Demand segmentation for solar-based irrigation bundles in Ziway and Wereta, Ethiopia

Technical Report

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Summary
Scaling small-scale irrigation (SSI) is critical in alleviating poverty and achieving Sustainable Development Goals in Ethiopia. There are several pathways to scaling SSI. Among these, the adaptive scaling approach has proven suitable for facilitating the private-led pathway and partnerships for scaling irrigation technologies and services, including solar-based irrigation bundles (SBIBs). Yet, operationalizing the adaptive scaling approach at a larger scale requires further action research to develop the tools to facilitate demand and supply linkages, de-risking the private sector investment in the SSI market. Addressing this need, this study develops a demand segmentation tool and applies it to the case of solar-based irrigation bundles in Ethiopia. It aims to understand and identify the different farmer segments, their resources, potentials, and preferences to better match demand and supply.

The segmentation was done in Ziway and Wereta woredas by applying participatory action research based on land and water access, arrangement for irrigation and production, financial capital and potential, and technology and service preferences. Data was collected in September 2022 using semi-structured interviews, focus group discussions, and stakeholder consultation workshops, involving farmers/farmer groups, government and non-governmental institutions, financial institutions, irrigation equipment suppliers and service providers, and output market actors.

Four segments include resource-rich farmers, resource-limited farmers, project-pilot beneficiaries, and organized irrigators. These segments have different needs and resources to invest in SBIBs. Challenges to investment in and scaling SBIBs relate to natural, financial, and human capital and the suitability of the available solar pump technologies to farmer needs, expectations, and contextual and value chain dynamics. Gaps in sales and distribution networks at local levels and limited availability of solar technology options in local markets are observed from the supply side. Also, government subsidies and credit-based financing for motor pumps may create a biased business environment and competition for Solar Powered Irrigation Pumps (SBIBs).

Innovative approaches to link private and other value chain actors and services are needed to create opportunities for the private sector to lead the market. These include developing effective mechanisms for linking organized and resource-rich irrigators with water-lifting service providers, technology suppliers, and financing institutes. Collective loans for resource-limited farmers and organized irrigators will enable investment in higher-capacity solar-powered irrigation pumps and deep wells for both user segments. Local sales agents/distributors should network with extension agents to connect technology supply with different farmer segments, facilitating an efficient information flow and building trust and credibility on the farmers’ side. Furthermore, suppliers should diversify the SBIBs in the market regarding capacity, multiple uses, solar energy storage, and mobility. Another opportunity is the availability of on-farm water storage and efficient irrigation methods that can address farmers’ concerns about the performance of solar-based irrigation. The inclusion of SBIBs in the government’s policies and programs for irrigation development should be fostered.
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Acronyms and Abbreviations
Africa RISING  Africa Research in Sustainable Intensification for the Next Generation
AgroBIG   Agro-Business Induced Growth Programme
ATI      Agricultural Transformation Institution
BDU IT  Bahir Dar University Institute of Technology
DAP     Di-ammonium Phosphate
FGDs    Focus Group Discussions
GHG    Greenhouse Gas
IAVC   Irrigated Agricultural Value Chain
ILSSI   Innovation Lab for Small Scale Irrigation
KOICA   Korea International Cooperation Agency
MEDA   Mennonite Economic Development Associates
MFI   Microfinance Institution
NGO    Non-governmental Organization
O&M    Operation and Maintenance
ORDA   Organization for Rehabilitation and Development in Amhara
PAYOWN   Pay-as-you-own
Rib SACCo Union  Rib Saving and Credit Cooperative Union
RuSACCo   Rural Saving and Credit Cooperative
SBIB   Solar-Based Irrigation Bundle
SME   Small and Medium Enterprise
SPIP   Solar Powered Irrigation Pump
SSI    Small-Scale Irrigation
WUA    Water User Association
1. Introduction

Scaling agricultural innovations plays a critical role in alleviating poverty and achieving Sustainable Development Goals in Ethiopia (Gebreyes et al. 2021). There are different approaches and pathways for scaling agricultural innovations. These may be driven by the private sector, public sector, non-governmental organizations (NGOs) and/or civil society organizations. Adaptive innovation scaling is referred to as “agile standing processes by which actor networks involved, cooperate, feed-off, adapt, support, compete and interact with each other and with actors to respond to the contextual dynamics of the system” (IWMI 2021). Such scaling processes are embedded in socio-economic-ecological-political-developmental contexts that pose systemic barriers, enablers, and drivers to catalyze innovations. For the transformation of agri-food systems, the scaling processes should be adaptive, inclusive, and responsive to dynamic contexts as well as changes and trade-offs encountered along the way.

Adaptive scaling has been applied to catalyze small-scale irrigation (SSI) in different countries in sub-Saharan Africa, including Ethiopia (IWMI 2021). The potential for SSI is well recognized in Ethiopia’s policy framework for agricultural development, food, and nutrition security, and building resilient agri-food systems against climate variability (e.g., FDRE 2011, 2019, 2020; MoANR et al. 2016; NPC 2016). SSI contributes to economic growth by generating higher profits and incomes for farmers than rainfed agriculture by potentially improving equity and profits along the agricultural value chains and enabling horticultural production to scale (ILSSI 2020). Work undertaken by Feed the Future Innovation Lab for Small Scale Irrigation (ILSSI) shows that climate variability, such as long dry spells, is pushing more producers to supplemental irrigation, while the demand for vegetables and fruit is pulling farmers into dry season irrigated horticulture (ILSSI 2021). Moreover, there is a strong demand among farmers for irrigation technologies, motorized or solar-powered pumps and other agricultural water management tools (ILSSI 2021).

Despite the support, importance and interests, the wide-scale adoption of SSI investment among Ethiopian smallholders remains low. The SSI scaling effort is ineffective (IWMI 2021), and most smallholders continue their rudimentary practices. Overemphasis on technological dissemination without due consideration for important ‘soft elements’ and nuances critical for successful scaling is one reason hampering the effort (IWMI 2021). Multi-actor learning and coordinated action to create solutions that fit and are affordable for farmers, value chain actors and the government are indispensable for the effective and sustainable scaling of agricultural innovations (Seifu et al. 2020).

Innovative and adaptive approaches are necessary for scaling SSI. IWMI (2021) confirms that bundled innovations have proven critical in successfully scaling irrigation technologies and services. The enabling environment for adoption is enhanced when one or more core innovations, such as solar-powered irrigation pumps (SPIPs), are accompanied by complementary services like financial services and technical support. The private sector is a key player in the scaling of innovation bundles. Private sector engagement in irrigated agriculture can help to drive economic growth and poverty reduction, with farmers, entrepreneurs and businesses already leading the way in SSI development (ILSSI 2021). Private sector actors, including smallholder farmers, can benefit from strengthened markets for irrigation equipment and irrigated produce.

Through continued action research, a suitable private-led pathway for scaling solar-based irrigation bundles (SBIBs) for irrigated agriculture has been identified by IWMI by examining the case of smallholders in Lemo, Ethiopia (Minh and Schmitter 2020). The pathway includes building irrigation equipment supply chains, farmers as business partners, and a scaling platform. Facilitating demand and supply linkages between users and providers of technologies and services is part of implementing the private-led pathway. Identifying and understanding the different user groups, their resources, potentials, and preferences are vital to successfully matching demand and supply.

This study analyses the segmentation for the SBIBs market in Ziway and Wereta. Specifically, it looks at:
• the context of irrigated agriculture and the solar-based irrigation market,
• SBIBs and their demand segments,
• challenges and opportunities for the identified segments to invest in SBIBs, and
• the way forward to catalyze the SBIBs.

This report presents an analytical framework for market segmentation (Section 2), followed by a discussion on the methodological approach (Section 3). Section 4 presents an overview of irrigated vegetable value chains in two areas to lay out the segmentation and SBIBs scaling context. Section 5 looks at SBIBs and their segments, followed by Section 6, which considers the common challenges and opportunities for investing in solar-based irrigation. The report concludes with the past, current, and possible future steps in catalyzing the SBIBs.

2. Analytical framework

From the business perspective, market segmentation refers to dividing the user market into smaller, more defined categories. Each segment or group shares similar characteristics—demographics, interests, needs, location, or preferences. Segmenting the market helps businesses and market actors facilitate their business targeting, develop tailored products and services, and inform investment decisions. The basis for such market segmentation is diverse demographical, geographical, behavioral, and psychographic indicators. The demographic segmentation considers details such as age, occupation, education, family size, and income. Geography splits up markets based on location. Customer behavior, such as likes and dislikes when interacting with a product or service, may also be used to split markets. Psychographic segmentation examines customer personalities and characteristics such as lifestyle, attitude, and motivations.

In this analysis, segmentation refers to identifying the specific demands for solar-based irrigation markets. Specifically, farmers’/clients’ demands for solar-based irrigation equipment and services are classified as the basis of the integrated business and agricultural value chain perspectives, as presented in Figure 1. Such a hybrid analytical lens allows the segmentation to be tailor-made, considering the needs of the farmers and businesses for the type of investment, available resources, irrigated agricultural value chain engagement, and preferences for technologies and related services.

