The Market Opportunity for Productive Use Leveraging Solar Energy (PULSE) in Sub-Saharan Africa

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IN PARTNERSHIP WITH

ESMAP
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LIGHTING GLOBAL
Catalyzing markets for modern off-grid energy

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EXECUTIVE **SUMMARY**

SECTION ONE

The context and scope of this study

Context and background

- Off-grid solar has grown rapidly over the last decade in Africa, with World Bank / IFC's **Lighting Global** playing a critical role in developing the market
- To date, the space has mainly focused on powering household lighting and appliances – to meet **consumption-related energy needs**
- **Productive use leveraging solar energy (PULSE)** presents a next frontier, providing income-enhancing opportunities for off-grid households
- Lighting Global engaged Dalberg to conduct a market study on the PULSE opportunity in Sub-Saharan Africa, with deep dives on **Kenya, Zimbabwe, Côte d'Ivoire**

Scope of the study

- **Global PULSE trends analysis:** to identify key innovators and competitive dynamics for a range of PULSE products
- **Detailed country/use case analysis:** to assess specific opportunities for PULSE use cases, with a focus on farmer economics
- **Market sizing** to assess demand for PULSE products for three priority use segments across Sub-Saharan Africa up to 2030
- **Ecosystem mapping:** to identify the regulations, policies, and actors that can advance the market
- **Case studies:** on two leading innovators in priority PULSE segments

Based on Lighting Global's traditional field of inquiry, the study has a focus on micro-scale applications up to 1kW, which typically overlaps most with the off-grid household solar space

Insights and Findings (1/10)

Key takeaways

Diverse actors are bringing PULSE products to market…

- **PULSE products are increasingly available in Africa** with general or specialist solar distributors testing sales of PULSE products, with most activity in in solar water pumps
- **There are circa 100 firms innovating on manufacture of PULSE solutions**, increasingly targeting '**micro-PULSE' applications (<1kW)**
- **Large international manufacturers** are following first-mover start-ups and looking to augment their more established product ranges to target smallholder farmers
- **Solar home systems (SHS) firms** see the potential of PULSE to deepen their customer's incomes, but need to **adapt their models for more expensive and technically complex products**

…driven by some key trends supporting a push to PULSE…

- Potential demand is high: (i) average rural electrification rates are below 25%, (ii) **agricultural production and small business remains significantly under-mechanized** and (iii) the costs of alternatives such as diesel can be prohibitively high when considering whole life costs
- Solar alternatives are falling in price, in part due to the emergence of **more efficient DC technologies** and **declining panel & battery prices**
- This is broadening the range of viable off-grid applications and standalone PULSE solutions

…however, maturity is early stage, and scaling faces value chain issues (not just energy access)

- The **maturity of technologies** varies by type, geography and system capacity. Use cases typically have **little/no incumbency from non-solar products, so raising awareness and piloting is critical.** Alongside which farmer training is needed to ensure technologies are applied alongside good agricultural practices
- Providers need to understand farmer-level commercial activities within value chains to tailor product offerings– **the case to invest is stronger today for solar water pumps than other PULSE products**
- Two more persistent challenges exist for processing / cold storage: 1) the **degree of aggregation needed** to make remote small-scale activities viable and 2) the **diurnal load variation and volatility which reduces solar system performance** against diesel

Insights and Findings (2/10)

Key takeaways

Irrigation is most 'ready' to scale, with targeted refrigeration uses next…

- **Solar irrigation** is well established globally, and has **a growing application at smallholder farmer scale in Africa**. Product innovation and declining prices have made micro application for DC pumps more viable, but **product lines have not yet reached commercial scale and significant costs remain in solar panels not pumps**
- **Solar refrigeration** (**cooling / freezing)** is starting to find a market for targeted applications, such as milk chilling and fish freezing, as well as walk-in cold storage for higher value crops. The economics are currently more attractive for larger farmers or organized farmer groups
- There are **more nascent applications for milling, threshing, grating, pressing, drying** – the economics for these activities rarely make sense at a small scale – solar or otherwise
- There are other niche use cases which could find a market, but they are likely to be small today and favor higher-income farmers – such as **egg incubation, milking, electric fencing**

… affordability remain key barrier to PULSE growth, with policy, data, awareness also being key…

- **Affordability and lack of consumer financing is a key constraint** across all PULSE use cases which limits serviceable market size significantly. PAYG and subsidies could further expand the serviceable market
- **Water pumps or cooling units can cost between $600-$2000.** Even with asset financing (rarely available), **monthly repayments for PULSE products can reach $20-75**
- **Whether the business case is feasible for a farmer** will depend on incremental net income from increased productivity and/or costs savings, and also seasonality/volatility of the crop cycle; **flexible financing and payments terms can unlock market here. In future feed in tariffs could also act as a cost offset**
- **Low awareness of PULSE benefits, unfavorable policies (especially tax), and weak quality & standards are also barriers.** Limited alignment with national development agendas presents a missed opportunity (often agriculture actors are not speaking to energy access actors)

…given complexity, PULSE for agriculture requires coordination, market building, and patient capital

- Patient capital, results based financing, and innovation grants have a critical role to play, as they did for the solar lighting sector in past decade; USAID, GIZ, CLASP are supporting in this way
- There is a need for more focused data on **agricultural markets** and **linkages to value chain actors.** This would help PULSE firms to **target/acquire the right customers** and **help to de-risk customers by making market linkages to large buyers** to ensure offtake. Post-sales training can help to ensure products are used well
- **Policy also has a significant role to play**; the tax treatment for solar DC appliances with AC equivalents is often unclear and applied unevenly

Insights and Findings (3/10)

Country nuances

	 Kenya (KEN)	 Zimbabwe (ZIM)	 Côte d'Ivoire (CIV)
Agriculture-Energy Nexus Overview	• Value chains are relatively well commercialized, with **strong aggregation of smallholder farmers, especially in export / cash crops** • **Rural electrification rates are low** at 13%, but growing fast at 6% year-on-year; solar home systems penetration is relateively high • At micro scale, there is **limited productive use of energy** (solar or otherwise), but with notedly higher penetration of water pumps relative to other product groups	• **Land reforms in the 90's / 00's caused significant disruption**, shifting much commercial farming to smallholder ownership • Value chains are still adapting to support smallholders, where there is limited formal aggregation • **Rural electrification is at 16%,** however many of these have weak grid connections only • There is **very limited incumbency for micro productive use of energy** (solar or otherwise)	• **Cash crops** are a key focus of the economy; however, there is increasing focus on **self-sufficiency** in staples such as rice & maize • Côte d'Ivoire has seen a **significant expansion of rural electrification**, now at 38% driven by the National Program for Rural Electrification (PRONER) • There is **very limited incumbency for micro productive use of energy** (solar or otherwise)
Key Bottlenecks to PULSE Uptake	• VAT on all solar appliances was removed in 2014 but the **Treasury have indicated they may re-introduce it to align with other EAC countries** • Access to finance is **relatively more available in Kenya** than other markets; however, it is still limited; the current rate cap has seized up the credit market	• The government has **removed 40% import duty on solar products** which has helped suppliers • But, access to finance is tough, underpinned by **limited capital and persistent FX challenges** • **Awareness, assured offtake and market confidence** will be key aspects of PULSE scale up	• **VAT reduced from 18% to 9% for solar products**, but other opaque fees push product costs up • **There is very low access to finance;** financing mostly available to smallholders in cash crops such as cocoa and cashew • Financing through cooperatives is more available but few value chains have strong aggregation

Insights and Findings (4/10)

Country nuances

	Kenya (KEN)	Zimbabwe (ZIM)	Côte d'Ivoire (CIV)
Irrigation	**Uptake is growing rapidly;** specialist providers / distributors and (now) larger OEMs are starting to enter segment using Kenya as entry point	**Solar pumps are available but uptake is limited;** there are several distributors targeting smallholders, but affordability is a major constraint	Penetration remains very low to date; climate patterns and market structure makes **water pumps difficult to market** other than for horticulture
Cold storage	**Nascent but growing market;** to date suppliers have intentionally targeted **aggregators in high value crops**	Opportunity for horticulture cold storage is limited, **post-harvest losses are largely driven by poor handling practices** and a lack of market access	**Limited to no uptake;** highest potential in higher value **exotic fruit for export**, and more difficult for domestically consumed vegetables
Milling/threshing	**Pilot activity only;** current actors are exploring segments where **distance to existing processors** is prohibitive but **technologies are untested**	**No activity;** there is potential to displace incumbent micro-scale milling, but services are usually **compensated in a % of produce not money**	**No activity;** Government wants more local processing, especially in rice, cocoa, and cashew; for rice there is a quality concern at smaller scales
Milk chilling	**Pilot activity only;** potential for farmers in **both formal and informal channels** but prices need to come down to be viable for smallholders	**Pilot activity only;** there is an opportunity to help boost smallholder incentives to utilize the government's **milk collection centers**	**No activity; local milk production is limited and mostly informal.** Powdered milk imports are a barrier to domestic sector development
Drying	There is **some latent demand** across several value chains, but no incumbent commercial equipment is currently being utilized	Farmers voiced some need for maize drying technologies, **but returns are low** and no incumbent technologies exist	Could reduce losses and time spent in cassava and rice processing but additional margins are limited, and there is **limited incumbency**
Other		**Retailer lighting:** The **unreliability of electricity supply in cities** creates demand for PULSE solar products from retailers mainly for task lighting	**Fish chilling:** Inland fisheries appear to offer better **incentives to preserve fish through cooling** than coastal regions, targeting traders not fishermen

Note: 1) OEM - Original equipment manufacturer

Insights and Findings (5/10)

Summary of use cases - KENYA

	Use case	Direct incumbent	Farm size	Break even versus incumbent	Two-year return on investment (ROI)	Full payback period	Summary of viability
KENYA	**Horticulture irrigation**	Diesel	0.5 ha	Year 1	204%[1]	< 1 Year	• High viability – payback in <1 year depending on commercial value of crop • **Market access is key for high returns**, suppliers can target customers with high potential for offtake of high value crops
	Dairy chilling	N/A	50L	N/A	11%	22 months	• Viability medium and highly dependent on 1) **production volumes and 2) extent of spoilage reduction** • **Payback is 22 months at 15L/day but at <10L/day payback is >30 months** needing aggregation to improve viability
	Maize milling	Diesel		Year 2	15%	21 months[2]	• Payback period assumes 60% utilization given typical market usage; **viability improves if 100% utilization can be achieved** (110MT/year and ~288 households) • **Value proposition is higher in remote areas** where distance to mills is a greater challenge, with the tradeoff that population density is lower in these areas

Key	Viability	Break even versus incumbent	Two-year ROI	Typical payback
	High	< Year 1	>100%	< 1 Year
	Medium	Year 1 - Year 2	<50%	< 2 Years
	Low	> Year 2	<0%	> 2 Years

Note: 1) Based on a farmer growing 25% high value crops (capsicum/tomato) and the remainder lower value (maize).
2) Payback period for milling assumes 60% utilization of 60MT/annum, based on typical aggregation dynamics within the maize value chain and typical rural population density in maize production areas

Insights and Findings (6/10)

Summary of use cases - ZIMBABWE

	Use case	Direct incumbent	Farm size	Break even versus incumbent	Two-year return on investment (ROI)	Full payback period	Summary of viability
ZIMBABWE	**Horticulture irrigation**	Diesel	1 ha	Year 1	140%	< 1 Year	• High viability - **payback in <1 year across multiple crops** • Returns can be **improved through market linkages** with off-takers, and tailored financing options
	Dairy chilling	N/A	50L	N/A	30%	19 months	• Medium viability, **highly dependent on increasing productivity, and sustained access to formal markets** • **Returns are boosted by premium price offered** for higher quality • Payback is 26 months for 5L/ day, shorter payback **requires farmer aggregation**
	Maize threshing	Diesel	0.25MT/h	Year 2	29%	14 months[1]	• Medium viability driven by reduced long-term costs of threshing • Can be increased by improving **mobility of the product and ability of the technology to be multi-purpose**

Key	Viability	Break even versus incumbent	Two-year ROI	Typical payback
	High	< Year 1	>100%	< 1 Year
	Medium	Year 1 - Year 2	<50%	< 2 Years
	Low	> Year 2	<0%	> 2 Years

Note: 1) Payback period for maize threshing assumes maximum utilization (operating at maximum annual capacity) based on the equipment's technical specification and typical utilization in incumbent technologies

Insights and Findings (7/10)

Summary of use cases – CÔTE D'IVOIRE

	Use case	Direct incumbent	Farm size	Break even versus incumbent	Two-year return on investment (ROI)	Full payback period	Summary of viability
CÔTE D'IVOIRE	**Cassava grating**	Diesel	50kg/h	Year 3	-34%	37 months	• **Viability low/medium (even at max utilization of 118MT/ year payback is 19 months**) due to high initial costs and low market rates for grating as a service • **Viability more probable for cooperatives** given high volumes processed
	Rice hulling	Diesel	60kg/h	Year 5	16%	21 months	• **Viability low/medium even at max capacity** of 68MT/year and ~75 farmers in a year • Likely to face uptake challenges due to slow processing (waiting time) and if solar is unable to match current rice quality of diesel/grid processors
	Fish freezing / chilling	Grid	20L	Year 4	101%	12 months	• **High viability (payback in <1 year) driven by high spoilage** and value loss, but incumbent ice usage is cheaper • Highest value proposition for traders further inland where access to ice is lower

Key	Viability	Break even versus incumbent	Two-year ROI	Typical payback
	High	< Year 1	>100%	< 1 Year
	Medium	Year 1 - Year 2	<50%	< 2 Years
	Low	> Year 2	<0%	> 2 Years

Note: 1) - Payback period for maize threshing assumes maximum utilization (operating at maximum annual capacity).

Insights and Findings (8/10)

Kenya use cases

Solar irrigation shows strong viability, but needs financing solutions

- **Uptake of solar pumped irrigation by smallholder farmers is growing but still low** as diesel pumps have prohibitively high upfront and operating costs
- Kenya is however ahead of the curve in terms of innovation and has seen the **most activity targeting smallholders** at <1ha, increasingly solar-powered
- **Commercial viability is strongest for horticulture crops** but still need financing coupled with strong customer service and agronomy support. Farmers typically grow a basket of crops to optimize returns year round

Milk chilling could be a significant opportunity if the market priced in quality (which it does not)

- Up to 250,000 smallholder dairy farmers could benefit from solar milk chillers, with **co-operatives providing a platform to help scale**
- Farmers who sell chilled rather than un-chilled milk, could **boost revenues by +60%, by reducing spoilage and getting full value from evening milk**
- Whole life costs for solar-powered solutions are much lower than diesel ones, despite higher upfront costs, but lower prices are needed to be viable for smallholder farmers

Cold chain, milling, threshing, drying, are all some way off and use cases are unproven

- Small scale agro-processing activity is limited to very few value chains and is most widespread in maize; solar **technologies at this scale are only at an early stage**, with the main supplier entering the market in 2018
- **There are no major incumbent technologies for cold storage targeting SHF directly**, but off-taker/processor solutions at >30 square meters are more established
- So while there is interest, suppliers targeting small holder farmers will need to **work on awareness and proof-of-concepts to scale**

Insights and Findings (9/10)

Zimbabwe use cases

Irrigation needs changed significantly alongside land reforms, adaptation is ongoing

- Zimbabwe's land reforms in the 1990s / early 2000s significantly increased the number of smallholder farmers, **leaving existing irrigation systems somewhat redundant**
- Addressing this is a key requirement to bring production levels up to those pre-land reform levels, **irrigation is currently very limited** for smaller farms
- **System size and customer targeting is complicated by the range of farm sizes and extent of utilization.** Smallholder farmers typically own 5 ha, significantly larger than other African countries but **farm as little as 30% in practice**

Cooling is much needed across value chains to reduce loss but stable offtake will remain a challenge

- Uptake of **cold storage and productive use refrigeration is restricted to large scale applications**, despite opportunities to reduce produce losses at a small-scale
- Taking dairy as an example, solar chillers would help improve market access for smallholders, especially by **better utilizing dormant Milk Collection Centers**
- Price drops and innovation would strengthen viability, but Zimbabwe's smallholders will need support to **improve aggregation systems and offtake arrangements**

Small-scale mechanized processing is uncommon – new solar products will need to be flexible and mobile

- Most cereals consumed go through the process of husking, threshing and milling, **>50% of processing is carried out by hand**, with time and quality implications
- Incumbent small-scale diesel equipment offers **flexibility in terms of operational use and mobility to reach remote customers**, providing processing as a service
- Commercial viability depends on **farmer willingness to pay**, incentives to switch from manual approaches, and the **viable catchment area of static solar solutions**

Insights and Findings (10/10)

Côte d'Ivoire use cases

More abundant rainfall reduces the demand for pumped irrigation – opportunities exist in horticulture

- The country has over **1,300mm of annual rainfall**, significantly higher than both Kenya and Zimbabwe, this **reduces the pressure for irrigation** across crop types
- There is potential to expand the irrigated area, **currently only 15% of the country's 475,000 ha potential land is under irrigation**
- **Horticulture and fruits** are viewed by suppliers as the **highest potential in terms of product viability** and smallholder farmer returns

There are several strong use cases for agro-processing equipment – but uptake is limited due to affordability

- There is significant agro-processing activity across staple and cash crops, with the government seeking to increase local processing in export crops to retain value locally
- High agro-processing activity is concentrated within a few value chains, including: **cassava, rice, cocoa, cashew, rubber and palm seeds**
- Off-grid small-scale innovations offer potential to further **decentralize processing activities to increase incomes of small-scale actors**, however **upfront product costs limit commercial viability** against well-established diesel-incumbents

Cooling could reduce losses across value chains with fisheries showing potential but technology challenges

- **Cooling equipment could help reduce losses in fishery and horticulture** where major post-harvest losses are registered, **fish: 30-50% and fruit: 20-40%**
- In fisheries, both inland and coastal **fish traders have strong incentives to invest** in improved cooling to increase the volume of fish sales by eliminating spoilage and capturing more value from fish throughout the day
- A key challenge is finding solar products that are appropriately-sized, affordable, and mobile – **there are currently no PULSE products specifically targeted to fish traders**

There are 8 areas in which governments, development partners, and private sector can partner to help build the market for PULSE products

1 **Demand generation/aggregation**

Support to selected value chain aggregators through TA and finance to extend PULSE products to farmer groups

2 **Technology & innovation**

Technical assistance and investment to support technology upgrading and skills transfer

3 **Access to finance**

Patient capital, seed capital, working capital and grants to support set-up, growth and scaling

4 **Business development support**

Work alongside PULSE innovators to provide business management, market entry and growth strategy advice

5 **Quality assurance**

Develop minimum product standards, especially for emerging DC appliances and service levels for post-sales support

6 **Market intelligence**

Develop detailed use cases across a range of products, provide annual PULSE surveys and market analysis

7 **Consumer education**

Work with existing value chain actors and donors to expand the awareness of solar product, focused on emergent products

8 **Policy development**

Policy papers, research and lobbying to enhance regulatory environment at interface between off-grid and agriculture

INTRODUCTION: **WHY IS PULSE CRITICAL FOR AGRICULTURE?**

SECTION TWO

Off-grid solar (OGS) has grown rapidly over the last decade worldwide and still has potential to grow further

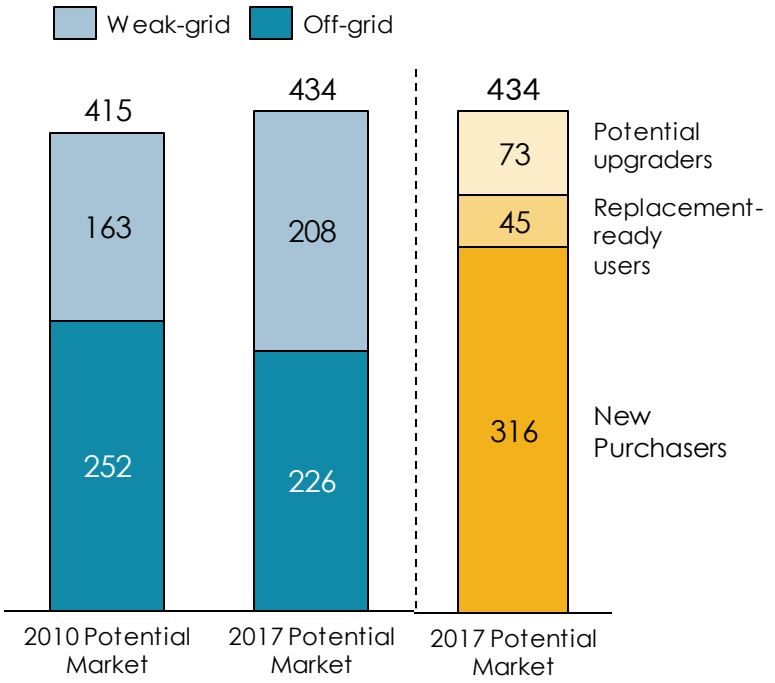
Overview of global off-grid solar market

Since 2010, the growth of OGS sector globally has been significant, noting:

- By 2017, total sales value exceeded **$3.9 billion**
- **Three product categories** have emerged: (i) pico, (ii) plug-and-play SHS, and (iii) component-based systems
- Household use of OGS is now moving **beyond lighting** to communication, entertainment (e.g. TVs), and refrigeration appliances
- Significant **market entry and private sector** engagement from global firms
- Increasing interest and commitments from investors; **$500 million raised in last 2 years alone,** with increasingly commercial return expectations
- Growing acknowledgement and commitment of resources by governments and **development partners**

Snapshot of potential market growth

- The potential market in 2017 is estimated to be **434 million households** globally
- By 2022, the market is expected to grow to 740 million households and a value of **$8 billion**

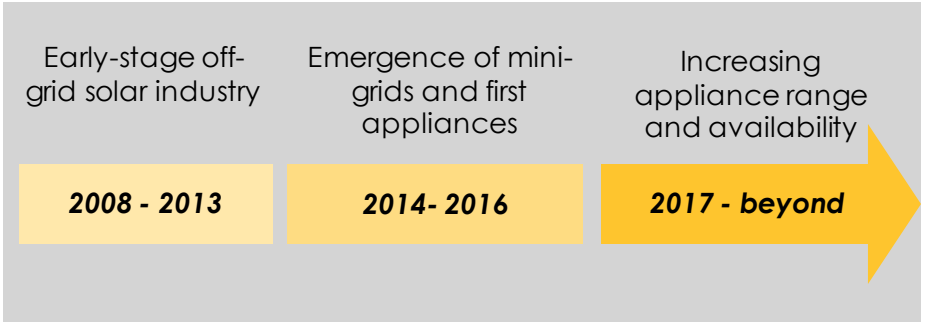


Sources: World Bank Group. 2018. Lighting Global's *Off-Grid Solar Market Trends Report*

For OGS, productive use represents the next frontier, providing enhanced income-generating opportunities for off-grid households

From consumptive to productive use…

- To date, the off grid solar (OGS) sector has mostly focused on powering household lighting and appliances in order to meet **consumptive energy needs**
- OGS has significant potential for **productive use applications** by individuals or micro-enterprises which are off grid or have "bad-grid" connection



Defining productive use leveraging solar energy (PULSE)…

- PULSE is defined in this study as:

  "any agricultural, commercial, or industrial activity that uses solar energy as a direct input to the production of goods or provision of services"

- PULSE promotes socio-economic development by **enabling and/or increasing income generation**

Sources: World Bank Group. 2018 Lighting Global's *Off-Grid Solar Market Trends Report;* Dalberg analysis. 2018.

The demand for PULSE products arises across a range of scales, with either standalone or mini-grid connected applications

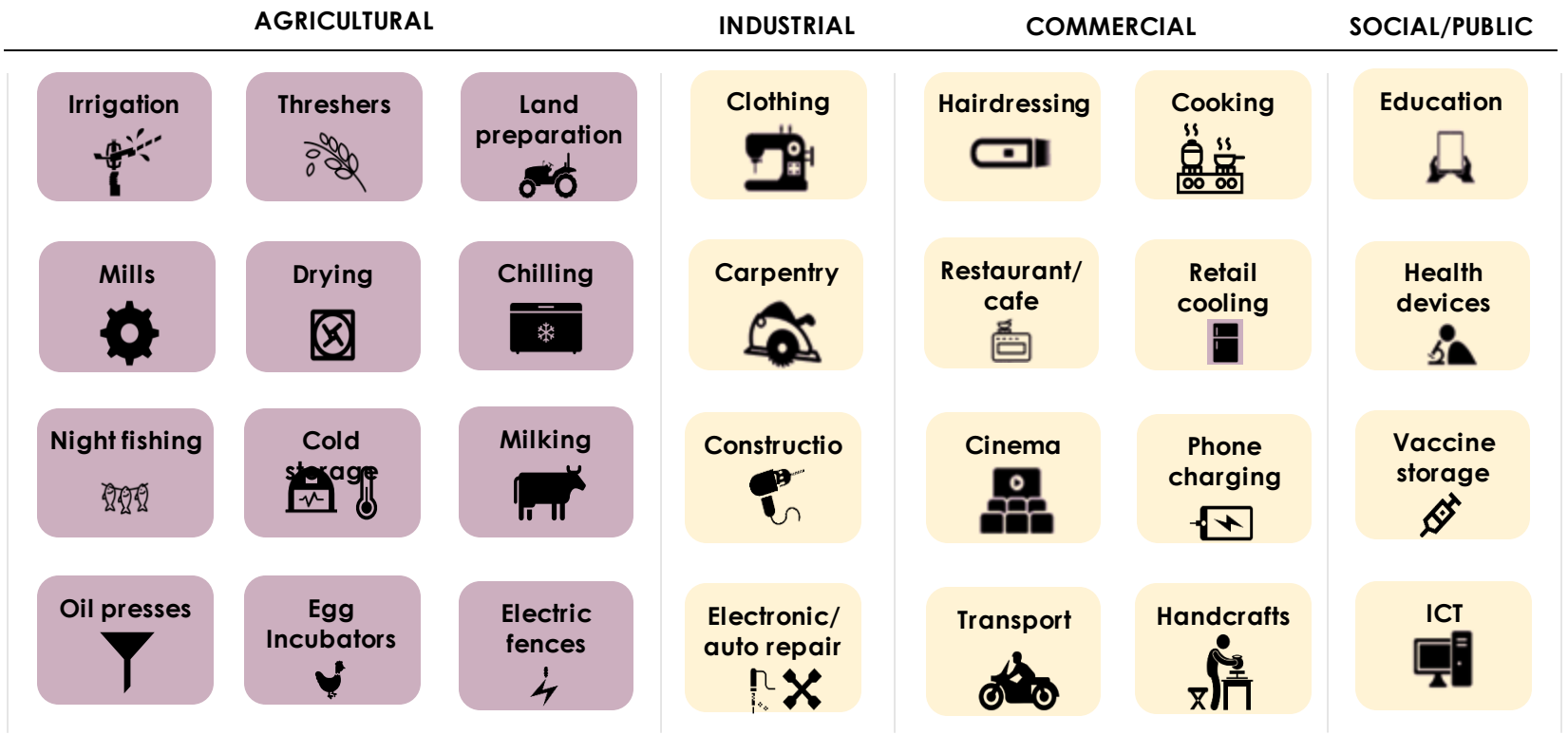
Scale	Stand-alone or SHS-connected	Shared or mini-grid connected*
Current	DC	AC or DC
System	Micro	Mini
Size (W)	1-1,000W	1,000-5,000W
Components	Generation, storage, cell charger, appliance	Appliance and mini-grid connection
User	Individual user or micro-enterprise targeting shared use	Individual users, micro and small enterprises
Application	Separate from existing systems and potentially needing to be i) mobile ii) remote from the homestead/village In some cases use could be combined with existing SHS systems to utilize existing generation capacity	Most similar to conventional grid connected productive use appliances, making PULSE most relevant in DC product applications
Example	Solar-powered irrigation systems or smallholder small-scale milk chilling	Small enterprise maize or rice milling at a village level

This study will focus on standalone product applications under 1kW, referred to for these purposes as "micro-PULSE". This aligns with Lighting Global's past focus areas in the off-grid household solar

Source: Dalberg analysis. 2018.
Note: Utilizes IRENA terminology for Pico-grid (<1,000W), Nano-grid (<5,000W) and Micro & Mini-grids >5,000W). Mini-grids can cover large individual farms, factories and mines in remote rural areas, with networked systems

Productive use leveraging solar energy (PULSE) cuts across diverse agricultural, commercial, industrial, and social/public activities

Non-Exhaustive list of activities



Source: Dalberg analysis. 2018.
Note: Utilizes IRENA terminology for Pico-grid (<1,000W), Nano-grid (<5,000W) and Micro & Mini-grids >5,000W).

