penetration of PUE technologies in Kenya

	Business Case	Counties	Interventions
Quick win	1. Smallholder farmers with petrol powered water pumps shift to solar water pumps 2. Dairy co-operatives with non-renewable energy based cold storage switch to solar energy	1. All counties 2. Machakos, Makueni, Kajiado, Kirinyaga	1. Results based financing / partnerships with PUE companies 2. Collaborations/partnerships between PUE companies and financial service providers to offer affordable tailor-made loans 3. Create awareness / cost reduction or savings
Intermediate / gradual win	Smallholder farmers with no irrigation technology adopt solar water pumps	All counties	*Same as above; increased capacity building and awareness*
Pilot	1. Dairy co-operative with no cold storage, invests in solar / hybrid cold chain infrastructure 2. Horticulture co-operative / group of farmers co-invest in drying technology	Kirinyaga (banana co-operative)	1. Collaborate with 1-2 co-operatives to evaluate and review business model and assess commercial viability, investment capacity 2. Facilitate 1-2 investments / transaction
Explore other options	1. Solar powered chaffcutters for dairy farmers 2. Partnerships with cold storage rental companies	Muranga, Meru	Discuss options with PUE companies and then develop business model; mainly to assess technical feasibility

5. Uganda

5.1 Introduction to the target sectors

The following section provides an overview of the two value chains or sectors, including key statistics of the production patterns, nutrition and consumption practices, the structure of the value chain, the differing roles for men and women, and the key constraints limiting productivity, market reach and farmer incomes.

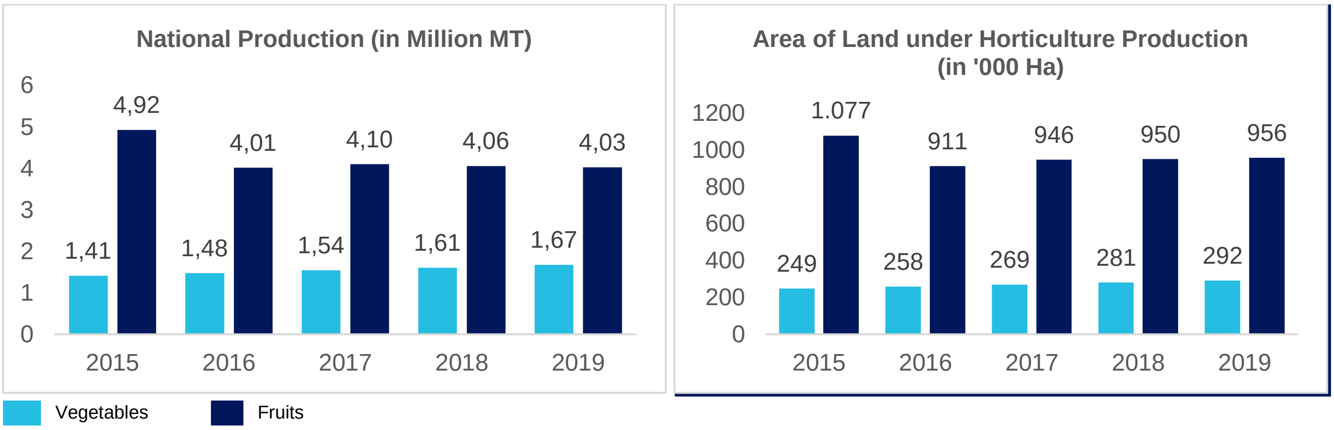
5.1.1 Horticulture

Production, consumption and trade balance

Uganda is located at the equator, with a very favourable climate for producing all kinds of fruits and vegetables. With a production of about 5.7 million metric tonnes (MMT) per year, Uganda is currently the second largest producer of fresh fruits and vegetables in sub-Saharan Africa after Nigeria. Fruit production includes at least 70 percent of the total production, and therefore more area of land is allocated for harvesting. There was a drop in fruit production in 2016, and since then it has continued to stagnate, whereas vegetable production grew by 18% between 2015 and 2019. Around 1,140,000 hectares of land is harvested in Uganda annually to produce these fruits and vegetables.

There are about 500,000 smallholders involved in the production of fruits and vegetables. The main production areas are Kabale, Kamuli, Kapchorwa, Kasese, the lake basin, Mbale, Masaka, Mubende, Mukono, Wakiso and North and Northeastern. Horticultural production is focused on traditional staple crops, in particular cassava, plantains, and beans. The main vegetables grown are onions and tomatoes. Others include eggplants, cabbage and chili peppers. While fruit production is concentrated around bananas and pineapples, other items produced include mangoes, passion and citrus fruits, avocadoes, and papaya. In terms of productivity, fruits (in MT) produced per hectare (ha) has reduced from 4.57 in 2015 to 4.22 in 2019, where as vegetables produced has increased slightly from 5.66 MT per ha in 2015 to 5.72 MT per ha in 2019. Overall the productivity in the country has reduced by 0.88 percent in the last five years.

Figure 28: Fruits and vegetables production in Uganda and area of land used for production



Source: Food & Agriculture Organization (FAO) Statistics for Uganda (2015-2019)

Table 25: Key fruits and vegetables produced in Uganda - *area harvested and production volumes*

Crop	Area harvested (ha)	Production (tonnes)
Roots and tubers	**1,762,628**	**4,973,005**
Pulses	**660,719**	**1,025,152**
Vegetables	**291,792**	**1,672,086**
Onions, dry	93,918	371,599
Tomatoes	8,243	44,235
Other vegetables	189,631	1,256,252
Fruits	**956,116**	**4,025,120**

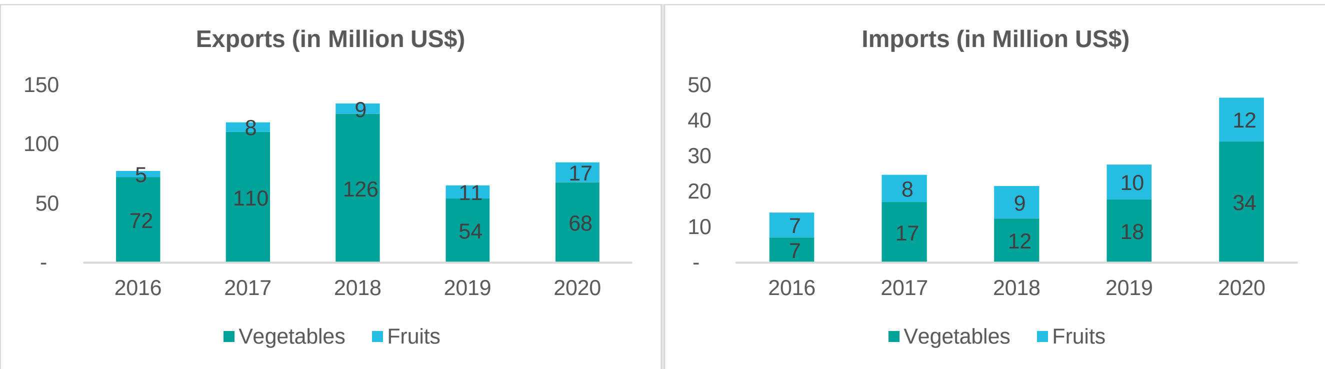
Plantains	817,470	3,423,844
Bananas	130,224	544,629
Other fruits	7,941	52,575
Pineapples*	481	4,072
Total	**3,671,255**	**11,695,363**

Source: Food & Agriculture Organization (FAO) Statistics for Uganda (2015-2019)

There is demand for horticultural products from the local market: According to a recent study, 85 percent of the households in Uganda indicated importance of fruits in their daily diet and 73 percent of the households indicated importance of vegetables for daily diet. Nevertheless, the volumes of the vegetables consumed per capita remain relatively low: 64.2 kilograms per year, as compared to an average of 105.5 kilograms per year for the African continent. Food insecurity is still an issue in some regions. Focus group discussions have highlighted demand for tomatoes, aubergine and cabbage, but also for fruits such as mangoes and citrus fruit. Uganda still imports fruits and vegetables, which highlights unmet demand. This is particularly true for processed products, such as fruit juices. In addition, local demand for fruits and vegetables is likely to increase with population growth and Uganda's transition to becoming a middle income country. Uganda's population has increased by more than 7 million over the past decade, and experienced moderate GDP growth (5% per annum).

Current export volumes of fruits and vegetables from Uganda are estimated by COMTRADE to be almost 400,000 tonnes of produce with a value of $96 million on average between 2016 and 2020. Uganda's location at the centre of the Great Lakes region and in the EAC offers Ugandan farmers access to a regional market with over 150 million consumers. For example, farmers from FDGs in Mukono,Luwero, andSoroti reported exporting fruits to Kenya, Sudan and Rwanda. Kenya is a key export market. The main crops exported include bananas, pumpkins, oranges and tangerines, lemons, pineapples, and watermelons, all through the Busia border. There is an export market not only for fresh fruits, but also for dried fruits. Processing companies also export products beyond the regional market. For instance, Sulma Foods exports fresh pineapples to the Middle East, and Jackfruit, bananas and dried pineapples to Japan.

Figure 29: Exports and imports of fruits and vegetables by Uganda



Source: International Trade Centre Statistics for HS Code 07 and 08

Uganda also exports vegetables, mainly climbing beans which comprises a very large proportion of the total exports. Most of these bean varieties can be dried and stored for a longer period and then used as pulses. Nearly $54 million worth of such beans are exported to neighbouring markets (mainly Kenya). In addition, the country also exports tomatoes, cassava, potatoes and onions. Uganda has a net positive trade balance for horticulture (fruits and vegetables, including beans) – while imports are around $26 million (on average between 2016 and 2020), the exports of $96 million allows the country to enjoy a trade surplus. Imported fruits include apples, mangoes, tamarind, grapes, oranges, pears, strawberry, mainly from South Africa and dates from Middle East. Imported vegetables include carrots, turnips, potatoes, onions, cow peas, green peas and garlic.