The business dimension indicates the solar-based irrigation supply chain, its suppliers, and how they provide products and services to farmer clients. The business model analyzes how suppliers bundle their products, operation, and maintenance (O&M), and support services to meet market demands. Water resource development services, for instance, focus on well digging, rig drilling, mechanization, and other services for groundwater development.

The irrigated agricultural value chain (IAVC) dimension attributes to, for example, the farming system, the input and output markets, and enabling environment for the actors engaging in the chain. It also includes the chain structure, power relations within, and how activities are organized in the chain. The activities of one actor within the value chain affect the activities of others in the chain. Consequently, support and intervention in the value chain development should be considered to ensure collaboration and connections among the chain actors in investing in solar-based irrigation.

In the farming system element, farmers within a locality may have different needs and capacities to access agricultural technologies and services (Anang and Asante 2020) as they have different land and water resources, irrigation and production arrangement, and financial capital and potential. Water sources for irrigation could be surface, underground, surface and underground water, or harvested water; the demands may differ depending on the type of water source.

The input market examines the availability of seeds, fertilizers, agrochemicals, and advisory services for end users. Financial services refer to farmer access and the potential of financial support from formal and
informal sources to purchase improved technology and augment farming activities. Access to credit/finance, inputs, extension services, information and communication technologies (ICT), and market infrastructure need consideration to gauge the farmers’ ability to afford the technology offered and the potential to capitalize on their investment in irrigation products.

FIGURE 1. An analytical framework for segmenting the demands for solar-based irrigation.

Source: Authors’ creation.

The behavior, demographic and psychographic dimensions refer to the farmers’ financial management, investment behavior and investment preferences. These dimensions also partly reflect the factors in the enabling environment that influence the farmers’ interactions with other actors in the IAVC and the solar-base irrigation market, enlightening or hindering their ability to invest in the technologies and services (Feyisa 2020; Van Loon et al. 2020). Technology and service preferences focus on, for instance, the water lifting and application methods and related services suitable for different farmers.

Segmenting the demand for solar-based irrigation includes using existing demographics, past projects and interventions data, rapid assessment and qualitative analysis. Innovative ways to segment the market include using digital innovation and appropriate technology for ease of use. It is important to consider the resource potential of the target market and the time or season to conduct the market segmentation (Ofosu and Minh 2022).

3. Methodology

3.1 Research approach

Irrigated vegetable value chain analysis was undertaken in September 2022 to identify and characterize the market segments for SBIBs. Consultations with producers, private actors, and governmental and non-governmental development actors engaged in irrigated value chains and operating in Ziway/Batu, Bahir Dar,
and Wereta towns were undertaken. These sources of information were identified with the help of Woreda agriculture staff, referrals from initial respondents, and professional networks.

### 3.2 Information sources and data collection

Data was collected via interviews, focus group discussions (FGDs), and stakeholder consultation workshops (Table 1). A total of 49 interviews were conducted using a semi-structured questionnaire, including individual and organized farmers, Woreda agriculture and irrigation office staff, private sector including agro-input dealers, irrigation technology suppliers, financial service providers, well diggers, and NGOs/development partners. Four FGDs were organized (two in Ziway and two in Wereta), where 103 persons participated, followed by two stakeholder consultation workshops. The farmers participating in the study were primarily selected from five kebeles around Ziway (Abine, Edo Gojola, Negalign, Ilca, and Ana Shisho) and three kebeles around Wereta (Koket, Kwar Micael, and Shina). These kebeles were selected because they are priority areas of local agriculture and irrigation offices.

**TABLE 1. Overview of primary data.**

<table>
<thead>
<tr>
<th>Information sources</th>
<th>Roles</th>
<th>Topics discussed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Semi-structured Interviews</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Twenty interviews with farmers and farmer groups</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Individual farmers and organized farmers in Ziway and Wereta</td>
<td>- Farming/production</td>
<td>- Production, irrigation technologies, and practices - Other livelihood activities - Access to services (input supply, extension, financial services, transport, output markets)</td>
</tr>
<tr>
<td>Two interviews with agro-input suppliers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agro-input dealers (Ziway, Wereta)</td>
<td>- Wholesale and retail of agrochemicals and seeds, fertilizers, and equipment</td>
<td>- Products and services offered - Business challenges - Cooperation with other value chain actors - Current and future investment in irrigation equipment and services</td>
</tr>
<tr>
<td>Ten interviews with governmental and NGOs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Woreda Agricultural office staff, extension agents, and development partners (Wetlands International, Spanish Aid, SNV, Farm Africa)</td>
<td>- Extension delivery - Input supply - Irrigation project pilots - Capacity building for farmers</td>
<td>- Mandate - Activities, support, and services related to small-scale irrigation - Challenges - Cooperation with other actors and organizations</td>
</tr>
<tr>
<td>Two interviews with financial institutions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buusaa Gonofaa Microfinance Institute in Ziway and Rib Saving and Credit Cooperative Union in Wereta</td>
<td>- Agricultural lending - Capacity building for farmers</td>
<td>- Mandate - Lending activities for irrigation - Challenges lending to smallholders</td>
</tr>
<tr>
<td>Four interviews with private groundwater developers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Individuals, organized groups, and one PLC in Ziway and Wereta</td>
<td>- Groundwater development by manual tube drilling and rig drilling</td>
<td>- Services provided - Challenges and opportunities in providing and expanding business</td>
</tr>
<tr>
<td>Six interviews with irrigation equipment supply and services</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pump distributors (motor, solar, electric), farm laborers in Ziway and Wereta, Bahir Dar</td>
<td>- Irrigation equipment supply - Irrigation support services</td>
<td>- Products in trade - Challenges - Organization of farm work</td>
</tr>
<tr>
<td>Five interviews with output market actors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetable wholesalers and retailers in Ziway, Wereta, Bahir Dar</td>
<td>- Sale of vegetables</td>
<td>- Trading activities, sources of produces, challenges in the business</td>
</tr>
<tr>
<td>FGDs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>103 farmer and farmer groups in Ziway and Wereta</td>
<td>- Farming/production</td>
<td>- Land and water resources - Irrigation and technology preferences</td>
</tr>
</tbody>
</table>


3.3 Data analysis

Information from the different sources was collected first in the local languages (Amharic and Afan Oromoo) and then recorded, transcribed, and translated into English. Qualitative content analysis was applied, wherein words, word senses, phrases, sentences, or themes were examined using a conceptual and relational analysis (Neuendorf 2017). Accordingly, each transcript was analyzed to identify and characterize the different types of irrigation farmers and investigate key actors and their roles in irrigated agriculture. The farmers were categorized according to their land size and access, water sources and access, irrigation methods, financial access and potential, and technology and service preferences. Relevant services were also examined for their influences on farmers’ access to improved technologies, including SPIPs.

4. Irrigated vegetable value chains

4.1. Structure of the irrigated vegetable value chain

Livelihoods in Ziway and Wereta are characterized by mixed systems with crop cultivation (rain-fed and irrigated) and livestock rearing. Other income sources noted include tree plantations and the sale of wood for construction and firewood, charcoal sale for coffee preparation, petty trading and fishing at Tana and Gumara rivers around Wereta and Hara Dembel Lake in Ziway. Smallholders dominate irrigated farming systems. Garlic, onion, tomato, cabbage, mango and pepper are among the main irrigated horticulture crops (along with maize, at times) in Wereta during the dry season. In Ziway, the irrigated crops include lettuce, Swiss chard, kale, papaya, banana, bean and maize, in addition to those grown in Wereta. Irrigators produce two to three times per year (Figure 1). Seeds are mainly acquired from private suppliers, agriculture offices, input cooperatives, NGOs and sometimes from other farmers.

Farmers often have several farms in multiple locations through individual ownership (plot near home), membership in associations or cooperatives, or rentals. Renting 0.5 ha of land for a year cost about Birr 10,000–12,000 (USD 189 to 227)\(^1\). Average plot sizes range from 0.25 ha (usually for backyard farming) to 1.5 ha (usually for main cash for food crops). The prevalence of organized irrigators is observed where there is surface water or significant groundwater development, and a single association usually has between 20–100 members (with a minimum of 12 members being necessary) according to the cultivated land size. They manage their land and crops individually, while the investment in pumps and managing water is undertaken collectively. Individuals must pay registration fees and periodic membership fees to cover fuel and other O&M costs, usually after harvest and sales. Women appear to have equitable access to land and irrigation water within the association. Water/irrigation associations have a secretary and deputy, finance, operation management, conflict resolution, and administration divisions. Members can also rent their land to other members if required.

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\(^1\) 1 USD = 52.88 Birr
FIGURE 2. Overview of the irrigated value chain in Ziway and Wereta.

Source: Authors’ creation.