The market for non-agriculture PULSE products is highly fragmented, with organizations exploring appliances across sectors for diverse uses

	Suppliers	Typical applications
INDUSTRIAL	BLACK+DECKER, BOSCH	• **Task lighting –** Task lighting to extend opening hours is the most predominant use • **Construction –** Solar-powered applications in rural areas are limited by standard construction practices • **Carpentry –** Wood saw applications are limited to larger scale mills running from mini-grids
COMMERCIAL	PHILIPS, BBOXX, mobisol, SELCO, M-KOPA SOLAR	• **Retail refrigeration** – often supplied for on-grid applications by drinks producers, who could move off-grid • **Hairdressing**- a range of solar charged hair clippers on the market – with limited scope to boost barber incomes • **Textiles –** solar-powered sewing machines exist but are yet to displace standard foot-powered machines
SOCIAL/PUBLIC	WE CARE SOLAR, TE TRUE ENERGY	• **Medical** – Application in medicine are increasing, for example portable units to power medical devices remotely or refrigeration for vaccine distribution • **Telecom** – SHS providers are seeing solar modems as a productive asset for customer to boost incomes • **Schools** – Lights and other adapted household products

The fragmented nature of PULSE applications means there is no single sector of focus, and therefore it is a difficult "space" to concentrate in

Productive use is a critical requirement for agricultural transformation

Why PULSE in agriculture?

1. Agriculture is the **single most dominant sector in rural economies**, where majority of off-grid populations are living

2. **Agricultural transformation** is high on government and donor agendas with a focus on value addition, agro-processing, mechanization, reducing post-harvest losses, not just increasing production as in the past – this will require energy access

3. In the last three to five years, **innovation in solar-adapted agricultural equipment** has increased but further domain knowledge is required to move the sector forward

4. PULSE in agriculture is **an important growth segment for SHS/PAYG providers** to expand market and deepen customer relationships – 50-60% of their customers are smallholder farmers already and they need them to grow their revenues

5. Agriculture has a **unique set of impact mechanisms:** creating multiplier effects on incomes, consumer spending, and growth in the real economy – see next slide

For off-grid communities, which are overwhelmingly rural, PULSE at the agricultural-energy nexus has unique potential for impact

Improve food security: 26% of the SSA population above 15 years suffers from food insecurity. PULSE solutions can help meet the growing demand for food through increasing production and productivity in key value chains

Increase farm productivity: Most land in SSA is tilled, ploughed and weeded by human power (65%) and animal power (25%). The use of machines could increase yields substantially by increasing efficiency up to 5x or higher

Create employment opportunities: Agriculture sustains the livelihood of more than 50% of the African population. Additional opportunities can be created by facilitating access to energy, a key limiting resource for productivity

Enhance resilience to shocks: PULSE products can reduce vulnerability to multiple shocks, by cushioning farmers from the impact of climate change, fuel price variations, and fluctuations in market prices of agricultural produce

Stimulate growth in real economy: By increasing agricultural productivity, PULSE products stimulate socio-economic development. UNEP estimates that, for every 10% increase in farm yield, there has been an estimated 7% reduction in poverty in Africa and more than 5% in Asia

Sources: FAO 2017; UN 2015; UNEP 2012.

If PULSE products for agriculture can be made widely available and affordable, they can significantly increase yields and farmer incomes

> 30% of crops are **lost to weed infestation and poor land preparation**

6% of Africa's cultivated land is under irrigation, **leaving ~13 million irrigable hectares**

30-40% of produce is estimated to be **wasted or lost post-harvest in Sub-Saharan Africa**, representing US$ 1.2B – US$ 1.6B annually

16% is the agriculture sector's[1] contribution to sub-Saharan Africa's GDP, **despite the sector employing 50%+ of its population**

Expand 1.5 to 8 ha. **Shifting from manual to mechanized[2] land preparation** could increase coverage and yields substantially – from 1.5 to 8 hectares

Grow yields 1x to 5x **Drip irrigation can increase farmer yields** by 1x to 5x depending on crop and soil conditions

Cut losses by 50% Refrigeration in storage & transportation **has potential to reduce total crop losses** which currently go up to 50%

Sources: FAO/UNIDO. 2008. "Agricultural Mechanization in Africa"; Lianghzi, Ringler. 2010. International Food Policy Research Institute. "What is the irrigation potential for Africa?"; Best S.. 2014. "Growing Power: Exploring energy needs in smallholder agriculture"; World Bank Dev elopment Indicators. 2018.
Note: 1) Includes agriculture, forestry, fishing. 2) Shift to using tractor power

STATE OF PLAY **IN PULSE TODAY**

SECTION THREE

Our study focuses on diverse PULSE use cases at the agriculture-energy nexus

	Production	(Near-farm) processing	Storage and transport
Cross-value chain use cases	Sprayers (pesticide/fertilizer)	Mills	Freezers/Refrigerators
	Irrigation pumps	Driers	Ice makers
	Tractors		Cold rooms/coolers
	Electric fences		Siloes
	Greenhouses		
	Animal feed mixer		
Value chain-specific use cases	Egg incubators	Butter makers	Milk Chillers
	Cow milkers	Maize threshers	Fish freezers
	Night fishing lights	Cassava graters	
	Fishing boats	Coffee pulpers	
		Oil presses	

Sources: GIZ. 2016. "Photovoltaics for productive use Applications"; World Bank. 2017. "The double dividend"; The Fish Site. 2014. "Photovoltaic Applications in Aquaculture: A Primer"; Engineering for Change. 2017. "A solar thermal aerator prototype could improve aquaculture in developing countries"; Vikaspedia. 2017. "Solar drying systems".
Note: Cross value chain refers to products designed to work across several agricultural crops/livestock groups.

Within each product group, there is a diverse range of technologies which have different system size requirements

Irrigation Pumps

Surface water pumps
- Wattage: 75w – 1.5kW
- Suction head: <7m

Submersible pumps
- Wattage: 0.45-22kW+
- Head: 4-310m

Other - Livestock

Poultry incubators
- Wattage: 75w – 100W
- Capacity: 48-1000 eggs

Milk machines
- Wattage: 1,1kW
- Head: 20 cows/day

Cooling/Drying

Cooling systems
- Wattage: 40-200W
- Capacity: Up to 45l of milk/day

Refrigeration
- Wattage: 40-400W
- Capacity: 50-400l

Freezing/ice making
- Wattage: 95W
- Capacity: 1.2kg/day

Walk-in cooling units
- Wattage: 2kW+
- Capacity: 9 tonnes+

Fan cooling/drying
- Wattage: <50W
- Capacity: 25-100kg

Agro-processing

Flour Milling
- Wattage: 500-750W
- Capacity: 25 -160kg/h

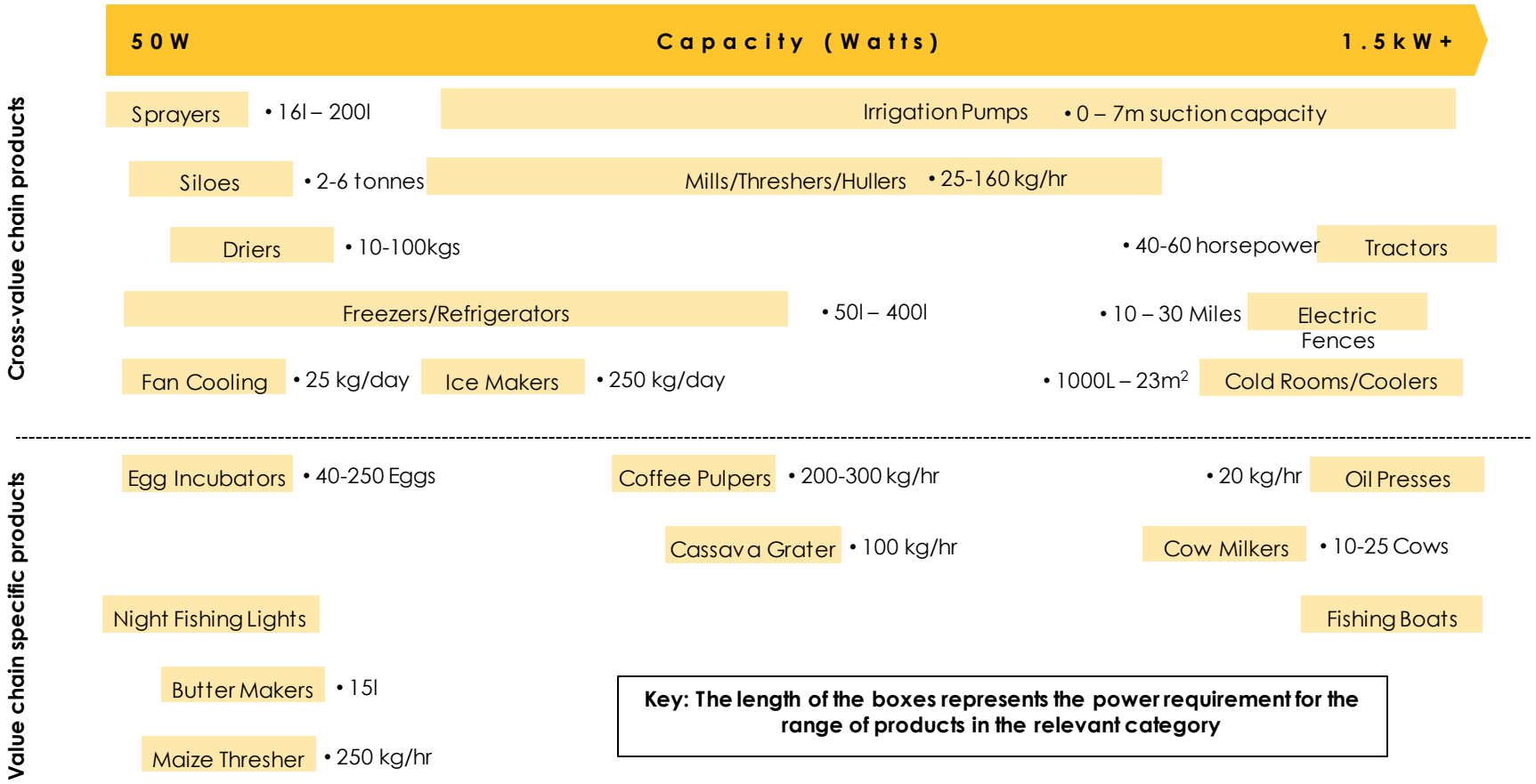
Husking/Threshing/Hulling
- Wattage: 100-375W
- Rice Capacity: 35 -70kg/h
- Maize Capacity: 250kg/h

Grating
- Wattage: 250W
- Capacity: 100kg/hr

Oil & nut presses
- Wattage: 1.5kW
- Capacity: 20kg/h

Sources: GIZ. 2016. "Photovoltaics for Productive Use Applications"; Dalberg analysis and interviews. 2018.

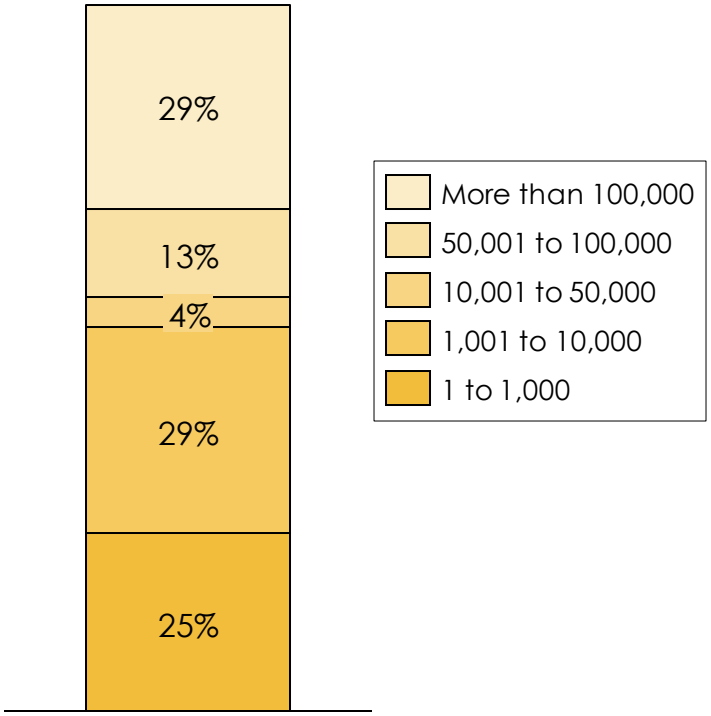
Some PULSE products relate to multiple agricultural value chains, while others are specific to a single crop or animal



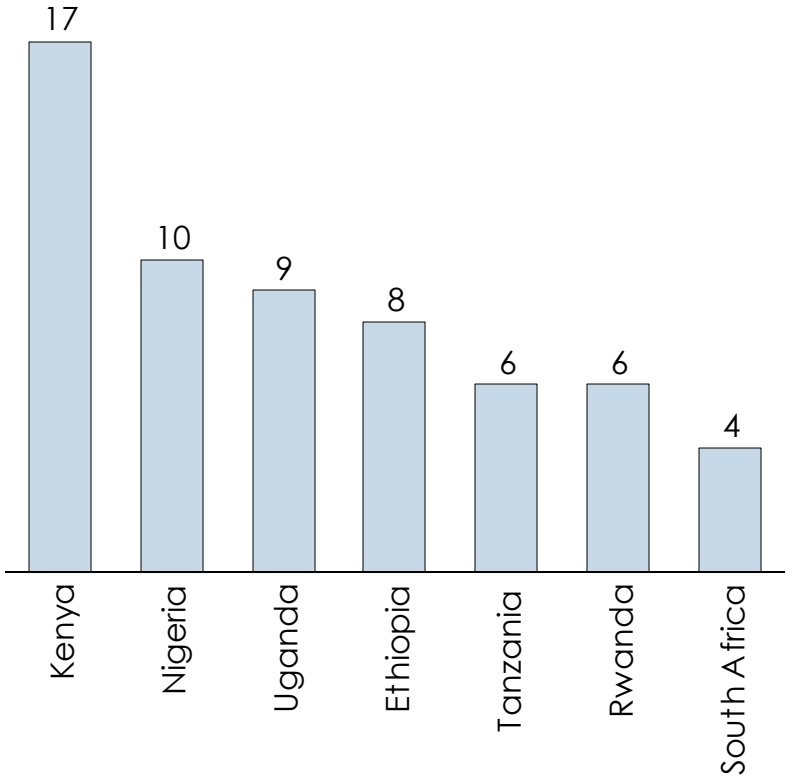
Sources: GIZ. 2016. "Photovoltaics for productive use Applications"; World Bank. 2017. "The double dividend"; The Fish Site. 2014. "Photovoltaic Applications in Aquaculture: A Primer"; Engineering for Change. 2017. "Asolar thermal aerator prototype could improve aquaculture in developing countries"; Vikaspedia. 2017. "Solar drying systems".

We conducted a short survey of suppliers of productive use appliances. Most firms have sold less than 10,000 PULSE units to date

Company size by units sold
(%), respondents = 49



African countries in each firms' top 5 by sales
Number of firms, respondents = 49

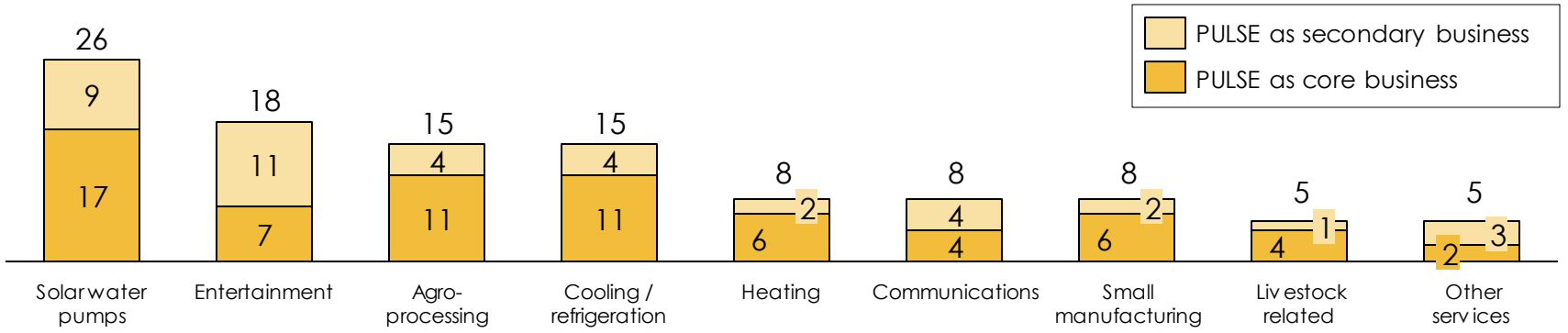


Source: IFC/Dalberg PULSE Survey 2018; Dalberg analysis

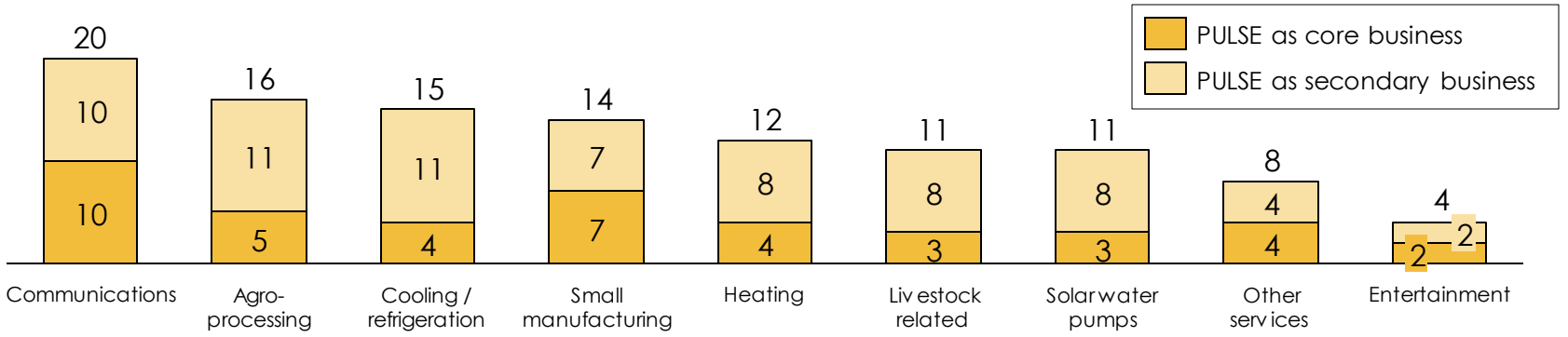
Note: Participants = 150, respondents = 49, Response rate 33%; 43% international manufacturers, 10% specialist solar distributors, 29% early stage PULSE firms, 18% solar home system firms. 40% CEO/founders, 47% executive team, 14% middle management

As of today, PULSE suppliers are most focused on irrigation; in the future, PULSE suppliers are looking at processing and cooling

Current PULSE products in portfolio
Number of firms, respondents = 49



Planned PULSE products in portfolio
Number of firms, respondents = 49



Source: IFC/Dalberg PULSE Survey 2018; Dalberg analysis

Despite growing activity and interest, only a few PULSE technologies are ready for commercial scale in Africa and market maturity is limited

	Irrigation Pumps	Cooling	Agro-processing
Large	**> 5 Ha**	**>10,000 L**	**> 10 MT/day**
	While technologies exists there are limited large scale applications in practice	*Typically applied as walk-in cooling, technologies are available at an aggregated scale, but uptake remains low*	*The main examples that exist are mini-grid applications as like-for-like replacement of grid-based processing*
Medium	**2 – 5 Ha**	**2000 – 10000 L**	**2 – 10 MT/day**
	The majority of supplier distributors are targeting this scale and uptake is reasonable depending on the geography	*Fewer technologies in this category as providers are either looking at large aggregated systems or smaller individual systems*	*The main examples that exist are mini-grid applications as like-for-like replacement of grid-based processing*
Small	**< 2Ha**	**100 – 2000 L**	**1 – 2 MT/day**
	Technologies are well developed and available but affordability and market development are barriers	*Productive uses typical adapt refrigeration intended for small retail enterprise use, uptake is low*	*Incumbent technologies exist but the system size is prohibitive for standalone applications*
Very Small	**< 1 Ha**	**<100 L**	**< 1 MT/day**
	Recent product development has increased affordability, precedents are emerging in some markets and are starting to scale	*Productive uses typical adapt refrigeration intended for household use and uptake is low*	*There are limited standalone technology choices and use cases are unproven*

Commercial readiness: High Mid Low

Note: 1) MT – Metric Ton

PULSE products face financial and operational barriers to converting customers and switching away from incumbent technologies

1 Financial barriers

Affordability is the initial hurdle that PULSE products face when compared with incumbents

- **Upfront costs** – Across segments PULSE products are (at least today) several times (1.5-4x) more expensive than diesel/grid-powered incumbents. Smallholder farmers have low disposable incomes, making them more likely to favour less capital intensive options in the short term
- **Access to finance** – This is compounded by the limited access to flexible and affordable credit to finance PULSE products

2 Operational barriers

Additional operational challenges could further disincentivise switching to PULSE products

- **Capacity/speed limitations** – Lower peak processing capacities may discourage investment as it increases operational times and limits revenue potential
- **Product availability** – For some product types, commercial players are only beginning to enter the SSA market. As a result, **availability of spare parts and maintenance services is limited**
- **Mobility** – Batteries and solar panels can make products less mobile compared to diesel products. Often applications in agricultural value chains require a product to move to customers or market
- **Product confidence** – Customers may lack knowledge of solar appliances. Diesel products are well known, and solar might be associated with consumptive uses only

Source: Dalberg analysis and interviews. 2018.

PULSE products are being brought to market by a diverse range of actors (1/2)

Use Case	Distribution presence	Firms	State of play
Solar water pumps 	Kenya, Zimbabwe, Côte d'Ivoire, Nigeria, Ghana, Sierra Leonne, Tanzania, Malawi, Botswana, and majority African markets	GRUNDFOS, SunCulture, Solartech, Jain Solar, Kirloskar, DAYLIFF, Yangchun, Future pump, LORENTZ	• Products are well established in the SSA market • Typical products target smallholder farmers directly • Suppliers frequently tie products with additional services e.g. business development support, and partner with actors in the value chain • There are a number of urban/ peri-urban independent distributors • Operational capacities of solar match incumbents
Milling/ processing 	Kenya	Solar Milling, AGSOL	• All companies in the market are new entrants, with only one with set up operations • Products have not been fully developed for the SSA market • The current capacities of solar products vis a vis incumbent are too low and not competitive • Current products in the market are not mobile • Targeted at micro-processors and not smallholder farmers directly
Poultry incubators 	Kenya, Zimbabwe, South Africa, and several others	LIFEWAY SOLAR sun driven, NANS	• Most incubators in SSA are grid or diesel-powered • A few suppliers are in the SSA market; distributors supply on order • There are solutions designed for smallholder farmers , i.e. at least ~100 eggs

Sources: Dalberg analysis and interviews. 2018; Company websites

PULSE products are being brought to market by a diverse range of actors (2/2)

Use Case	Distribution presence	Firms	State of play
Milk chilling 	Various African markets	promethean power systems SunDanzer Simply Solar	• There are a few established players targeting Smallholders • Suppliers mainly distribute products through aggregation, e.g. dairy cooperatives; a few new entrants directly target Smallholder farmers • Most models in the market are designed for higher production volumes i.e., >50 L • Most models in the market are not mobile
Cold storage 	Kenya, Rwanda, Nigeria, South Africa	wakati Cold Hubs **Services:** business development (aggregation points), financing, leasing space, joint ownership models	• There are a few new entrants in the market • Suppliers tend to operate in tight and structured value chains, e.g. horticulture for export • Products are designed to serve mid- to large- scale farmers • Target aggregators who serve smallholder farmers • Suppliers tend to be heavily involved in providing support to existing customers, e.g. demand aggregation
Drying 	Various African markets	SURIA INFINITI KASCADE SNAP-FAN **Services:** Lease space out to traders in urban markets	• Very few solutions developed or launched in the SSA market • Products in development are targeting small scale operators in the value chain e.g. ~200kg/ day

Sources: Dalberg analysis and interviews. 2018; Company websites

There are a diverse range of actors bringing these products and services to market, with varying levels of maturity

PULSE innovators

There are a bunch of innovating **start-ups looking to scale.** Either at piloting stages or with proven technologies in single markets

PULSE for Ag multinationals

Established international firms are looking to **augment existing product ranges** with PULSE products targeting the smaller use segments

SHS/PAYGO leaders

SHS providers are getting into PULSE looking to **adapt their existing business models** to PULSE while strengthening farmer-consumer incomes

Portfolio distributors

Looking to distribute PULSE to expand ranges, **but quality/warranty is a concern.** The main channel for Chinese manufacturers entering the segment

Mini-grid operators

Mini-grid firms are actively **promoting productive use appliances to be anchor users.** Their interest in DC provides some synergies with PULSE

Sources: Dalberg analysis and interviews. 2018; Company websites
Note: Portfolio distributors provide a range of products (product neutral)

Their unique characteristics means they are positioning in different ways to provide PULSE solutions

	Unique characteristics and PULSE positioning	Prime archetype example
PULSE innovators	• Some still **require R&D and piloting support**, while others are ready to scale • Typically vertically integrated; often subsidized with grant funding	***AgSol*** *is trying to build market for solar-powered milling equipment, pilot testing product and building awareness*
International manufacturers	• Could start moving to smaller scale PULSE applications, but **price point and quality are concerns** • Have the **potential to scale quickly** after market entry, if they can find the right distribution partners	***Lorentz*** *is planning to launch a smaller scale solar water product and looking to partner with SHS players in East Africa*
SHS/PAYGO leaders	• Can **leverage their customer profiles and credit histories** to target PULSE buyers • Will need **to adapt to longer term financing** and more complicated technologies	***FENIX International*** *has the intention to add PULSE products, currently deciding whether to manufacture or buy to meet demand from customers*
Portfolio distributors	• Have the best view of take-up vs non-solar alternatives – up to 25% of sales in East Africa • Have traditionally **focused on mid-size farms** based on limited affordability of Smallholder farmers	***Davis & Shirtliff*** *is an existing partner of PULSE focused firms with significant distribution networks ready to leverage*
Mini-grid operators	• PULSE is incorporated at a larger scale, often as **anchor clients for mini-grids** given consistency/level of demand • Ownership and operations can be tailored **to boost mini-grid operator incomes**	***Devergy's*** *village scale mini-grids already incorporate some water supply and milling technologies into systems as anchor clients, and are looking to bring prices down*

And based on their business models/core activities actors will face different challenges when adapting to targeting small-scale PULSE

Business model	Activities		Implications for PULSE
	Pre-sale	**Post-sale**	
END-TO-END INTEGRATION	Manufacture Assembly Distribution Customer acquisition Pre-sale support Sales/retail	Financing Installation Customer service Maintenance/repair Control/monitoring	• Helping to build market and customer awareness • **Allow for better quality control, customer targeting and support**. The implications of poor product use/malfunction are high • But can create burdensome overhead costs that can reduce profitability
	Pre-sale	**Post-sale**	
HARDWARE MANUFACTURER	Manufacture Assembly Distribution Customer acquisition Pre-sale support Sales/retail	Financing Installation Customer service Maintenance/repair Control/monitoring	• **Will have difficulty leveraging existing distribution without active agriculture sector partners** • Established players are looking to partner to overcome customer awareness challenges • Product design can be improved by working closely with existing agriculture value chain actors
	Pre-sale	**Post-sale**	
DISTRIBUTION SPECIALIST	Manufacture Assembly Distribution Customer acquisition Pre-sale support Sales/retail	Financing Installation Customer service Maintenance/repair Control/monitoring	• SHS providers are looking to join traditional distributors in this PULSE sub-sector • The need for more hands-on customer service and higher financing costs mean **business models may need to adapt** • May require addition collaboration with agriculture players to ensure effective customer engagement

Service provision: Full Partial

SunCulture is a pioneer in solar irrigation in Africa, with a vertically-integrated model including R&D, finance, distribution, and after-sales

SunCulture

***SunCulture** is an innovative company that designs, manufactures, finances, and distributes **solar water pumps and micro-irrigation systems**. They are growing rapidly from their HQ in East Africa and are expanding to serve smallholder farmers across the region.*

Company Profile

Year founded: 2013

HQ location: Nairobi, Kenya

Markets Served:

- Has own distribution network in Kenya
- Distribution partnerships in Uganda and Zambia
- Aggressive plans for growth across Africa

Employees: 76 full time employees + 54 field sales agents

Value Proposition

Leveraging **renewable energy** to **enhance agricultural productivity** for smallholder farmers:

- Affordable solar-powered water pumps and micro irrigation systems
- First company in Africa to commercialize solar irrigation
- Farmers can achieve up to 200% increase in yields with 80% less water
- Productivity gains increase household income, as well as time savings
- Solar technology reduces CO2 emissions and limits usage of scarce water resources

Products and Services

Provides end-to-end solutions to smallholder farmers including soil and water analysis, installation, and after-sales support. Recently introduced Africa's first ***Pay-as-you-Grow*** model, to reduce upfront costs and enable smallholder to purchase on credit.