Table 26 : Uganda's top 90 percent fruit exports and imports

Exports (average 2016-2020)	Value (US$)	Imports (average 2016-2020)	Value (US$)
Fresh or dried plantains	1,290,800	Fresh apples	4,131,200
Fresh or dried pineapples	1,456,000	Fresh or dried guavas, mangoes and mangosteens	1,377,600
Fresh watermelons	1,138,800	Fresh tamarinds, cashew apples, jackfruit, lychees, plums, passion fruit	351,200
Fresh tamarinds, cashew apples, jackfruit, lychees, passion fruit, carambola, ...	1,544,600	Fresh grapes	1,007,600
Fresh or dried macadamia nuts, shelled	507,400	Fresh or dried oranges	904,000
Fresh or dried oranges	1,231,200	Fresh or dried citrus fruit (excluding oranges, lemons)	277,200
Fresh or dried bananas (excluding plantains)	450,200	Fresh or dried dates	187,200
Fresh pawpaws	197,200	Fresh or dried cashew nuts, shelled	118,400
Fresh or dried avocados	136,800	Dried grapes	79,400
Fresh or dried guavas, mangoes and mangosteens	913,800	Fresh pears	79,800
Fresh or dried citrus fruit (excluding oranges, lemons)	101,600	Fresh kiwifruit	59,800
Dried peaches, pears, papaws "papayas", tamarinds	116,200	Fresh strawberries	109,200
Top 91.54% of the total	**$9.08 million**	**Top 94.58% of the total**	**$8.69 million**

Source: International Trade Centre Statistics for HS Code 08

Exports (average 2016-2020)	Value (US$)	Imports (average 2016-2020)	Value (US$)
Dried, shelled beans	12,043,400	Fresh or chilled carrots and turnips	3,171,600
Dried, shelled beans whether or not skinned or split (excluding beans ...	30,126,000	Shelled or unshelled beans	2,941,000
Tomatoes, fresh or chilled	4,225,600	Fresh or chilled potatoes (excluding seed)	2,277,000
Dried, shelled kidney beans	11,372,800	Dried, shelled peas	1,837,400
Mixtures of vegetables, uncooked or cooked by steaming or by boiling in water, frozen	7,846,600	Fresh or chilled onions and shallots	2,055,000
Dried, shelled leguminous vegetables	2,680,000	Garlic, fresh or chilled	1,337,600
Vegetables and mixtures of vegetables provisionally preserved	885,600	Dried, shelled beans	979,400
Fresh or chilled beans	3,211,200	Fresh or chilled peas	929,800
Dried, shelled cow peas "Vigna unguiculata",	765,800	Fresh, chilled, frozen or dried roots and tubers of manioc "cassava"	711,800
Fresh, chilled, frozen or dried roots and tubers of manioc "cassava"	2,834,400	Dried, shelled cow peas	303,200
Fresh or chilled potatoes (excluding seed)	3,464,200	Dried, shelled kidney beans	117,600
Fresh or chilled onions and shallots	415,800		
Top 92.63% of the total	**$79.88 million**	**Top 93.37% of the total**	**$16.67 million**

Source: International Trade Centre Statistics for HS Code 07

Structure of the value chain and key challenges

Uganda's horticulture production is mainly dominated by smallholder farmers, while contract farmers and commercial farmers also exist but mainly supply to processors and exporters. The smallholder farmers are usually grouped into co-operatives whose role is to assist farmers in aggregation and market access. The smallholder farmers harvest their products and transport these directly or through middle men, usually transporters with bikes / cycle.

The main players in the Ugandan horticultural sector include small-scale farmers, cooperatives and a limited number of commercial businesses. Most inputs however are imported, mainly from Kenya, South Africa and the Netherlands. In-country seed production is very limited with 21 seed companies present in Uganda (3 have breeding locations, 5 processing facilities) (Access to Seed Index, 2019). Seeds are mostly distributed to smallholders through around 4000 agro-inputs dealers present in the country (Uganda National Agro-input Dealers Association). The majority of horticultural crops are produced by an estimated 500,000 smallholder farmers. Some farmers are organized in cooperatives or farmer associations. Other players include large/medium commercial farmers, and large farm companies. Unfortunately the processing segment of the value chain is not well developed in the country and the few players in the fruit processing sector are mainly engaged in the domestic juice market. Produce is typically transported and marketed by middlemen, traders, and large scale exporters, even though some smallholders are involved in contract farming (There are 64 registered exporters of fresh and processed fruits and vegetables (MAIIF)).

Government and donor programming play a major role in creating an enabling environment for the development of the horticulture sector in Uganda. For instance, the Agriculture Cluster Development Project (ACDP) aims to raise on-farm productivity, production, and marketable volumes of selected agricultural commodities (maize, beans, rice, cassava and coffee), in specified (12) geographic clusters (spanning over 57 districts). Extension in Uganda is under the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) and the National Agriculture Advisory Services (NAADS). The main extension methods used in the project area include trainings (individual and group), demonstrations, model farmers, radio outreach programs and farm visits. The use of extension services is relatively low. Only 18% of smallholders use extension provided by NAADS. Extension services from input suppliers, NGOs, cooperative/farmer associations are negligible. Key donor interventions in the value chain include: USAID's Feed the Future, Powering Agriculture (PAEGC), World Bank's- Agriculture Cluster Development Project and FCDO- Northern Uganda: Transforming the Economy through Climate Smart Agribusiness (NU-TEC)

An assessment of the role played by various members of the household shows that although most decision making in the sector is still done by men, women and the youth are highly involved in both production and marketing of fruits and vegetables. While sourcing for planting materials is usually done by the owners of the farm, which are usually men, and by the youth, everyone takes part in production, including men, women, and the youth. Participation of women and youth is greater in vegetable production, because the maturity period is shorter, and start-up costs less important. Most often, men, as head of households, decide on how farm labour is allocated. In most cases, each household member is individually responsible for cultivating a specific area of land, rather than sharing various tasks like planting, weeding, harvesting etc. Youth dominate transportation, especially with motorcycles. In terms of marketing, intermediaries are mostly men, but most fruits and vegetable vendors in markets and roadside stalls are women, and youth. Decisions related to selling are usually made by the head of household, which is usually a man.

An analysis of the sector shows that structural weaknesses in the horticulture value chain contribute to low productivity, preventing demand from being met. For instance, farmers have inadequate access to high quality equipment and inputs such as greenhouses. It is estimated that 30-40% of seeds in Uganda are counterfeit. Production is hampered as farmers have to face prolonged droughts, with limited access to irrigation, and hence fail to produce enough to meet customer demand for seasonal crops, in particular during the dry season. This situation is further exacerbated by transportation challenges as roads become impassable in the rainy season and overproduction during this period leads to storage problems and post-harvest losses. Farmers are also at a disadvantage while marketing their produce due to low bargaining power when not organised in groups. Fruit processors too face challenges as they struggle to source enough fruit to satisfy demand, lack maturing storage facilities and face competition from imported foreign products made cheaply abroad.

5.1.2 Dairy

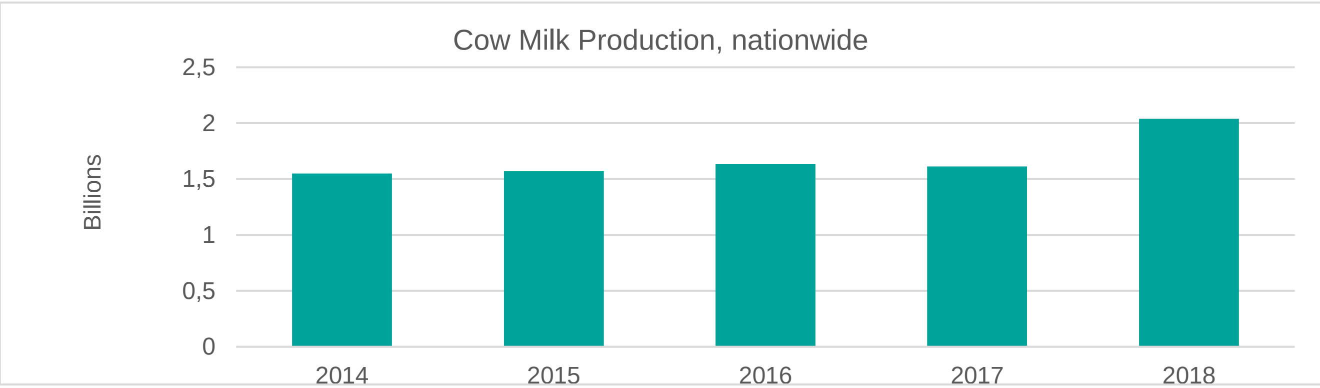
Production and consumption

Dairy accounts for an estimated 9% of total agriculture GDP (and about 3% of total GDP). The dairy industry is estimated to contribute 40-50% of livestock-related GDP. The dairy sector is growing at an annual rate of 8-10%, which can mostly be attributed to expanding national cattle stock. The dairy sector is dominated by cow milk and almost 70% of the milk produced is marketed. While statistics on other milk producing cattle are limited, cow milk is believed to account for about 80% of total milk production, which stood at $ 2.5 billion in 2018. There are medium and large-scale farmers involved in the sector, with the latter (50 cattle heads and above) dominate production. In some places a single farmer may have his/her own cooling unit and may be producing approximately 2000 litres of milk per day, averaging 15 litres per animal. Some farmers rely on pure zero grazing. Here, feeds are provided as fodder in form of silage and hay. A second category of farmers use both zero grazing and supplementary grazing. A third category use paddocking for direct grazing of pastures.

The Western region contains 22.3 percent of the Uganda's cattle population and produces the highest volume (37%) of the milk. The Central region has the highest milk productivity (9.8 liters per cow per day thanks to its higher population of improved breed, and greater investments from farmers. The Eastern region has a 21% share in production, while the Karamoja region only produces 7 percent. It is an arid area with limited access to pasture and water. The Northern region is progressively recovering from the effects of civil war.

It is estimated that 70% of total milk production reaches the market, while the producing households consume the remaining 30%. Kampala, with a population of 1.2 million, is the largest urban centre and by far the biggest market for milk. Entebbe, Jinja, Gulu, Mbarara, and Mbale are other big urban centres with a sizable milk demand. The per capita consumption of milk products is a mere 58 litres/person/year, far lower than the 100 litres/person/year in neighbouring Kenya or the 200 litters/person/year recommended by the Food and Agriculture Organization. Local demand remains unmet, as Uganda is a net importer of dairy products. Even though official imports were less than $6 million in 2007, actual imports were estimated to be about $ 20 million in the same year. Such a huge difference is mainly caused by the practice of non-declared imported dairy products (in particular milk powder) put in place by importers to avoid import taxes. In the informal market, which accounts for 75% of the total value of the Ugandan dairy industry, only Ugandan milk is sold. In the formal market, though, imports account for ~20% of total value (most of which is milk powder). Almost all Ugandan production goes to satisfy local demand. Exports are low ($1 million). However, data show a significant increase in export.