Notes: MFIs = Microfinance Institutions; RuSACCo = Rural Saving and Credit Cooperatives; WUAs = Water User Associations.
Surface water is the main irrigation source, although groundwater is sometimes used. Irrigators in Ziway depend on Lake Ziway and other rivers in the watershed, while those around Wereta utilize Tana, Gumara, and other smaller rivers. Hand-dug shallow wells are operated for small-scale backyard irrigation, household consumption, and livestock. This is partly because of ample surface water availability (historically) and a lack of willingness or inability to purchase pumps for the shallow well. It is common for farmers to have multiple wells—a mix of had dug and manual tube drilled—in their plots. Individual farmers invest in well development and pumps by themselves, but shared uses are also observed. Some farmers in Wereta also use multiple pumps for different plots. They have diesel and petrol pumps to ensure they can continue to irrigate in case either of the fuels is unavailable in the local market. For individual irrigators with smaller land sizes, the 2-inch motor pumps are the most common, while the 3-inch ones are observed for larger plots and shared use in multiple plots. Organized users usually have higher capacity (3-inch and higher) motor pumps for collective use. There are some SPIPs and electric pumps. Using SPIPs has enabled irrigators to save O&M costs and invest the difference to cover input costs. In Ziway, some informants mentioned that the groundwater was becoming increasingly saline as it got deeper, only suitable for some salinity-tolerant crops. Flooding and furrow irrigation is the most common water application method. With the introduction of SPIPs, few model farmers use drip systems with the support of research centers and NGOs.

Farmers have access to both local and regional markets for irrigated output. Output sales and the actors involved are contingent upon the volume produced. Brokers may be used to link farmers to wholesalers and retailers. A direct link between farmers and wholesalers is largely non-existent despite attempts by the Woreda agricultural office to create direct linkages, especially in Wereta. A broker usually goes to the farmer to buy produce when volumes are a 35-quarter truck or above. Prices are negotiated at the farm gate. Brokers and traders sell produce at local markets in Wereta, Bahir Dar, Ziway, or markets in Addis Ababa. Produce may also be sent to neighboring countries such as Djibouti. Higher-grade crops are sometimes exported. Products with moderate quality are sent to local markets, while low-grade outputs are earmarked for home consumption.

Farmers having smaller volumes of the same product may sell their produce together to brokers collectively to avoid the cost of transportation to the market along with the loading and unloading fees. Farmers sell directly to wholesalers and retailers in local markets when growing various crops in small volumes, especially fruits, and vegetables. Women farmers may sell the farm produce themselves in local markets. Donkey carts or small trucks may be used to transport the produce. Farmers may also walk to the market when a means of transport is not readily available or local markets are close to farms. Wholesalers and retailers in local markets may source their products from different regions, sometimes through middlemen, depending on the season of the year.
Wereta. The main buyers of irrigated products are individuals, public institutions, hotels, and fruit and juice shops.

The unavailability of inputs and the high cost of production are the most reported challenges in irrigated agriculture, i.e., the rising costs of vegetable seeds, agrochemicals, fertilizers, and fuel. It is often difficult to access inputs when they are required. The price of diesel and petroleum has more than doubled in the last two years, with local markets often facing shortages. This has led to irrigators having to buy from the black market, incurring an additional cost of about 50% of the current price. Another challenge is market development, information, and linkage for irrigated produces. Others include access and affordability of manual tube drilling, uncertainties in water availability in areas of interest, and water shortage from shallow wells (mostly hand-dug) during dry seasons. While most producers are members of some savings and credit services, some individual farmers are not using (or plan to use) financial services from Microfinance Institutions (MFIs) and credit cooperatives to purchase pumps. The reasons for non-availing such services include perceived and real risks such as market and weather, requirements such as group collateral, and insufficient amounts of loans (usually up to 30,000 per individual).

### 4.2 The supply of irrigated technologies and services

The supply chain for irrigation technologies and services in Wereta and Ziway is illustrated in Figure 3. The supply chains in the two locations are generally very similar, including the actors involved, technologies, and services. There are a few key differences that are highlighted in the discussion below.

**FIGURE 3.** The supply chain of irrigation technologies and services in Wereta and Ziway.

*Source: Authors’ creation.*

*Note: SMEs = Small and Medium Enterprises*
Supply of motor pumps

Motor pumps operating on diesel and fuel are the most common irrigation technologies used for lifting water around Ziway and Wereta, followed by manual pumps. Motor pumps are mainly imported from China, including brands such as FKR, Haomax, Leo and Kama. The Koshin brand imported from Japan is also common in the trade. The pumps come in two sizes: those suitable for 2-inch hoses and those suitable for 3-inch hoses. Private distributors and retailers dominate the supply of pumps. Most of the suppliers also sell accessories and spare parts. Equipment for water conveyance is sold in private shops in Ziway and Bahir Dar. These include PVC pipes and irrigation hoses imported from China and Saudi Arabia. However, suppliers do not provide maintenance and are often outsourced to local technicians via them. In the case of Wereta, two types of private actors are involved in providing O&M services for motor pumps—youth trained and certified by the local irrigation office and individuals that operate informally based on experiences.

Local agriculture and irrigation offices are actively involved in the supply chain of motor pumps — they evaluate technical specifications, process purchases and distributions, and provide O&M services through technicians (Figure 2). These include small-capacity 2-inch pumps for individual smallholders and larger-capacity pumps (4-inch or higher) for organized irrigators. They also assist NGO projects and facilitate the linkage of organized irrigators with MFIs to access loans to purchase pumps. The offices facilitate motor pump access on credit and co-financing schemes where producers purchase motor pumps with a 40% down payment and are given 3–5 years to finalize the remainder.

The major challenge in the irrigation supply chain is the high rate of increase in the price of motor pumps. Suppliers in Ziway and Bahir Dar mentioned that the average price of diesel pumps rose from roughly Birr 13,000 (USD 245.9) to Birr 24,000 (USD 453.9) in just over a year. Distributors and retailers also mentioned that they are facing challenges in accessing motor pumps for distribution and retail because the importers in Addis are facing a shortage of forex for imports. The price increase excludes resource-poor farmers from purchasing. Consequently, some suppliers look for cheaper (and unknown) brands that may be less quality but affordable to local users. High cost and availability of spare parts are particularly reported among organized users with high-capacity motor pumps purchased from suppliers in Addis through government projects. This is because the local suppliers do not sell such pumps and cannot provide parts and O&M services.

Supply of SPIPs

SPIPs are not readily available in local markets; few local suppliers and agents were identified. There are suppliers of solar technologies for home systems, but these actors have limited engagement in the sale of SPIPs. Information regarding sales agents is difficult to access since the suppliers don’t usually hold stock of SPIPs and may not have their own shops for this purpose. This is because the pumps are capital-intensive to stock and have a relatively slow sale rate. There is only one official SPIP supplier in Bahir Dar, the regional marketing office of Rensys PLC, and none in Ziway, with only two sales agents for Rensys PLC, identified in this study. They place orders on behalf of farmers when there is a demand for SPIPs. The Ethiopian Agricultural Transformation Institution (ATI) is engaged with the supply of SPIPs. ATI uses similar schemes to pilot and promote SPIPs via a 40-60% co-financing mechanism where ATI covers 60% of the pump cost. NGOs working on irrigated agriculture are also increasingly playing a significant role in supplying SPIPs in the targeted locations. For instance, Farm Africa in Ziway promotes SPIPs where farmers pay 45% of the cost of the pump while Farm Africa supports 55%.

Regarding the SPIP supply, farmers have very little information about the availability and performance of the technologies in their localities, the types of pre- and after-sales services/support services available, the provision of the information, and where to access it. The suitability of SPIPs inlet tubes with manually drilled wells is a concern. Sometimes, SPIPs do not meet farmer expectations regarding the area coverage and discharge rate. Farmers believe that SPIPs are suitable for household use and gardening but not in the coverage of main plots. Also, battery-less SPIPs pose limitations on when one can irrigate because irrigating during high solar intensity is not recommended for some crops. In
addition, most farmers in the two locations have more than one land in different places, and it is difficult to move SPIPs from place to place. Therefore, it is exposed to theft and may need its own water well. Local availability and reliability of O&M services for SPIPs is a great concern for investing. Most of the drilled wells for individual farmers have 3-inch widths that can only take in 2-inch pumps, while the SPIPs that are being promoted have wider sizes. Cases have been noted in Wereta where farmers have opted into co-financing schemes for SPIPs, but the pumps have not been able to fit into existing wells after their purchase and delivery.

**Water resource development services**

Groundwater is used for irrigation, livestock, and household consumption in both locations. **Shallow well** development is mostly undertaken by traditional hand diggers using hand tools and manual tube drilling systems, and in a few instances, with mechanical rigs around Wereta. Traditional wells are usually shallow, about 10 meters (m) deep. Manual tube drilling providers develop wells of up to 30 meters.

Regional governments of Oromia and Amhara are both involved in developing infrastructures for water resources development as well as the supply of pumps to meet national targets. There are youth groups and individual manual tube diggers in Wereta and Ziway. They are trained and organized with the support of irrigation, water, and energy offices at the federal, regional, and local governments and other actors like the World Food Programme (WFP). While most such well diggers are also farmers and possess lands, their income from digging services is becoming notably significant as well. For instance, Tamire Mamo, an individual digger outside of Ziway digs on average about 10 wells per year that are of 3- and 4-inch widths for a price of Birr 13,000–30,000 (USD 245.8–567.3) respectively for different clients. Agreements between diggers and farmers are verbal and based on trust. If water is not found after digging once — which can happen often — the diggers will try another nearby place for free. Diggers may end up digging up to three locations within a farm before abandoning the idea of procuring groundwater in that location. The farmers have the responsibility to cover the cost of pipes and provide food and drinks for the whole team during digging, which can be between 5–10 people working generally for about a week.