Their Rainmaker2 with ClimateSmart product is an all-in-one battery, charge controller, and IoT enabled control system for productive use off-grid solar home systems tailored to needs of SHF:

- 24V DC output to power high-efficiency water pumps + 4 12V outputs + 2 5V DC USB outputs
- 260W panel or 160W foldable panel
- 25.9V battery and controller

Source: Dalberg analysis and interviews. 2018.

SunCulture's initial years were focused on R&D and product testing; the launch of its ***RainMaker*** product and ***Pay-as-you-Grow*** financing has now unlocked a larger market

Company journey

2013
- Began operations and launched first prototype in Kenya
- Grant/donor funding

2014
- Research and development
- Prototyping
- In-field testing
- Marketing and distribution testing
- RainMaker 1 launch in 2017

2015

2016

2017
- RainMaker2 product testing and launch (Jan 2019)
- Advanced its commercialization strategy (including PAYG financing options) & AgOptimized data
- Operations scaling across Africa

2018

...

Experience bringing *RainMaker* to market

The *RainMaker* system is designed for off-grid rural households as a near-zero recurring cost replacement for diesel, electric, and manual water pumps used for irrigation, livestock and household water supply. In bringing the product to market, SunCulture has invested significantly in distribution – both building its own network in Kenya and identifying key distribution partners across other markets

Market context

- *RainMaker2* designed as a result of 2 years of intensive customer testing with smallholders
- Clear market need for a more affordable product fitting both agricultural and domestic needs
- Eliminates costly recurring diesel fuel costs for incumbent technology
- PAYG model brings down upfront costs making product affordable to many

Product specifications

- Submersible pump with 70 meter (230) feet) maximum pumping head
- 50% peak wire-to-water efficiency
- Suitable for direct pumping to sprinkler or drip irrigation systems
- Up to 3,000 liters per hour with recommended SunCulture CimateSmartTM Solar Energy System
- 24V Brushless DC motor with 10-year lifetime

Source: Dalberg analysis and interviews. 2018.

SunCulture sees solar-powered irrigation as the first step for its customers on the *"productivity ladder"*

The market opportunity for *RainMaker2*...

Target customers

- In Africa, there are approximately 70 million smallholder farms and 600 million people living in rural households
- *SunCulture's* target farmers are small-scale (e.g. up to 5 hectares), off-grid, and near an available water source
- *RainMaker2* has a 70 meter maximum pumping head, so can extract water at very low depths
- Irrigation is attractive for all crops, but farmers stand to benefit most where crops are high value and water intensive

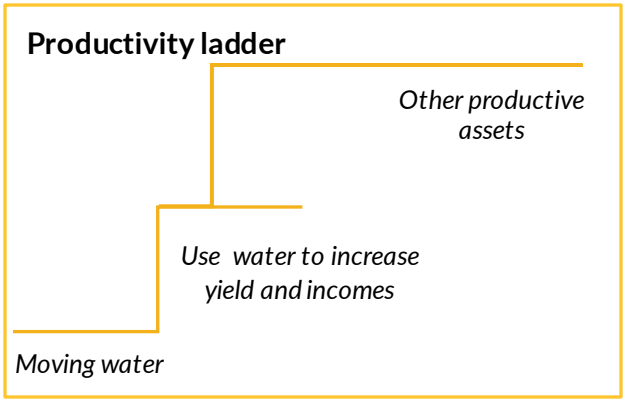
Customer needs

- Irrigation is one of the first key steps in a smallholder's productivity toolkit alongside quality seeds and fertilizers
- While productive asset used for farming, some customers use the *RainMaker2* for domestic use as well (e.g. washing)
- Customers require (i) simple plug-and-play product with limited scope for malfunction / misuse (ii) adaptable, modular product for different terrains and farm sizes and (iii) flexible and affordable payment terms

Financing

- Retail price of c.$970 is cheaper than alternative solutions (e.g., diesel pumps) – however, many smallholders still cannot afford the upfront cost
- SunCulture provides flexible a financing structure for SHFs via the Pay-As-You-Grow model
- The PAYG platform gives farmers access to affordable financing and incremental payments

The smallholder case for *RainMaker2*



An assessment of RainMaker2's impact indicates:

- Increase in productivity & income generation:
  - 75% of customers said that their productivity had increased since using RainMaker2
  - 23% net income increase (from a petrol generator to RainMaker2)
  - Production increases by 2-5x
- Decrease in spend on water:
  - Prior to purchasing RainMaker2, users spent an average $6.62 average a week acquiring water, now they spend $0.57 (91% decrease)

Source: Dalberg analysis and interviews. 2018.

SunCulture has developed an end-to-end service model to respond to market challenges and serve a rural customer base

Key challenges & solutions

	CHALLENGES	SOLUTIONS
Inputs	• Sourcing quality inputs for portable products • High lead times, managing cross-border duties efficiently	• To address sourcing constraints, SunCulture switched to flatter and lighter materials • Efficient supply chain logistics and reliable partners in China
Product	• Reduce cost • Being closer to the customers	• Remote monitoring • Increased investment in R&D resulted in more affordable product • Sales and Services Centers set up to increase efficiency
Markets	• High transportation costs for installations and technical support • Low awareness of product and high dependency on farmers trusting the product	• GPS guided technicians in motorcycles to optimize routes and reach customers faster • Extensive training and education for agents and farmers • Weather-forecasts sent to farmers to help them increase efficiency
Finance	• Initially tested loan pilot with local bank • However, limited uptake as bank not set up to finance these assets and low awareness by officers	• Ran own consumer financing portfolio to test product terms and refine offering • Partnering with specialist lenders with better understanding of market

Success Factors

Product innovation

- ✓ Product testing and rapid prototyping
- ✓ R&D hub in the field in close proximity to farmers)

Focus on the smallholder farmer

- ✓ Affordable pricing / Pay-as-you-Grow financing
- ✓ Sales agents from local area with farming experience
- ✓ Training at point of installation
- ✓ After-sale service centers close to point of use

Partnerships

- ✓ Financing i.e. to provide asset finance solutions for customers
- ✓ Distribution partners with strong rural networks e.g, agro-vets, hardware stores, etc.
- ✓ Technology e.g. *SunCulture* has partnered with Microsoft for internet of things functionality

Source: Dalberg analysis and interviews. 2018.

SunDanzer is a specialist solar refrigerator/freezer manufacturer; ***African Energy*** is a pan-African distributor that sells their products

The two companies have been working in partnership for about a decade and have together provided an estimated 3,000 solar products across 10 African countries

HQ location & year founded: Nevada, USA, 1999

Markets Served: Products in 35-40 countries, Africa (45%), North America (35%) and Latin America (>20%)

Estimated annual revenue: $10-15M (depending on project cycles, projects represent 60-70% of sales)

Employees: 15-35 in US, 1 in China, 1 in Kenya

Product (%*)	Specification	Applications
Walk in coolers (2%)	40' unit, 40kWh/day	• Household, • Medical, • Military, • Commercial (Micro-enterprises, Farms, Medical Clinics, Remote Stores)
DC Fridges (23%)	50-225L, 114-198W, 34-64kg	
DC Freezers (70%)	50-390L, 280-800W, 34-107kg	
Milk chiller (5%)	105L (510W @ 43C – no batteries)	

HQ location & year founded: Arizona, USA, 2002

Markets Served: Presence in 40 countries and depots in 10 African countries

Estimated annual revenue: $10-12 Million

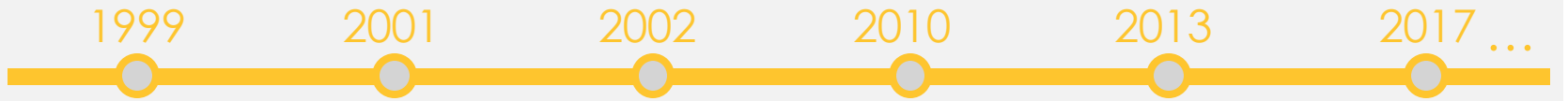
Employees: 7 in US, plus numerous independent in depots across SSA

Product	Specification	Manufacturers
Panels	85-335W, 12V	Suntech
Charge Controller	6-100A; 12-48V	Morningstar + others
Batteries	100-300A; 12V	Deka, Surette/Rolls;
Inverters	20A, 0.4-1.2kW;	Imeon, Kisae, Magnum,
Lighting	0.5W; 12V	Little Sun, Magnaray,
Fridges	50-225 L;	SunDanzer
SWP	0.7-1.2kW	Grundfos, Sunpumps

Sources: Dalberg analysis and interviews. 2018; Sundanzer website. 2018.

SunDanzer has spent the past eighteen years developing its range and testing small-scale productive use applications for its products

Company journey



- **1999** – Founded by NASA's Advanced Technology Refrigeration's project leader
- **2001** – NASA technology translated into the world's first battery-free solar-powered refrigerator, designed for small, off-grid consumers
- **2002** – Continued to develop high efficiency DC fridges mainly for the north American market
- **2010** – In 2010, worked with the Gates Foundation to develop a battery free technology for vaccine refrigerators, being 1/3 of total sales by 2013
- **2013** – Following a partnership with USAID to develop milk chillers and in 2017 won two Global LEAP innovation awards

Experiences in the SSA market

Product development – Initially ***SunDanzer*** did not target SSA markets. Then starting in 2010 SunDanzer supported several donor funded projects to adapt it's technology to SSA use cases. Notably in vaccine refrigeration and more recently in milk chillers

Installation & transferable expertise - During previous projects have gained delivery expertise including training technicians, including the installation of over 1200 vaccine fridges in Tanzania. This has helped to strengthening connections into regional technical partner organizations

Staying targeted – Noting the potential of their products to enable economic development, ***SunDanzer*** wish to focus more on emerging markets and potentially diversify product ranges through current projects and collaboration with SHS suppliers

Distribution experience with African Energy

In addition to it's donor-project contracts, ***SunDanzer*** maintains relationships with several distributors in SSA.

African Energy has been a **steady buyer for 10 years**, a key success factors is their open commercial terms, but **reliable payment and a strong dealer network**. Credit is usually only offered on major purchases, otherwise distributors self-finance.

Milk Chillers in Kenya with USAID

SunDanzer developed a **small-scale portable chilling system** tailored for use in the Kenyan dairy market.

Several design innovations were used: **bespoke sizing** to accommodate 5-10L milk cans, using **thermal energy storage** to avoid the need for batteries and using brine water bags used to **rapidly chill the milk** and limit bacteria growth

Sources: Dalberg analysis and interviews. 2018; Sundanzer website. 2018.

African Energy is one of the largest solar distributors in Africa – it has a growing PULSE portfolio with cooling, freezing, and irrigation products

Africa Energy's business model

- **Product selection –** ***African Energy (AE)*** distribute solar products through a network of 600 dealers. A major role for ***AE*** is the selection of quality products, using their network to identify specific customer needs
- **Dealer selection -** Dealers are typically individual entrepreneurs with potential to grow into enterprises
- **Dealer training** – To recruit and train dealers ***AE*** runs up to 8 events each year with 40-60 participants. These cover technical skills, manufacturer product displays, basic marketing and financial training. About 50% of trainees become dealers
- **Distribution & stock management –** ***AE*** have 10 country depots serving domestic and regional markets. Typically a local agent anchors these establishments, assisting with set up and inventory management. Each depot has on average $250,000 of stock, allowing for quick response times, even for larger donor contracts
- **Working capital –**All stock is self financed, since starting ***AE*** have invested profits back into the company to grow. In addition, ***AE*** have up to $1M of goods in transit with dealers, with 30-60 day payment terms
- **Customer sales & support** – Dealers are responsible for sourcing customers and all post-sales support

Specific experiences with PULSE products

- PULSE product sales are increasing, in part due to falling prices. But ***AE*** don't target the small-scale farmers, client acquisition and customer finance is harder
- Instead dealers typically target village groups, co-operatives or NGO/public sector clients on a project basis. Village-scale applications have been preferred as boreholes/pumps tend to be shared by a community
- However, this client mix can make demand volatile, ***AE's*** largest market was Nigeria, but recently donor spending has increased in East Africa
- ***AE*** have a hands-off approach to post-sale support, it is more cost-effective for manufacturers to provide spare component than warranties, repair services

Experiences distributing SunDanzer products

- Initially shipping costs were not affordable, but higher volumes have allowed AE to freight by sea not air
- Products are usually used for consumptive activities, with productive opportunities being at a larger scale. ***AE*** is working with ***SunDanzer*** to develop village level solutions, including walk-in cold storage.
- ***AE*** see the potential of targeting ***SunDanzer*** products to farmers that have already purchased irrigation pumps, higher productivity creating incentives to reduce loss

Sources: Dalberg analysis and interviews. 2018; Sundanzer website. 2018.

To scale, ***SunDanzer*** must adapt products further and diversify its relationships; ***African Energy*** has wide reach but requires working capital

Manufacturer side: What are key constraints for ***SunDanzer*** to take its products to scale?

1. **Market readiness -** solar refrigeration in dairy, horticulture, fish cold chains is not well known. The market is immature with little incumbency
2. **Product development** – there is a need to further tailor products for new value chain applications. SunDanzer is currently working with IFAD on a R&D project in dairy, fisheries and horticulture
3. **Flexibility –** combine different uses in one product, e.g. adding USB chargers to meet customer needs
4. **Field serviceability** – simple products needed, with limited moving parts to make repairs easier for in-country partners in remote supply-chains
5. **Channel diversification –** Outside project and distributor sales channels, the firm wants to connect with other actors e.g. SHS players. Have recruited staff to get closer to Kenyan market
6. **Product cost** – To help optimize costs, ***SunDanzer*** have already adjusted their supply chain with more component sourcing/assembly in Europe & East Africa,. But a significant driver of landed costs is the tax-treatment of productive-use appliances

Distributor side: What are key constraints for ***African Energy*** to scale up its portfolio of PULSE products?

1. **Few commercially-driven farmers** - Many smallholders are still in transitional stages from subsistence to commercial farming. Demand is mainly from donor-funded products, otherwise it is difficult to find viable customers ready to purchase
2. **Limited commercial viability –** In addition to product affordability, for many farmers the underlying commercial viability is a challenge
3. **Inconsistent taxation –** PULSE products do not benefit from fiscal incentives, despite being key agricultural inputs. Import duties and VAT can reach up to 45% while other ag equipment doesn't
4. **Working capital –**In some places their $250k of stock is not enough but bank charges are too high local bank interest rates are typically 18% or more. This is becoming a constraint to AE's growth
5. **Distributor financing –** Also, ***AE*** have an average annual debt (receivables) of $1-2 million. Default rates are low, but despite this, affordable financing is not available. ***AE*** only lend to dealers, not end-users, this manages risks but does not solve for affordability and consumer financing

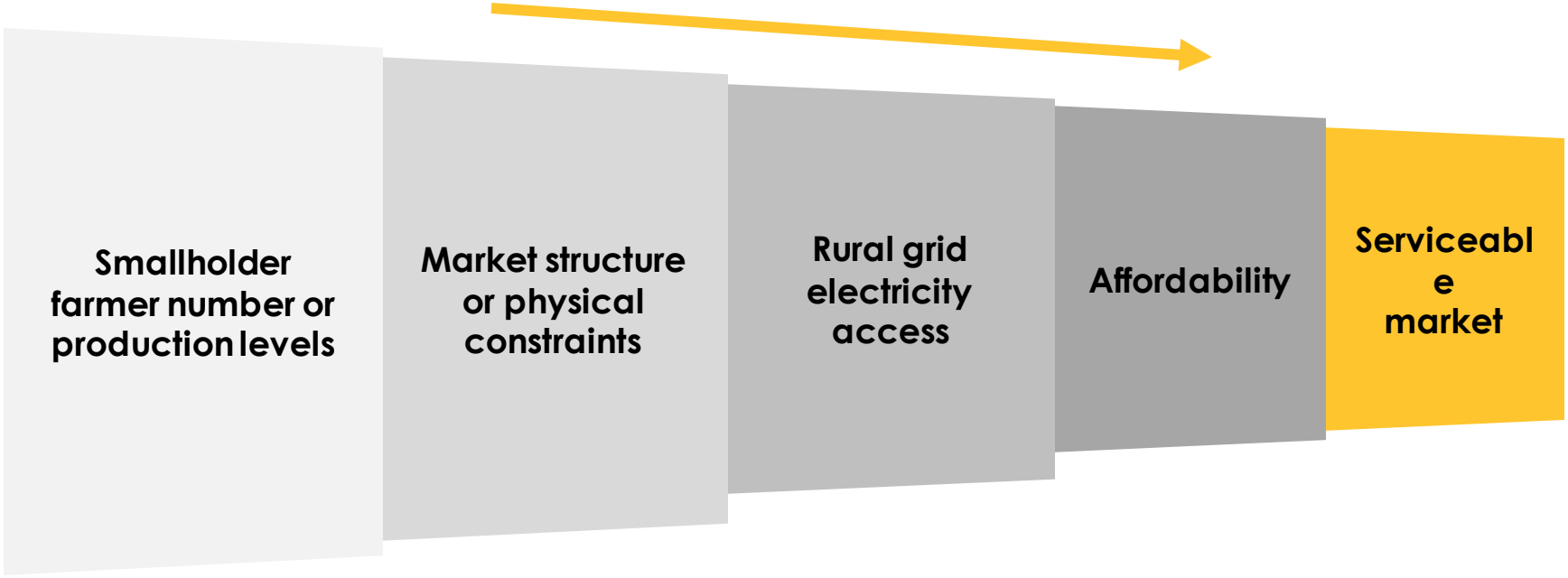
Sources: Dalberg analysis and interviews. 2018; Sundanzer website. 2018.

SUB-SAHARAN AFRICA: **OPPORTUNITIES AND CHALLENGES FOR PULSE**

SECTION FOUR

Market sizing must account for smallholder farmer dynamics, grid access, and affordability to reach the serviceable market

Market sizing approach



Market forecasts out to 2030 also factor in: production growth, commercialization, rural electrification rate, income increases, and anticipated product costs decreases

We estimate the total SSA market for micro-PULSE to be $734M factoring in affordability / ability to pay[1], and up to $11.3B without

2018 Sub-Saharan Africa market

Micro-PULSE applications	Units	Unit price	Market value
Solar water pumps	5,398 K **701 K**	*$650*[2]	$3,509 M **$456 M**
Agro-processing	941 K **54 K**	*$1,625*[3]	$1,529 M **$87 M**
Cooling & refrigeration	6,480 K **225 K**	*$825*[4]	$6,250 M **$191 M**
Total			$ 11,288 M **$734 M**

Key:

Addressable (without affordability)

Serviceable (with affordability)

Source: Dalberg analysis. 2018.
Note: 1) Affordability here means ability of prospective customer to pay on credit – further details on credit terms are set out on slide 58. If assumption of access to credit is removed, only those who can afford upfront cost of product would be included, thereby reducing market size significantly.2) Market leader price. 3)Average across small-scale processor types. 4) Average across 100L refrigerator prices.

Across selected markets, there is a modest opportunity today, but more attractive if affordability constraints are addressed

2018 country markets	KEN Market	ZIM Market	CIV Market
Micro-PULSE applications			
Solar irrigation pumps	$157 M $25.3 M	$115 M $7.3 M	$56 M $8.0 M
Agro-processing	$68 M $1.2 M	$15 M $0.1 M	$65 M $3.7 M
Cooling & Refrigeration	$125 M $9.1 M	$53 M $0.7 M	$96 M $12.5 M
Total	$350 M $35.6 M	$183 $8.1 M	$217 M $24.2 M

Key:

Addressable (without affordability)

Serviceable (with affordability)

Source: Dalberg analysis. 2018.

Solar-powered irrigation: Irrigation presents a large market, but limited water access and affordability are key constraints (1/2)

Sub-Saharan Africa market assumptions (2018)

Crops

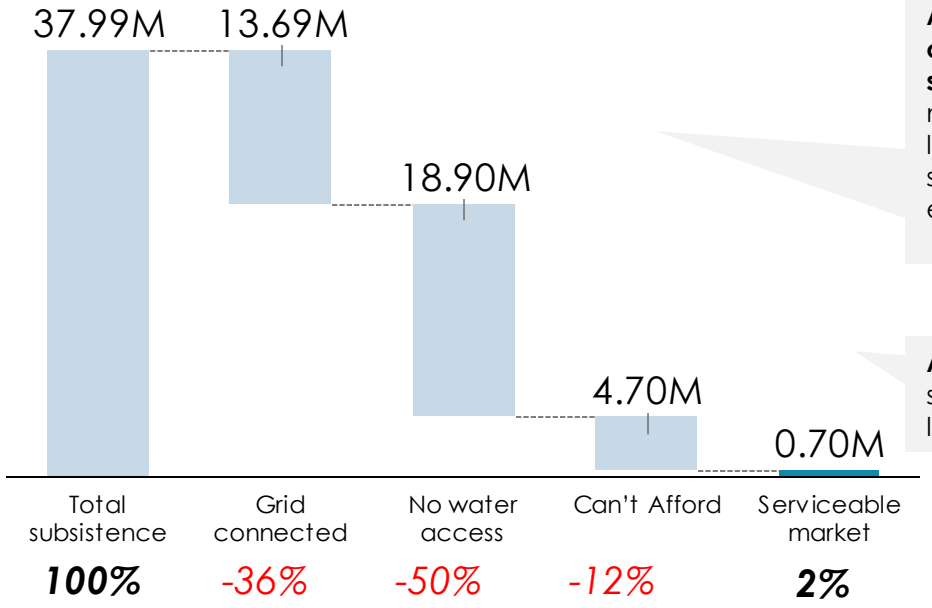
Rural households **121M** → Smallholder households **95M** → Non-subsistence SHF **38M**

Taking rural households as a starting point, only 78% of these are engaged in small holder farming, and of these 60% only grow subsistence produce. This leaves a target 38M non-subsistence SHF

Serviceable market (Smallholders)

Serviceable market waterfall

Smallholder farmers (millions)



Access to a renewable water source is a critical consideration when targeting smallholder farmers with solar water pumps, many will not have access to either 1) localized year-round surface water or 2) shallow accessible ground water. IFPRI estimates this to be only 16% of total numbers

After affordability considerations, the total serviceable share of smallholder farmers is limited to 0.70M

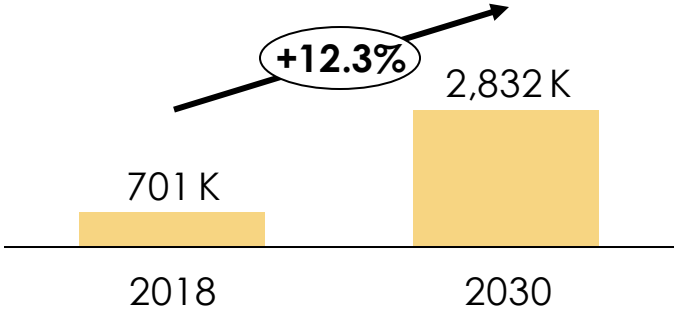
Source: Dalberg analysis. 2018.
Note: MT – Metric Tons of produce

Solar-powered irrigation: Irrigation presents a large market, but limited water access and affordability are key constraints (2/2)

Sub-Saharan Africa market size (2018-2030)

Serviceable market projection (2018-2030)

Potential number of units



	2018		2030
Product cost	$650	-11%	$577
Affordability (% who can afford)	10%	→	51%
No. of customers	0.70M	→	2.83M
Market size ($)	$456M	→	$1,633M

The potential market for micro-PULSE irrigation pumps could increase by up to **12.3% year on year** given population and demographic trends

There has already been considerable effort to reduce product prices therefore a conservative **11% reduction in product cost has been assumed,** which coupled with increasing income will increase affordability

Source: Dalberg analysis. 2018.
Note: Market size values based on current prices.

Solar agro-processing: Affordability will limit the serviceable market, while larger processors already aggregate other produce (1/2)

Sub-Saharan Africa market assumptions (2018)

Crops

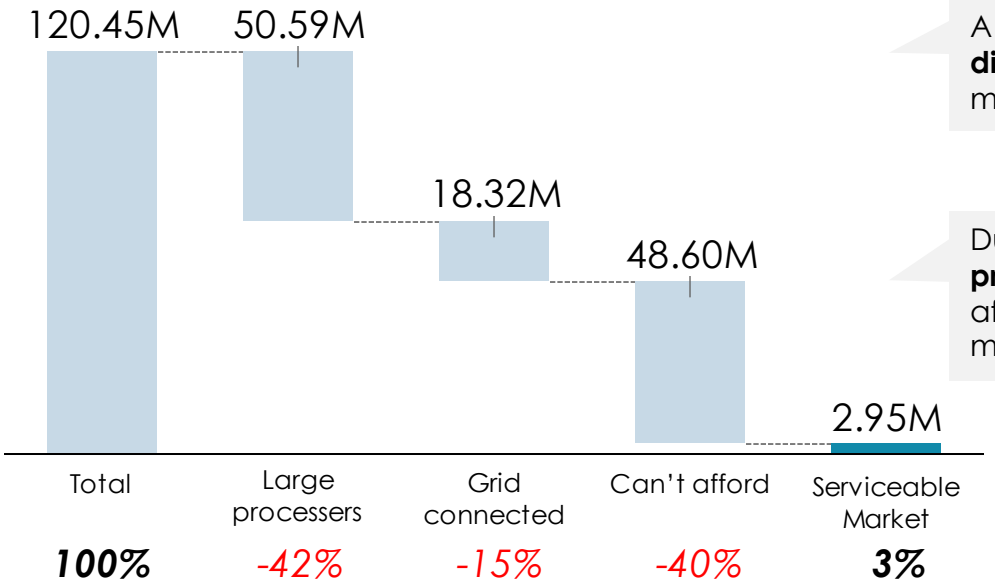
Cereals Pulses Roots/Tubers	→	Total production **401M MT**	→	Smallholder production **120M MT**

Across crop types most relevant for agro-processing over **a quarter is in smallholder farmer production systems**. Both producers or traders could be targeted with PULSE products

Serviceable market

Serviceable market waterfall

MT of produce



A large proportion of produce is **sold directly to large-scale processors** where micro-PULSE interventions are not required

Due to the **high current prices of agro-processing equipment** they are not affordable to smallholder farmers or micro-enterprises

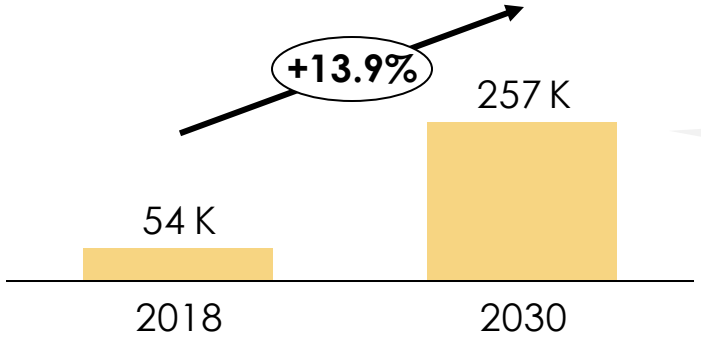
Source: Dalberg analysis. 2018.
Note: MT – Metric Tons of produce.