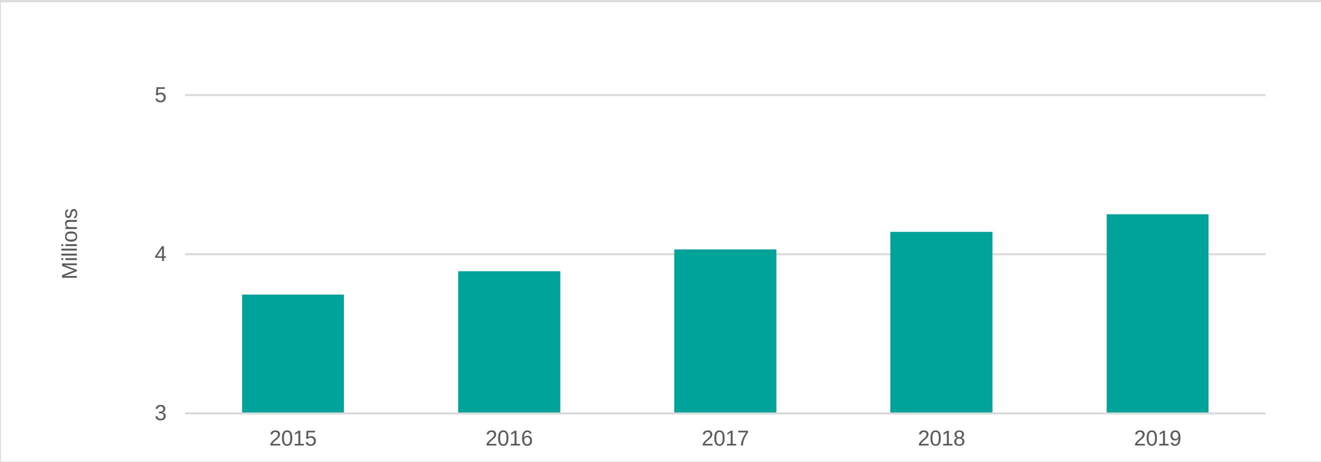
Figure 23: Cow Milk Production



Source: MAAIF, IGC, 2017

The dairy industry in Uganda is built around an estimated 11.4 million milk producing cattle. The key input suppliers to the farmer include service providers such as companies selling farm machinery and equipment, veterinary drugs, chemicals and biological (hormones and vaccines), genetics and related supplies, milk processing equipment and additives, animal feeds, pasture seeds.

Figure 24: Number of dairy cows



Source: FAOSTAT

Structure of the value chain

An estimated 1.2m smallholder farmers are involved in dairy production, besides 8000 large farms. The sector also has 367 milk producer cooperatives. The cooperatives buy milk from farmers and sell to processors. The key players involved in creating an enabling environment for the dairy sector, include government agencies/ extension officers, NGOs (e.g. Heifer International, Send-A-Cow Uganda, Land O' Lakes, Techno Serve etc.) as well as donor programming (e.g. East Africa Dairy Development Project - Phase I (2008-2013), Phase II (2014-2018), TIDE-II SNV Netherlands Development Organisation (2015-Present) and IFC and GAFSP- 2013- present)

The milk processing industry is growing by an estimated 11% per year. Production of pasteurized milk is the largest processing activity in the dairy industry. Next in order of importance is ghee which also contributes to farming household income and nutritional needs, followed by yoghurt: Some of the main products produced by processing milk are as follow:

Pasteurized Milk: Production of pasteurized milk is the largest processing activity in the dairy industry. About 80% of processed milk goes into the production of pasteurized milk currently. There are about nine firms involved in the production of pasteurized milk.

UHT Milk: As of 2008, two (2) firms in the country produce UHT milk with a combined annual installed capacity of 64,970 tons. The two companies Sameer Agricultural Livestock Limited and GBK currently handle about 30% of their installed capacity and 10% of this is exported to Kenya, Sudan, Rwanda, Tanzania, Egypt, Syria and Ethiopia.

Butter and Ghee: The butter demand and production are expected to increase, even though farmers produce ghee mainly on a small scale and mostly for domestic consumption. However, a number of small-scale processors have now started production and selling of ghee.

Yoghurt: The yoghurt produced in the country is mainly the set and drinking type. The production of yoghurt has continued to increase due the growing market for this product. Since 1995, a number of small and medium scale dairy processors have started producing and marketing yoghurt.

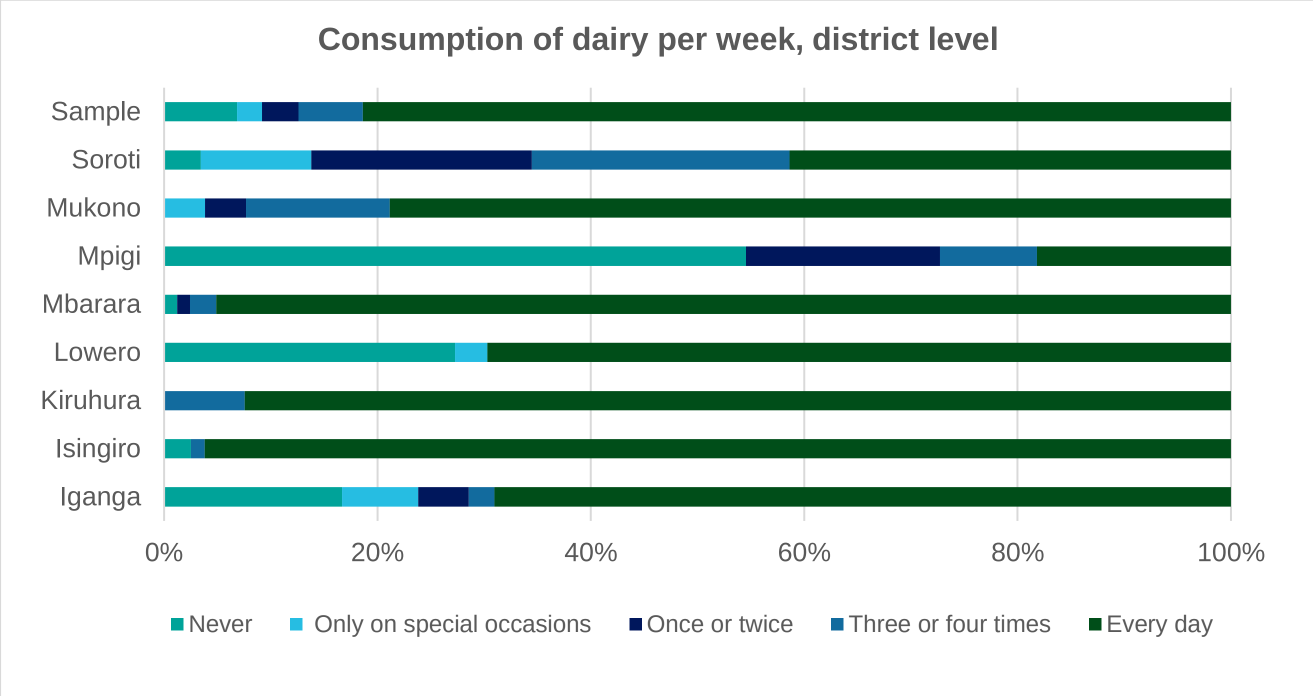
Cheese: Although cheese is produced locally, Uganda still continues to import this product. The Sameer Agricultural Livestock Limited produces 3.0 metric tons/year, which mainly includes Cheddar, Gouda, Maribou cheeses. Other private firm like Paramount Dairy Ltd in Mbarara have exploited the growing cheese market and started production of Cheddar and Gouda types.

Cream and Ice Cream: Five out of the twelve firms produce cream but this is mainly an input product. The Sameer Agricultural livestock Limited produces substantial number of creams, which it uses in the production of Ice cream.

Cultured milk: Commercial cultured milk is newly developed from indigenous cultured milks. Several small-scale dairy processors are involved in production and marketing of this product.

The processing function has been improved over the last few years, with 15 registered formal processors (Pasteurization, UHT, Milk powder, etc.), informal processors (Batch pasteurization, milk chilling, small scale processors). Milk is usually collected by entrepreneurs called "Abacuunda" on bicycles, motorcycles, who bring the milk to cooperatives and collection centres. A few farmers who have pickups use them to carry the milk.

Figure 25: Weekly Consumption of Dairy



Key Challenges

The key issue faced by the value chain is productivity. Ugandan productivity ranks among the lowest in the world, appearing to perform much worse than Kenya (slightly more than 500 litres per cow in Uganda versus more than 1,000 litres per cattle in Kenya) and Rwanda (500 vs. 700). Countries such as the United States, Argentina and New Zealand have productivity ratios from 18 to 7 times higher. The reason for such a difference is twofold:

- **Poor breeding practices**. The bulk of Uganda's dairy herd has a relatively low genetic base due to years of inbreeding and the use of unproven bulls. The dairy industry stakeholders are confronted with multiple constraints, including low cattle productivity and low-capacity utilization of processing plants; lack of extension/veterinary services; limited availability of pastures and water; limited milk-cooling infrastructure; poor road infrastructure; seasonal variability in milk prices; poor quality of raw milk; limited stakeholder coordination and regulation enforcement mechanisms; and limited purchasing power in urban centres
- **Poor and inadequate feeding.** Most cows produce well below their potential because their nutrient intake is insufficient in both quantity and quality. Most smallholders feed their cows by letting them openly graze, mostly on common land, by the side of the road. This does not provide cows with a sufficient quantity of food. Grazing is not normally supplemented by feeds, depriving cows of required level of proteins and minerals. The main reason for not using commercial or home-made feeds is their high cost. Also, farmers often complain that the quality of commercial feeds varies and is inconsistent. At the same time, some ingredients to make home-made feeds, such as cotton seed cake are not locally produced, and occasional shortages can increase the cost of production.