These actors also work on water development projects with NGOs and governments, receiving training and other support. The private sector leads the development of groundwater resources for irrigation, livestock, and household consumption. Trained manual well tube diggers and traditional hand diggers dominate the services for farmers. For manual tube diggers in the two locations, machinery that can dig through stone, that works on different landscapes and soil types, and that saves labor and time is required to expand the business operation and to reach clients in different locations. Financial support and additional training in improved technologies and O&M are also vital.

**Borehole drilling services** are offered mainly by the private sector in Ethiopia to farmers, projects, and institutional clients. The rigs can drill wells up to 180 m. Teshome Tadesse Water Works is a rig drilling service provider based in Wereta, offering services in Wereta and surrounding towns, at times beyond the region, depending on the volume and value of the business. The company imported its rig machine tax-free from China. It collaborates with other individuals and organizations to provide a package of drilling services to clients.

Sighting experts begin the service package by surveying the location. This is outsourced to other companies or individuals adept in carrying out sighting for water. Sighting experts use local knowledge and/or water-sighting equipment to identify potential areas for drilling a borehole within the farmer’s field. The geological survey helps to determine water availability, quantity, and quality. The rig supplier and mechanization expert use the reports from the sighting expert, resource discussions, and farm visits to determine the type of services to offer the farmer. Reports help to determine well depth, type of pump to use, water application technologies, and mini-grid connection and installation:
We study the farmer selected. According to their capital, we present them with the kind of pumps (surface, submersible) and give them advice on which one they should use including the discharge rate and head specifications, diesel versus solar, the casing inch size between wells and pump types, etc… We also engage in pump purchase from Addis and install to clients as necessary. Even though there is demand for solar in areas without electricity, usually it’s very expensive. (Source: Interview with Teshome Tadesse Water Works, Wereta)

The price charged for drilling differs between farmers and other clients. Farmers get a discounted price of 2,500 Birr/meter (USD 47.3) while other clients are charged 3,000 Birr/meter (USD 56.7). However, the recent doubling of fuel prices and rise in operational costs is compelling the company to revise its pricing. The company has a social mission that seeks to improve the access of farmers to SPIPs using credit plans. This has however not been fully implemented because of the lack of guarantee/intermediary institutions: ‘farmers’ incomes are seasonal, and they need the well before they plant and harvest. We want to provide credit service, but we need third parties like MFIs, the government or NGOs, to guarantee the contract between us and the farmers. NGOs can support clients through cost-sharing mechanisms. And government can provide guarantee/enforce if farmers cannot pay back once service is provided.’

Currently, farmers may make an initial payment of 25% of the total price, with the remainder paid after installation according to the contract signed. After drilling, well rehabilitation services can be provided if clients cover operation expenses. The company also has a plan to manufacture modified drills that can drill between 30–100 m locally and at a lower cost compared to importing. Wells dug by rigs provide additional sources of water to ensure a consistent supply of water throughout the growing season.

Rig drillers face several challenges. These include a lack of working capital, the rising cost of equipment and maintenance, poor access to higher-capacity machinery, and limited availability of spare parts. Pipes required for drilling are usually only available in Addis Ababa. O&M tools such as wrenches, cutters, and gear makers are also expensive. On the farmer side, access to information on drilling services and SPIPs is generally low due to overdependence on word-of-mouth advertisement and minimal awareness creation on services: ‘…we get our customers through a middleman in the sector, projects, and individual farmers contact us themselves by word of mouth and looking at our work…’ Crop and market failures, such as the devastating market failure for irrigated onions in 2020 in Wereta also act as hurdles for the drilling business—as farmers lose incomes and interest—and consequently, the demand for drilling services declined significantly.

Agronomic Inputs

In both locations, farmers generally have access to different types of agronomic inputs for irrigated and rain-fed production. Fertilizers, agrochemicals, seeds, and seedlings are primarily accessed through private suppliers, input cooperatives, and sometimes through NGO and government projects that operate locally. Some private suppliers provide farm equipment such as chemical sprayers, protection materials, and liquid organic fertilizers. These are mostly imported from India, Turkey, Holland, and other countries through importers in Addis Ababa, while some of the organic fertilizers are produced in Ethiopia. Denbel Pesticides in Ziway town also provides inputs on a credit basis for trusted clients when they face cash shortages before planting season.

Urea and Di-ammonium Phosphate (DAP) fertilizers are supplied and accessed through input cooperatives that are organized for this purpose and that most farmers are members of. ATI has established Farm Services Centers and One Stop Shops — some of which have been transferred to private actors — to provide a range of products such as inorganic and organic liquid fertilizers, vegetable seeds, some farm equipment, and several agrochemicals including herbicides, pesticides, and fungicides. The private suppliers also provide some advisory services on which inputs to use and when and how to apply them.
Challenges include timely availability and increasing costs of these inputs. In particular, the price of inorganic fertilizers (DAP and urea) is a major obstacle for farmers because they no longer access these via credit from the cooperatives and instead must pay in cash upfront. There is a significant knowledge gap among farmers and suppliers about the safety and protection measures and application (mixing, timing, application, and methods) of agrochemicals. Even though suppliers are required by law to employ professionals to sell their products, it is a rare occurrence. Counterfeit seeds and agrochemicals that are illegally ushered into the country are also causing loss of income and crops as reported by farmers and suppliers.

Financial services
Agricultural and rural financing is primarily undertaken by MFIs and Rural Saving and Credit Cooperatives (RuSACCco), Rib Saving and Credit Cooperative Union (Rib SACCo Union) and Tsedey Bank (formerly known as Amhara Saving and Credit Institute) are among the key players in irrigation financing in Wereta. In Ziway, Buusaa Gonofaa MFI, Metemamen MFI, and Sinqee Bank (formerly known as Walqo MFI) are prominent. Such public and private financial institutions are the main sources of credit and loans for producers including those in Ziway and Wereta. Target clients are Small and Medium Enterprises (SMEs), women, youth, entrepreneurs, and low-income communities including smallholder farmers.

Buusaa Gonofaa Microfinance Institution focuses on irrigation financing as a key business strategy and has supported the sector for over 15 years. Their products include irrigation loans, personal loans, SME loans, and investment loans for farmers with land sizes above 0.25 ha. They also offer input credit for rain-fed agriculture. Seeds and fertilizers are provided for organized farmers using group collateral, the beneficiaries of which include landless youth. Regular loans are also provided for beneficiaries including women, women groups, and low-income businesses. For instance, five or more women may organize themselves to access a loan of Birr 7,000 (approximately USD 135) each. SME loans are provided for businesses that have reached the value addition and manufacturing stage. Irrigation loans cover the cost of farming under irrigated conditions such as seed, labor, fertilizer, other agro-inputs, and fuel. It ranges between Birr 10,000 and 30,000 (approximately USD 189.1 to 567.3) and is given at an interest rate of 18% using a reducing balance. Additional services for clients include the promotion of recommended irrigation agronomy practices through field follow-up visits (about three times during the growing season), training in record keeping, and financial literacy. MFIs may collaborate with the government or NGOs to execute projects. Collaboration with the government includes the monitoring of loan facilities for women and the sourcing of fertilizers and seeds from the agriculture office by MFIs. Projects with donors and NGOs were observed to be declining at Buusaa Gonofaa for unclear reasons.

Rib SACCo Union covers 6 Woredas in the Amhara region including Wereta, supplying financial services to the members of the 161 saving and credit cooperatives that form the Union. Credit and loans for dairy and livestock, irrigation, fishery sectors, and supporting the member cooperatives are the key services offered. Smallholder farmers and pastoralists are the main target groups. The union also develops specific products and service packages based on the needs of development actors and projects such as AgroBIG projects and development partners like the World Bank, CARE, and the Organization for Rehabilitation and Development in Amhara (ORDA). It also tests innovations such as climate insurance for smallholders with Waliya insurance company in pilot areas. Despite not being based at Wereta, Rib SACCo Union provides loans for WUAs and irrigation associations to purchase pumps through a co-financing mechanism where there is an agreement with other actors (government, and NGOs) to cover part of the cost. Members of the cooperatives can access up to six-fold of their individual savings using group collateral. In potential areas, some individuals can get the same service based on a house plan or property but using the land book as collateral is not yet permitted as per regulations. The general interest rate for loans is 12% but depends on the duration of repayment. For project packages, Rib SACCo Union may only charge them service charges (5%) if projects provide the union cash with zero interest. While products and services primarily consider
membership and savings, Rib SACCo Union has project packages that particularly target women and youth such as the AgroBIG project where 80% of the loan is set aside for women and youth and 20% for other borrowers.

Despite the wide number of financial institutions operating in the country, access to financial services is still a challenge for many farmers for several reasons. First, there is little financial literacy. Low levels of formal education as well as poor access to financial training in local languages limit farmers’ access to formal credit. Second, poor record-keeping limits farmers’ ability to show proof of operations and income to access credit. The majority of farmers do not record expenses and incomes for farming separately from other sources of income and expenditure. Third, unfavorable attitudes and fear of credit prevent farmers from making inquiries about credit relevant to their farming activities. Although farmers may access credit for inputs such as seeds, fertilizers, and pesticides within farmer associations, there is a general fear of accessing credit from mainstream financial services due to the perceived complexity. Fourth, smallholder farmers in Ziway and Bahir Dar often have fragmented farm operations with an average farm size of 0.25–2 ha, sometimes up to 5 ha, scattered around major surface water bodies such as Lake Ziway, Lake Meki, the Nile and River Gelda, and the Mismo Spring. The cost of managing credit among smallholders is therefore high and unattractive to mainstream financial service providers.