Solar agro-processing: Affordability will limit the serviceable market, while larger processors already aggregate other produce (2/2)

Sub-Saharan Africa market size (2018-2030)

Serviceable market projection (2018-2030)

Potential number of units



	2018		2030
Product cost	$1625	-35%	$1056
Affordability (% who can afford)	6%	→	25%
No. of customers	54K	→	257K
Market size ($)	$87M	→	$417M

Assumes a single unit can process on average **55MT/year**, based on typical manufacturer specifications and use case analyses

Prices of agro-processing equipment are likely to come down **if suppliers were able to increase their scale** and there is further innovation in DC processing technologies

Customers are mostly cooperatives and micro-enterprises - the products will remain **outside the affordable price range** of most smallholders

Source: Dalberg analysis. 2018.
Note: Market size values based on current prices.

Cooling & refrigeration: Increasingly viable across a range of use cases but product costs limit potential market size today

Key SSA market assumptions (2018)

Crops

Dairy
Fisheries
Horticulture

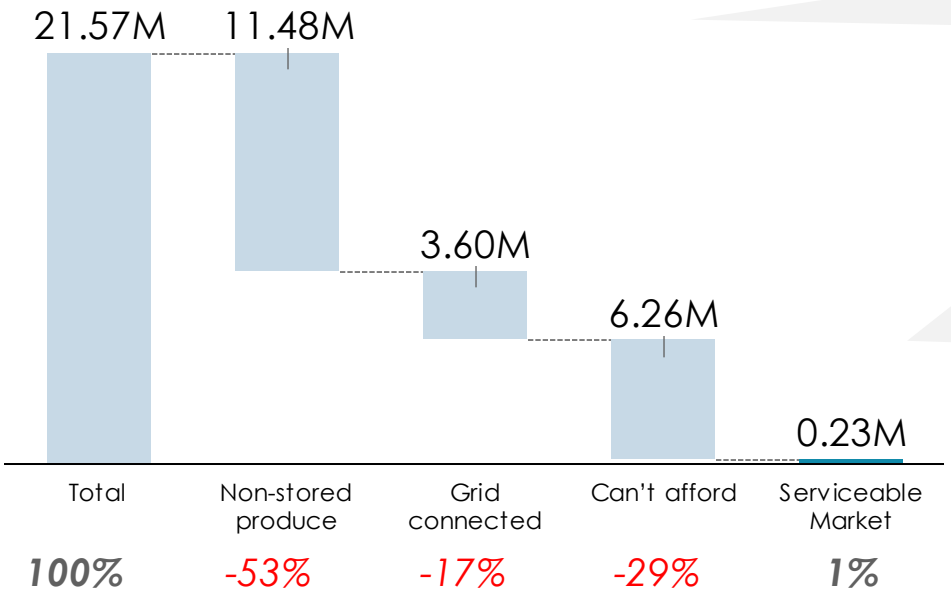
→ Total Production **160M MT** → SHF production **51M MT** → SHF small-scale traders* **21M**

Across produce types most relevant for refrigeration and cold storage over **a third is traded through small-scale trade where micro-PULSE solutions could be provided**

Serviceable market

Serviceable market waterfall

Small-scale traders (Millions)



A proportion of traders **do not need direct storage and produce is traded immediately**, across diary, fisheries and horticulture we find this to be approximately 50% of their produce reducing demand for units

Affordability again remains a constraint, for this reason **horticulture cold storage accounts for 0% unit demand currently.** The smallest units targeting only larger aggregated suppliers above the micro-PULSE scale

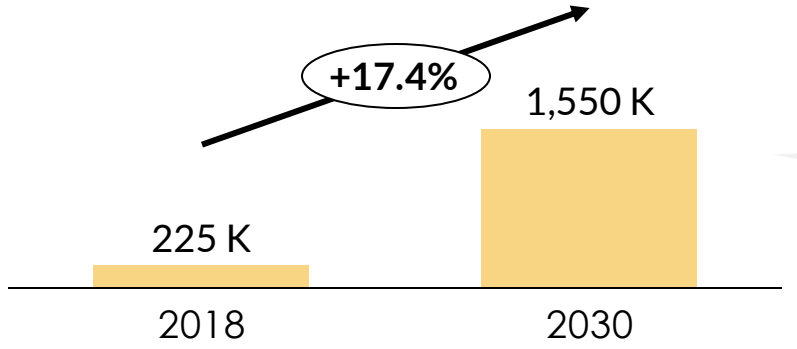
Source: Dalberg analysis. 2018.
Note: MT – Metric Tons of produce; * 21M small-scale traders are involved in trading the produce of smallholders.

As incomes rise and costs decline, refrigeration solutions will become viable for growing number of small-scale farmers

Sub-Saharan Africa market size (2018-2030)

Serviceable market projection (2018-2030)

Potential number of units



Product cost	$825	*-10%*	$743
Affordability (% who can afford)	5%	→	50%
No. of customers	225K	→	1,550K
Market size ($)	$191M	→	$1,318M

The micro-PULSE cooling and refrigeration market will continue to be **driven by refrigerators rather than walk-in cold storage sales** out to 2030

The costs of units is likely to come down, largely driven by **technology improvements, economies of scale and supply chain efficiencies**

Rising incomes will sharply increase the number of smallholders who can afford refrigerators

Source: Dalberg analysis. 2018.
Note: Market size values based on current prices.

Three main levers could reduce product costs: a) technology and efficiency improvements b) increased economies of scale c) reduction in duties / tariffs

Component costs will continue to reduce, and system sizes optimized

- Rapid decline in product costs was a large driver in the uptake of solar home systems and LED lighting solutions
- For PULSE products, companies like SunCulture and FuturePump have already been able to **bring entry-level pump prices down from $1,000+ to under $600** with donor support
- But the rate and **extent of cost reduction will be limited by non-solar balance of system components that have more static cost projections**. Taking SunDanzer as an example, refrigerator shells and compressors are relatively mature components
- A fuller review of the drivers of price and costs of goods could identify more specific opportunities here, but could vary significantly by PULSE product segment

Increasing distribution scale will make supply more efficient

- **Sales volumes are low across product segments** and no segments yet benefit from fuller economies of scale
- Distributors rely on small scale purchasing from manufacturers, sometimes relying on **air shipment over seas shipment, or partial container shipments**
- Suppliers also struggle to find working capital to stock larger volumes
- Component sourcing and **supply chains can still be optimized for SSA markets**

Rationalization of import duties could bring down end-consumer prices

- Finally, PULSE asset often **don't qualify for either solar fiscal incentives or agricultural fiscal incentives**, or fit in grey areas that are not evenly applied between jurisdictions or inspectors
- While local manufacturing is possible and increasing, in the short term PULSE products and components will continue to be imported
- In some jurisdictions import duties are as high as 25%, for example Tanzania. A rationalization of taxes could directly impact prices of productive use products

Source: Dalberg analysis. 2018.

Many target users cannot afford to purchase products upfront, for market sizing we have made several assumptions on financing terms

Financing assumptions

Interest rates	Loan terms	Affordability threshold
15% per annum	***36 months repayment***	***15% of monthly incomes***
• For consistency, an annual interest rate of 15% is adopted as standard across markets, noting the potential for significant variation even within countries	• The availability of patient capital is limited, however several financiers said that should PULSE products become more commonplace within proven commercial returns, they could lend out to three years • For use cases we take a more aggressive view that repayment is needed within an two year period	• We have used a 15% threshold for the proportion of monthly household income available to service debt • Post-investment this threshold might increase given incremental income from PULSE use • Based on current product prices, and typical financing arrangements, a SWP requires **$28 month in loan repayments**

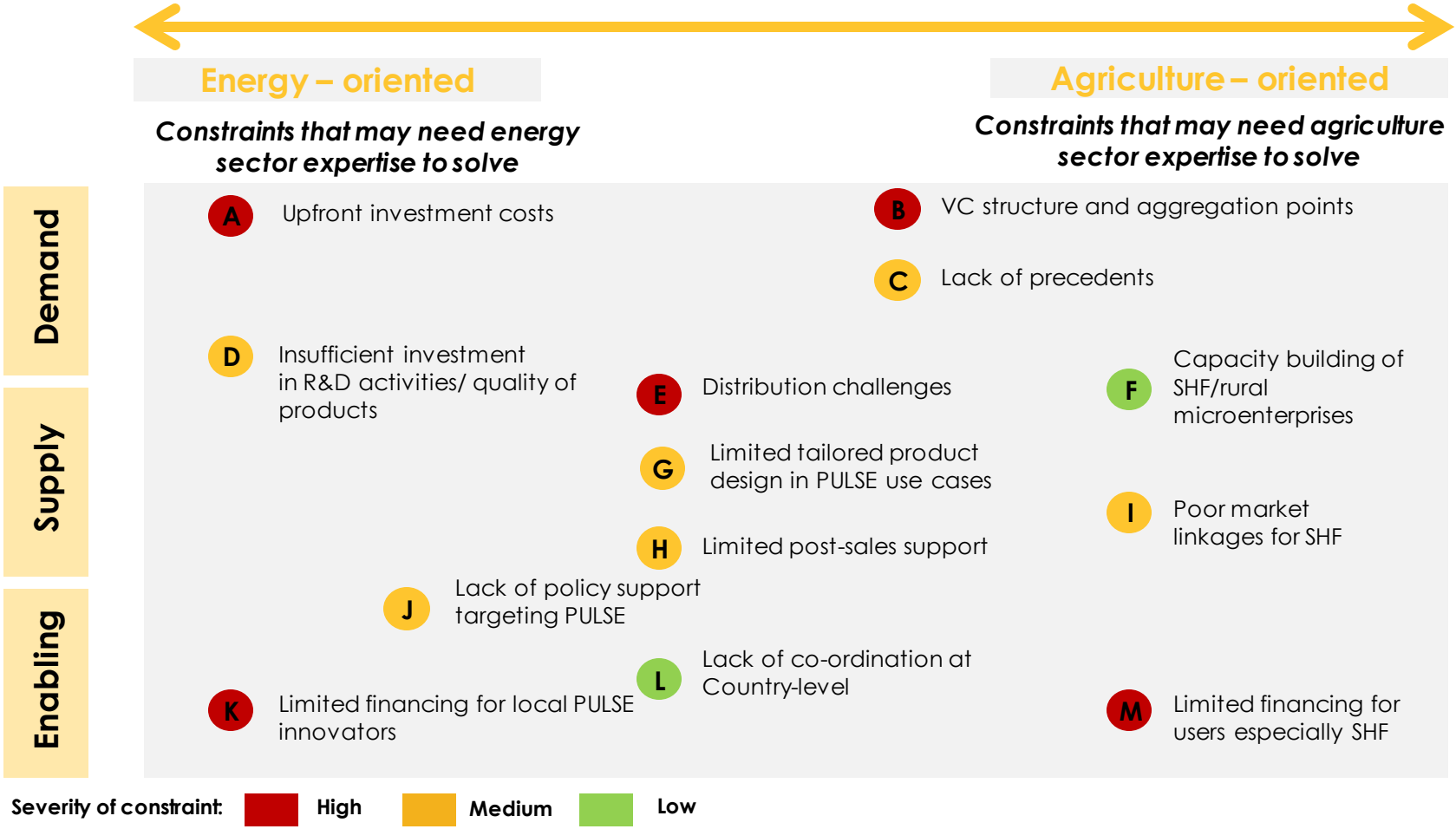
"From experience it is important that customers see positive returns within 1-2 years, we might be optimistic but this would make us confident in bringing in PULSE products" – Regional SHS player

"Typically for agricultural inputs we would expect repayment under a year, if collateral is provided the maximum we would lend to would be 3 years" – Zimbabwean Financial Service Provider

Incremental income is an additional consideration, tied to yield uplift and produce type, which enhances an individuals ability to repay after product purchase

Source: Dalberg analysis. 2018.

Across SSA several constraints to scaling PULSE across exist, they are likely to need a range of energy and agricultural expertise to unlock



Note: SHF refers to Smallholder farmers; VC refers to Value chain

The most severe of these challenges are potential focus areas for interventions and many require agriculture sector expertise (1/3)

Description & Gap			Ease to unlock
Focus:	Energy	**Severity:**	**Difficulty:**

Upfront investment costs

- PULSE products are out of the affordability range of most SHF/rural microenterprises
- Even with innovative funding models, payback periods for some use cases are long (more than two years) making investment a low value proposition for customers to invest in cases where income benefit is only marginal

Although there are downward trends in solar costs they might not be as sharp for PULSE product, due to more established parts such as pump impellors. Focusing on **distribution channel efficiency, tax/fiscal policies and financing costs will be important**

Focus:	Agriculture	**Severity:**	**Difficulty:**

Limited financing for users, especially SHF

- SHF financing needs are dictated by existing obligations: school/education fees, milestone life events (weddings), and purchases of other agricultural inputs
- As with agricultural equipment, there is a gap for larger, longer life PULSE products which require larger loan sizes, term lengths, and lower interest rates
- Existing financial service providers do not fully appraise the potential for significant incremental income creation. In addition, asset-backed financing is not well established, in part because confidence secondary/re-sale markets is low

Requires partnerships between suppliers, financial institutions, and in some cases value chain actors, e.g. off-takers to de-risk farmers. **Some models, e.g. with SunCulture in Kenya, have shown promise and can be replicated**

Focus:	Both Agri and Energy	**Severity:**	**Difficulty:**

Distribution challenges

- Logistics chains in many places are not developed and demand not aggregated enough to make nodal manufacturing and investment in distribution viable
- Several suppliers haven't identified in-country and value chain partners and business models to facilitate efficient and cost effective last mile distribution including the necessary training/technical support given alongside sales

While there is a gap in connecting value chain actors, suppliers, and distributors, this is in part because demand for solar products have not reached a critical mass. Collaboration is increasing, but **activities are mostly limited to peri-urban customers**

Evaluation: High Medium Low

Source: Dalberg analysis. 2018.

The most severe of these challenges are potential focus areas for interventions and many require agriculture sector expertise (2/3)

Description & Gap				Ease to unlock
Focus	Energy	**Severity**		**Difficulty**
Limited financing for local PULSE innovators • Limited local equity capital; bank loans are the main form of local financing but difficult to **secure because of high collateral requirements** (especially difficult for start-ups) • Some local firms are wary of international investment given business or proprietary risk, this **limits scaling product trials and expanding once proven**				There is a gap in PULSE specific credit guarantees to banks, and other funding mechanisms backed by both local and international investors. International players are entering the market but in some countries connections with local players are less easy than others
Focus	Agriculture	**Severity**		**Difficulty**
Value chain structure & aggregation points • Several use cases' viability requires aggregation of SHF output to be viable but **unstructured value chains make it difficult to reach a critical mass of farmers**. Conversely, where aggregation is already standard practice, it can push the PULSE use case above a pico-scale, with systems likely needing mini-grids • In some cases aggregation doesn't make sense for SHF due to market dynamics (e.g. SHF preferences of where to sell produce, pricing in different markets, etc.)				In some cases aggregation is occurring which pushes capacity/processing speeds above pico-PULSE products. In other cases where aggregation is needed for viability, either the supplier or a third party needs rely on **behavior change/incentives to aggregate**, which introduces mobilization costs
Focus	Both Agri and Energy	**Severity**		**Difficulty**
Lack of precedents (little incumbency) • There are **PULSE-enabled value chain activities**, where existing technologies have high operating costs or fuel-access makes activities prohibitive • So, despite underlying commercial viability many **use cases do not have incumbent technologies** or currently have very low uptake • This presents potential untapped opportunities for PULSE providers, but **awareness raising and market development are required** alongside products				PULSE providers need to invest to highlight commercial opportunities and sometimes create market linkages to ensure viability. In addition, this also means there may be broader knowledge and business skills gaps, especially for entrepreneurs that need to adapt

Evaluation: High Medium Low

Source: Dalberg analysis. 2018.

The most severe of these challenges are potential focus areas for interventions and many require agriculture sector expertise (3/3)

Description & Gap				Ease to unlock
Focus	Energy	**Severity**		**Difficulty**
Limited tailored product design in PULSE use cases • In some cases, existing products have **not targeted small or micro** segments predominantly due to the limited affordability for SHF and cost of technology • There is also **a mismatch on scale and value chain targeting,** e.g. value chain activity may require higher mobility or higher performance than the product is built for				SHF targeted innovation is increasing and component costs are reducing. However, **product design needs more practical consideration in terms of value chain realities**, but this has cost implications for suppliers
Focus	Energy	**Severity**		**Difficulty**
Insufficient investment into R&D funding (quality of products) • Sector growth could be slowed by a lack of incentives for large manufacturers to invest in micro-scale products, given perceived small market size compared to other opportunities, higher return products, and limited manufacturing capacity • As a result R&D is being carried out in a fragmented way by smaller firms with less experience in manufacturing at scale				Difficult to incentivize large firms to take on cost of R&D due to them having other profitable markets and the threat of competition of cheaper generic products from Asia. Such products are still at the start of product quality curves which could damage long term PULSE reputation if unaddressed
Focus	Both Agri and Energy	**Severity**		**Difficulty**
Lack of policy support targeting PULSE • Limited policy support for PULSE versus traditional approaches or energy sources • **Some markets have reduced import tariffs and taxes for solar panels, but benefits do not extend to all PULSE equipment** • For example, it is hard to differentiate at port between solar and non-solar enabled products, especially if not packaged with panels. This is especially true where a DC pump looks very similar to an AC grid/diesel pump				Involves a broad range of stakeholders, with certain policies based on regional harmonization, e.g. ECOWAS. There can be problems with the enforcement and awareness of incentives/waivers.

Evaluation: High Medium Low

Source: Dalberg analysis. 2018.

Constraints are largely similar across PULSE product segments, but there is some variation in the severity and therefore importance

Letters correspond to annotation on slide 60

		PULSE use cases / product groups			
	Severity of constraint:	**Irrigation**	**Cold storage**	**Agro-processing**	**Refrigeration**
A	**Upfront investment costs***	Medium	High	High	Medium
M	Limited financing for users especially SHF	High	High	High	High
E	Distribution challenges	High	High	High	High
K	Limited financing for local PULSE innovators	High	High	High	High
B	**VC structure & aggregation points***	Low	High	Medium	High
C	**Lack of precedents***	Low	High	Low	Medium
G	**Limited tailored product design in PULSE use cases***	Low	Medium	High	Medium
D	Insufficient investment in R&D activities / quality	Medium	Medium	Medium	Medium
J	Lack of policy support targeting PULSE	Medium	Medium	Medium	Medium
H	Limited post-sales support	Medium	Medium	Medium	Medium
I	Poor market linkages for SHF	Medium	Medium	Medium	Medium
L	Lack of co-ordination at country level programming	Low	Low	Low	Low
F	**Capacity building of SHF/microenterprises***	Low	Medium	Medium	Low

High **Medium** **Low**

Source: Dalberg analysis. 2018.
Note: *Challenges showing variability across product types are described in more detail on the next page

Aside from costs, aggregation limitations, lack of precedents and product design are the challenges that vary widely across use cases

Upfront investment costs	• **Solar water pump product costs (c.$650) are lower when compared to other PULSE products.** Several cheaper small-scale refrigeration/chilling solutions are increasingly available (<$1,000). For both there is room for improvement in upfront costs, but still less critical than for agro-processing ($1,500+) and cold storage ($5,000+)
Value chain structure & aggregation points	• Solar water pumps are less dependent on specifics of a given value chain, though smallholder access to market is critical for smallholders to reap benefits from irrigation • While aggregation is needed for agro-processing, **business models used by incumbent technologies** (such as service / rental models) **already overcome these challenges.**
Lack of precedents	• In irrigation and agro-processing, diesel and grid-powered precedents are common, **reducing the need for market development/behavior change** activities • For both cold storage and refrigeration (milk, fish and horticulture), there are limited incumbent technologies, so more market development and awareness-raising is needed
Limited tailored product design in PULSE use cases	• **Solar pumps are increasingly being tailored for the SHF scale,** but most refrigeration products are adapted from consumption use applications and could be better adapted to value chain needs (e.g. size and mobility) • Many PULSE agro-processing products are still at an R&D stage, for those that exist there can be a **mismatch with the product capacity and needs on the ground**
Capacity building of smallholders and microenterprises	• For irrigation and chilling, activities will be limited to product use training as **product use is for individual purposes**, and less so when incumbent technologies are being used • In agro-processing and cold storage, as activities are typically offered as a service, additional training may be needed on **best business practices for new entrepreneurs**

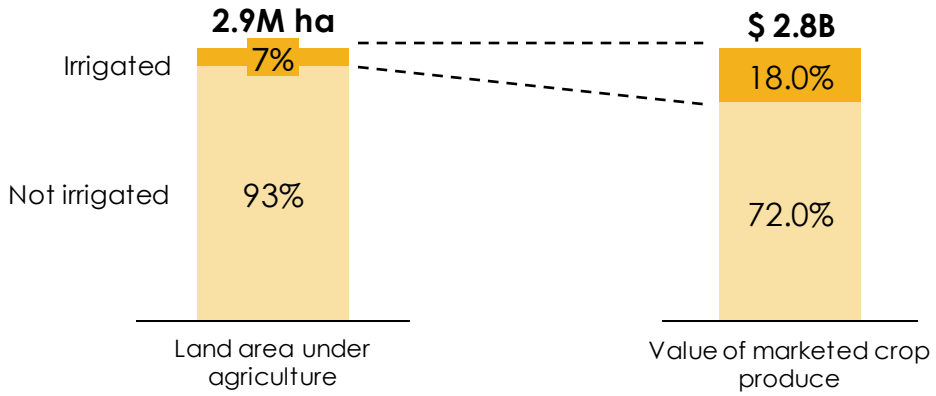
Source: Dalberg analysis. 2018.

KENYA MARKET **DEEP DIVE**

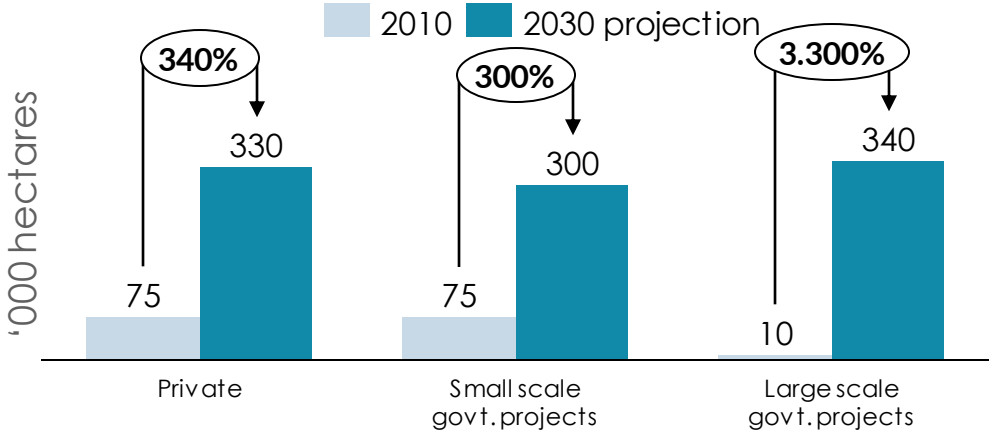
SECTION FIVE

Kenya is not fully utilizing its irrigation potential, but there are plans to expand coverage significantly through public and private projects

Contribution of irrigated land to value of production



Projected evolution of irrigation capacity by scheme typology



Irrigation needs in Kenya

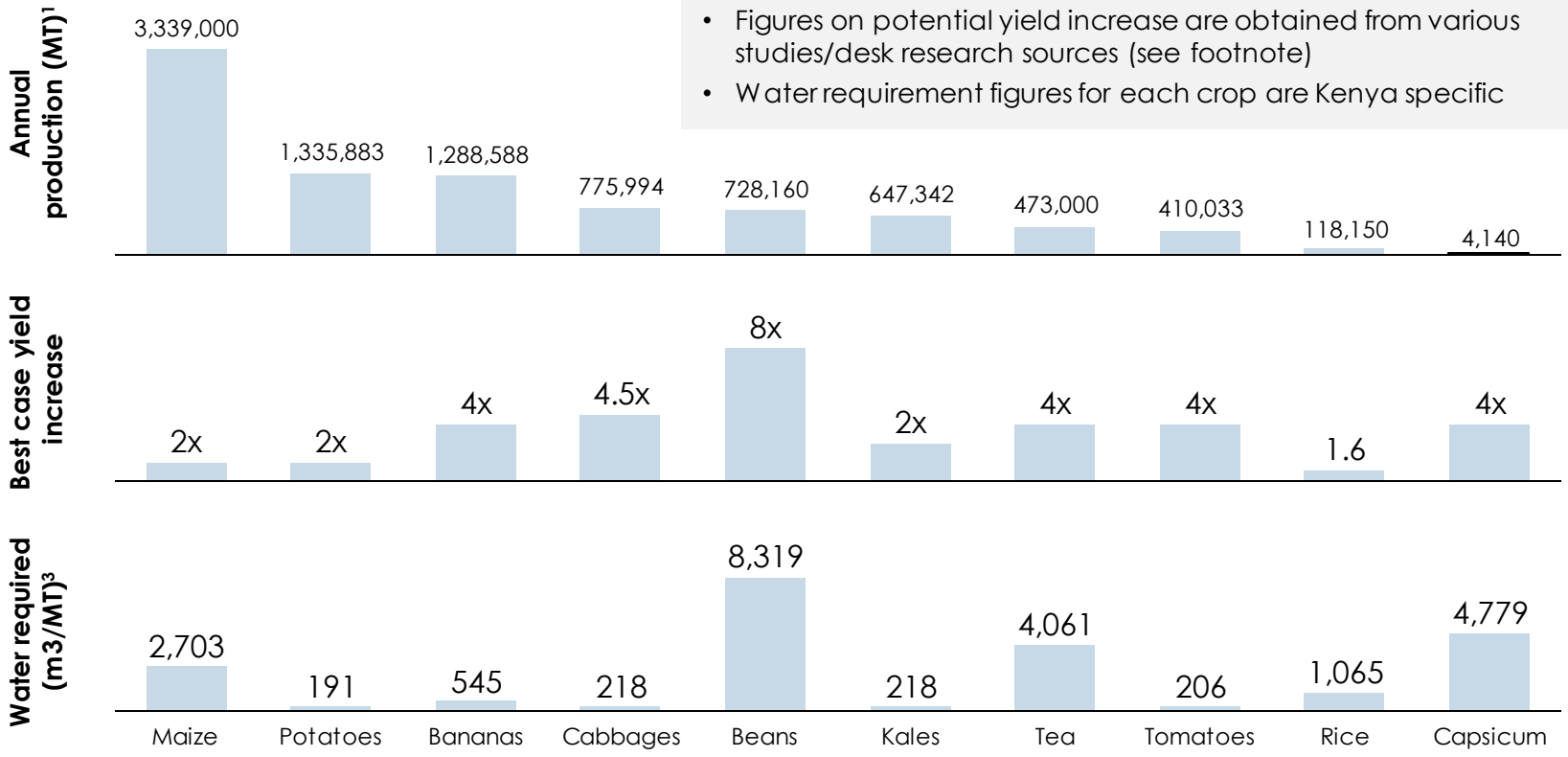
- Increasing irrigation supply is critical for maximizing value in the agriculture sector
- The need for irrigation is increasing, with a **decrease in long rains** by more than 100mm since the 1970s and a shift in rainfall patterns and annual distribution
- Small holders farmers are the least resilient to these climatic shocks and are already **losing out on commercial returns** due to low productivity
- To address these challenges, the government plans to increase land under irrigation to **~1M ha by 2030**
- Alongside the larger government planned schemes, solar water pumps will likely be a key opportunity for the private sector to step up supply

Sources: Ministry of Water and Irrigation. 2017. "3rd medium term plan"; FAO. 2015. "Kenya Irrigation market brief"; FAO. 2018. "The benefits and risks of solar-powered irrigation - a global overview"; Ngigi. 2010. "Review of irrigation development in Kenya; USAID - A climate trend analysis of Kenya".