Role of women and youth

Women participate throughout the dairy value chain, but are particularly prominent in processing. A study even found that they contributed to over 50% of all labour requirements. Youth are particularly involved in collecting the milk from individual farmers and delivering it to cooperatives or collection centres, usually on bicycles or motorbikes. Processing is traditionally done by women, who are responsible for skimming the milk, and involved in cottage processing of ghee or yogurt. They dominate in these functions which are perceived as less muscular/ energy intensive. Women and the youth are also involved in marketing milk, but are to a large extent marginalized in terms of decision making and utilisation of the cash income and other benefits from the dairy enterprise.

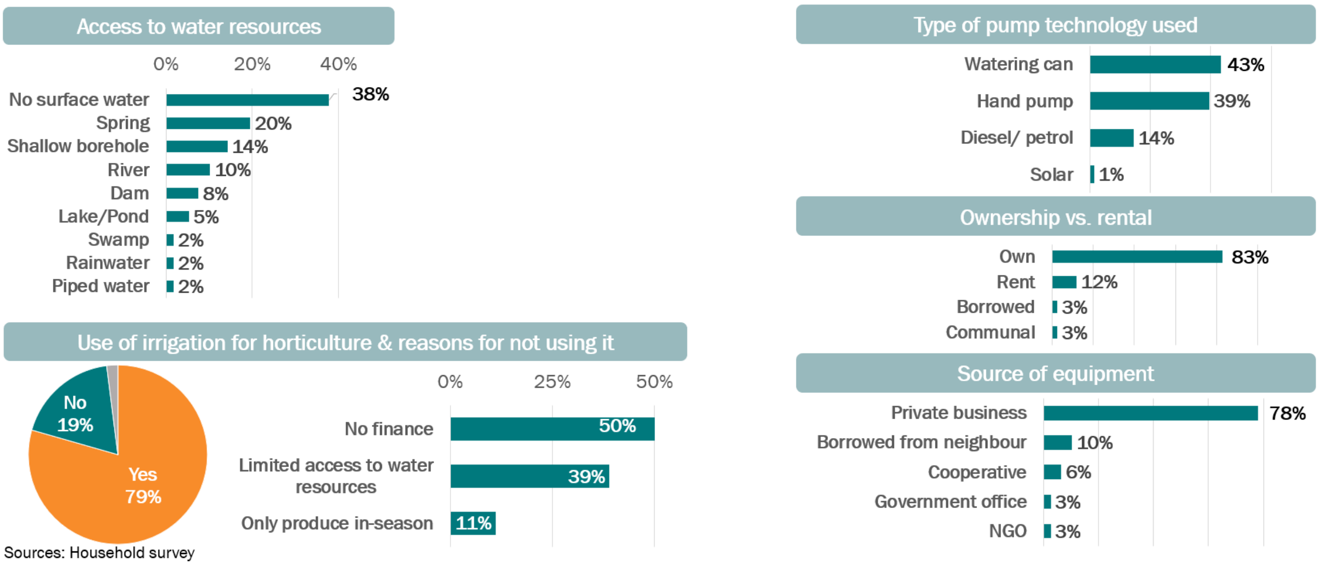
5.2 PUE technology solutions currently in use in Uganda

The following section takes each of the prioritised PUE technologies – irrigation, cooling and processing – in turn and outlines the current patterns of use, the prevailing practices where PUE technologies are not available or not in use, and the structure of PUE technology supply.

5.2.1 Solar-powered irrigation

While the solar irrigation sector is in the early stages of its development, there is ample evidence that horticultural producers, in particular, recognise the importance of irrigation and are willing to invest in it. As Figure 30 demonstrates, the findings from the baseline survey indicate that, despite the fact that a significant (38%) share of producers do not have access to readily available water, the vast majority make an effort to irrigate their horticultural crops. Overall, watering cans and hand pumps are, by far, the most common methods adopted, with most farmers purchasing (rather than leasing) equipment from private enterprises.

Figure 30: Key findings on irrigation use among smallholder farmers



Based on KIIs and literature review, the PUE technology in highest demand is solar irrigation. The reasons for this are as follows

- **Reduced vulnerability to droughts:** These technologies reduce exposure of smallholders to increasing dry spells. This is a priority for many farmers as lack of irrigation during dry spells can lead to significant losses and threaten their livelihoods. Droughts are particularly consequential in the fruit sectors, as some trees can die, and it takes many years for them to reach maturity. They also have an impact on the dairy value chain since water and fodder scarcity can not only reduce production but also cause cattle loss.
- **Increased profit:** Irrigation can also improve yields, enabling farmers to increase their income. Based on focus group discussions, smallholders reckon that irrigation could increase their yields by 40-50%. In addition, by allowing them to produce during dry seasons, it provides smallholders with a competitive

advantage and enables them to sell certain crops or dairy products when supply is lower, leading to higher prices.

- **Cost savings:** The main alternative to solar pumps in rural areas are diesel pumps. While a solar pumps have higher initial costs than their diesel pump alternative , they have a lower maintenance cost, and don't get affected by fuel shortages. Over their lifespan, solar pumps are estimated to be between 22-56% cheaper than diesel pumps, and payback can be achieved in 2 years only.
- **Affordability:** although higher than their diesel alternative, the investment cost is lower than other solar PUE technologies

The business models for standalone solar PUE appliances vary. Stakeholders are involved in one or more stages of the value chain from manufacturing to after sales services. There aren't however any vertically integrated players across the entire value chain: some companies focus on the design and manufacture of products; some specialise on distribution, system integration and after sales support, and others provide services across the value chain. The predominant market players are established global manufacturing companies based outside Uganda (such as Lorentz and Grundfos), which work with local distributors, such as Aptech Africa, Davis & Shirtliff and Adtritex. Some of these distributors also integrate the systems with other use cases, for example offering solar water pumps with irrigation kits tailored to end-users' needs. Specialised PUE companies like Chloride & Exide Uganda limited and Water Works are also operating in the market. PAYG SHS operators such as M-KOPA and Azuri are also diversifying their product range to include PUE technologies.

5.2.2 Cold storage

Spoilage is mainly an issue in horticulture, where farmers lose on average 8% of their crops post--harvest. Iganga, Kiruhura and Mbarara are particularly affected. For dairy, farmers do not report any issue with spoilage at their level of the value chain. They deliver the milk immediately after milking. Responses from the household survey indicate that cold storage ownership remains very rare – Only 8% of smallholders have access to cold storage and that too mostly in the dairy sector. They tend to use jointly owned electricity powered cold storage units of over 10MT. Insufficient size of cold storage available is a concern for both private owners and cooperative members. Prices range substantially, depending on capacity – although it is worth noting that the only example of solar cooling in use, identified through the survey so far, is also associated with the highest quoted cost – USH 8 million.

5.2.3 Processing

As previously mentioned, horticultural processing is primarily the domain of formal factories, with little in terms of farmer linkages or out out-grower arrangements. However, many of these factories have demonstrated the value for dried fruit, in particular, by setting up exports to Europe. Processing plays a major role in the dairy value chain. Production here is diverse and includes yogurt, ghee, cheese and bongo (traditional cultured milk drink). Production levels of ghee are around 30-70kg per year. In the fruit value chain, processing includes drying, jam and juice. Production levels are at around 400-500kg per year for fruit jams, juice and dried processing. A significant proportion of smallholders (35%) use solar energy to process their products. Survey respondents who use solar energy for processing have done so mainly for cheese and ghee production. There is also evidence from interviews that, in cases where the household has a solar system already installed, women can use solar powered freezers for processing of yoghurt. Other sources of energy used include electricity, or biomass such as firewood or calabash.

5.3 Gaps and constraints that limit expansion of PUE technologies

The following section presents the findings from interviews with PUE sector stakeholders, including companies, federal and regional government ministries and regulators, and potential users of the relevant technologies. The constraints to PUE technology expansion are addressed from both the demand and the supply side.

5.3.1 Demand side

There is limited consumer awareness of the benefits of PUE technology. Smallholders are often not aware that renewable energy can be used for other uses than lighting and are generally unaware of the potential of PUE technologies for irrigation, cooling and processing. Customers are often dissuaded from purchasing PUE technology due to the large investment costs of a system, until they are aware of the benefits either from demo sites or by word of mouth from other farmers utilising the technology. In addition, sales agents do not always have agricultural expertise, which makes it difficult to train consumers and leaves some farmers poorly trained and unable to optimise the appliance.

Market spoilage due to low quality products on the market has discouraged consumers from purchasing quality systems. The solar water pump and refrigeration unit markets are flooded with poor quality systems which try to persuade consumers only based on price. These systems break quickly which creates a negative impression for potential customers

Smallholders have low affordability and willingness to pay. Despite recent increases in efficiency and declines in component costs, many customers still cannot afford the high upfront costs for these systems. Consumer financing is difficult to obtain, and PAYG companies have struggled with repayment rates. For instance, for solar water pumps, the initial deposit is higher than that for solar lighting products, limiting purchase. The absence of water sources for some smallholders also requires spending resources for digging boreholes etc. which increases the upfront cost. Solar refrigerators are perceived as a luxury for middle income households. For cold storage, cheaper alternatives exist, such as boiling milk to keep it from spoilage and use of smoking or drying to store fish. Members from a dairy cooperative in Isingiro stated that they usually did not use water pumps because most members could not afford it.

Table 27: Example service offering of financial institutions operational in the target regions

	Opportunity Bank	EBO SACCO	Centenary Bank	PostBank Uganda Limited	Rushere Savings and Credit Cooperative Society
Loan size	N.A.		N.A.	UGX 300,000 to 10 million	N.A.
Loan terms	ACF: 12% Normal loans: 22% (principle>5m), 24% (principle<5m)	No PUE loans as of now. Biogas and solar loans at 0.5% and% and 1.6% respectively	12% if under ACF	22%	Interest rate of 2% for loans given in partnership with SNV. Loan tenor ranging between 3-7 years
Target customers	Every actor in the horticulture value chain from production to marketing	95% of loan portfolio in agriculture sector	Agriculture loans approx. 30% of portfolio. Largely cattle keepers with more than 40 cattle heads looking to finance purchase of water-pumps	Micro, small and medium enterprises. 25% of the loan book is in the agriculture sector	Portfolio in agriculture production stands at 57%. Including other segments of the value chain it stands at 70%
Qualification for loans	Proof of farming, ability to repay based on cashflows, security/ collateral, business plan, guarantors etc.		Applicant should have an account with the bank, credit reference bureau card and collateral	Have an account with Post Bank, be engaged in a revenue generating economic activity, demonstrated capacity to service the loan	Loan applicant should have a guarantor and should have a savings account. Also, loan applicant should present collateral

				from the business cashflows or income sources, good credit history, guarantors, sufficient collateral covering 120% of the loan amount, quotation from approved suppliers etc. Also, supplier should have an bank account with PostBank	
Concessionality	N.A.		N.A.	N.A.	N.A.
Horticulture/ dairy/ PUE track record	N.A. Have not given specific loans for PUE		Debt servicing appears to be generally satisfactory	Solar loans are doing better than bio-digesters	N.A.
Interest in PUE	N.A.		See great potential with farmers wanting to purchase pumps, especially for consumption by cattle during the dry season	Especially in renewable energy for irrigation	N.A.