Fifth, there is a limitation of financial institutions in terms of available capital and funds, and reach. Demand for financial services outmatches supply, with institutions potentially not having the financial resources to meet the pace of increasing demands. Grants from development partners like the World Bank and projects have been crucial in addressing some of this capital gap. Finally, smallholder agriculture is perceived to be high risk. Input prices and availability are unpredictable, especially fuel for powering motored pumps. Also, smallholders still engage in basic farming practices such as the use of hoes and manual labor for planting, irrigating, fertilizer application, weeding and harvesting of crops. Output is therefore low even when the purpose of production is mainly for the market. This has been further worsened by climate change and climate variability which has led to unpredictable rainfall patterns and decreasing volume of water in lakes coupled with increasing incidences of pests and diseases. Moreover, farmers have little control over market access and prices of output. Market prices are often decided by one or more brokers that serve as their link to retailers and wholesalers in the main towns. Political unrest in parts of the country also limits the desire of financial institutions to lend to smallholder farmers. The Buusaa Gonofaa MFI, for instance, indicated that in 2022 they are short of about 3 million Birr (USD 56,732) in repayment collection targets out of the 51 million Birr (USD 964,477.8) given out as irrigation loans due to such risks.

Interventions from the government and NGOs

Woreda offices of agriculture and irrigation lead the provision and facilitation of key and supporting services — technical and advisory services, financial services, capacity building, and organizing users. Capacity building services cover short-term training on how to operate and maintain pumps (for private actors), soil and water management, irrigation agronomy, plant protection, harvest and postharvest (for producers), and facilitating access to market and market information. The offices organize farmers and youth groups (water user associations [WUAs] and producer cooperatives) near water sources and facilitate access to high-capacity motor pumps through government schemes. They also partner with the private sector including input and technology suppliers and MFIs to link with producers. In Ziway for instance, local offices linked with a local NGO (Rift Valley Development Association) and supported the purchase and distribution of 20 motor diesel pumps for a women’s group, along with providing technical support on irrigated agronomy and crop selection. Another example is the facilitation of formal agreements between user associations and well-development service providers in Wereta.

Additional support from NGOs and other governmental actors is also observed in Ziway and Wereta. These include interventions from Spanish Aid, Stichting Nederlandse Vrijwilligers (SNV), World Vision,
Korea International Cooperation Agency (KOICA), Wetlands International, Mennonite Economic Development Associates (MEDA), and Farm Africa, among others. KOICA supports farmers in acquiring greenhouses for vegetable production in Wereta while Farm Africa and Wetlands International provide capacity building for farmers and agricultural institutions such as training on water efficiency, irrigation agronomy, and sustainable natural resource management practices in Ziway. Farm Africa also pilots SPIPs via co-financing and credit where farmers pay 45% of the cost in a year and the rest is covered by the organization. Under a new project called CULTIVATE, Farm Africa intends to strengthen WUAs. ORDA provides targeted support for irrigated agriculture around Wereta through provisions of agrochemicals and vegetable seeds at a discount of 25% and 50% respectively. ORDA also provides continued professional supervision as well as advisory services in selected potential kebeles by assigning one expert for 50 irrigation farmers. The intervention prioritizes high-value crops including tomatoes, pepper, and cabbage rolls, and targets farmers that have a minimum of about a half hectare of farmland to allocate for a single crop. The Small Holder Irrigation Development Project (SHIDP) and AgroBIG projects are also actively supporting irrigation development in Wereta.

ATI has established a research center in collaboration with the Debre Tabor University in Wereta. In addition to offering researchers opportunities to study aquaculture and new plant varieties, it also serves as a center for capacity building for farmers. Improved plant varieties are produced for sale here using drip irrigation powered by a Shakti solar pump. These include papaya, coffee, and mango seedlings.

There are gaps, limitations, and challenges in providing these services. Local offices do not have adequate access and options to learn about the latest innovations and technologies in irrigation, including solar pumps. They are few projects and rare training opportunities. Severe logistic and resource constraints are also significant barriers. NGOs face some challenges in carrying out their mandate in Ziway, Bahir Dar, and its surroundings. For example, an NGOs approach to executing a project may conflict with the government’s policy direction for that sector or may appear to conflict with regulations guiding NGO activity in Ethiopia. Farm Africa for instance, has experienced challenges with the local government in its efforts to distribute pumps by cost sharing. The money collection aspect of their strategy raised issues as NGOs are usually not allowed to collect money from communities. Also, there are challenges with projects’ sustainability and effectiveness because of problems in managing and monitoring money collection in cost-sharing projects, over-exploitation of surface water, low volumes of surface water (such as Meki and Bulbula rivers which have periodic dry spells), and low development of groundwater. In addition, there is excess chemical use, especially in the flower industry, low affordability of solar technologies, and low access to solar technologies and services due to a limited number of suppliers and narrow geographical coverage.

5. Solar-based innovation bundles and market segments

5.1. Solar-based irrigation bundles

SPIPs are increasingly becoming a part of promising SSI innovations and offer multiple advantages. Solar-based irrigation supports resilience to climate change and mitigation. The operation of SPIPs does not produce any greenhouse gas (GHG) emissions, and life cycle assessments indicate a potential reduction in GHG emissions per unit of energy used for water pumping (CO\textsubscript{2}-eq/kWh) of 95–98% as compared with pumps operated with grid electricity and diesel pumps (Hartung and Pluschke 2018). Increasing rural women’s access to solar energy can help them build resilience against climate change.

National policies on SSI, such as the National Smallholder and Drainage Strategy of 2016, plan for 80% of Ethiopian farmers to have at least one source of water for irrigation and 50% to be supported to use the full package for modern irrigation including SPIPs (MoANR et al. 2016). Institutions such as the ATI, and research for development projects including Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) and ILSSI have been actively working to promote solar-based irrigation in different parts of the country. It is necessary to bundle packaged approaches and
recommend innovations and solutions to support the development of solar irrigation in Ethiopia, including market-led approaches and financing mechanisms along with solar pumps, and technical services (Otoo et al. 2018; GIZ 2020).

Accordingly, using evidence from Lemo in Ethiopia and through a partnership with private technology supplier Rensys PLC, IWMI has co-identified and co-designed a pathway to support the scaling of SBIBs. This pathway follows the ‘Supplier model with bundled financing’ where a business model facilitates farmers’ access to finance from solar irrigation suppliers, manufacturers, or importers. The SBIB supplied by Rensys PLC with the support of ILSSI and Africa RISING includes SPIPs, pre- and after-sales services, and pay-as-you-own (PAYOWN) financing service. The details are provided below as described in the Africa RISING Technical report (Melaku et al. 2022).

SPIPs and matching accessories

In Lemo, three different types of SPIPs are being promoted by Rensys PLC to farmers (Table 2). One of these is the Rainmaker 2C with a climate-smart battery (Picture 2). All SPIPs work for surface (river, pond) or well (shallow or deep) water and are packaged with a 50 m pipe; made in Kenya by SunCulture, they are imported to Ethiopia by Rensys PLC. They are supplied with accessories, if required, including a battery with a USB port and light bulbs. With a 2-year warranty, customers can contact the sales agent or the toll-free hotline for technical support. Rensys dispatches a technician if needed or replaces the pump at no cost within the warranty period.

<table>
<thead>
<tr>
<th>Characters</th>
<th>The Rainmaker 2C Kubwa direct</th>
<th>The Rainmaker 2S direct</th>
<th>The Rainmaker 2C with climate-smart battery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of 310 W panels</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Best working depth (m)</td>
<td>30</td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>Pump capacity (liters/hour)</td>
<td>2,750</td>
<td>1,110</td>
<td>3,000</td>
</tr>
<tr>
<td>Irrigable area (ha)</td>
<td>1</td>
<td>0.5</td>
<td>1</td>
</tr>
<tr>
<td>Battery</td>
<td>-</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>Price in Birr (upfront cash)</td>
<td>99,652.38</td>
<td>59,783.29</td>
<td>105,905.13</td>
</tr>
<tr>
<td>Additional features</td>
<td>-</td>
<td>-</td>
<td>Light bulbs, USB port</td>
</tr>
</tbody>
</table>

Pay-as-you-own financial services

Together with SPIPs, Rensys offers the PAYOWN financing service to make the equipment more affordable for farmers. It is a financing model that allows farmers to pay in small installments until they have disbursed an agreed total amount to finally own the pump. When the sale agreement is signed, the customers will deposit 50% of the product down payment when installing the product as an upfront cost; the rest can be paid as a loan within 6 to 12 months. Currently, customers pay their fees through bank payments, and there are plans to operationalize mobile payments in the future. The online PAYOWN platform Sentinel—provided to distributors by SunCulture—assigns unique serial numbers for clients and monitors payments. It can even block the pumping services remotely whenever the customer does not pay according to the agreed installment schedule. The services are

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unblocked once the payments are received. Due to unexpected complications in the payment system, payments are so far being managed manually using sales agents.