Irrigation has the potential to boost production across major crops, though yield potential and water requirements vary significantly

Comparison of annual production, potential for yield increase, and water requirements

- Crops highlighted are a combination of crops with the highest production volumes and commonly irrigated crops in the country
- Figures on potential yield increase are obtained from various studies/desk research sources (see footnote)
- Water requirement figures for each crop are Kenya specific



Both the potential for yield increase and the water requirement of crops are important considerations underpinning the commercial viability of use cases, especially in small-scale applications

Sources: 1) FAOSTAT; 2) 2030 Water Resources Group. 2016. "Agricultural and irrigation opportunity in Kenya, 2016; Various desk research sources"; 3) Mekonnen, M.M. and Hoekstra, A.Y. 2010. "The green, blue and grey water footprint of crops and derived crop products"
Note: 1) MT – Metric Ton

Diesel pumps are well established in the market for large scale farms; uptake at micro level is low for both diesel and solar

	Mid-scale applications	Small-scale applications	Very small-scale applications
Typical products & capacity	  *2->5ha*	  *1-2ha*	  *<1ha*
Degree of uptake	**Grid/Diesel**: High **Solar**: Low (>5ha); Med (2-5ha)	**Grid/Diesel**: High **Solar**: Medium	**Grid/Diesel**: Medium **Solar**: Low
State of play	• Limited large scale applications for solar at >5ha	• Technologies are available from a range of suppliers, some are innovating to provide both small and micro product ranges • Solar sales are driven by distance from grid and awareness of long-term cost savings. Solar sales account for up to 25% of pump sales of leading suppliers	• Suppliers operating at this level are beginning to scale following improved affordability. Scaling through distributors or direct sales (>1000 units in the last year) • Largely include surface pumps and submersible shallow well pumps. Costs are coming down rapidly, in part due to innovations in DC pump technology

Several suppliers are working to improve uptake in the micro segment, e.g. through partnering with financial institutions to lend to farmers, or providing credit themselves

Source: Dalberg analysis and interviews. 2018.

Two innovators are already targeting the micro segment, while two established players are moving downstream into the segment

Organization	Stage	PULSE products & services	Outlook
Future Pump	Integrated	**Product:** Sunflower2, DC Surface Pump for farms less than 1 acre, 6m head, $650 **Services: B2B** with Davis and Shirtliff as main distributor	Partners with other solar distributors e.g. SolarNow to reduce operational costs of supplying to multiple markets Focus on micro segment (<1ha)
Davis & Shirtliff	Distributor	**Product:** Distributes a range of DC pump brands including FuturePump **Services: Cash sales only**, remote monitoring of pumps	Moving heavily towards solar and marketing strongly due to large demand for solar products Do not offer financing, unlikely to depart from current model
SunCulture	Integrated	**Product:** RainMaker, 100m head DC pump with, backup battery, $500 **Services: Pay as You Go** in-house credit	Developing a pump with higher capacity based on modularization. Are lower cost than most competitors Using PAYG to enhance uptake
Lorentz	Manufacturer	**Product:** Developing a micro scale DC solar pump to target SHFs **Services:** Have an **accredited distributor system**, generally have a hands-off approach	Continuously have new products and could quickly build on their distribution networks to expand Increasing focus from R&D to installations and sales, want to serve SHFs but wary of repayment

Source: Dalberg analysis and interviews. 2018; Company websites
Note: Size = annual turnover

More broadly, Kenya has a range of suppliers providing solar pumps, many of whom are increasingly serving farmers at a smaller scale

Solar product distributors (some offer non-solar products as well)

solar now	Provide several types of solar products, including SHS, business solutions and irrigation pumps
Sollatek	Offers a range of solar products including solar pumps
Amiran	Provides large and small scale irrigation systems. Also offers a broad range of agri-support services including input supply, and training
FineTouch Africa	Provide pumps along with complimentary equipment e.g. water tanks, greenhouses etc.
IRRICO INTERNATIONAL	Provides irrigation system design and installation, maintenance & consultancy for both solar and diesel pumps
KickStart The Tools to End Poverty	Provides human-powered (treadle) pumps, building a solar prototype due to demand from customers
ELGON KENYA	In addition to pumps, supply seed, agro-chemicals, and packaging materials
Suntech	Supplies a range of solar-powered solutions including pumps, lighting, and solar-wind hybrid solutions

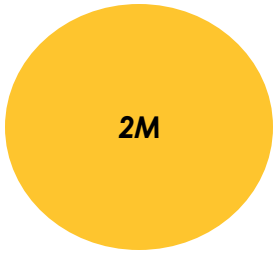
Other manufacturer brands in the market

Some distributors mentioned above and on the previous page are also manufacturers. In addition to **Lorentz**, other manufacturers whose pumps are distributed in the market (through local partners) include:

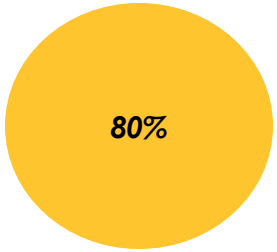
KOHLER, KOSHIN, GRUNDFOS, JIANGDONG, JAIN Jain Irrigation Systems Ltd. Small Ideas, Big Revolutions.®, SHURflo, PEDROLLO ... the spring of life, MARQUIS®, BRIGGS&STRATTON, DAISHIN

Source: Companywebsites

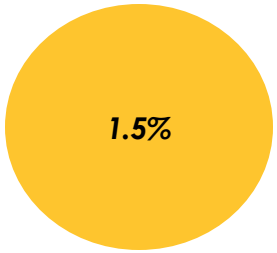
Horticulture is already an active sector for these providers, with potential to expand further and boost incomes for up to 2M farmers



Number of people employed in the sector



% of producers that are smallholders



Contribution to national GDP

Horticulture - Overview

- Kenya's horticulture production is **8 million MT per year**, with 1.5% annual growth over 5 years, and >720 ha under production
- Total production from the sector was valued at **$3B in 2017**, with **exports at $1.1B**
- Kenya is a **net exporter of horticultural produce**, exporting the bulk of it's produce to the EU. Exporters mostly outsource from certified small-scale out growers
- Leading crops for domestic market are **potatoes, tomatoes, kale, cabbages, bananas**
- French beans, snow peas, avocadoes, sugar snaps & mangoes dominate exports
- **High market demand locally and internationally** provides an opportunity to boost incomes and production via irrigation

Sources: Match Maker Associates. 2017. "Mapping of production of fruits and vegetables in Kenya"; Kenya National Bureau of Standards. 2017.
Note: 1) MT– Metric Ton

In horticulture, various PULSE products could add value by increasing production, enhancing quality, and reducing post harvest losses

	Production	Transportation & Storage	Transformation	Distribution & Retail
PULSE opportunity	**WATER PUMPS AND TRACTORS** • Pumps to irrigate produce • Tractors to increase efficiency by powering planters, sprayers and combine harvesters	**COLD STORAGE** • Cold storage facilities to reduce spoilage at farm/ first collection point • Cold chain transport to reduce spoilage in transit • Spoilage is ~10-30% depending on value chain	**DRIERS AND SMALL PROCESSORS** • Driers to convert produce into higher value dried forms • Solar-powered juicing/ pulping processors	**REFRIGERATION** • Commercial refrigeration units to allow vendors in remote areas to stock products for longer periods
Power capacity of sample products	 0.45-22kW  30-45kW	 1-10kW  1-5kW	 100-200W	 40-400W
Current small scale activity	• SHFs use both **labour and land intensive practices** • Grow a variety of crops **depending on season and market prices** • Women heavily involved in production & industrial farms	• May transport to markets using public transport, or produce is collected at the farmgate by brokers • Little use of cold storage, where available it is facilitated by off-takers		• Traders sell in local markets, off-takers sell to super-markets and some export • 3% of locally sold produce is sold in supermarkets the rest is through local markets (mostly women)

Sources: Dalberg interviews. 2018' GIZ. 2016. "Photovoltaics for productive use applications";
Note: Women provide ~80% of the French bean industry labour

Irrigation has high potential to increase incomes and food security; however, water access and technical capacity could hinder uptake

What are the incentives to invest?

There are four interrelated incentives to invest:

- **Increasing total incomes** by having higher yields and sales per hectare
- **Providing flexibility to produce out of peak season** to capture higher market prices, boosting overall yields and having higher volumes to sell
- **Improving certainty of income** and resilience to cushion against climate fluctuations
- For those currently irrigating (a minority of SHFs), **reduce operational costs of diesel pumps or time-burden of manual labour**

> *"The pump allowed me to extend the growing season so instead of just growing vegetables when it rains I also plant when it's dry when I can make more money" – **horticulture farmer***

What constraints are there to uptake?

Upfront costs	At ~$670, the **cost of a solar pump is 1.5x or higher than that of diesel.** Additionally, costs of additional equipment like **pipes, water tanks, and boreholes** (regardless of pump type) can **increase upfront costs by ~$600 or more**
Require access to ground or surface water	A prerequisite of pump viability is having a consistent supply of source water, either close proximity to surface water or groundwater at a reasonable depth
Technical capacity	In order to encourage uptake, there is a need for upfront market creation (pre-sale and post-sale support). Farmers need training to understand the best irrigation practices, how to operate the system, etc.

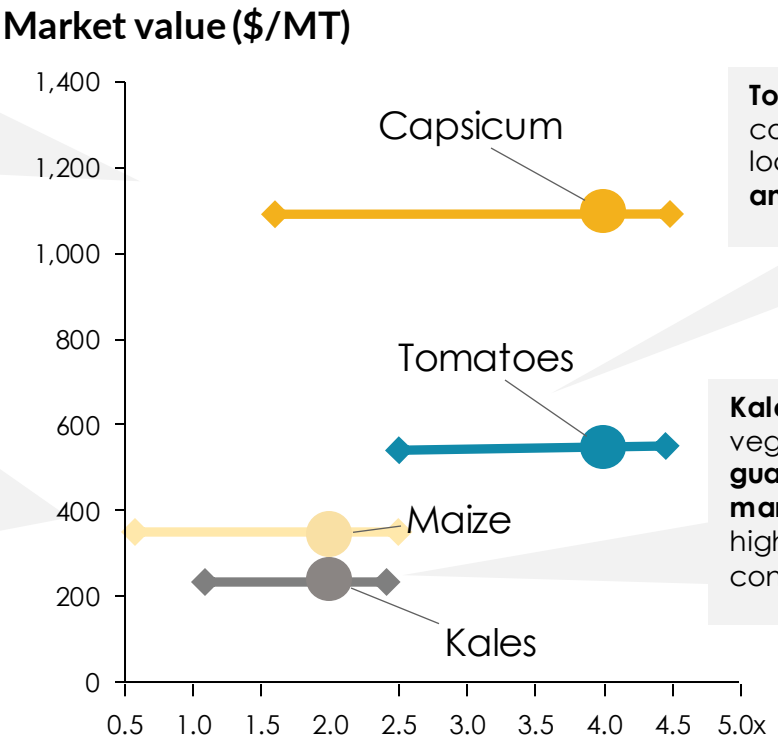
Source: Stakeholder interviews

To explore this further, four typical crops can be used to showcase the range of potential yield uplifts and motivations for irrigation

Yield uplifts and market value across crop varieties

Capsicum – less common, exotic and **higher value crop**; sell slower than more common vegetables like tomatoes and kales in local market, usually grown by farmers who have already secured a market with a bulk trader

Maize – **lower market value but key for food security;** in drier regions where food security is a major concern maize is irrigated to ensure food availability. In these areas, irrigation facilitates higher yields and production during more than one season



Tomatoes – one of the most common vegetables consumed locally; **offers guaranteed market and high market value**

Kales – one of the most common vegetables consumed locally; **guaranteed market but lower market value than tomatoes** and a higher percentage of production is consumed at home

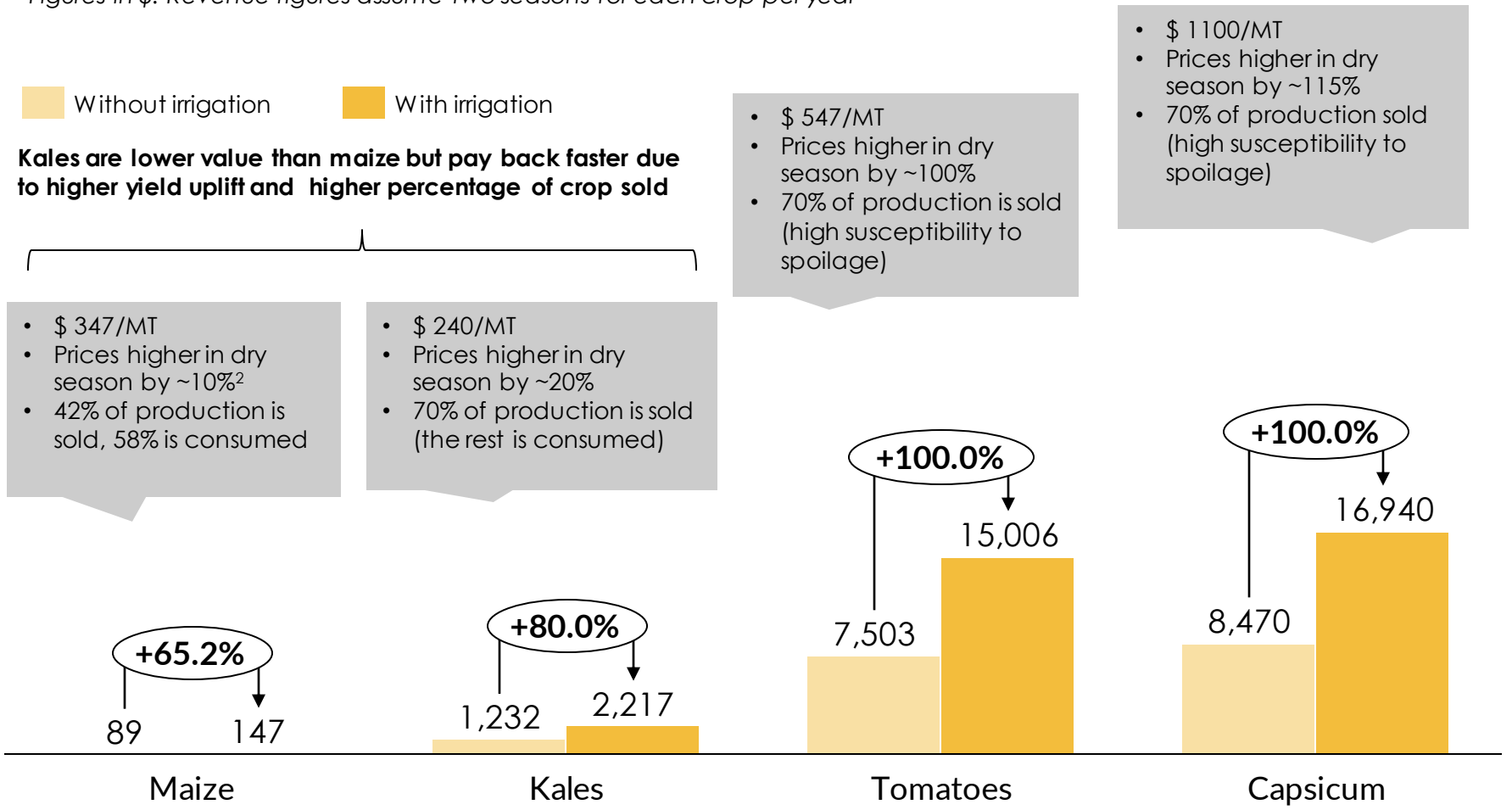
- All crops are sold locally and **easy to market** without having linkages to formal off-takers
- **Value is higher in the drier season due to scarcity***, there is strong incentive to irrigate at this time
- Yield uplifts vary, in Kenya farmers reported 200% or higher for vegetables and only 50% for maize.

Sources: 2030 Water Resources Group. 2016. "Agricultural and irrigation opportunity in Kenya"; Dalberg analysis and interviews. 2018.

Annual returns from irrigation are affected by crop value, commercial sales vs domestic use, and price fluctuations in the dry season

Impact of irrigation on annual revenue per acre by crop[1] (assumes each crop is grown on an acre)

Figures in $. Revenue figures assume two seasons for each crop per year



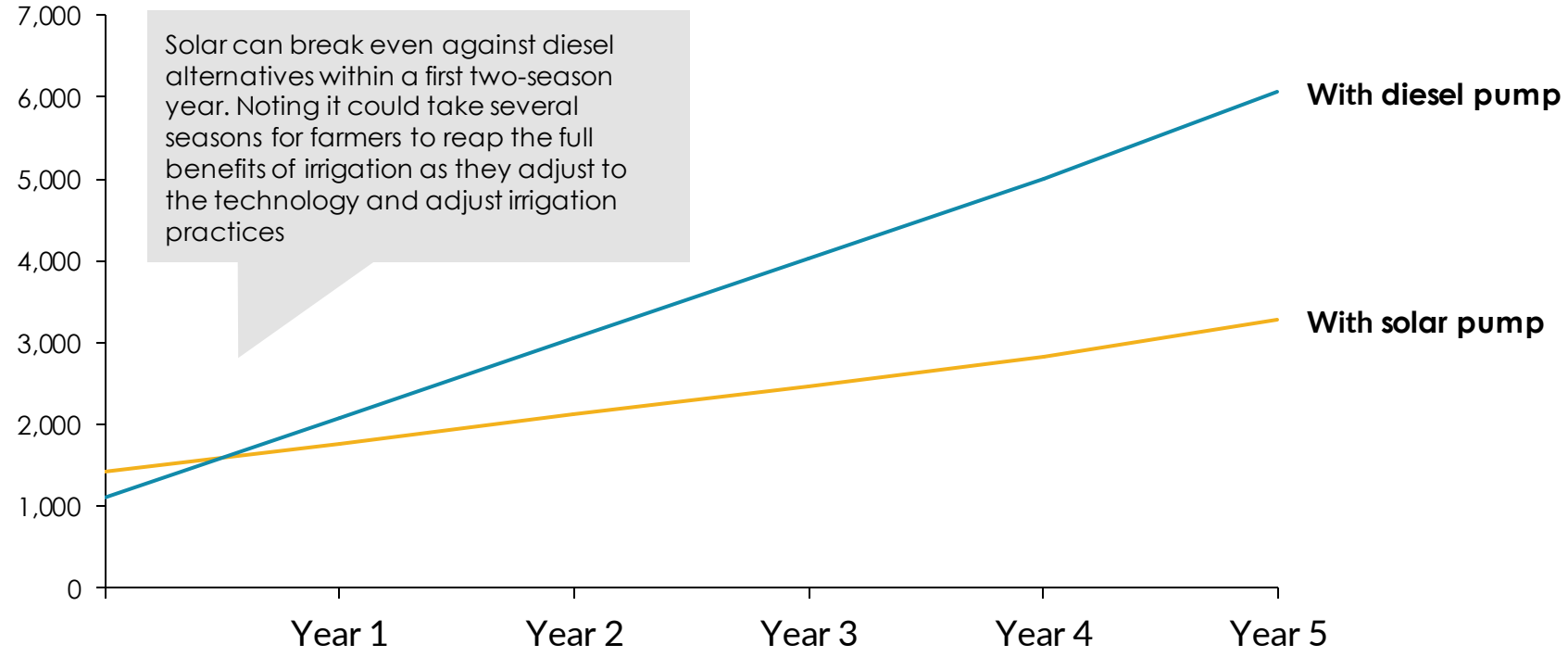
Note: even when conservative estimates for realized yield uplifts are used, irrigation still significantly boosts income

Sources: FAOSTAT. 2018; FAO. 2015. "The economic lives of smallholder farmers"; Dalberg analysis and interviews. 2018.
Note: 1) FAO estimates the average land size by smallholders in Kenya to be 0.47 hectares (~1 acre) 2) Assumes two seasons as most farmers with incentive to irrigate are in areas that grow in 2 seasons. 3) MT – Metric Ton

The upfront cost of a solar pump is 1.6x that of diesel-powered alternatives, but can have lower whole life costs after a single year

Five-year cumulative costs across a basket of crops produced on 1 acre[1]

Figures in $



Key assumptions

- **Product costs:** $670 for solar and $400 for diesel
- **Additional costs** i.e. shallow well, tank, and pipes: $620
- **Maintenance cost:** $67/year (solar), $100/year (diesel)
- **Fuel costs:** Fuel costs: $1.2/L; 2.5 L/day

Sources: FAOSTAT. 2018; Dalberg analysis and interviews. 2018.
Note: 1) Basket of crops includes maize, kales, tomatoes and capsicum, and assumes 0.25 acres for each crop 2) Maintenance costs for solar assumed to be 10% of upfront asset cost covering ad-hoc repair, system cleaning etc.

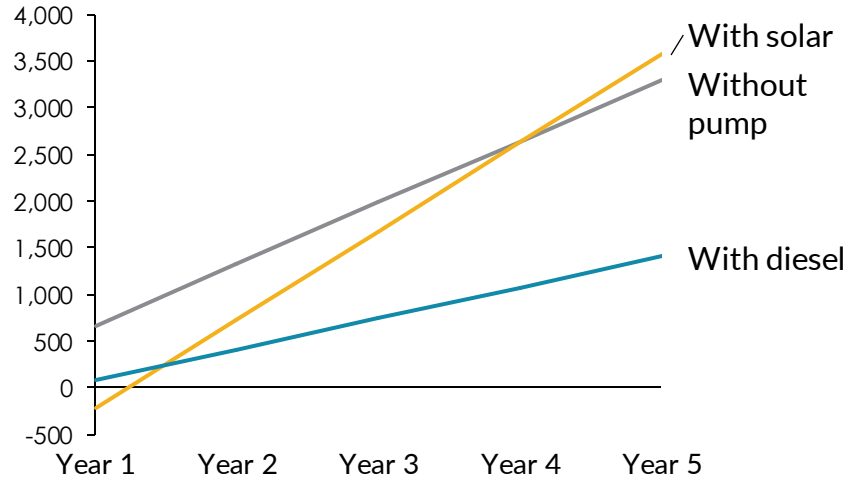
Solar outstrips diesel across crop values, however for low value crops or cases of high domestic consumption pumps payback more slowly

Most farmers grow a mix of crops depending on the season, for both consumption and sale. Solar is only marginally more beneficial than diesel when high value crops are grown; **the higher revenues cushion against fuel costs**

Five-year cumulative free cash flows for solar and diesel across a basket of crops produced on 1 acre

Figures in $

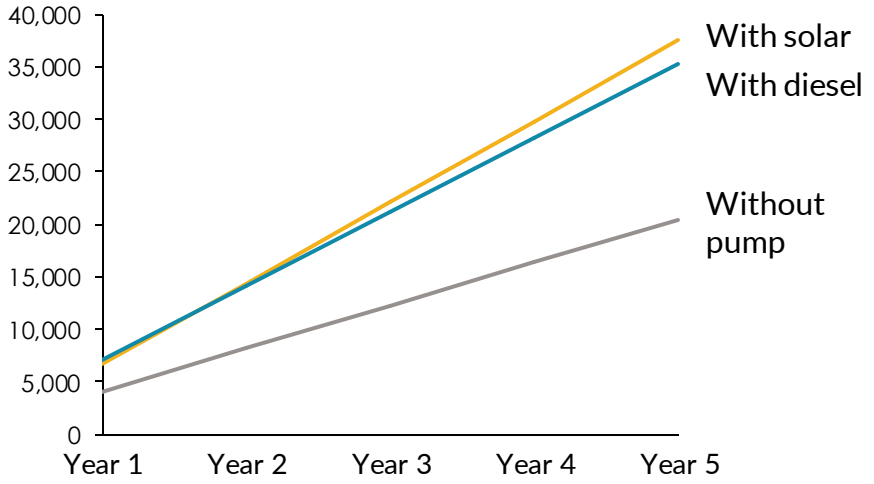
Maize* and kales (each on ½ an acre)



PAYBACK PERIOD

Solar: 23 months
Diesel: 52 months

Maize (¼ acre), kales (¼ acre), tomatoes (½ acre)



Solar: 3 months
Diesel: 2 months

Key assumptions:

- **Product costs**: $670 (solar) and $400 (diesel) with financing of 18% per year over 2Y, and after 20% is paid upfront
- **Additional costs** i.e. shallow well, tank, and pipes: $620
- **Maintenance cost:** $67/year (solar), $100/year (diesel)
- **Fuel costs:** Fuel costs: $1.2/L; 2.5 L/day
- **Crop value**: maize ($347) kales ($240/MT), tomatoes ($547/MT)

Source: Dalberg analysis and interviews. 2018.
Note: 1) MT – Metric Ton

The commercial viability and use cases of micro-irrigation are clear, but further measures are needed to accelerate uptake

FACTORS TO STRENGTHEN BUSINESS CASE			
	 **Select farmers based on potential horticulture offtake**	 **Select suitable scale of water pump**	 **Pre-sale support to help identify irrigation and technical needs**
	Incentive for farmers with guaranteed market	*Appropriate product selection maximizes benefits*	*Technical training improves viability*
EPXLANATION	• Farmers supplying off-takers have guaranteed market access • They are therefore **more likely to invest as income is assured** • It is also **easier for them to secure financing** (through the off-taker or financial institution) • For farmers currently not supplying to a guaranteed off-taker, **suppliers may need to be involved in helping farmers secure market**	• Farm assessments to determine appropriate pump type and equipment based on irrigation needs – **this would help avoid unnecessary costs that could increase payback periods** • Some suppliers are starting to look into providing systems with **modular capabilities to enable starting small and expanding land under irrigation** – farmers often start by irrigating a small portion and gradually increase it as their incomes grow	• Workshops, trainings, and demonstrations to build **product awareness** and **competency on operational requirements** have proven beneficial in the market • Pre-sale support by suppliers can yield stronger results when accompanied by a financier to provide capital and an off-taker to guarantee purchase of the produce

Source: Dalberg analysis and interviews. 2018.