5.3.2 Supply side

Supply side constraints persist as companies have not yet fully tailored PUE products to meet demand, and some products cannot be easily scaled. Some products require significant customization to become scalable. For instance, solar mills are currently unable to produce the right type of end product or process sufficient volumes, and solar irrigation kits often must be customised to meet the needs of customers. There is also a product and market mismatch as consumers expect a certain product design that operators need to cater to as they refine their products. Solar refrigerators are bulky to transport, especially to hard-to-reach areas with poor transportation infrastructure, which discourages their sales.

Supply is also affected as there is limited access to finance for PUE companies. Many businesses are in the pilot and early development stages and are thus perceived as high risk by financial institutions. Local debt to PUE companies has been limited, even among impact investors (USAID et al.) Local banks generally have limited lending experience to solar businesses and are still largely unfamiliar with the technologies, business models and financial needs. Most banks still perceive solar businesses as high-risk and low return. The lending processes are complex and lengthy, and minimum investment amounts are too high for most Ugandan OGS companies.

5.4 Analysis of opportunity

In order to prove the business case for a given PUE technology, it must be demonstrated that a number of key conditions are met, namely:

1. That farmers are willing to invest in the technology (which, in turn requires them to be aware of it, and for it to be technically feasible in the environment in which the farmers operate);
2. That farmers are able to invest in the technology (which requires the will and ability of private companies to provide the technology, the willingness of financial institutions to provide financing, and the existence of suitable financial modalities);
3. That farmers are able to derive benefits from the technology, as evidenced by i) a positive return on investment (driven by higher volumes sold, higher prices obtained and/or a reduction in cost as a result of using the technology), ii) knowledge on how to apply the technology, and ii) the ability to repair and maintain the technology, and thus ensuring it is used throughout its productive life.

5.4.1 Solar irrigation for horticulture

Interest in technology. Multiple interviewees with stakeholders indicated that there is very high interest among smallholder farmers, especially in drought prone regions.

Commercial rationale for the farmer. Commercial rationale of solar irrigation for the farmer seems to be high as the overall cost is low in the long run. KII suggests that access to irrigation could lead to significant increases in yields. Cost estimated at between 22-56% of diesel pumps; can achieve payback in as few as 2 years.

Table 28: Key assumptions for cost-benefit analysis

Metric	Value	Rationale
Average farm size	2.7 acres	Baseline survey
Area of farm dedicated to horticulture	1.6 acres	Baseline survey
Average number of cows/ farmers	20	Baseline survey
Crops under consideration	Bananas Tomatoes French Beans	• Most farmers produce 3 different crops (survey) • The 3 crops are some of the most widely grown in the target regions (survey) • Yield figures with and without mechanised irrigation and prices taken from baseline survey
Inflation	12.60%	As per CPI
Interest rate	8%	Based on interviews with SACCOs
Loan term	3 years	Based on interviews with financial service providers
Farmer Cost of Equity/ discount rate	20%	Conservative estimate to account for high risk aversion & high interest rates
Diesel expenses per annum	UGX 370,000	Average value given by interviewees
Capex – Solar Irrigation	UGX 5,500,000	Interviews with manufacturers
Capex – Milk Cooling	UGX 5,667,000	Interviews with manufacturers
Capex – Drying Technology	UGX 978,000	Interviews with manufacturers
Annual maintenance cost of solar pumps	1.5% of purchase cost	Interviews with manufacturers
Annual maintenance cost of solar milk cooling	3% of purchase cost	Interviews with manufacturers
Annual maintenance cost of solar drying	1% of purchase cost	Interviews with manufacturers

The cost-benefit analysis was carried out with two objectives in mind: i) obtaining key financial metrics (NPV and IRR) in a scenario where no donor support is provided, and ii) considering scenarios where donor support is used to subsidise the initial cost of purchasing the solar pump, to negotiate with the financial service provider for a lower interest rate, or to negotiate for a longer loan term.

Another important consideration is the size of the negative cashflow – while it is expected that it will take a number of years for the farmer to breakeven, negative cashflows are not easy to sustain for smallholder farmers with limited alternative income-earning opportunities and savings. Therefore, the peak negative farmer cash flow is another key metric

Financial viability was estimated for the following scenarios:

1. Individual farmer moving from diesel irrigation to solar irrigation

   Farmer's equity IRR of 13%

   Negative free cashflows in first 3 years. Peak negative cashflow of UGX 1,921,557 in year 3

2. Group of 4 farmer moving from diesel irrigation to solar irrigation

   Farmer's equity IRR: 88%

   Negative free cashflows in first 3 years. Peak negative cashflow of UGX 159,354/ farmer in year 1

3. Individual farmer moving from no mechanised irrigation to solar irrigation

   Farmer's equity IRR: 38%

   Negative free cashflows in first 3 years. Peak negative cashflow of 1,164,018 in year 3

As can be seen from the above scenarios, the equity IRR for all scenarios except for the first one are quite high. However, in all scenarios, there is a considerable debt servicing burden in the first 3 years. This may be acting as a deterrent to farmers embracing solar irrigation, and may require intervention

Affordability. The affordability of solar irrigation is limited due to high upfront cost, with cheapest technology priced at UGX 2.2 million.

Technical feasibility. Technical feasibility is moderate as it depends on availability of water sources.

Commercial rationale for the PUE Companies. Commercial rationale of solar irrigation for PUE companies is high. All companies consulted reported accelerated sales in recent years and agree that solar irrigation is a profitable, high-potential subsector

Potential form of GIZ/SNV Support. Training of farmers on the potential and use of solar pumps, supply chain finance facility for PUE providers, guarantee facility for farmers to access credit, etc.

5.4.2 Cold storage for horticulture

Interest in technology. There is limited demand among smallholders, due to little to no awareness of the technology. Demand is higher among cooperatives and processors.

Commercial rationale for the farmer. Cold storage can effectively prolong the shelf life of fruit and vegetables by a matter of weeks – depending on the crop. However, the ability to benefit and avoid spoilages from increased prices depends on market linkages and the extent of peaks and troughs of production in a given geographic area.

Affordability. The price of a 50L solar refrigerator is almost twice the price of a solar water pump, at about UGX 6-7m.

Technical feasibility. This is still to be determined. Experience from other countries (e.g. Rwanda) suggests that low-energy cold storage for horticulture is frequently technically inadequate, breaks easily, and does not achieve the required temperature drop.

Commercial rationale for the PUE Companies. There is less demand than for water pumps, although there are a few players providing cold storage solar products.

Potential form of GIZ/SNV Support. Training, supply chain finance facility for PUE providers, guarantee facility for farmers to access credit, etc.

5.4.3 Cold storage for dairy

Interest in technology. There was evidence of demand in the KIIs, but it came mostly from cooperatives –likely due to low awareness of the technology.

Commercial rationale for the farmer. For larger smallholder farmers (66 cows), it can preserve milk from spoiling overnight. Similarly, it could help cooperatives. For a tank of 100L, the annual income saved could range between $292-730. For a tank of 3000L, between $8760-21,900. Diesel operated generators are expensive to operate in the long run. However, most farmers surveyed did not experience any spoilage.

The business case for an individual farmer purchasing a solar cooling facility was analysed, giving us the following results:

Farmer's equity IRR: 86%

Negative cashflows in first three years of operations. Peak negative cashflow of 653,328 in year 1

Hence, as in the case of solar irrigation technology, the main deterrent to farmers adopting and investing in solar based milk cooling may also be the debt servicing burden till the loan is paid off

Affordability. The price of a 150L milk cooler is over UGX 6m, which is higher than what individual smallholders would be willing to pay. It is better suited to dairy cooperatives than individual farmers. However even in that case, a 25000L milk cooler costs $31,500.

Technical feasibility. Research by Wageningen University (2015, "Milk Cooled by Solar Power") suggests that the technical feasibility is sufficient

Commercial rationale for the PUE Companies. There is less demand than for water pumps, although there are a few players providing cold storage solar products.

Potential form of SNV Support. Training, supply chain finance facility for PUE providers, guarantee facility for farmers to access credit, etc.

5.4.4 Processing for horticulture

Interest in technology. None of the farmers interviewed mentioned this as an interesting opportunity. However, there was demand from processors.

Commercial rationale for the farmer. For the processor, using solar energy for processing such as drying or juice extraction can lead to significant cost saving, since these are highly energy demanding. This in turn can enable the company to increase its production, which can indirectly benefit smallholders.

Affordability. No solar processing technologies for horticulture are currently on offer. One company interviewed had to import it from Austria

A scenario where a banana farmer invests in solar drying machines was analysed. The following results were obtained assuming about 20% of the produce was processed into dried banana

Farmer's equity IRR: 18%

Negative cashflows in first 3 years of operations. Peak negative cashflow of UGX 315,280 in year 3

Technical feasibility. This is still to be determined

Commercial rationale for the PUE Companies. The technology would be new to the market, untested and unproven, and facing many of the same restrictions in terms of import regulations, FOREX and inflation as solar irrigation.

5.4.5 Processing for dairy

Interest in technology. Very high – highlighted by multiple focus groups as a top priority for the sector.

Commercial rationale for the farmer. For the processor, using solar energy for processing such as milk churners this can lead to significant cost saving. This in turn can enable the company to increase its production, which can indirectly benefit smallholders.

Affordability. No solar processing technologies for horticulture are currently on offer. One company interviewed had to import it from Austria.

Technical feasibility. This is still to be determined

Commercial rationale for the PUE Companies. The technology would be new to the market, untested and unproven, and facing many of the same restrictions in terms of import regulations, FOREX and inflation as solar irrigation.