**Pre-sales services**

Pre-sales services include the credit and product-client fit assessment to decide the creditworthiness and solar-based irrigation systems that are the most affordable and appropriate for the clients. The credit assessment tool was developed by the ILSSI partnership activity with Bahir Dar University Institute of Technology (BDU IT). The decision support tool assesses various weighted socioeconomic criteria and determines the eligibility status of potential clients. The eligibility assessment is particularly critical in minimizing the risk for Rensys in financing the pumps for and with the farmers (Picture 3).

![Picture 3. Screenshots of the Digital Client Assessment Tools. Credit: Rensys PLC.](image)

Subsequently, Rensys’ customer finance officer reviews the information and determines the eligibility status for credit services. The final decision is transferred to the technical team responsible for undertaking the Product-Client Fit Assessment. This ensures that the biophysical and technical requirements of clients match the technical specification and performance of the pumps. The call center team (# 8544 from Monday to Saturday) and fit assessment tool developed by Rensys (with the support of the manufacturing company SunCulture\(^3\)) will be used for this. The assessment evaluates factors such as water source, irrigation size, income, and livelihood of the client, among others.

**After-sales services and support systems**

After the purchase, the technical team performs the product installation and usage orientation. After-sales services are supported by a web-based system (also developed by BDU IT with the support of ILSSI). It offers different functionalities such as encoding information on clients, sales agents, products, debt, payment, commission, warranty, and maintenance. The system greatly enhances the management of key information for Rensys, i.e., the volume of sales, payment tracking, and maintenance requests and records. The hotline call center and technical team follow up and respond to maintenance needs, repairs, and spare parts. The after-sales system is vital for Rensys for data organization and management, customer interaction, and after-sales support. It is also a feedback and learning system that may help to detect patterns in marketing and facilitate a systematic tracing of technical challenges.

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\(^3\) https://sunculture.com/products
5.2. Farmer segments identified in Ziway and Wereta, Ethiopia

Resource-rich farmers have access to their land, often near their residence, over two or more hectares for cultivating fruits and vegetables such as avocado, carrots, cabbage, tomatoes, and pepper (Table 3). They may have access to other farms away from their homes that are individually owned or as part of a farming group. They have access to their own (multiple) sources of water, usually a hand-dug well and/or a borehole of depths 30–70 m. Hand digging costs about Birr 150–200 (USD 3–4) per meter by trained hand diggers based on general knowledge. Water extraction is carried out by hand, pulley systems, motorized pumps, or solar pumps often acquired with the help of development partners such as Farm Africa. Water application is mainly by flooding and occasionally by drip irrigation. These farmers require large-capacity SPIPs for large farms and small-capacity pumps for home gardens. They have the financial capacity to make an outright payment for small pumps. They may be able to purchase large capacity pumps by paying cash upfront or making a down payment and paying the rest in installments. Another preference is investing as a group (4-5 adjacent households) in large capacity pumps and deep well development for common use. A few resource-rich farmers use rig drilling services, often introduced to them by other farmers or extension agents. While such farmers may use community tube wells, dugouts and surface water bodies, they nevertheless also require other sources of water they can control.

Resource-limited farmers rent land for farming, paying fees of about Birr 13,000 (USD 250) a year. They have access to shared water resources, mainly surface water such as Lakes Ziway and Meki, Rivers Nile and Gelda and the Mismo Spring. Irrigation is done manually or using motor pumps through flooding. Farmers may belong to a formal or informal WUA. Informal water associations exist in some communities, where those farming close to a water source share the resources through an informal rotational arrangement. This is common with surface water but may also be practiced for groundwater. Although one farmer may bear the cost of digging a well for water, he/she is expected by the community to share water with other members of the community, although the crops have priority in times of water scarcity. Farmers may have alternative income sources such as animal rearing for milk and meat, especially cows, sheep, and chicken. Individually, farmers require low to medium-capacity solar pumps. Large-capacity pumps may be required in cases where farmers irrigate as a group. Pumps may be acquired by making a down payment and paying the rest in installments.

Project pilot beneficiaries have access to their own land for farming, about 0.5 hectares in size. Due to project pilots, farmers have access to groundwater from hand-dug wells of about 6 m and tube wells of about 30 m provided by NGOs such as AgroBIG. Farmers may have access to storage facilities as part of the pilot. Depending on the technology being piloted, farmers may irrigate using motorized pumps or solar-powered pumps, or a combination of both. Pilots may only cover a portion of the farmer’s field, requiring them to use other means of irrigation on portions of the field not covered by the pilot. Farmers may have income from other sources — cow rearing for milk and meat, sheep and chicken. Poor access to market information and low availability of solar pump suppliers within farming communities and immediate environs act as barriers, limiting farmers’ availability to acquire additional solar technologies to complement the project pilot. Farmers can acquire low to medium-capacity pumps through a deposit and subsequent installment payments to complement existing solar pumps from projects.

Organized irrigators are usually formally registered entities (WUAs and Producer Cooperatives) with elected officials including a chief/head, finance officer, and financial auditor. Groups are often of mixed gender. Farmers may join a WUA by registering with a minimal fee of about Birr 50 (approximately USD 1) depending on the rules of the association. The associations collect fees of Birr 500–1500 (approximately USD 10–30) per season at harvest from each farmer depending on the land size and the agreement of the farmers. The fees collected are deployed to buy and lay PVC pipes for farms of members, pay for fuel for motor pumps, and for repairs and maintenance of motor pumps and PVC pipelines. Fertilizers, herbicides, and pesticides are also acquired using these fees.
### TABLE 3. Farmer segments for solar-based irrigation bundle in Ziway and Wereta, Ethiopia.

<table>
<thead>
<tr>
<th>Resource-rich farmers</th>
<th>Resource-limited farmers</th>
<th>Project pilot beneficiaries</th>
<th>Organized irrigators</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Land and water access</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Access to own land</td>
<td>- Rent land for farming</td>
<td>- Access to own land</td>
<td>- Own or rent land close to farms of other group members</td>
</tr>
<tr>
<td>- Having additional cultivation land for group</td>
<td>- Access mainly to surface water (e.g., Lakes Ziway and Meki, Rivers Nile and Gelda, and the Mismo Spring)</td>
<td>- Access to groundwater through tube wells or hand dug well from project pilots</td>
<td>- Access mainly to surface water (e.g., Lakes Ziway and Meki, Rivers Nile and Gelda, and the Mismo Spring)</td>
</tr>
<tr>
<td>- Access to multiple water sources mostly 30–70 m boreholes and/or hand-dug wells about 10 m deep</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Arrangement of irrigation and production</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Individual decisions on crops to grow each season</td>
<td>- Individual decisions on crops to grow each season</td>
<td>- Individual decisions on crops to grow each season and irrigation application</td>
<td>- Individual decisions on crops to grow each season and production with collective support during planting, weeding, chemical application, or harvest</td>
</tr>
<tr>
<td>- Individual irrigation for home plots</td>
<td>- Irrigation is done individually or in groups</td>
<td>- Water lifting is done using solar or motor pumps and water application is by flooding and/or drip</td>
<td>- Group-based irrigation on a rotational basis of 2-3 times and individually supplemental irrigation</td>
</tr>
<tr>
<td>- Collective irrigation for group-based plots</td>
<td>- Water lifting is done manually or using motor pumps and application by watering cans or flooding</td>
<td></td>
<td>- Using motored pumps and flooding irrigation</td>
</tr>
<tr>
<td>- Water lifting is mainly by motor pumps and application by flooding</td>
<td>- Individual cultivation and sale of produce</td>
<td>- Irrigation is done individually or in groups</td>
<td>- Individually or collective marketing of products</td>
</tr>
<tr>
<td>- Individual cultivation and sale of produce</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Irrigated vegetable value chain</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Grow high-value crops including avocado, tomato, cabbage, and pepper</td>
<td>- Grow high-value crops including tomato, cabbage, and pepper but have limited incomes because of the small size of farms</td>
<td>- Grow high-value crops including tomato, cabbage, and pepper</td>
<td>- Cropping 2-3 times/year offers significant returns to farmers as a group</td>
</tr>
<tr>
<td></td>
<td>- Having limited incomes because of the inability to irrigate full land and home consumption of the majority of output</td>
<td>- Having limited incomes because of the inability to irrigate full land and home consumption of the majority of output</td>
<td>- Cultivating different vegetable crops</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Benefit members through better access to input and output markets and technical and advisory support</td>
</tr>
<tr>
<td><strong>Marketing</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Selling produce at the farm gate brokers for the export market</td>
<td>- Selling produce in local markets to retailers or directly to consumers</td>
<td>- Selling produce in local markets to retailers or directly to consumers</td>
<td>- Individual selling to brokers at the farm gate or retailers and wholesalers in local markets</td>
</tr>
<tr>
<td>- Selling produce wholesalers at the farm gate for local markets</td>
<td></td>
<td></td>
<td>- Collective selling to brokers for the export market in Djibouti and other neighboring countries</td>
</tr>
<tr>
<td><strong>Financial capital and potential</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>- Harvesting of vegetables and fruits 2-3 times a year offers significant returns for the farmer</td>
<td>- Limited financial capital due to cultivation of 0.5 ha or less, partly for home consumption</td>
<td>- Low to medium financial capital due to limited access to improved technologies and financial services</td>
<td>- High financial capital as a group</td>
</tr>
<tr>
<td></td>
<td>- Lack of information and fear of formal credit system limit access to bank loans</td>
<td>- High potential to expand production to increase incomes</td>
<td>- Benefit members through better access to credit</td>
</tr>
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<tr>
<td><strong>Technology and service preferences</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Small capacity solar pumps for home gardens</td>
<td>- Small capacity pumps for home gardens</td>
<td>- Require low to medium-capacity pumps to complement existing solar pumps from projects</td>
<td>- Require high-capacity solar pumps for group use</td>
</tr>
<tr>
<td>- Large capacity pumps for larger farms</td>
<td>- Large capacity pumps to be shared with neighboring farmers.</td>
<td>- Payment may be done through a subsidy system or a down payment and subsequent payment plan (quarterly or bi-annual payment over 1-2 years)</td>
<td>- Low to medium-capacity pumps to supplement group irrigation</td>
</tr>
<tr>
<td>- Group investment (with adjacent farms) on deep water wells and/or larger capacity solar pumps possible</td>
<td>- Payment may be done through a down payment and subsequent payment plan</td>
<td></td>
<td>- Outright/down/subsequent installment payments depending on the collective financial possibility</td>
</tr>
<tr>
<td>- Outright or through a payment plan</td>
<td></td>
<td></td>
<td>- Require SPIPs bundled with water application equipment</td>
</tr>
</tbody>
</table>
Farms are often close to a water source and to each other to limit the PVC piping required to channel the water. The land is individually owned and managed by members of the association with support from the group. Water is drawn mainly from surface water sources such as Lakes Ziway and Meki, Rivers Nile and Gelda, and Mismo Springs. Groundwater from boreholes and shallow dugouts may be used where the salt content is tolerable for cultivation.