KENYA MARKET **DEEP DIVE**

COOLING (DAIRY USE CASE)

Post-harvest losses cost the Kenyan economy $1.5 billion annually; a large proportion of this could be avoided with more cooling uptake

Cold storage needs in Kenya

- **Post harvest losses are ~20% of production**, a large proportion due to lack of proper storage & transportation
- Demand for cold storage is highest in certain value chains:
  - **Horticulture;** e.g. ~**10%** losses in tomatoes (**$ 20M** in 2017); **20-30%** in potatoes (**$ 197M** in 2017)
  - **Dairy; 7-33% losses** depending on level of formalization in the value chain (~**$ 120M** lost in 2017)
  - **Fish; 31% losses** but often overlooked due to lower contribution to the economy (<0.3 GDP contribution,. compared to e.g. 7% for dairy)
- Demand is largely unmet as cold storage is **mostly limited to high value, export value chains,** and formal retail markets in urban centers who use grid power

Existing models of cold storage supply for agriculture

Cold storage equipment supplier

Sells to aggregator **(dominant model)**

Sells or leases to farmer **(nascent model)**

Aggregator

- Common model: **aggregator purchases produce** and keeps it cool before selling/processing
- Common in horticulture, dairy and fresh meat value chains
- Emerging model: aggregator purchases cold storage facility and leases space out to the farmer for a fee

Farmer/retailer

- Supplier owns facility and **leases space out** to a retailer/farmer for a fee
- **Sales of standalone equipment are rare** due to cost, and in horticulture, produce is too bulky for small products
- In fish value chain, vendors sell ice to fishermen/traders

Cold storage and refrigeration suppliers focus on aggregators and formal value chains, reflecting the challenges of single ownership models for smallholder farmers

Sources: Kenya National Bureau of Standards. 2018; International Food Policy Research Institute. 2018. "Post Harvest losses in fruits and vegetables"; Dalberg analysis and interviews. 2018.

Incumbent grid solutions have limited uptake, and the range of small and micro scale solar cooling solutions are still at pilot stage

	Medium-scale applications	Small-scale applications	Very small-scale applications
Typical products & capacity			
	>2000 L	*201 – 2000 L*	*<200 L*
Degree of uptake	Grid: **Medium**; Solar: **Low**	Grid: **Medium**; Solar: **Low**	Grid: **Medium**; Solar: **Low**
State of play	• Co-ops and processors chill using grid (& diesel backup) • **Solar providers build customized walk-in cold rooms** and have done so for some dairy customers in Kenya, but their **sales are largely in horticulture** • Others are conducting pilots with aggregators, beginning sales in 2018	• Are usually standalone units as opposed to cold storage walk-in units that can hold numerous smaller containers • New entrants are providing small-scale grid-powered solutions for smaller aggregation points and transport • However, there is **a gap in solar options in the 200-1000L range**	• Some solar solutions are currently being piloted in Kenya, several are available for retail. Standalone **DC fridges are the most common of these** • On average the **smallest solutions hold ~50L**; smallholders at the lower end may need to **aggregate for financial viability**

Source: Dalberg analysis and interviews. 2018.

Multiple actors distribute standalone solar cooling equipment; those with larger walk-in cold rooms are mostly focused on grid solutions

Standalone fridges and freezers

- Distribute **small- and micro-scale solar fridges** and freezers
- Most common brand supplied is **SunDanzer; others include Minus 40, Beier, and Phocos**
- Common uses by clients are for home, small-scale retail, and hospital use in rural areas
- **None of the suppliers focuses solely on cold storage**, they also provide a range of solar products, including backup batteries, water heaters, charge controllers, and lighting systems

Cold storage / rooms

- Hoist Refrigeration provide Non-solar, standalone milk ATMs and dispensing machines that keep milk chilled. They also provide installation of grid-powered cold rooms
- Provides installation and maintenance services for domestic, commercial, industrial air conditioning and refrigeration solutions (chillers, cold rooms)
- Currently **provide grid solutions** but have capability to do **solar installations upon request**
- Thermoteq also provides ice block and ice cube making machines

Source: Company w ebsites

However, several solar cooling suppliers are working with aggregators and are gaining traction quickly, targeting horticulture and dairy

Organization	Size	Stage	PULSE products & services	Outlook
InspiraFarms	15 units sold	Integrated	**Product:** Cold storage walk-in units, 30 up to 1600 m^3, $ varies considerably with size **Services:** Custom facility design and development	Target aggregators in horticulture, de-prioritized dairy (as Kenya lacks premium quality payments) Addressing financing challenges for customers by lending directly
SunDanzer	>10K units sold/ year	Manufacturer	**Product:** Freezers/fridges, <200L, ~$700+ **Services:** Sell household, medical, commercial & military products	Increasingly working with development partners to support smallholder farmers and traders Piloted solar milk cooler in Kenya with USAID and GIZ
FreshBox	1 unit in pilot	Integrated (Pilot)	**Product:** Cold storage walk in units, 9 m3 – 90 m^3, ~$4500-$13000 **Services:** Lease space out to traders in urban markets	Looking to move to rural areas as losses are higher here Currently using grid solution and piloting a solar version for rural areas
Solar Freeze	1 unit in pilot	Integrated	**Product:** Mobile cold room (walk-in units), 26m^3, ~$15,000, in testing phase **Services:** Lease space out to farmers/traders	Using a full supply chain approach to help traders get produce to market E.g. to support milk dispensing ATMs for storage and sales

Sources: Dalberg analysis and interviews. 2018; Company websites. 2018.

At micro scale, certain demand and supply side factors currently make dairy use cases more compelling than horticulture

Supply side considerations

- **Cold storage for horticulture is currently focused on aggregators** – suppliers design equipment for horticulture cold storage at a scale that largely targets off-takers
- This equipment ranges from between **$20,000 and $30,000,** well beyond the income of smallholders
- Additionally, the power required of existing equipment in the market ranges from 4K to 10kW+. This is **above the 1,000W threshold in consideration** for products suitable for smallholder farmers in this study

Demand side considerations

- Fruits and vegetables at farmer level require a **high volume product at once (right after harvest),** whereas **milk and fish are produced and traded in small daily volumes**, all year round
- In horticulture, **a small fridge may make sense for a small-scale trader operating at small volumes daily, but traders have less incentive to invest** as they buy and sell daily, and can control spoilage based on ripeness of produce they buy
- Overall, the value proposition for cold storage for horticulture is higher for a farmer than a trader - the **farmer is more susceptible to price fluctuations**, usually has less bargaining power, and incurs **higher losses in case of weather issues** as they hold produce in the highest volumes

Current cold storage equipment designed for individual and micro-/small-scale use is unsuitable for horticulture farmers as their produce is bulky and it all requires to be stored at once

Sources: Dalberg analysis and interviews. 2018.

PULSE products could impact 1M dairy smallholders and boost rural incomes, support domestic production, and reduce spoilage

4.3M *Number of dairy cattle*

800K -1M *Number of smallholders*

6 – 8% *Contribution to national GDP*

25 - 50% *Level of spoilage at small-scale*

Dairy - Overview

- **Domestic demand is strong**, with 122 liters consumed per capita annually
- National milk production is 3.43 billion liters with **90% sourced from smallholder farmers**
- Making dairy a major income earner for rural communities
- Consumption is broken in formal (13%), informal (39%) and self household consumption (48%)
- These systems have varying degrees of cold storage with **implications for quality and spoilage**
- **Spoilage can reach 25-50% in informal markets**, compared to 6-7% in formal market

Sources: Odero-Waitituh J A. 2017. "Smallholder dairy production in Kenya"; USAID. 2014. "Kenya Agricultural Value Chain Enterprises dairy value chain analysis".

For dairy, solar energy could play a role across the value chain, but overall use at a micro-scale (even of incumbent solutions) is low

	Production	Collection & Storage	Transformation	Distribution & Retail
PULSE opportunity	**WATER PUMPS AND MILK EXRACTORS** • Pumps to increase access to ground water for livestock • Milk extractors to reduce time and labor costs of milking	**MILK CHILLERS AND COLD TRANSPORT** • Milk chillers to reduce spoilage at farm/collection point • Cold chain transport to reduce spoilage in transit	**SOLAR-POWERED PLANTS & SMALL PROCESSORS** • Opportunity in e.g. solar-powered mini-grids • Butter makers for value addition	**REFRIGERATION** • Household to commercial fridge units to allow vendors in remote areas to stock milk products for longer periods
Power capacity of sample products	 0.45-22kW 550W	 40-200W 1-5kW	 150-250W	 40-400W
Current small scale activity	• Few farmers use pumps to draw water. Milking is usually done by hand • **Women provide much of the production labour**, but men usually own the cows and control income	• Farmers transport in plastic containers by foot or motorbike • Cooperatives collect in **non-refrigerated pick-up trucks**	• **Little processing at micro-scale**; few co-ops produce yoghurt and other processed output • In some areas, evening milk is culturally considered the woman's milk, she controls distribution & sale	• Traders who are off-grid buy milk daily, **only those with grid access buy for overnight storage** and chill at point of sale

Sources: Dalberg analysis and interviews. 2018; GIZ. 2016. "Photovoltaics for productive use applications"

Milk chillers have high potential to improve farmer incomes by reducing milk loss to spoilage, but market access is a challenge

What are the incentives to invest?

- There are two farmer profiles, **those producing 1-8L/day and those producing 8 or more L/day**
- **Refrigeration increases the volume of milk sold** by reducing spoilage (spoilage can reach 25-50% in informal markets, compared to 6-7% in formal supply-chains)
- Both segments sell either to co-ops at $0.3-0.35/L, **or informally for $0.45-0.6/L**
- While the bulk of sales are done informally, co-ops/processors may offer **$0.01/L more for chilled milk**
- Chilling also provides **flexibility to sell milk to different markets** at a higher price
- While preserving milk for **sale at times when demand is higher**

"With a cooler I can keep the milk fresh so I can sell it the next morning. Especially in January and December, milk can even spoil daily because it is very hot." – ***dairy farmer***

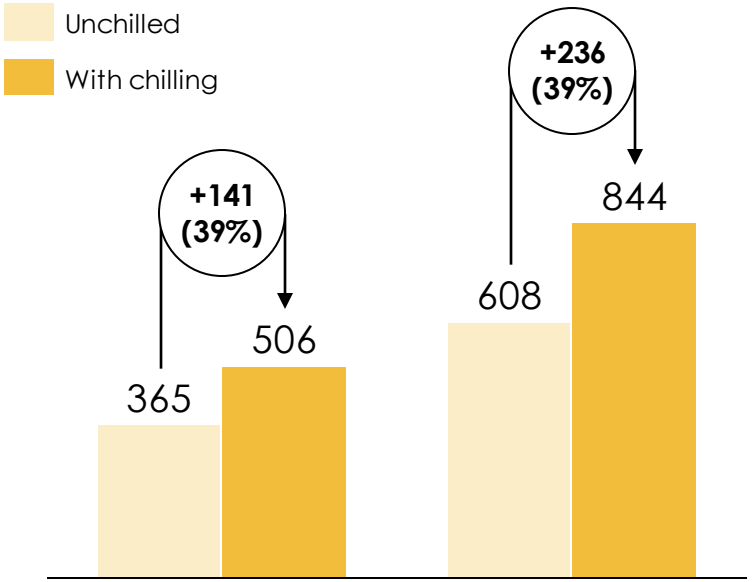
What are the constraints to uptake?

Upfront costs	At entry price of ~$800, affordability is a barrier e.g. for a farmer earning ~$36-72/month* from selling 4L/day. Making limited access to finance a barrier to uptake for smaller farmers
Transportation	Most **solutions are not mobile and do not address spoilage that occurs during transport**; this is an issue for farmers who reside far from co-ops/markets
Lack of incentives for quality	In Kenya there is **no incentive for quality** milk as in other markets. Though the Kenya Diary Board has been considering the introduction of a premium for quality
Commercial interest	For smaller cattle owners, dairy may not be the primary farming activity, so while an important source of household income **they do not immediately approach it as business**

Note: Assumes $ 0.3/L price for co-ops, and $ 0.6/L for informal market, with 10L sold daily for 30 days

Revenue increase from selling chilled milk varies based on the difference in spoilage rates, and prices offered by different markets

Annual revenue selling chilled vs. unchilled milk
(annual revenues in $)



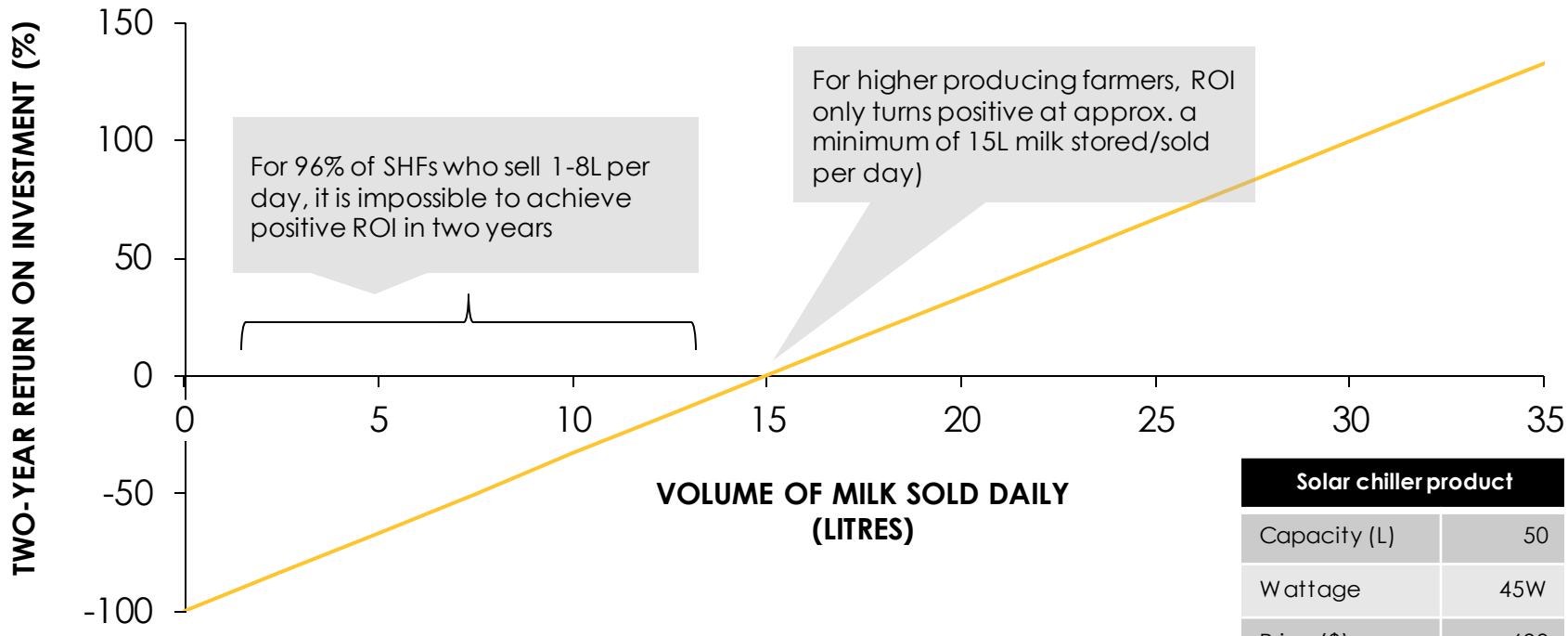
	Sold to the formal market	Sold to the informal market
% of SHF	**25%**	**75%**
Liters sold /day	**6**	**6**

- **% revenue increase varies based on extent of reduction in spoilage** – in this case from 33% losses common in the informal value chain to 7% observed in the formal channels
- As there is no premium for chilled / quality milk in Kenya, the **value from milk cooling solutions is in their ability to boost the total volume of marketable milk**
- Those selling to the informal market would realize higher revenues due to better prices ($0.5/L vs $0.3/L offered by co-ops)
- **While the analysis shows a farmer selling 6L/day (~10% of farmers), the majority of SHF (87%) sell 1-4L a day;** they produce enough milk for household consumption and some surplus for sale

Sources: Njonge F. 2017. "Challenges faced by smallholder dairy farmers in Kirinyaga county"; Dalberg analysis and interviews. 2018.
Note: Farmers sell at $ 0.3/L to cooperatives, and 0.5/L to the informal market.

However, solar chillers do not appear viable for the majority of SHFs; positive ROI for these chillers are only achieved at 15L daily sales

Minimum volume sold to achieve positive ROI over 2 year period



Solar chiller product	
Capacity (L)	50
Wattage	45W
Price ($)	699

Aggregation (cost sharing) between only 2-8 smallholder farmers is required for positive returns on investment, depending on farmer productivity

Source: Dalberg analysis and interviews. 2018.

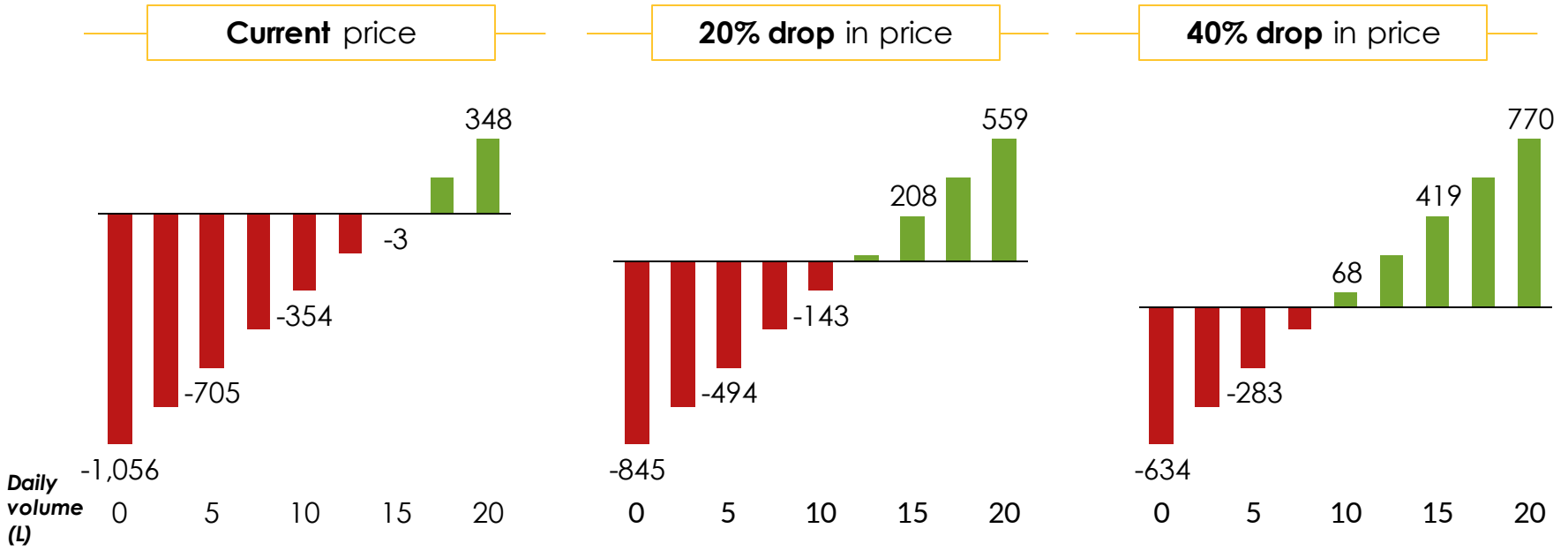
Even if solar chiller price reduces by 40%, SHFs selling 5L/day would only be able to pay back the asset in ~4 years

Two-year net operating income by product price*

X-axis = Volumes sold. %; Y-axis: operating income in US dollars ($)

Negative ROI

Positive ROI and payback period <= 2 years



PAYBACK PERIOD	Current price	20% drop in price	40% drop in price
	72 months @ 5L/day	58 months @ 5L/day	43 months @ 5L/day
	36 months @ 10L/day	29 months @ 10L/day	22 months @ 10L/day

Source: Dalberg analysis and interviews. 2018.
Note: Product price without financing = $804. Financing costs are 18% compound interest over 24 months. The economic analysis assumes 25% sales to a to-operative and 75% sales to the informal market. In reality, those selling to co-operatives will have lower

Factors which could reduce payback periods include: aggregation, premium pricing for quality, and targeting farmers in hot regions

FACTORS TO STRENGTHEN BUSINESS CASE	Promote farmer aggregation – with a caveat	Help boost milk quality and introduce premium pricing	Target dairy farmers in hot regions
	Cost-sharing to improve product viability	*Lower rejection rates in formal markets*	*Compelling value prop. around spoilage reduction*
EPXLANATION	• **Farmers with low daily production (e.g., 5L per day) could pool together to purchase a small cooler at current prices** – and pay back their share of the product costs within 1 year • **However, aggregation is likely easier through cooperatives, which pay a lower price per liter for the milk.** Co-op prices would need to increase for this case to be attractive to farmers	• While Kenyan farmers do not access a premium today, **better quality milk can help keep the rejection rates low (critical to the investment case)** • This is particularly the case for farmers who sell to cooperatives, which are more selective about product quality • Initiatives to secure a premium for chilled milk would also **incentivize investment by farmers supplying to formal channels**	• **Farmers in hot regions are more susceptible to milk spoilage** • The value proposition for chilling would be particularly compelling to these farmers, as the **percentage increase in revenue from chilling would be higher** • **However, productivity** is largely determined by **feed quality.** The **cost of feed and availability of pastures** is an exogenous barrier to increased production

Source: Dalberg analysis and interviews. 2018.

KENYA MARKET **DEEP DIVE**

AGRO-PROCESSING (MAIZE USE CASE)

Agro-processing in Kenya typically occurs after aggregation in on-grid systems; PULSE could help reduce minimum viable scales of products

State of play

- Agro-processing in Kenya is a $3.25B market with 85% of it focused on the domestic market
- Agro-processing in the export market is dominated by fruits and vegetables (though levels are still low, with **only 16% of these being processed before export**)
- In the local market the leading value chains in agro-processing activity are maize, sugarcane, and wheat
- Activities are concentrated at an industrial level for most value chains, except for maize, where the small-scale ("posho")* mill market is larger than the commercial maize flour market

Characteristics of the domestic agro-processing market

Industrial processing

- **Ownership:** run by private entities and in some cases parastatals may have an ownership stake
- **Business model:** purchase produce from farmers (aggregate), process and sell higher value finished product
- **Opportunity for solar:** using solar to feed into overall power supply as opposed to standalone solar processors due high power requirements

Small and micro scale processing

- **Ownership:** owned by an entrepreneur, usually a wealthier person in the locality serving a few hundred households
- **Business model:** offer processing as a service and charge a per kg fee. In peri-urban/low-income urban areas may sell finished product
- **Opportunity for solar:** solar technologies could enable decentralized services to more remote populations, by reducing transport and operational costs

Both solar and non-solar small-scale innovations could increase viability of agro-processing closer to the farm, and facilitate extra income through value addition

Source: World Bank. 2015. "Agriculture and food processing in Kenya"
Note: "Posho" mill refers to the artisanal maize mills

Small- and micro-scale grid and diesel machines are common in small towns / market centers; solar options are only present in a few pilots

	Medium-scale applications	Small-scale applications	Very small-scale applications
Typical products & capacity	 *No solar products in Kenyan market operating at >5MT/day*	 *No solar products in Kenyan market operating at 2-5MT/day*	 
	>2 MT/day	***1-2 MT/day***	***<1 MT/day***
Degree of uptake	Grid/Diesel: **High** Solar: **Low**	Grid/Diesel: **High** Solar: **Low**	Grid/Diesel: **High** Solar: **Low**
State of play	• Largely in use in industrial applications where high volumes are processed to meet demand in the **formal retail market** • There are no solar products in Kenyan market operating at >5MT/day	• Current grid- and diesel-powered solutions are based in **small towns and large market centers** where demand is high • There are no solar products in Kenyan market operating at 2-5MT/day	• Grid- and diesel-powered solutions are common in **small market centers** where demand is lower than in small towns • Some solar solutions are currently **being piloted** in Kenya. These are 5-6x less efficient than the smallest diesel/grid competitors

Source: Dalberg analysis and interviews. 2018.
Note: The range of agro-processing machines includes maize mills, threshers, sugarcane processors, oil presses, rice hullers nut processors, coffee processing machines, chaff cutters, etc.
Note: 1) MT– Metric Ton

There may be opportunity for solar suppliers to access the market by partnering with distributors already providing incumbent products

Suppliers of grid- and diesel-powered products

Current suppliers consist of a mix of those manufacturing equipment in-country and those importing assembled products to on-sell. Some focus on agricultural equipment while others have a wide range of equipment outside of agriculture. A few examples are highlighted below:

Have a **focus on agricultural equipment** and manufacture locally. Supply maize mills, shellers, hullers, polishers, nut processors, silage choppers, mixers, and chaff cutters

Supply a range of **agricultural and small-scale industrial equipment**. Supply maize mills, chaff cutters, concrete mixers, generators, and wood work and welding machines

Supply a range of **agricultural and industrial machinery,** e.g. maize shellers, mills, destoning machines, juicers, coffee processing machines, oil extractors, water pumps, harvesters, and tractors

Supply **agricultural and construction machinery**. Products include maize mills, forage choppers, fodder processors, hay balers, bale shredders, maize shellers. milking machines, pumps, and ploughs

Supply coffee and grains machinery including pulpers, dehuskers, hullers, polishers and driers

Suppliers of solar products

Organization	Size	Stage	PULSE products & services	Outlook
Agsol	>200 units in other markets, pilot in Kenya	Manufacturer	**Product:** Maize mill, 50kg/h, $1800 **Services:** B2B sales of mill (to other solar companies)	Working with SHS companies with strong retail networks & customer base Not aiming to replace diesel mills but to reduce distance to mills for smaller villages (300-500 HH)[1]

Sources: Dalberg analysis and interviews. 2018. Company websites

Many suppliers provide processing products for the maize sector, an important staple, that involves ~98% of Kenya's 3.5 million SHFs

3.5M *Number of smallholders*

70% *Average acreage under maize for a smallholder*

90kg *Annual per capita consumption*

58% *% of maize produced by SHFs consumed at home*

Maize - Overview

- Production is 3.3M tons annually, **70% produced by SHFs who grow on an average of 0.8ha**
- Yield is around the SSA average (1.8MT/ha), but the country **imports maize from neighboring countries almost annually** to meet consumption
- **Most maize is milled at a consumer level by local "posho" mills**; industrial mills produce sifted flour for formal retail markets
- At $ 685M, the posho mill market is **67% of the maize milling market and 21% of Kenya's agro-processing market**
- **78% of rural households consume posho meal**, only 22% consume sifted flour; opportunity for solar mills if they can provide time or cost savings to incumbent diesel mills

Sources: International Maize and Wheat Improvement Center. 2015. "Drought tolerant maize for Africa"; Kamau. 2017. "Maize value chain development for poverty reduction in Bungoma county, Kenya"; Dalberg analysis and interviews. 2018.

The maize sector offers significant opportunity for PULSE products to boost yields, reduce losses, and provide alternative processing options

	Production	Storage & preservation	Transformation
PULSE opportunity	**IRRIGATION PUMPS AND TRACTORS** • Pumps to irrigate maize in dry seasons • Tractors to increase efficiency by powering planters, sprayers and combine harvesters	**DRIERS AND SILOES** • Driers to reduce high moisture content which usually leads to spoilage • Siloes to preserve/keep grain dry for extended time periods	**THRESHERS, MILLS AND DRIERS** • Threshers to remove maize grains from cobs • Driers to further reduce water content after threshing • Mills to produce flour, or animal feeds
Power capacity of sample products	 0.45-22kW  30-45kW	 100-200W  Varies based on size up to~350Kw	 100W  0.75-2.4kW
Current small scale activity	• Most farmers grow maize once a year, **planting during the long rainy season**. In drier areas some farmers irrigate maize • Women account for ~61% of smallholder production	• Drying is done under direct sunlight. Short rains season occurs during harvest or drying, causing spoilage • Brokers offer **lower prices when moisture content is high,** as they have to incur additional drying costs	

Sources: Dalberg analysis and interviews. 2018; GIZ. 2016. "Photovoltaics for productive use applications"
Note: Solar-powered trucks are in testing, with benefits including powering air conditioning, refrigeration, liftgate operations, and less in providing fuel savings.

Solar milling provides an opportunity for entrepreneurs to address a large market, and provide time and cost savings for customers

What are the incentives to invest?