5.5 Support Required

Below, we have summarised the extent of support required for each stakeholder from GIZ and SNV:

Smallholder farmers and cooperatives

- **Awareness:** need for sensitization and training of farmers on PUE technologies' benefits and how to use them. There is a need to set up learning demonstrations on the use of PUE solutions. This includes how to overcome storage challenges. The planned irrigation demonstrations are few and there is need for more sites so as to make impact. Demonstration should include the production stage but also other stages of the value chain including storage and processing (FDG Mpigi, Iganga, Mukono, Luwero, Isingiro, Mbarara, Kiruhura, DPOs).
- **Affordability/Finance**: need for subsidies, a credit facility or financial support to access cheap loans to access PUE but also inputs (FDG, Iganga)
- **Facilities:** farmers need facilities for storage and value addition (FDG, Iganga, Mukono)
- **Cooperatives** should get loans to acquire PUE solutions (FDG, Soroti). Farmers should be supported to form groups, associations, or cooperatives so that they can access irrigation or any other renewable energy solution as a group rather than individuals (FDG, Iganga). Cooperatives would also need support with conducting a cost/benefit analysis. Coopertives also need access to transportation trucks (KII, Abesigana Dairy cooperative, Soroti Fruit Factory)
- **Marketing:** need help to access stable markets, and free trade with additional countries like the DRC. Bilateral, truparty or other business agreements needed to expand on markets for fruits and vegetables (FDG, Iganga, Luwero)
- **Quality assurance**: farmers need to access quality products and be assured of their quality (FDG, Isingiro)

Processors

- **Affordability/Finance:** need to access grant or subsidy to build (bigger) plants, increase production capacity and meet demand (KII, SULMA Foods). Need to provide subsidy support towards the acquisition of solar dryers.
- **Marketing**: need for support to certify products by the Uganda Bureau of standards and linkages to markets (KII, Bulan Tuklerewamu Farmer Group)
- **Policies**: need for policies that make renewable energy investments affordable for SMEs (KII, RECO industries). Need for for a policy that protects actors adding value to local produce. There should be some form of barriers restricting imports. In the end, the factories would support farmers. Uganda needs to borrow an example from India and Ghana who protect their local brands (KII, Soroti Fruit Factory)

PUE Companies

Need for additional investments / financial support in transportation and courier services, equipment acquisition through imports, facilitation for technical personnel, and backstopping of clients.

Facilitating companies to expand marketing and outreach activities, including setiing up local branch offices.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Solar Milk Cooling
giz
Solar Milk Cooling
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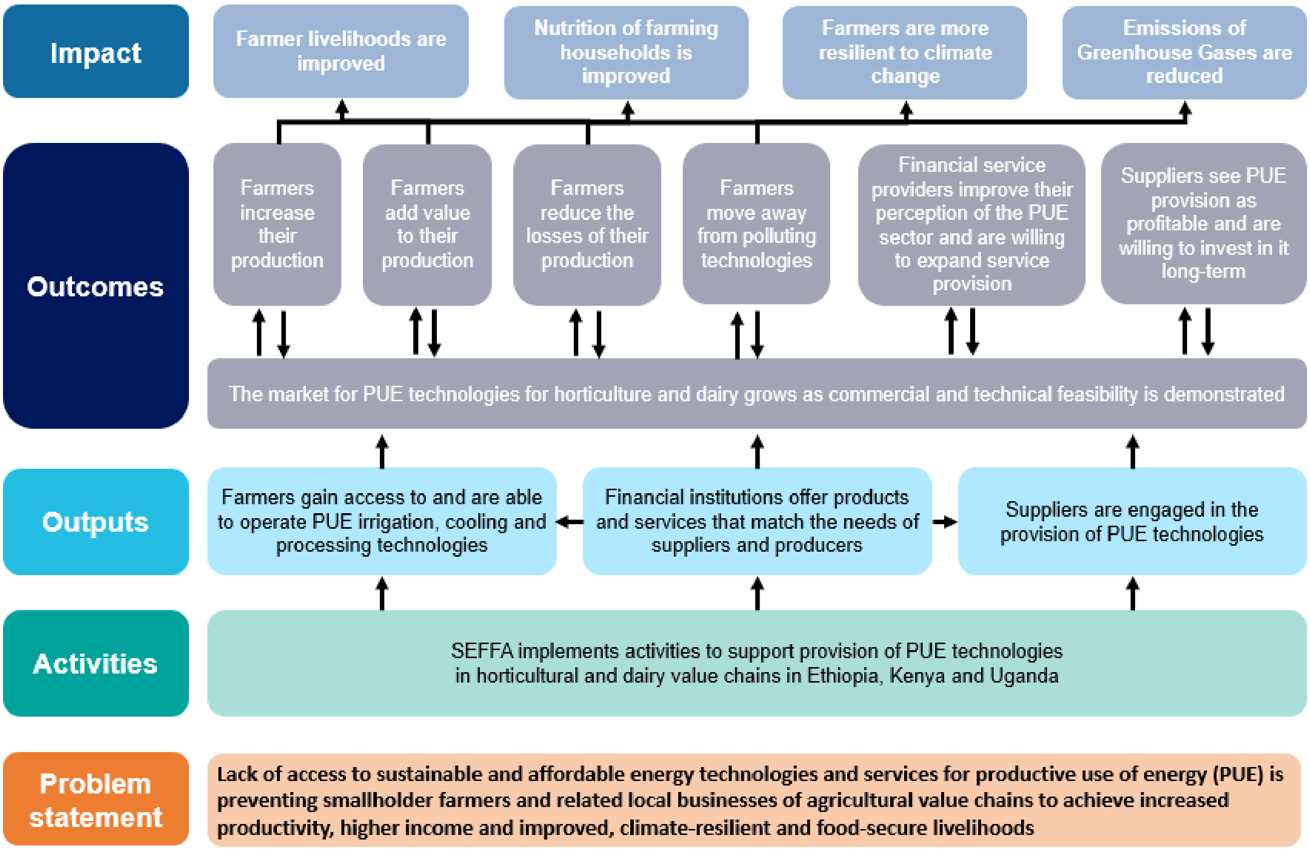
6. Results Measurement Framework

One of the fundamental objectives of the SEFFA project is to pilot and test high-potential business cases for expanding PUE technology provision, with an eye towards scaling up successful solutions. As such, it is essential to be able to clearly identify the target state, *what* to monitor, and *how* to monitor it. The following section therefore sets out the proposed results measurement framework that would enable SEFFA to not only ensure that the project activities are on track but also to assess the extent to which the piloted business cases can be replicated and scaled up.

6.1 Theory of Change

The following graphic presents the intervention logic for the SEFFA project which builds on the original project Theory of Change included in the Terms of Reference and incorporates the findings and lessons learned from the market assessment study. This Theory of Change indicates how country-level activities (i.e. the interventions proposed in this report) are expected to lead to the desired end results of improving farmer livelihoods, nutrition and resilience to climate change, as well as reducing greenhouse gas emissions.

Figure 31: Theory of change



The immediate **outputs** from the proposed activities relate to the improved ability of the key groups of stakeholders to, respectively, use and provide PUE technologies. An important element at output level is the ability of financial institutions to provide appropriate financial products and services to further boost the use and provision of PUE technologies.

At **outcome** level, the demonstration of commercial and technical feasibility of PUE technologies will generate a self-reinforcing, market-building effect: as the improved access to PUE technologies enables farmers to demonstrably increase their produce, add value and reduce waste, demand for PUE technologies will increase. This will strengthen the confidence of PUE technology providers in the sector and encourage them to expand service provision. In addition, the resulting higher revenues from both users and suppliers and, as could be expected, their improved ability to meet their loan repayment obligations, will strengthen the confidence of financial service providers in the sector and encourage the expansion of loan provision to the sector.

The **income** level encompasses socioeconomic, health and environmental effects. Due to increases in productivity, added value and reduced waste of produce, farmers will have a higher marketable surplus and will be able to obtain better prices, leading to higher incomes and livelihood improvements. Due to the higher production and reduced waste, it is also expected that the volume of nutritious horticultural and dairy produce available to the farming households will also increase, boosting their nutritional status. While the subject matter of resilience to climate change is complex and multifaceted, it is expected that SEFFA's activities will make a contribution to increased resilience of farmer households both directly, through increased physical resilience of production (i.e. irrigation technologies decoupling production from rainfall, cold storage solutions reducing post-harvest losses due to heat stress, etc.), and indirectly through financial channels (i.e. boosting incomes and savings). Lastly, the move away from polluting technologies to renewable-energy-fed alternatives is expected to contribute to a reduction in greenhouse gas emissions.

6.2 Selecting the indicators

While monitoring the implementation of activities usually involves a straight-forward process-orientated reporting practice, tracking progress in terms of the higher levels of the Theory of Change requires a careful consideration of the appropriate indicators. The subsections and tables below present the decision-making process for selecting these indicators for output, outcome and impact level.

6.2.1 Output level

The levels of engagement of value chain actors, which concern the first stage of expected outputs, can be monitored as part of regular project activities, and does not require a separate consideration of suitable indicators.

6.2.2 Outcome level

The results at outcome level largely depend on the ability to demonstrate the commercial and/or technical feasibility of PUE technologies, which requires a consideration of both observable metrics and stakeholder perceptions.

Commercial feasibility relates to the ability of farmers to profit from the use of PUE technology, and the ability of companies to supply the technology at a profit. Concerns around commercial sensitivity may make it difficult to estimate the latter directly. Therefore, a practical set of indicators could include the following:

- Difference in price obtained as a result of using the technology (*farmer side*)
- Difference in volume sold as a result of using the technology (*farmer side*)
- Changes in production costs as a result of using the technology (*farmer side*)
- Number of loans/ leasing agreements issued to facilitate the purchase of technology (*farmer side*)
- Willingness to obtain a loan to cover the purchase cost of the technology (*farmer side*)
- Number of units of technology sold as part of the pilot (*company side*)
- Willingness to expand technology provision *without* SEFFA support (*company side*)
- Willingness to expand financial service provision *without* SEFFA support (*financial service provider*)

Technical feasibility depends on the ability of technology in question to achieve demonstrable changes in crop productivity as well as the ability to store and/or process produce. Appropriate indicators, therefore, include the following:

- Average yield, with and without irrigation
- % of post-harvest loss
- Processing capacity relative to non-PUE alternatives
- Degree of user satisfaction with the cooling/ processing ability of technology and the quality of the final product

An additional indicator would be required to measure the extent to which "farmers move away from polluting technologies". This could be measured by collecting data on the number of farmers who have switched from diesel irrigation pumps to solar irrigation pumps, since this is the most prominent example of technology replacement in the country contexts under consideration.