Irrigation is done collectively by the group as per a schedule. Farmers get access to water two to three times a week using group-acquired motor pumps. Part of the fees collected by the WUA is used to pay for a pump administrator who oversees scheduling, protecting the association’s pumps, and maintaining the pumps at regular intervals. Farmers sometimes own individual motored pumps to supplement the irrigation received from the group. Individual-owned pumps are also used when group-owned pumps are not available due to breakdowns or repairs and maintenance.

Extension services are arranged by the association and there are three-to-four visits from extension experts in a season, including training programs to build capacity of the farmer groups. Extension agents may also buy inputs on behalf of the cooperative. Production is done individually, although farmers in the group may help each other in some instances such as harvest times. Crops grown include avocados, cabbage, tomatoes, and onions. Each farmer decides what to grow in a particular season. Output may be sold individually or collectively depending on the association. Output may be selected for export to Djibouti and other neighboring countries or for the local market. Higher-grade crops are often exported, and output with moderate quality is sent to local markets; low-grade output is for home consumption. As a group, they require high-capacity SPIPs with options for bundles of pumps and water application equipment. They have the financial capacity to make outright payments for pumps or use a payment plan depending on the size and financial strength of the association. Individuals within the group may require low to medium-capacity solar pumps to supplement irrigation from the group, obtained via a deposit and subsequent installment payments.

In addition to the above farmer segments, institutional users such as NGOs, private businesses and public institutions are also actively present in the solar pump markets. Private businesses and public institutions such as hotels and hospitals sometimes purchase SPIPs (usually higher-capacity ones) to meet their water requirements. Government institutions such as ATI and NGOs like Farm Africa and MEDA actively purchase different types of SPIPs from private importers for their irrigation development projects, to provide for project beneficiaries via subsidies, co-financing mechanisms, or in some cases for free demonstration and piloting purposes.

6. Common challenges and opportunities to investing in solar-based irrigation

6.1 Challenges

Several challenges limit the ability of farmers to invest in solar-powered irrigation pumps. These are related to capital, value chain dynamics, best-fit packages, supply-side challenges, and technology financing options.

Capital-related challenges

Natural capital challenges include the under-exploitation of groundwater for irrigation. Irrigation in Ziway and Wereta is traditionally focused on surface water from lakes, rivers, and springs despite a low water table that allows groundwater to be obtained from 6 m and beyond. This is mainly due to the historical availability of sufficient surface water in the past. Current trends are, however, bringing to the fore the need to exploit groundwater for irrigation. Groundwater development requires financial capital and access to digging/drilling and related services. These can be more of a constraint for resource-limited farmers as compared to, for example, organized irrigators, who have a greater chance to access the services and mobilize the financial capital as a group.

There are declining volumes of surface water due to climate change and increasing competition for water for irrigation. This is especially visible from September to March each year during the dry
season. In addition, periodic flooding destroys farms and the homes of farmers. Minor floods occur in Wereta and its environs annually that do not cause major damage, leading to improved soil fertility. Major floods, however, occur every 5–10 years, damaging farms and homes. Natural capital challenges hamper the ability of farmers to increase production and save towards investments in augmented technology including solar pumps for irrigation.

**Financial capital challenges** include the limited ability of farmers to make initial investments for SPIPs, low savings culture, poor financial management, and low business capital, constraining their ability to buy SPIPs. The initial capital investment in SPIPs is high compared to the investment required for motor pumps in Ziway, Wereta, and its environs. A compounding factor is the low level of savings. Many farmers reinvest their earnings into buying inputs, saving minimal amounts or with no savings at all. This limits their ability to purchase SPIPs. Additionally, some farmers do not manage their farming as a business and do not keep financial records. Accessing credit is therefore a challenge. Resource-rich farmers and organized irrigators usually have relatively better access to credit and loan services from formal institutions (MFIs and RuSACCos) because of the assets they own and their legal status, respectively.

On the supply side, some pump distributors do not have sufficient business capital to stock products, especially at local level retails. They, therefore, order products for farmers as and when dictated by demand. Farmers are often required to make full payment for the pump before it is ordered by the supplier. This makes it difficult and risky for individual farmers to place an order on a given pump unless they have had a previous opportunity to observe that model operate in their locality.

**Human capital challenges** include inappropriate irrigation practices, high cost of labor, inadequate extension support, and limited access to skilled repair and maintenance professionals. Farmers irrigate mainly by flooding, wasting a lot of water in the process. Although farmers have a fair idea about which crops require more water, the knowledge is more from practice than from formal training. Water is applied directly from the source of water to the field by hand or motor pumps running for several hours during the day. The use of storage devices is uncommon. The cost of irrigation is therefore high, limiting farmer’s income. Farming is also labor-intensive due to the limited use of machinery such as planters and harvesters. Labor is often required during the planting, weeding, and harvesting of crops. For instance, for planting onions on a 4-meter furrow, one farmer pays the hired labor 2.5 Birr (approximately 0.05 USD). The cost of labor may limit a farmer’s ability to cultivate a bigger portion of land to raise capital to invest in solar technology.

Extension support is generally available to farmers as extension agents visit them frequently. Under specific programs targeting irrigation, extension agents have a target to visit 7–10 farmers in a day, with a weekly target of at least 50 farmers. However, extension support seems more focused on input supply than technology and agronomic support. This may be a result of the inadequate capacity building of extension agents. The farmer, therefore, depends more on previous knowledge, and advice from agro-input suppliers and from other farmers to solve agronomic challenges. Furthermore, access to skilled repair and maintenance services is limited. Motor pumps break down frequently due to poor and expensive maintenance services. While organized irrigators have a better chance to access O&M services from the extension offices, this still curbs the production of farmers and their incomes, and their ability to save towards the purchase of improved technologies.

**Challenges related to value chain dynamics**

Some value chain challenges include poor linkages and limited market power. Farmers are unable to produce in sufficient quantities due to poor value chain linkages. Inputs such as seeds, pesticides, and fertilizers are sometimes in short supply; when available, high prices often limit the quantities farmers can buy.

Farmers have *limited market power* for several reasons. The high cost of motor pumps limits the ability of farmers to produce in significant quantities to migrate to solar technology. Where motor pumps
are available, availability and price of fuel may also limit usage. The agriculture office has made efforts to address this by implementing a coupon system. It enables farmers to present coupons to fuel stations to be prioritized in the purchase of fuel. This has however not been wholly effective, since fuel stations prioritize other users who are often prepared to pay more than the official price for the fuel. Also, the low availability of output storage facilities does not permit farmers to store output to target higher prices. In addition, low access to market information on demand, prices, and brokers as well as low use of collective bargaining for the sale of output hinders the farmers’ ability to determine prices. Prices are usually determined by brokers who act as middlemen. Although it differs from association to association and how they operate, organized irrigators generally have better linkages to input and output markets, storage facilities, and bargaining power.

**Challenges related to best-fit packages**

Challenges were identified that relate to the suitability of SPIPs for farmer needs across all segments. Poor access to SPIPs suited for depths beyond 40 m limits the farmers’ ability to use the pumps in some areas as the farmers may have boreholes up to 70 m. Few SPIP suppliers provide pumps suitable for depths beyond 40 m. Also, farmers have a major preference for battery-operated systems. There is little use of water storage devices for irrigation despite the availability of locally manufactured storage tanks by Roto PLC. Farmers often prefer to use battery-operated pumps instead of storing water for irrigating by gravity which is more affordable. Additionally, there are prevalent misconceptions about the effectiveness of SPIPs. All farmer segments believe that a SPIP may not be suitable for production on their main plots because it does not have a high-water discharge when compared to motorized pumps. This perception is in part related to farmers’ expectations to keep practicing flooding irrigation with large volumes of water.