- Target buyer is a wealthier individual in the village, whose mill would serve smallholders
- There is strong demand for milling & threshing. Threshers are deprioritized as existing solutions are mobile and provide the convenience of on-farm services that diesel mills currently do not
- Farmers typically **walk to market centers** to mill, travel distance is ~500m to 3km and can go up to 5km. The target users are **off-grid communities greater than 2km** from the nearest diesel mill[1]
- Milling is done by women or children, for whom **time costs could be reduced by having a solar mill closer to home**
- **In very remote areas, solar mills would also reduce transport costs.** Bicycles and motor-cycles are often used, and costs could go up to $ 2.5 per round trip[2]

> *"If the solar mill was close to home that would be easier for me when the children are in school, I wouldn't have to go far – **maize farmer***

What are the constraints to uptake?

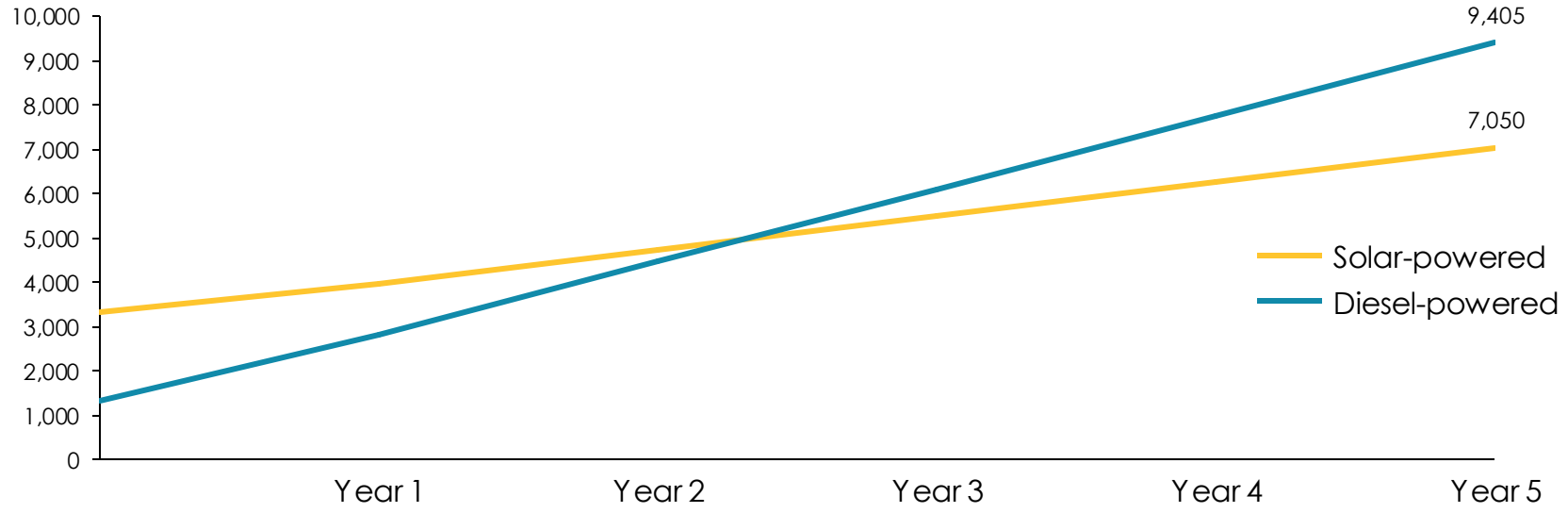
Upfront costs	Solar mills are **~2x or more the cost of diesel** mills. **Minimum price** of a solar mill is **$1,800** and could go up to **$3,300**
Efficiency of solar	Solar mills have lower performance than diesel ones in terms of 1) **peak processing capacity** (8-10x lower than the smallest diesel mills), and 2) **efficiency in cloudy & rainy** weather. A small diesel mill can do ~1100 MT annually at 8h/day, but **solar can only do ~110MT**
Low farmer aggregation	Solar mills could be targeted at farmer groups or co-operatives, but the maize value chain in Kenya lacks co-operatives or strong farmer aggregation dynamics

Source: Dalberg analysis and interviews. 2018.
Note: Agsol's field research identified that 2km is the distance at which walking becomes a pain point for customers. MT – Metric Ton

A solar mill may be the more attractive option for remote customers, and become cheaper than a diesel mill after two years

Five year cumulative annual product + operating costs for solar vs. diesel

Figures in USD dollars ($)



Key assumptions

- **Product costs**: $ 3,250 (solar); 1,350 (diesel), with financing of 18% per year over 2Y, and after 20% is paid upfront
- **Revenue/MT:** $ 50 (~$0.05 per kg market price for milling as a service in Kenya)
- **Annual operating days:** 310 for solar, 365 for diesel i.e. both the solar and diesel mill operate for 6h/day, but solar mill only operates at 40% effectiveness for ¼ of the year (translating to 310 6h days or annual utilization of 85%)
- **Quantity milled:** 83MT per year i.e. annual capacity of a solar mill based on 75% utilization (75% of annual days)

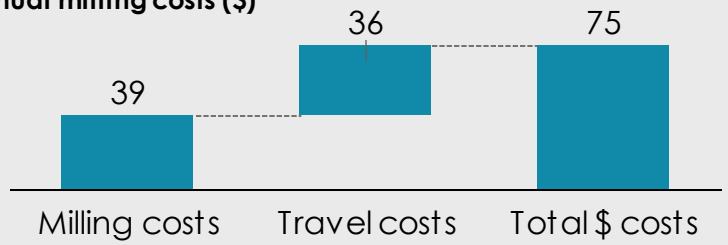
While these long-term economics of a solar-powered mill look favorable, due to capacity limitations solar millers will likely serve a more localized market for more remote villages

Source: Dalberg analysis and interviews. 2018.
Note: 1) MT– Metric Ton

Solar products could bring services closer to home; convenience, affordability, and quality can affect customer willingness to pay

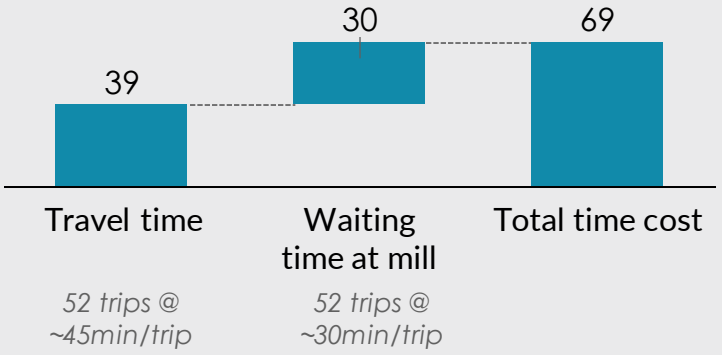
Sample household costs in terms of money & time

Annual milling costs ($)



Annual time costs (hours)

Note: walking to mills is common so a solar product is likely to save more time than money



Implications for pricing of solar milling services

Charge more – customers may be willing to pay for **convenience of shorter travel distances**. Diesel mills have a catchment of 3-5km and walking distances of >2km are a pain point. Round-trip time per km is ~1 hour (foot) and 30 min (bike) or up to KES 250, excluding waiting time (~30 min on average)

Charge the same – customers may be insistent on current market pricing. The target user segment is **extremely price sensitive and may not be willing to pay more**, particularly if time costs are not considered a significant loss

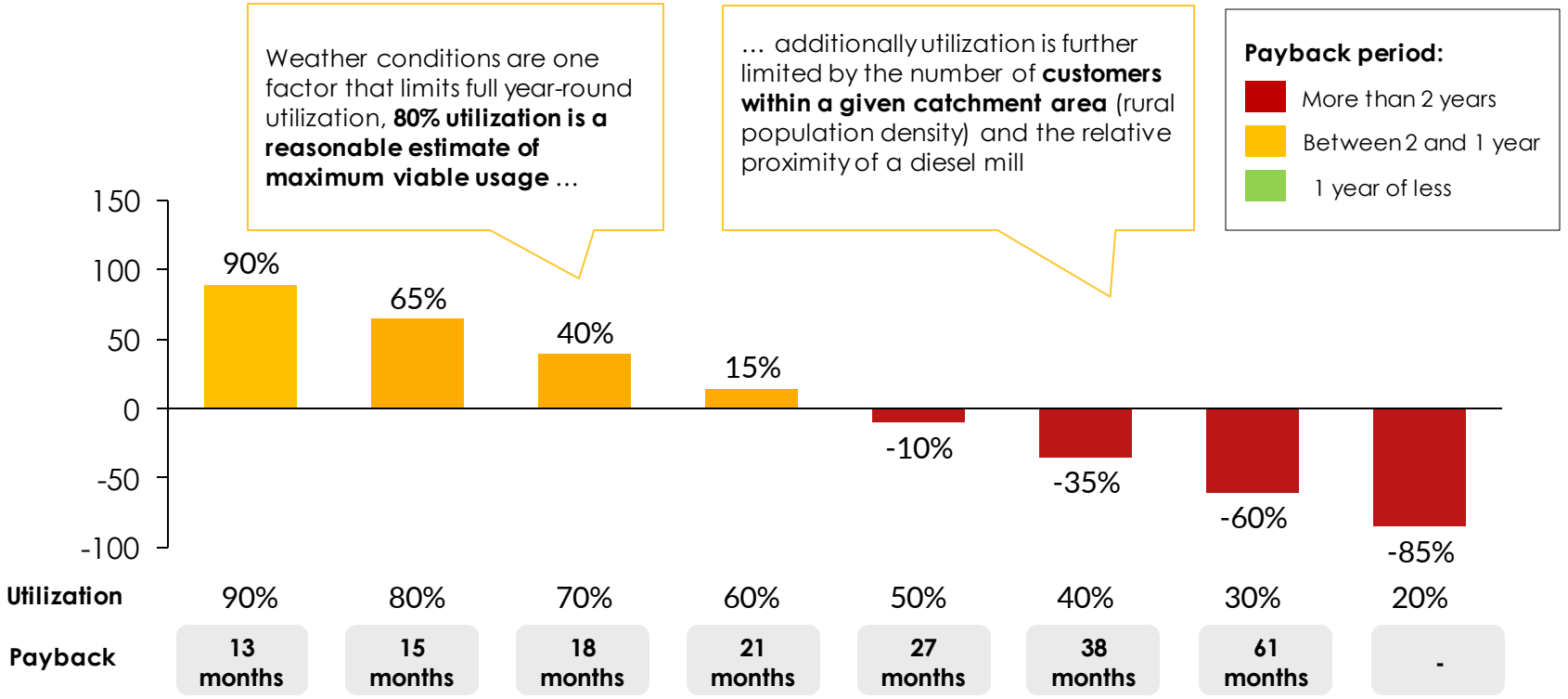
Charge less – customers may be unsure about quality of solar equipment. F**ineness of the maize flour is valued**, if the quality of the solar mill is not at par with that of alternatives, users may want to pay less

Source: Dalberg analysis and interviews. 2018.
Note: 1) Spend per trip varies greatly depending on distance from mill, $ 0.7 is used as an approximation, and average distance travelled ranges from 500m to 5km. In reality, many people walk to mills and time costs are a bigger factor than travel costs.

Seasonal capacity and customer catchment will limit utilization, should 60% (66MT) be achieved a solar mill can payback in 2 years

Two-year ROI and payback periods at different utilization points

X-axis: Utilization: Y-axis: Two-year ROI in %. Current service fees = $50 per MT



Higher service fees above $50/MT might be paid due to added convenience of nearby mills; however the target population is extremely price sensitive

Source: Dalberg analysis and interviews. 2018.
Note: 1) Milling is offered as a service. Households pay per kg for the crops milled. Analysis assumes financing costs of 18% per year. 2) For cost and revenue assumptions refer to the previous two slides 3) MT – Metric Ton

A solar mill needs to serve 104 households to reach 85% utilization (94MT/year), which requires population dense areas to be viable

Number of households served per mill required for 85% utilization

94 MT volume/year[1]

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0.9 MT/farmer[2] (average yield of 1.6MT per year of which 58% is consumed at home)

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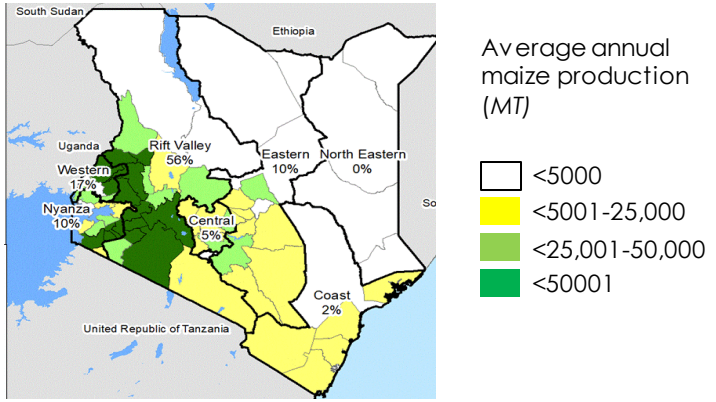
104 households/year or 470 people/year

Ideal regions to market a solar mill



- While average rural population density provides a view on minimum area required for commercial viability, in reality a solar mill will be **most viable in regions where maize production (and consumption of posho meal) is highest**
- **Western Kenya and the Rift Valley regions** have the highest maize production. They also have high population density, and are therefore ideal target regions

Sources: FAO and World Bank population estimates. 2018. Dalberg analysis and interviews. 2018.
Note: 1) Volume that a solar mill can process in a year at 85% utilization (expected maximum utilization in a year) 2) MT– Metric Ton

KENYA MARKET **DEEP DIVE**

POLICY ENVIRONMENT

The tax regime favors solar and PULSE products, but costs will rise if the recent proposal to re-introduce VAT on solar products is approved

TAXES, DUTIES & SUBSIDIES

- **VAT on all solar products** was removed in 2014 to reduce cost to consumers
- In 2018 the Treasury filed a motion to **reintroduce VAT on solar products;** following a unified decision with other East African countries
- The move is partially informed by the governments view that not all suppliers have been passing benefits of the VAT exemption to consumers in their pricing
- Kenya **does not provide any other incentives or subsidies for solar PV systems**
- Irrigation **equipment is exempt from customs duties and VAT**, spare parts are subject to 16% VAT
- Other **incentives for irrigation** include capital deductions and investment allowances

Parameter	Solar Products	Diesel/Grid Products	Agriculture Equipment
Import Duty	0%	~25%	0 (I) 25%(L)[1]
VAT	0%	16%	0 (I) 16%(L)
Other levies	2.25% (IDF) [2]	2.25% (IDF)	2.25% (IDF)
Subsidies	No	No	No
Incentives	No	No	No

BROADER POLICY ISSUES

Energy & solar

- **Rising costs of alternative energy sources:** The government has introduced **8% VAT on petroleum** in 2018, with plans to increase this to 16% by 2020. A **43% excise duty on kerosene** has also been introduced. This offers a platform to push for solar solutions in certain industries, to reduce operational costs
- **Costs of compliance**: Complexity, bureaucracy, and costs of getting certificate of conformity for bringing new or sample products into the country are prohibitive for smaller companies, particularly those supplying multiple products and conducting pilots of different prototypes

Agriculture

- **Local manufacturing vs imports:** Local manufacturers pay VAT on materials, importers of assembled equipment do not, making local manufacturers less competitive. This **may hinder long-term local manufacturing**

Co-ordination/Cross-sector

- PULSE products in agriculture intersect the jurisdictions of different government actors in energy, agriculture, & water
- A coordinated approach to policy is therefore needed to realize the most comprehensive and impactful results

Sources: Kenya Climate Innovation Centre. 2018. "Kenya Solar PV Market Assessment"; USAID. 2016. "Drip irrigation in smallholder markets"; Kenya Revenue Authority. 2018.; Dalberg analysis and interviews. 2018.
Note: 0% for imports but 16% (exempt) for local manufacturers. 2. IDF = Import Declaration Fee.

ZIMBABWE MARKET **DEEP DIVE**

SECTION SIX

ZIMBABWE MARKET **DEEP DIVE**

IRRIGATION (HORTICULTURE USE CASE)

Land reforms and a changing agricultural landscape has opened up smallholder production opportunities in Zimbabwe, which solar irrigation could help to fill

Land reforms disrupted agricultural production in the country …

- **The launch of the Fast Track Land Reform Programme (FTLRP) in 2000 disrupted the country's agricultural production.** E.g., between 2000 and 2002, the production of cereals in the country dropped by 36%
- **Over 10M Ha of large commercial farms land was distributed** into A1 (150,000 households, 4.2M Ha) and A2 (20,000, 2.7M Ha) farms
- **This introduced many small-scale farmers into production systems,** often unsupported by institutions such as co-operatives and farmer unions

…and left existing irrigation infrastructure largely unsuitable …

- In recent years **private and public organizations** have supported SHFs, and productivity is rising. E.g., in 2016, A1 and A2 farmers increased their maize production by ~300%.
- However, **many farms are still undercapitalized with low levels of production**, and low utilization of land
- <50% of existing irrigation systems on resettled land are suitable for small-scale activities. After land reforms, about 72, 000 Ha of developed irrigated land collapsed and its existing irrigation equipment is now neglected

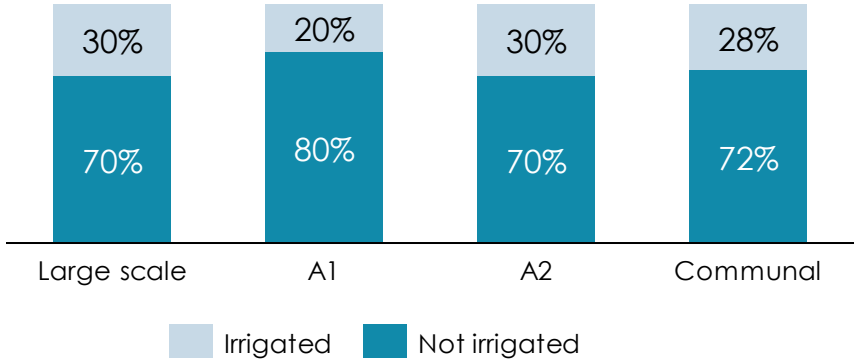
… which could be addressed through small-scale irrigation

- There are still **significant productivity challenges on the resettled areas.** Given a willingness of government to push forward SHF farming development, investment in irrigation for this target demographic is opportune
- **Smaller scale pumping solutions, integrated with existing solutions or new alternatives, can help boost productivity**
- Despite the relatively large land size, **expanding SHF irrigation will likely begin at smaller scales (.5 – 1 Ha)** within existing plots, in part due to the limited finance available to SHFs

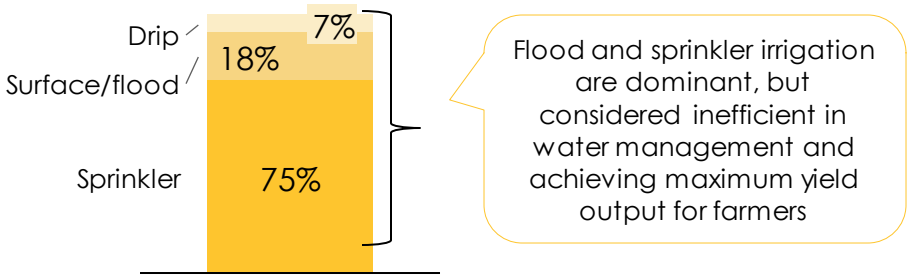
Sources: World Bank. 2018; Zimbabweland. 2018; The Herald. 2017; Dalberg analysis and interviews. 2018.
Note: A1 and A1 land designations are typical land categories in Zimbabwe following land reform policies (A1 – small-scale settlements, A2 – Small farms)

Smallholder irrigation in Zimbabwe is very limited, despite the availability of water across key agricultural regions

Irrigated land in Zimbabwe by scheme typology



Types of irrigation practiced in Zimbabwe



Flood and sprinkler irrigation are dominant, but considered inefficient in water management and achieving maximum yield output for farmers

Irrigation needs in Zimbabwe

- Zimbabwe has sub-tropical climatic conditions and only one rainy season between November and March. **Only 37% of the country receives rainfall adequate for agriculture**
- **However, the country holds 60% of all the dammed water in southern Africa,** including Kariba dam, the world's largest dam based on water capacity. Internal renewable surface water resources are estimated at 11,260 million m³/year and renewable groundwater resources at around 6,000 million m³/year
- **Less than 50% of the area equipped for irrigation in Zimbabwe is currently under irrigation,** this unutilized infrastructure requires rehabilitation. Also, 3% of SHFs produce using irrigation
- **Prior to the land reforms, irrigated crops contributed to half of the crops marketed in the country** with different cropping systems and economic models prior to land redistribution

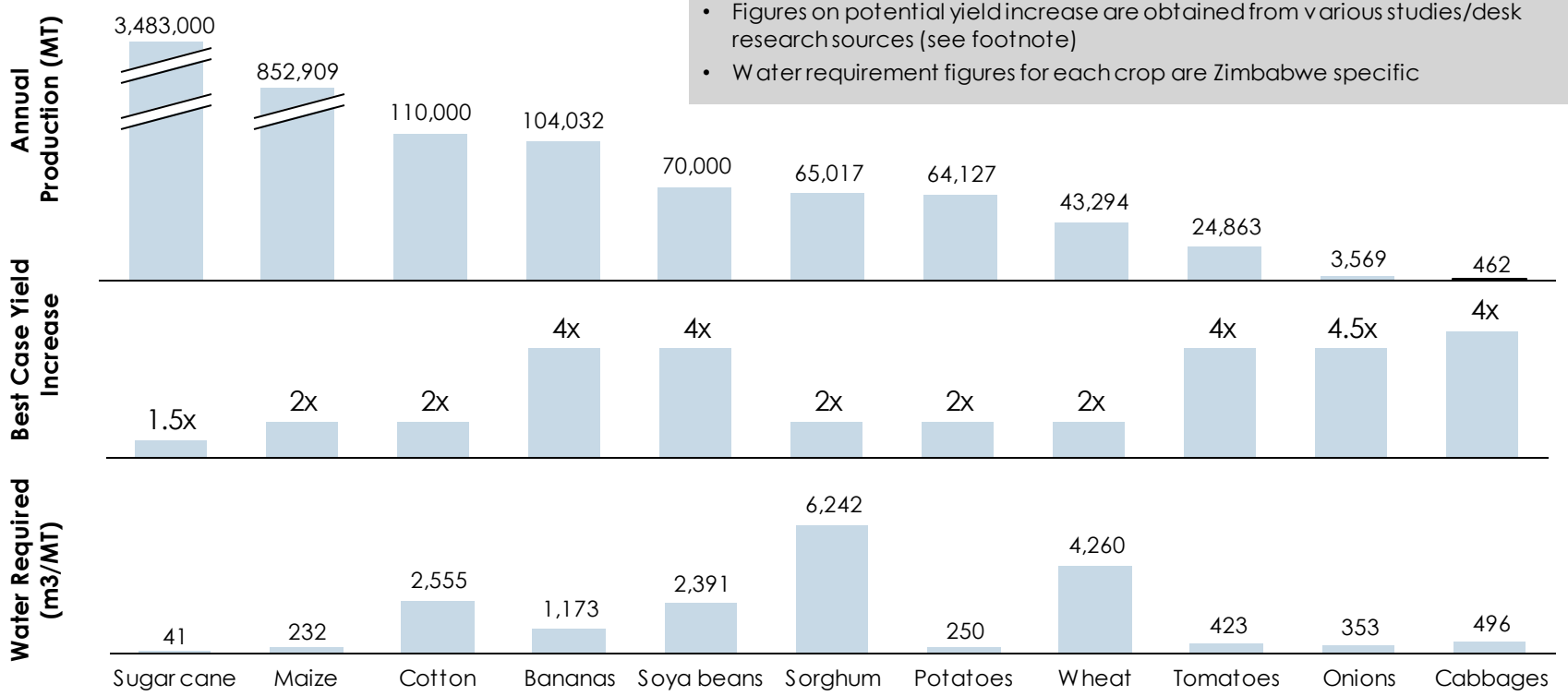
There is a lot of potential in the country to bring more arable land under irrigation, as well as to switch to more efficient irrigation systems, an opportunity which solar pumps can address

Sources: International Centre for Tropical Agriculture. 2010. "Livelihoods after land reform in Zimbabwe"; Poulton et al. 2002. "A review of Zimbabwe's agricultural economic policies"; FAO. 2015; AQUASTAT. 2016; The Fish Site. 2018; Masiiwa. 2004. "Post independence land reform in Zimbabwe"

Efficient irrigation has the potential to significantly increase the production of the main crops grown in Zimbabwe

Comparison of annual production, potential for yield increase, and water requirements

- Crops highlighted are crops with the highest production volumes in the country
- Figures on potential yield increase are obtained from various studies/desk research sources (see footnote)
- Water requirement figures for each crop are Zimbabwe specific



Both the potential for yield increase and the water requirement of crops are important considerations underpinning the commercial viability of use cases, especially at a micro-scale

Sources: FAOSTAT. 2016; Mekonnen, M.M. and Hoekstra, A.Y. 2010. "The green, blue and grey water footprint of crops and derived crop products"; Various desk research sources; Dalberg analysis and interviews. 2018.
Note: 1) MT – Metric Ton

Awareness on solar products is growing but still under-penetrated; incumbent technologies have much wider reach

	Medium-scale applications	Small-scale applications	Very small-scale applications
Typical products & capacity	 	 	 
	2->5ha	*1-2ha*	*<1ha*
Degree of uptake	Grid/Diesel: **Medium**; Solar: **Low**	Grid/Diesel: **High**; Solar: **Medium**	Grid/Diesel: **High**; Solar: **Medium**
State of play	• Large-scale diesel machines are commonly found around communal farms and resettled irrigation schemes • There are limited large-scale applications for solar in the market. Primarily, this is the segment of pumps that are neglected and are in need of replacement or adaptation	• Both diesel and solar applications for small-scale farmers are readily available with an increasing number of suppliers in the market • There are a few key solar suppliers in the market who largely serve peri-urban players	• There are a number of established diesel suppliers in the market • There are some solar equipment suppliers who provide small-scale farmers with flexible payments and technical assistance. Solar suppliers have multiple branches across the country in order to capture more rural markets

Source: Dalberg analysis and interviews. 2018.

Zimbabwe has a number of solar pump importers and distributors in the market (1/2)

Organization	Type	PULSE products & services	Outlook
Samansco	Distributor	**Product:** Lorentz pumps, Suntec and Trina panels, Deco batteries, Morningstar controllers, Schneider lanterns (*African Energy*) up to 1hp **Services:** provide 90-day credit to customers	Initially focused on rural areas but looking at urban areas as well Have 200 dealers in the country and looking to expand.
Solarpro	Importer	**Product:** Shurflo 9325-043-101 Submersible DC Pump **Services:** provide delivery across Zimbabwe, accept online payment as well as evaluation design and monitoring services	Have been in operation for 3 years Import directly from manufacturers and mainly target the urban market and smaller pump sizes.
Solar shack	Importer	**Products:** varying sizes of panels, water heaters and water pumps (*Magnum, Genus, Su-kam, African Energy, Grundfos, Power bank, Shurflo*), ~400W **Service:** provide training sessions to dealers	Operating for ~10 years Partnering with bigger companies to distribute in remote areas Partnering with MFIs to offer credit for solar pumps, in order to address this financing gap.
Vondex Solar	Importer	**Products:** Lorentz controllers and pumps 180-750W, includes pumps and cables **Services:** provide installation services, design and support	Target market is rural customers, are interested in the tobacco value chain

Source: Dalberg analysis and interviews. 2018.