6.2.3 Impact level

The expected results at impact level are broad and complex and, as such, can be measured in a variety of ways. The table at the end of this subsection presents the comparative assessment of common indicators and assessment methods under each impact-level result against a set of key criteria, namely:

- Robustness, i.e. the accuracy and reliability of the data that would be collected using a given approach
- Attributability, i.e. the extent to which observable/ measurable data could be explicitly and logically tied to SEFFA's activities
- Ease of collection
- Level of detail that would be required to construct the indicator
- Relevance of the data to the impact objective
- Comparability with other donor programmes, which might enable SEFFA to benchmark the extent of results achieved against the experiences of others
- The ability to use one indicator to measure progress against multiple impact objectives, with a leaner set of indicators requiring less effort for data collection

The measurement approaches considered for assessing **livelihood improvements** include the following, with the recommended indicators highlighted in bold:

- Poverty rate, as measured by the proportion of the sample population living under the poverty line. One of the most widespread methods for assessing this is the Poverty Probability Index which requires asking a survey respondent 10 multiple-choice questions which have been selected to allow for the estimation of the likelihood that the respondent is under the poverty line;
- **Average income uplift (self-reported), which involves asking the respondents directly about the extra revenue obtained as a result of technology use**;
- Average income uplift (beneficiary model), which involves recording all costs and revenues at baseline and at endline in order to calculate the exact net benefit from taking part in the programme;
- Time saved from using the technology, converted into a monetary value using average wage rates;
- Jobs created as a result of increased technology provision.

The measurement approaches considered for assessing **resilience to climate change** include the following, with the recommended indicators highlighted in bold:

- Increase in the respondents' perceived ability to withstand shocks to income, as a result of reduced production;
- **Number of farmers adopting new technologies that have been proven to make production and marketing more heat/ drought/ flood resistant;**
- **Average post-harvest losses (%) – expected to worsen as a result of higher heat stress and other climatic extremes;**
- **Average amount saved by farmers between seasons – the higher the savings "cushion", the greater the farmers' ability to withstand shocks to their incomes from failed harvests;**
- **Average income uplift (self-reported) – as above;**
- Number of farmers with climate-resilient homes and/or knowledge of climate-smart agriculture which would help to protect their crops from future shocks.

The measurement approaches considered for assessing the **contribution to reducing GHG emissions** include the following, with the recommended indicators highlighted in bold:

- Average consumption of GHG-emitting energy
- Change in the use of chemical fertilizer or manure
- GHG avoided or reduced
- Number of farmers reporting reduction in consumption of GHG-emitting energy
- Number of farmers reporting reduction in the use of nitrogen fertilizer

- Finally, the measurement approaches considered for assessing the improvements in nutrition include the following, with the recommended indicators highlighted in bold:
- Number of farmers reporting increase in household dietary diversity
- Number of farmers reporting higher frequency of nutritious food consumed (specifically, nutrient-rich vegetables and dairy products that fall within the scope of SEFFA's engagement)
- Number of farmers with a lower Household Hunger Scale score[19]
- Amount of horticultural/ dairy production consumed per household member
- Amount spent on food per household

Table 29: Comparative analysis of measurement approaches and indicators at impact level

Legend: Red shading indicates weak performance against criterion/ low contribution to the objective, **Amber** indicates medium strength/ performance/ contribution, and **Green** indicates best case/ high performance/ contribution.

	Measurement approach	Robustness of data	Attributability	Ease of collection	Level of detail	Relevance	Comparability with other programmes	Multiple outcomes	Priority?
Improved livelihoods	Poverty rate (% of people living under the poverty line)						YES	NO	
	Average income uplift (self-reported)						NO	YES	
	Average income uplift (beneficiary model)						NO	YES	
	Time saved						NO	NO	
	Jobs created						NO	NO	
Greater Resilience to Climate Change	Increase in perceived ability to withstand shocks						NO	NO	
	# of farmers adopting new technologies						NO	YES	
	Average PHL (%)						NO	YES	
	Average amount saved by farmers between seasons						NO	NO	
	Average income uplift (self-reported)						NO	YES	
	# of farmers with climate-resilient homes/ knowledge of climate-smart agriculture						NO	NO	

[19] https://www.fantaproject.org/monitoring-and-evaluation/household-hunger-scale-hhs

Contribution to reduction in emissions	Average consumption of GHG-emitting energy						NO	NO	
	Change in use of chemical fertilizer/ manure						NO	NO	
	GHG avoided or reduced						YES	NO	
	# of farmers reporting reduction in consumption of GHG-emitting energy						NO	NO	
	# of farmers reporting reduction in use of nitrogen fertilizer						NO	NO	
Improved nutrition	# of farmers reporting increase in HH dietary diversity						YES	NO	
	# of farmers reporting higher frequency of nutritious food consumed						NO	NO	
	# farmers with a lower Household Hunger Scale score						YES	NO	
	Amount of production consumed per HH member						NO	NO	
	Amount spent on food per household						NO	NO	

6.3 Monitoring plan

The following tables represent the monitoring plan for each of the three countries of SEFFA's operations, with differing activities, baselines and targets. However, several commonalities should be emphasised:

1. Annual household surveys are going to be a key monitoring component in all three countries. These should be supplemented with farmer group discussions in each implementation district in order to explore the findings in more detail, understand the reasoning for behaviour change (or absence thereof) and make any tweaks required to the programme activities
2. Separate surveys and interviews will be required for partner PUE companies and financial service providers.
3. Targets are not necessary for indicators at outcome level. When trying to establish commercial and/or technical feasibility, it is useful to maintain an explorative approach. The tangible benefits from using the technology can be established by collecting quantitative data as part of the annual household survey, or a more frequent, direct surveys as part of the smaller pilots (e.g. for horticultural processing in Ethiopia), with a more qualitative discussions on whether these benefits are sufficient to promote behaviour change and establish commercial/ technical feasibility to be held in the course of targeted interviews and focus group discussions.

6.3.1 Ethiopia

	Indicator	Baseline	Year 3 target	Data collection protocol	Calculation required?
Outcome	Average price obtained per kg/ of produce	See Annex C	n/a	Annual household survey	Jointly, these figures provide estimates of revenue which should be calculated per farmer, depending on the basket of horticultural crops produced, as well as costs – which would allow to sense-check commercial viability of the technology for the farmer
	Average price obtained per litre of milk	See Annex C	n/a		
	Average volume of horticultural produce sold per season	See Annex C	n/a		
	Average volume of milk sold per farmer per week	See Annex C	n/a		
	Average annual operating cost of equipment (per technology)	ETB 90,000 per year for using a diesel pump	n/a	Annual household survey & consultation with PUE providers	
	Number of loans/ leasing agreements issued to facilitate the purchase of technology	0	250	Interviews/ records review with financial service providers, quarterly basis	n/a
	Willingness to obtain a loan to cover the purchase cost of technology	n/a	n/a	Annual household survey	n/a
	Number of units of technology sold as part of the pilot (irrigation pumps)	0	250	Company records/ interviews, quarterly basis	n/a
	Willingness to expand technology provision without SEFFA support (measured on a Likert scale)	n/a	n/a	Endline company survey, investigated	n/a

				further in interviews	
	Willingness to expand financial service provision without SEFFA support (measured on a Likert scale)	n/a	n/a	Endline financial service provider survey, investigated further in interviews	n/a
	% of post-harvest loss	9%	5%	Monthly surveys with participating businesses	n/a
	Processing capacity relative to non-PUE alternatives	Tbd	n/a		
	Degree of user satisfaction with the cooling/ processing ability of technology and the quality of the final product (Likert scale)	n/a	n/a		
Impact	Average income uplift from horticulture (USD/ season)	USD 436	USD 700	Annual surveys, sense-checked during annual farmer focus groups	n/a
	Average income uplift from dairy (USD/day)	USD 0.68	USD 5.00		
	# of farmers adopting solar pumps	2	250		
	# of cooperatives adopting milk coolers	0	2		
	# of processors adopting solar grinding tech	0	1		
	Average PHL – horticulture (%)	9%	5%		
	Average PHL – dairy (%)	3%	0%		
	Average amount of savings (USD)	USD 255	USD 300		
	Average consumption of diesel (litres per year)	334	0		
	Average GHG avoided or reduced (kg of CO2)	0	900		
	% of farmers consuming Vitamin A-rich foods every day	25%	50%		
	% of farmers consuming dairy every day	41%	70%		
	Average fruit and veg consumed per HH member (kg/week)	2	3		
	Average dairy consumed per HH member (litres/ week)	1.5	2		

6.3.2 Kenya

	Indicator	Baseline	Year 3 target	Data collection protocol	Calculation required?
Outcome	Average price obtained per kg/ of produce	See Annex C	n/a	Annual household survey	Jointly, these figures provide estimates of revenue which should be calculated per
	Average price obtained per litre of milk	See Annex C	n/a		

	Average volume of horticultural produce sold per season	See Annex C	n/a		farmer, depending on the basket of horticultural crops produced, as well as costs – which would allow to sense-check commercial viability of the technology for the farmer
	Average volume of milk sold per farmer per week	See Annex C	n/a		
	Average annual operating cost of equipment (per technology)	KSH 40,000 per year for using a diesel pump	n/a	Annual household survey & consultation with PUE providers	
	Number of loans/ leasing agreements issued to facilitate the purchase of technology	0	250	Interviews/ records review with financial service providers, quarterly basis	n/a
	Willingness to obtain a loan to cover the purchase cost of technology	n/a	n/a	Annual household survey	n/a
	Number of units of technology sold as part of the pilot (irrigation pumps)	0	250	Company records/ interviews, quarterly basis	n/a
	Willingness to expand technology provision without SEFFA support (measured on a Likert scale)	n/a	n/a	Endline company survey, investigated further in interviews	n/a
	Willingness to expand financial service provision without SEFFA support (measured on a Likert scale)	n/a	n/a	Endline financial service provider survey, investigated further in interviews	n/a
	% of post-harvest loss	7%	4%	Monthly surveys with participating businesses	n/a
	Processing capacity relative to non-PUE alternatives	Tbd	n/a		
	Degree of user satisfaction with the cooling/ processing ability of technology and the quality of the final product (Likert scale)	n/a	n/a		
Impact	Average income uplift from horticulture (USD/ season)	USD 1,240	USD 2,000	Annual surveys, sense-checked during annual farmer focus groups	n/a
	Average income uplift from dairy (USD/day)	USD 7.50	USD 10.00		
	# of farmers adopting solar pumps	0	250		
	# of cooperatives/ farmer groups adopting solar drying technology	0	2		
	# of dairy cooperatives adopting solar cooling technology	0	2		
	Average PHL – horticulture (%)	7%	3%		