Another technical challenge is the compatibility of SPIP inlet pipe size versus the width of common shallow well sizes — which was highlighted by farmers and extension agents in Wereta. Shallow wells that are dug with manual tube drilling method are usually 3-inch wide, and the inlet pipe sizes of most solar pump models in the market (including by Rensys PLC) are wider than that — which can’t fit. This is a major problem as some farmers may need to consider only hand-dug wells that are wider in diameter or develop additional wells with wider sizes to use the solar pumps currently available in the market.

**Supply side-related challenges**

Establishing and maintaining active and effective sales and distribution networks at local levels is among the key strategies for promoting the bundles and increasing accessibility to different segments. It was observed during the segmentation that Rensys and other pump suppliers must be more robust in supporting their sales and networks at local levels to reach more farmers. Farmers, governmental actors, and even some non-governmental actors possess very limited information regarding technology options and performances and the availability of services and suppliers in their vicinities. With reference to SPIPs, some resource-rich farmers wish to migrate to solar pumps but lack knowledge of where to find suppliers. Suppliers such as Lorentz for instance, only operate from Ethiopia on a project basis due to security concerns. Other suppliers in Addis Ababa also do not have adequate rural networks to bring the technology closer to farmers.

**Challenges related to financing options**

Regional and local governments finance motor pumps, being engaged in the purchase, distribution, and O&M services to support the technology supply chain and increase technology access. Motored pumps are provided for smallholders in a co-financing mechanism with medium to long-term credit and in some cases for free. This may distort the market and create a biased business environment for solar pump suppliers. The fact that SPIPs have much higher initial costs and the presence of a large-scale subsidy that does not include solar pumps fosters conditions for unfair competition.
6.2 Opportunities

There are several opportunities for the different farmer segments, technology suppliers, and development actors that enable and facilitate investment in solar pumps.

Opportunities for farmers

Efficient on-farm water management practices provide alternative solutions to some of the challenges mentioned by farmers. For instance, storing water in elevated tankers during high radiation intensity times in the day, coupled with efficient water application methods (as opposed to the commonly practiced flood irrigation) can address the limitations of irrigation timing and the low water discharge volume of solar pumps.

SPIPs will remove the costs of fuel such as diesel and petroleum and have a significantly lower maintenance requirement; this may present an opportunity to invest, particularly in the face of an increasing price of fuel (doubled in the last two years), motorized pumps, and spare parts. In addition to price increases, fuel shortage in local markets is posing a significant threat to irrigated production, forcing farmers to spend a considerable amount of time in search of fuel, and to buy fuel at more than 50% of the current price from the black market. Some resource-rich farmers have even resorted to purchasing multiple motor pumps (a mix of diesel and petroleum) to minimize the risk of losing crops in case of the unavailability of either of the fuel types.

Organized irrigators can better access technical and advisory services on irrigated agriculture and technologies including higher capacity SPIPs via loan and credit services as a legal entity. Also, in the development of their groundwater resource, such irrigators receive technical and financial support from the local government.

Another opportunity explored during the study is the possibility of group loans and investments by farmers that own adjacent plots. Resource-rich farmers that require medium to high-capacity solar pumps and that have the capacity to develop deep wells can benefit from this by investing as a group and sharing the use of the pumps and water resources. Resource-limited farmers within a similar context can also benefit from such opportunities using a group loan or subsidy arrangements to facilitate the purchase of pumps and well development.

Opportunities for suppliers and actors

Understanding that natural resources, potentials, and preferences are different among user groups is an opportunity for actors involved in the solar irrigation value chain. Solar technology and service providers can use the knowledge to develop tailored products and services based on the needs and contexts of different user groups. For instance, sales can be augmented from the supply of pumps with different capacities and financial services according to the varying needs of the different groups, rather than following a general business approach based on the assumption that user groups are homogeneous. Governmental and non-governmental actors can also use the information about user segments to inform and guide their planning and efforts in the promotion and supply of SBIBs.

Moreover, events and platforms to facilitate linkages between the demand and supply of solar irrigation technologies and services provide the prospect of actors, suppliers, and users alike exchanging information, exploring business opportunities, and networking with each other.

Finally, there are opportunities arising from the increasing support from NGOs and government policies and strategies for irrigation and climate-smart agricultural development in Ethiopia. Even though efforts may not always be packaged and are mostly at the piloting and demonstration stages for solar irrigation, they are vital in introducing the technologies, creating awareness, and facilitating social learning and experience sharing among farmers and extension agents.
7. Conclusion and recommendation

The action research around Ziway and Wereta confirms that smallholders operate in different contexts, with their needs for SBIBs varying accordingly. Investigating land and water resources, financial capacity and technology preferences has enabled the identification of four farmer segments in the SBIB market, namely resource-rich and resource-limited farmers, project beneficiaries, and organized irrigators. These segments differ from each other in terms of, for example, access to land and water sources, needs and preferences for solar-based irrigation, and financial capital and investment payment plan. Actual mismatches between the diverse context, the needs of the four farmer segments, the SPIPs supplied through development actors, and the lack of packaged approaches were witnessed during the study. Adequate considerations of bio-physical context, value chain dynamics, technology options, and local availability of pre- and after-sales services are necessary for achieving effective scaling of SBIBs. Understandings from user segmentation should guide the development of services and best-fit packages for different groups.

Challenges and opportunities to invest in SBIBs are important findings applicable to all segments and to specific user groups in some cases. Still, the promotion and supply of SPIPS are mostly at the piloting and demonstration stages. Packaged approaches are rare, with a limited understanding of the technology options and farmer requirements which can at times lead to mismatches with serious consequences. Non-governmental and governmental development actors and projects are still the key players in facilitating farmers’ access to solar technologies. The market and the private sector have not taken the lead so far. At local levels, there is a very limited presence of suppliers and information sources, pre- and after-sales services, and a significant awareness gap among development actors, private actors, and users.

There are also existing and emerging opportunities to enable and facilitate scaling of and investing in SBIBs if these are exploited. Catalyzing SBIBs should include components to improve awareness of the technologies alongside on-farm water management practices. Capacity building through experience sharing and training including solar irrigation, O&M of solar pumps and the different technology options is necessary, particularly for Woreda extension agents. Feasible water storage technologies and appropriate application methods should be demonstrated for farmers. This is important to address the prevalent perceptions that SPIPs do not have enough water discharge and can only irrigate during high light-intensity hours.

Supporting the organization of irrigators is an efficient way to use the opportunities and benefits when compared to individual farming, including better access to financial services and storage facilities for produce. It can address challenges such as input and output market access and weak bargaining power. Linking water development services with users is a key requirement for ensuring water access for irrigation and thereby encouraging investment in solar pumps by different groups. Connecting rig drillers with organized irrigators and with resource-rich and resource-limited farmers that are interested in investing in deep wells as a group is also recommended. In addition, the individuals, SMEs and private companies engaged in groundwater development need support via training on the latest technology developments and operation and maintenance of machinery that can operate under a wide range of landscapes and soil types.

There is a need for innovative solutions to address the financing challenges and unsustainable business competition environment for SBIBs arising from the large-scale government subsidy for motored pumps. One such way could be exploring the possibility of the inclusion of SBIBs in government subsidy systems in the future. Climate financing mechanisms may be utilized at the federal level for this purpose, if applicable. For organized irrigators, devising ways to facilitate partnerships with technology suppliers and financing institutions will enhance the uptake of SBIBs.

In most cases, farmer access to SPIPs is still carried out through development actors and projects with a significant gap between suppliers, development actors, and users. The presence of suppliers at local levels is rare except in larger regional cities, with the establishment of local sales and service networks.
still at a nascent stage. There is an urgent need to enhance local actors’ capacities and support their marketing and promotion efforts. Moreover, there is very weak networking at local levels, hindering the knowledge and information flow among development actors, suppliers, and users. Reasonably, some farmers are skeptical about the suitability, reliability, and accessibility of products, quality assurance, and pre- and after-sales services. Connecting suppliers and local actors are instrumental in addressing the information and linkage gap between suppliers and farmers.

For the private sector to lead the solar-based irrigation market, establishing an active sales and service network at Zone and Woreda levels is essential. Linking sales agents or distributors with local irrigation extension agents is also necessary to better connect technology supply and different farmer segments efficiently. This will also contribute to the credibility and trust among farmers and help facilitate the flow of information on solar technologies. Financing mechanisms should be integrated whenever possible, and the possibility of formal arrangements with MFIs should be considered for this. Feasible and tested mechanisms, approaches, and tools are necessary for the private sector if they are also to finance pumps. Suppliers should diversify their solar technology options, keeping in mind pump and tested mechanisms, approaches, and technologies for multiple uses. The unfolding energy price crisis can be a turning point for scaling SBIBs if actors and the private sector can leverage the situation by clearly demonstrating the comparative cost-benefits against motor pumps.

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