	Average PHL – dairy (%)	8%	4%		
	Average amount of savings (USD)	USD 238	USD 300		
	Average consumption of diesel (litres per year)	334	0		
	Average GHG avoided or reduced (kg of CO2)	0	900		
	% of farmers consuming Vitamin A-rich foods every day	26%	50%		
	% of farmers consuming dairy every day	56%	75%		
	Average fruit and veg consumed per HH member (kg/week)	1.68	2.5		
	Average dairy consumed per HH member (litres/ week)	1.2	2		

6.3.3 Uganda

	Indicator	Baseline	Year 3 target	Data collection protocol	Calculation required?
Outcome	Average price obtained per kg/ of produce	See Annex C	n/a	Annual household survey	Jointly, these figures provide estimates of revenue which should be calculated per farmer, depending on the basket of horticultural crops produced, as well as costs – which would allow to sense-check commercial viability of the technology for the farmer
	Average price obtained per litre of milk	See Annex C	n/a		
	Average volume of horticultural produce sold per season	See Annex C	n/a		
	Average volume of milk sold per farmer per week	See Annex C	n/a		
	Average annual operating cost of equipment (per technology)	UGX 370,000 per year for using a diesel pump	n/a	Annual household survey & consultation with PUE providers	
	Number of loans/ leasing agreements issued to facilitate the purchase of technology	0	250	Interviews/ records review with financial service providers, quarterly basis	n/a
	Willingness to obtain a loan to cover the purchase cost of technology	n/a	n/a	Annual household survey	n/a
	Number of units of technology sold as part of the pilot (irrigation pumps)	0	250	Company records/ interviews, quarterly basis	n/a
	Willingness to expand technology provision without SEFFA support (measured on a Likert scale)	n/a	n/a	Endline company survey, investigated further in interviews	n/a

	Willingness to expand financial service provision without SEFFA support (measured on a Likert scale)	n/a	n/a	Endline financial service provider survey, investigated further in interviews	n/a
	% of post-harvest loss	See Annex	n/a	Monthly surveys with participating businesses	n/a
	Processing capacity relative to non-PUE alternatives	Tbd	n/a		
	Degree of user satisfaction with the cooling/ processing ability of technology and the quality of the final product (Likert scale)	n/a	n/a		
Impact	Average income uplift from horticulture (USD/ season)	USD 4,031	USD 5,000	Annual surveys, sense-checked during annual farmer focus groups	n/a
	Average income uplift from dairy (USD/day)	USD 2.15	USD 4.00		
	# of farmers adopting solar pumps	0	250		
	# of cooperatives/ farmer groups adopting solar drying technology	0	2		
	# of dairy cooperatives adopting solar cooling technology	0	2		
	Average PHL – horticulture (%)	8%	4%		
	Average PHL – dairy (%)	6%	3%		
	Average amount of savings (USD)	USD 259	USD 300		
	Average consumption of diesel (litres per year)	334	0		
	Average GHG avoided or reduced (kg of CO2)	0	900		
	% of farmers consuming Vitamin A-rich foods[20] every day	24%	50%		
	% of farmers consuming dairy every day	54%	75%		
	Average fruit and veg consumed per HH member (kg/week)	5.90	6		
	Average dairy consumed per HH member (litres/ week)	1.79	3		

[20] Vitamin-A-rich foods include carrots, mango, watermelon, papaya, dodo, bean leaves, amaranth, cassava leaves, kale, and spinach (including wild forms)

A. Research questions

Market assessment component	Key research questions	Analytical methods
I. Value chain mapping	Which horticultural and dairy products should be the focus of this assignment?	Quantitative data analysis Client interviews
	For the key functions in the target value chains in Ethiopia/ Kenya/ Uganda, i) who are the key actors? ii) how many actors are there performing each function?	Stakeholder analysis Field observations Literature review Key technical expert interviews
	What role do women and youth play in the target value chains?	
	How can we characterise smallholder livelihoods, nutrition status and climate resilience?	Baseline survey Focus group discussions
II. Current energy solutions	Within the target value chains, where are the *potential* uses for renewable energy?	Literature review Key technical expert interviews
	Who are the current users of renewable energy within the target value chains, and what is the energy used for?	Baseline study Stakeholder interviews Field observation Key informant interviews Literature review
	Who are the current suppliers of renewable energy solutions? How are these solutions i) purchased, ii) set up, iii) maintained, and iv) paid for?	
	Who are the main stakeholders in the PUE subsector, and what is their influence and interest with respect to the Project?	Literature review Key informant interviews
	What benefits do those renewable energy solutions bring to their users, and how can those benefits be quantified?	Focus group discussions Quantitative data analysis
III. Gaps and constraints	Which of the common uses of renewable energy are NOT observed in the target value chains in Ethiopia/ Kenya/ Uganda? Why?	Key informant interviews Focus group discussions Field observations
	For the existing solutions, what are the key factors that limit broader uptake and business expansion, in terms of the supply side, the demand side and the enabling environment?	
IV. Analysis of opportunity	What is the potential space for the Project to intervene in order to boost access to sustainable and affordable energy technologies and services for productive use of energy?	Comparison of current energy use patterns against potential and existing constraints
	What is the business case for addressing these opportunities?	Key informant interviews Baseline survey Quantitative data analysis
V. Definition of support required	What forms of support can the Project provide in order to facilitate the implementation of the business cases?	Key informant interviews Literature review Stakeholder analysis
	Which stakeholders can be brought on board for the implementation, and which would require other forms of management?	
	How should progress towards achieving Project aims be tracked?	

B. Validation workshop participants

Stakeholders and representatives from following organizations (governments, associations, PUE companies, financiers and among others) participated in the workshops conducted for each country.

Ethiopia

1. Ethiopian Institute of Agricultural Research
2. Ethiopia Agricultural Transformation Agency
3. Ethiopian Meat & Dairy Development Institute
4. Ministry of Water, Irrigation & Energy
5. Bureau of Agriculture from SNNP, Amhara, Oromia and Sidama regions
6. Bureau of Livestock & Fishery from SNNP, Amhara, Sidama
7. Bureau of Energy, Oromia Region
8. Bureau of Water, Irrigation & Energy, Amhara Region
9. International Water Management Institution
10. Solar Village Plc
11. Yasrat Engineering Plc
12. Agri-Terra
13. GIZ
14. SNV

Kenya

1. CLASP
2. Digifarm
3. ECLOF Kenaya
4. Enviu East Afirca
5. Epicenter Africa
6. DAVIS & SHIRTLIFF
7. Equatorial Sunpower
8. Fortune SACCO
9. Fresh Produce Consortium of Kenya
10. InspiraFarms
11. Savanna Circuit
12. Juhudi Kilimo
13. KEREA
14. Kijani Testing Limited
15. Krep Fedha Services
16. MESPT
17. Sun Culture
18. Solar Freeze
19. Katheri Dairy Co-operative
20. GIZ
21. SNV
22. Solar Now
23. Suntransfer

Uganda

1. Ministry of Energy & Mineral Department
2. Ministry of Agriculture, Animal Industry & Fisheries
3. Agriculture Department, Mukono District
4. Agriculture Department, Iganga District
5. USAID
6. UN Capital Development Fund
7. Global Green Growth Institute
8. Solar Today
9. GIZ
10. SNV

C. Baseline volumes and prices

Ethiopia		
	Average volume marketed (kg/ litres)	Average price received (ETB/ KSh/ USh)
Avocado	305	15
Banana	127	14
Beetroot	337	5
Cabbage	1,463	6
Carrot	150	3
Chillies	280	17
French beans	1,400	19
Garlic	150	47
Green pepper	1,559	9
Lettuce	8	40
Mango	420	15
Onion	1,742	5
Orange	1,221	21
Papaya	225	14
Peach	35	20
Pepper	84	79
Potato	1,100	9
Tomato	1,589	11
Milk	6	27
Kenya		
Apples	130	68
Avocado	1,268	39
Banana	2,091	102
Beetroot	217	73
Broccoli	1,100	50
Cabbage	1,270	45
Carrots	244	33
Cowpeas	104	68
Capsicum	480	65
French Beans	1,827	64
French Peas	898	50
Irish Potatoes	191	54
Kales	1,353	29
Macadamia	1,323	59
Mangoes	3,954	31
Okra	600	50
Onions	1,351	50
Oranges	4,623	45
Passion Fruit	345	68
Plums	68	83
Pumpkins	4,590	88
Sukuma	1,917	24
Tomato Tree	500	100
Tomatoes	1,215	52
Watermelon	15,170	41
Milk	53	46

Uganda		
Amaranth	434	3,050
Aubergine	699	4,620
Avocado	356	3,100
Banana	3,854	4,455
Cabbage	1,506	3,224
Carrots	780	21,841
Chilli	230	3,000
Cucumber	273	4,086
Gauvas	99	3,333
Green chilli	875	6,198
Ground nuts	273	3,719
Jackfruit	1,040	2,625
Lemon	442	2,667
Mangoes	688	3,457
Okra	1,283	3,929
Onions	384	3,038
Oranges	1,001	3,948
Papayas	1,245	2,375
Passion fruits	1,136	3,387
Pineapple	1,220	3,012
Spinach	721	3,309
Sukuma	230	9,175
Tomatoes	1,768	8,239
Watermelon	6,333	3,227

Funded by:

german cooperation
DEUTSCHE ZUSAMMENARBEIT

Ministry of Foreign Affairs of the Netherlands

Norad

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Agency for Development and Cooperation SDC

Co-financed by:

IKEA Foundation

Coordinated and implemented by:

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Netherlands Enterprise Agency

SNV

Published by:
Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH
Registered offices Bonn and Eschborn,
Germany

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As of: December 2021

Photos:
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