Zimbabwe has a number of solar pump importers and distributors in the market (2/2)

Organization	Type	PULSE products & services	Outlook
Clamore	Distributor	**Product:** Sunkam panels, vitron inverters and Sunpump and Greenforce pumps, both AC and DC (.75-3 hp) **Service:** distribution and installation (maintenance fee is covered in the product price for the first 6 months)	Operating for >10 years Focus on medium to large scale customers for home and industrial use Provide financing through the salary service bureau (SSB).
Cool Solar	Distributor	**Products:** JS3/1.8/100270 W pump **Services:** provide two year warranty and technical training to their hired installers	Target the peri-urban market. Have a network of distributors and installers in Harare e.g. Clamore, Solartech.
Forrester irrigation	Integrated	**Products:** Locally manufactured pumps .5hp – 75hp **Services:** provide technical assistance and conduct feasibility studies	Operating for >30 years. Manufactures, supplies and installs solar pumps. Specialize in drip irrigation. looking to grow their rural customer base and increase set up of irrigation schemes.
Zonful	Importer and Distributor	**Products:** Lorentz pumps, 5W **Services:** PAYG, installation and maintenance service inclusive of cost	Providing opportunities to test commercial viability among potential customers by providing them with market linkages to pay off pump costs.

Sources: Company websites. 2018; Dalberg analysis and interviews. 2018.
Note: List is not exhaustive, other companies that sell solar products but not solar pumps: Solar City, Solar Tech Africa, Powerite, Solar Tech Systems, Genking

PULSE products have the potential to increase smallholder farmers participation in the horticulture value chain and grow the sector

~90k

Number of people employed in the sector

70%

% of horticultural produce channeled through informal markets

7%

% of agricultural exports that are horticulture

Horticulture - Overview

- **Zimbabwe produced 645,000 MT of horticultural products in 2016.** The value chain has an annual growth rate of 1.6% over the last 5 years.
- Zimbabwe's **horticultural exports amounted to $ 96 million in 2015, which was a ~100% increase from 2014 values**, but still half of the country's peak output as at the year 2000.
- The bulk of Zimbabwe's horticultural produces are exported to the EU, with the largest crops being: citrus peas, dried legumes, vegetables, and berries

Sources: Proctor et al. 2000. "Facilitating the effective production and marketing of processed food products by small-scale producers in Zimbabwe"; UNCTAD. 2000. "The growth and development of the horticulture sector in Zimbabwe"; SNV. 2010. "RARP Commercializing smallholder farming".
Note: 1) MT– Metric Ton

Sufficient energy is required to source water for production. Then most losses are due to poor handling rather than a lack of cold storage

	Production	Transportation & Storage	Transformation	Distribution & Retail
PULSE opportunity	**PUMPED WATER AND TRACTORS** • Pumps to irrigate produce • Tractors to increase efficiency by powering planters, sprayers and combine harvesters	**COLD STORAGE** • Cold storage facilities to reduce spoilage at farm/first collection point • Cold chain transport to reduce spoilage in transit	**DRIERS AND SMALL PROCESSORS** • Driers to convert produce into higher value dried forms • Solar-powered juicing/pulping processors	**REFRIGERATION** • Commercial refrigeration units to allow vendors in remote areas to stock products for longer periods
Power capacity of sample products	  0.45-22kW 30-45kW	  1-10kW 1-5kW	 100-200W	 40-400W
Current small scale activity	• Smallholders use labour-intensive practises to till land • Grow a variety of crops in a year as part of good soil management practises	• Off-takers transport produce to markets using pick-up trucks • Little use of cold storage, and where available, it is run by off-takers for the export market	• Some basic processing is done, particularly sun drying of produce at point of production to minimize spoilage	• Farmers/traders sell in local markets, off-takers sell to supermarkets and some export

Source: Dalberg analysis and interviews. 2018.

Irrigation pumps could help improve farmer yields and subsequently incomes, however the cost of the product could limit uptake

What are the incentives to invest?

- **Increase farmer income** through yield uplifts and subsequently revenue gained through farming

> *"With the pump I can plant crops throughout the year. I'm always guaranteed a market" –* ***small-scale horticultural farmer***

- **Expand markets** by targeting different markets, both urban and rural, with extra and more produce. Additionally, with storage facilities, farmers could participate in the export market
- **Reduce operational costs** by eliminating the cost of fuel for farmers
- **Improve water management practices,** if at the same time switching to efficient irrigation methods using solar products
- **Improve resilience to rainfall seasonality and climate shocks,** and providing more resilience to major drought, such as that experienced in 2016

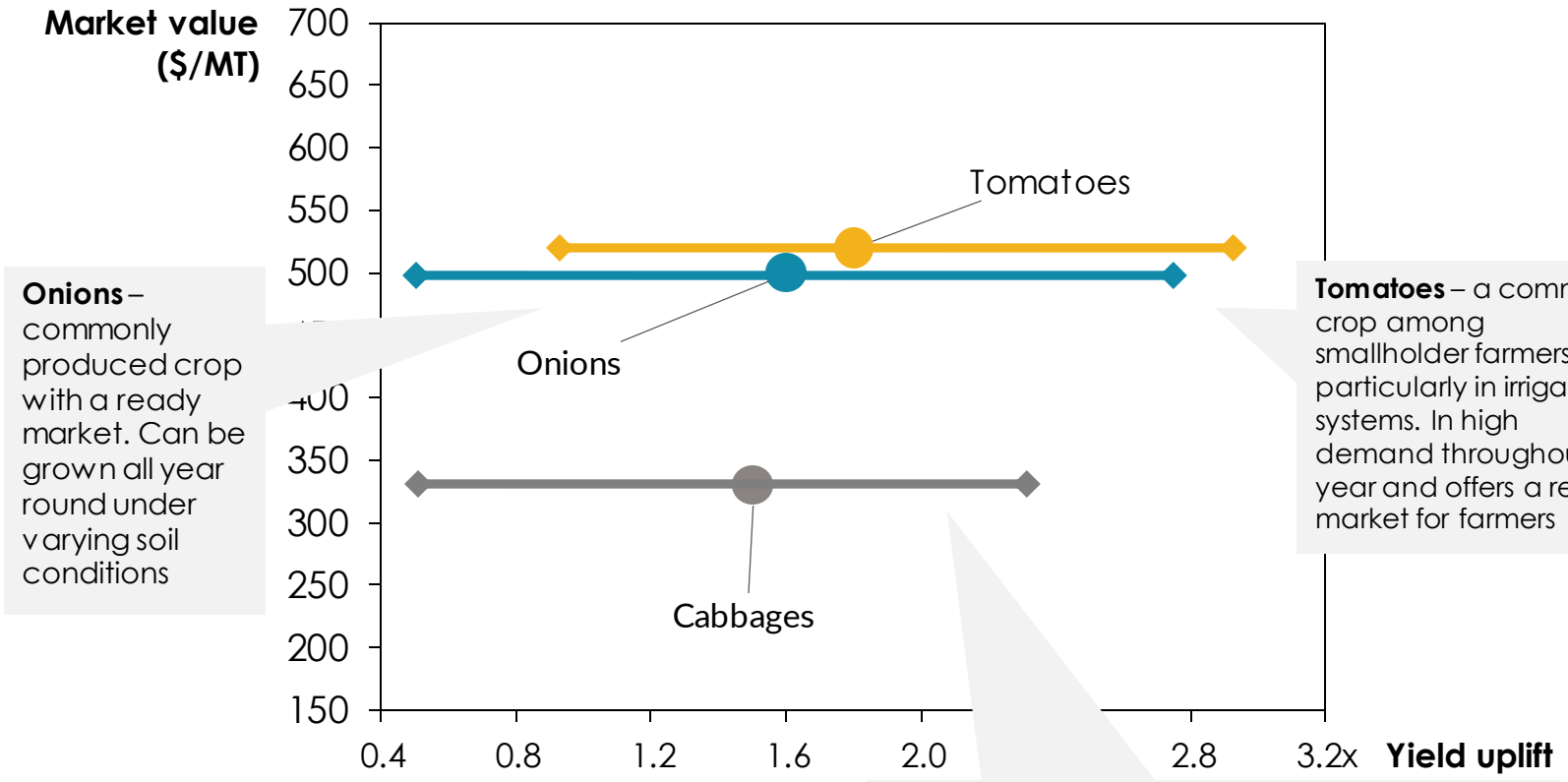
What constraints are there to uptake?

Cost	**The cost of a solar pump is almost 4 times that of a diesel machine,** which is a key barrier to entry. Also, the costs of additional equipment such as pipes, installing water tanks and boreholes where there were none increase upfront costs. ~77% of SHFs have limited access to water
Solar product reputation	There is an **influx of low quality imported pumps** and panels which can negatively skew the experience of first-time solar pump users
Technical support	Most small-scale farmers have **limited understanding of best irrigation practices**, nor have incumbent diesel pumps to know about pumping systems (solar or diesel)
Familiarity	There is **limited knowledge on the long-term cost-benefits of solar pumps vs diesel pumps**

Sources: Mutambara. 2017. "Water supply system and the sustainability of smallholder irrigation in Zimbabwe"; Dalberg analysis and interviews. 2018;

Based on current farmer activity, three crops can be used to showcase the range of potential yield uplifts and motivations for irrigation

Yield uplifts and market value across crop varieties



Onions – commonly produced crop with a ready market. Can be grown all year round under varying soil conditions

Tomatoes – a common crop among smallholder farmers, particularly in irrigation systems. In high demand throughout the year and offers a ready market for farmers

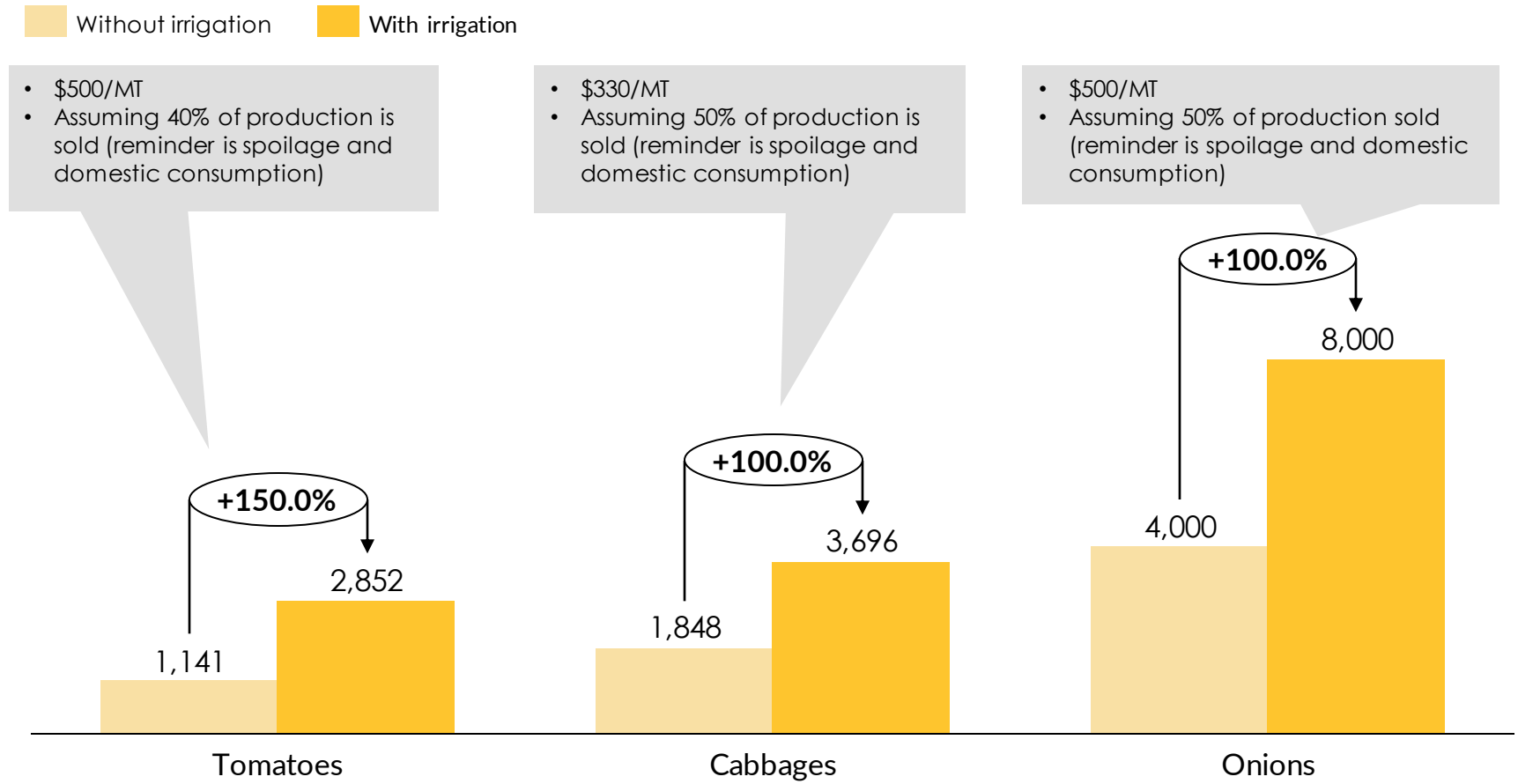
Cabbages – highly produced crop with high consumption within households; part of the staple diet. Has a guaranteed market at a fairly high price

Sources: 2030 Water Resources Group. 2016. "Agricultural and irrigation opportunity in Kenya, 2016; Various desk research sources"; Dalberg analysis and interviews. 2018,

Note: 1) MT– Metric Ton

Using conservative estimates for yield uplifts, irrigation still boosts income significantly, enough to pay back the solar pump in one year

Impact of irrigation on annual revenue per acres by crop (assumes each crop is grown on an acre) *Figures in $. Revenue figures assume two seasons for each crop per year*



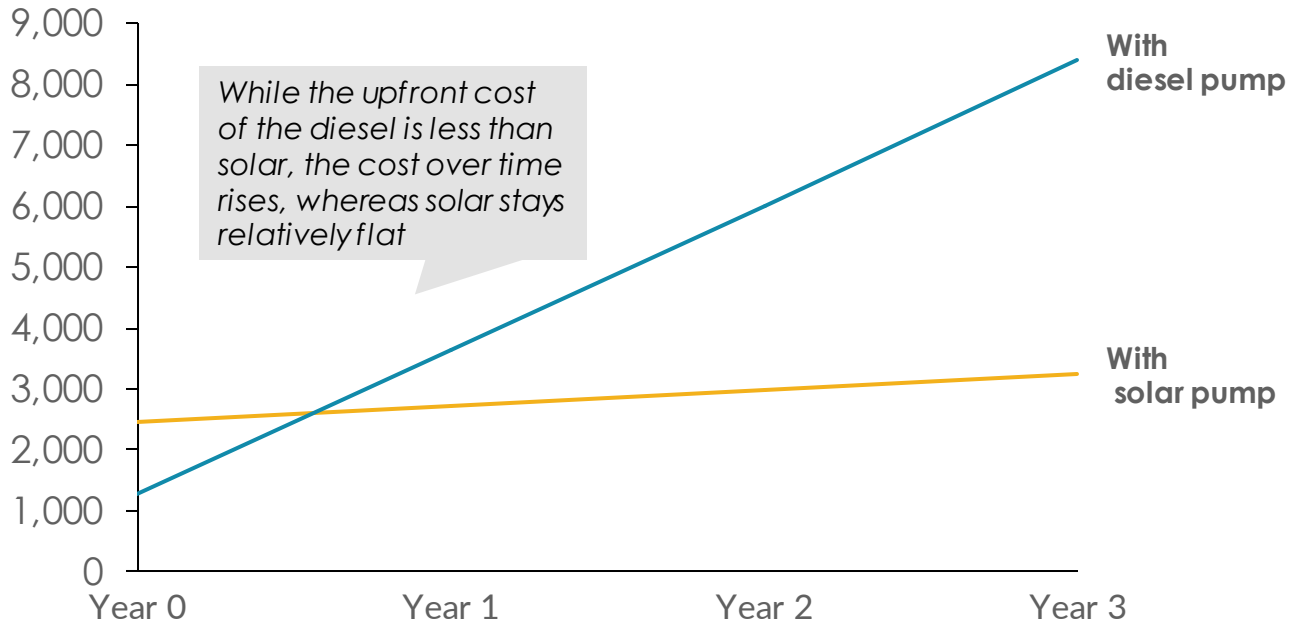
Note: even when conservative estimates for realized yield uplifts are used, irrigation still significantly boosts income

Source: FAOSTAT. 2018; Dalberg analysis and interviews. 2018.
Note: SHFs in Zimbabwe typically farm on 0.5 – 1 Ha; 0.4 Ha= 1 acre. MT – Metric Ton

Upfront cost of solar is higher; however solar becomes more attractive than diesel within first year of operations

Three-year cumulative costs across a basket of crops produced on 1 acre

Figures in $



- Solar irrigation is a more attractive option; it increases production yield while eliminating fuel costs, which further boosts farmer income
- However, **it could take several seasons for farmers to reap the full benefits of irrigation** as it may take time to adjust to the technology and improve skills in best utilizing irrigation systems

Key assumptions:

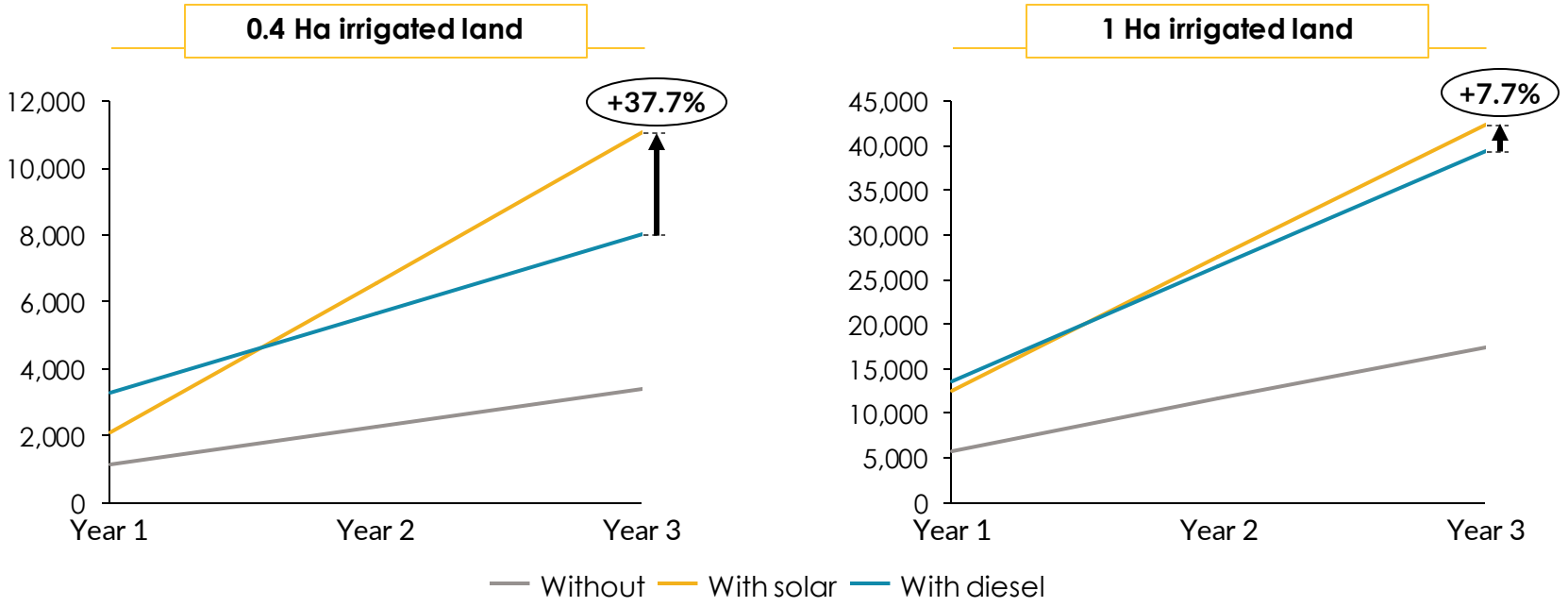
- **Product costs:** $1700 for solar and $500 for diesel with financing of 24% per year over 2Y, and after 20% is paid upfront
- **Additional costs:** i.e. shallow well, tank, pipes, $550
- **Maintenance cost:** $30/year (solar), $50/year (diesel)
- **Fuel costs:** $1.32/L; ~4 L/day
- **Crop basket:** Onions (33%), Tomatoes (33%), Cabbage (33%)
- **Crop value:** Onions ($500/MT), Tomatoes ($500/MT), Cabbage ($330/MT)

Source: FAOSTAT. 2018; Dalberg analysis and interviews. 2018.
Note: SHFs in Zimbabwe typically farm on 0.5 – 1 Ha; 0.4 Ha= 1 acre. MT – Metric Ton

Irrigation pays back for either technology within 1-2 years; the relative benefit of solar over diesel pumps can be higher at smaller scales

Three-year cumulative net income with solar and diesel across a basket of crops*

Figures in US dollars ($)



	Solar	Diesel
Payback	2 seasons	>2 seasons
Two year ROI	22%	-9%

	Solar	Diesel
Payback	1 Season	1 Season
Two-year ROI	166%	106%

Source: Dalberg analysis and interviews. 2018.

Note: Crops: tomatoes ($500/MT), cabbages (330/MT), onions ($500/MT), Split of land: 1/3 for each
Assuming a full season is approximately 6 months. MT – Metric Ton

Small-scale farmers demand for solar pumps can vastly increase with additional support

FACTORS TO STRENGTHEN BUSINESS CASE

EPXLANATION

Market linkages with guaranteed off-takers

Assured markets support product commercial viability

- A **guaranteed market provides a consistent source of income** for farmers, which will help increase their access to the product
- Additionally, a **formal off-taker agreement assists farmers to access financing** to fund purchase of the product and other relevant equipment

Tailored financing options for potential customers

Flexible financing reduces barriers to access

- The **high upfront cost, which starts at $1,700** is out of reach for the majority of small-scale farmers
- Current **financing options are out of reach** for the target market
- Potential financing options will **need to consider SHF's economic situation**, i.e. target farmers earn <$50 per month, and current interest rates are ~24% pa.

Pre- and post-sales support

Product knowledge increases uptake

- SHFs are **largely unaware about how to operate solar pumps**
- Suppliers can try to increase their market **by providing pre- and after-sales services, as well as demonstrations** to build consumer confidence and product such as Zonful

Source: Dalberg analysis and interviews. 2018.

ZIMBABWE MARKET **DEEP DIVE**

COOLING (DAIRY USE CASE)

40% of Zimbabwe's agricultural produce is lost post-harvest, additional cooling supply could reduce this by as much as half

State of play

Post-harvest losses in the agriculture sector are due to poor storage practises, including a lack of cooling. Appropriate storage is limited in value chains as follows:

Horticulture

- In the vegetable value chain alone, Zimbabwe has average **annual losses of 20-30%** due to lack of cold storage
- **Cold storage solutions are expensive and limited to grid-powered products** and catered for commercial processors, particularly for the export market

Dairy

- The value chain is characterized by **spoilage of up to 50%,** particularly at transit to aggregation points
- **Refrigerators are designed for large scale producers**, the majority powered on the grid, not for small-scale off grid

Livestock

- There is a demand for cold storage in Zimbabwe for livestock products such as fish, processed meat and poultry. However, commercial supply chains are limited, e.g. in poultry only 25-30% of produce is commercially processed

Example of uptake of cooling products across different value chains in Zimbabwe

Horticulture (Tomatoes)	Dairy	Livestock (Fisheries and Poultry)
40% *of losses due to spoilage*	**50%** *of losses due to spoilage*	**10%** *of losses due to spoilage in fisheries*
~77% *of commercial produce passes through cooling facilities*	**32%** *of milk sold passes through chilling facilities*	**~30%** *of poultry is transported in cooling systems*

Cold storage and refrigeration applications, target more commercialized and large-scale farmers, highlighting a gap in the market for smallholder use

Sources: Dalberg research and interviews. 2018; Matekenya. 2016. "Large Scale Diary Value Chain in Zimbabwe"; Macheka. 2018. "Postharvest losses in Zimbabwean supply chain"; SNV. 2012. "Zimbabwe's dairy subsector study"; FAO. 1995. "Recent developments in the fisheries of Lake Kariba"

Uptake of both incumbent technology and solar products is low, DC solar refrigerators are slowly entering the market for household use

	Large-scale applications	Small-scale applications	Micro-scale applications
Typical products & capacity	 N/A	 	 
	>2000 L	*201 – 2000 L*	*<200 L*
Degree of uptake	Grid: **Medium**; Solar: **None**	Grid: **Low**; Solar: **Low**	Grid: **Low**; Solar: **Low**
State of play	• **Large refrigeration solutions are usually grid-powered** and used by industrial processors • **Grid walk-in cold room solutions are increasingly being used in horticulture** by large aggregators and exporters • There are **currently no solar solutions that meet large- scale demand** for cooling	• There are **few small-scale grid applications,** operated by aggregated small-scale producers in community projects • The majority of the grid products are tailored for retail and household use • **There are only limited small-scale solar products utilized in the market**	• Few solar solutions in the market targeted to micro-scale applications • The smallest solar products have a capacity of 50L to 165L targeting peri-urban customers, but uptake remains low

Source: Dalberg analysis and interviews. 2018.

Distribution of solar cooling products in Zimbabwe is limited to only a few suppliers, most focused on growing consumptive use sales

	Organization	Type	Stage	PULSE products & services	Outlook
Solar	**Solar Shack**	SHS/PAYG leaders	Distributors	**Product:** Sundanzer freezers/ fridges, 75 W, 165 L, $2,700 **Services:** provides flexible payment terms, warranty and maintenance support to farmers	Serve peri-urban clientele, and are looking to focus on expanding their urban consumptive market Want to work with more MFIs to reach rural customers
Solar	**Nongerai**	Portfolio distributors	Distributors	**Product:** Pro solar chest freezer, AC/DC, 95 W, 190 L, $814 **Services:** provides warranty and technical advice from inhouse experts	Focused on increasing supply in urban and on-grid customers Could potentially stock coolers of 73 – 110 L depending on demand
Solar	**Solar Tech**	PULSE innovators	Integrated	**Products:** branded (SolarTech) solar fridge and cooler **Services:** provides warranty and installation	Targeting rural customers, at both a household and retail level; not considered going into agriculture yet
Grid	**Capri**	Manufacturer	Integrated	**Products:** Capri grid refrigerators and chest fridges, 68 – 340 L, $295 - 545 **Services:** backup service and local warranty support	Continue to manufacture and upgrade models for the urban market in Zimbabwe Currently focused on serving grid connected consumers only

Source: Dalberg analysis and interviews. 2018; Company websites. 2018.

Suppliers are yet to explore the dairy sector, where off-grid cooling could reduce spoilage while helping to meet government targets

3.5M *Number of dairy cattle**

300K *Number of smallholders**

9% *Contribution to agriculture GDP***

50% *Level of spoilage at small-scale*

Dairy - Overview

- Zimbabwe's dairy sector has a **supply deficit, importing up to 50% of its dairy products, with only 65 million liters produced locally**
- **Land reforms caused a large reduction in herd sizes** and participation in the dairy sector. The national milk output has fallen drastically from a peak of 260 million liters in 1991
- To revitalize local production, **the government has put in place various import restrictions (e.g. 40% duty on milk imports) and tried to engage small-scale dairy farmers**
- **With support from USAID, the government established** 35 Milk Collection Centres (MCCs) to channel smallholder produce to large scale processors; of these, only 10 are currently operational and on the grid
- **Currently, only ~5% of the formal dairy sector is served by small-scale farmers** and out of the potential 300,000 smallholder dairy farmers only 1,743 farmers are utilising MCCs

Sources: Dalberg analysis and interviews. 2018; SNV. 2012. "Zimbabwe's dairy subsector study"; Marecha. 2013. "Zimbabwe dairy industry case study; GAIN. 2015. "Zimbabwe agricultural economic fact sheet"

Note: 1) Includes those both in the formal and informal sector; 2) Agriculture sector GDP is 10% of national GDP

PULSE products can be used across the value chain, but a strong opportunity lies in initial collection and storage to avoid spoilage

	Production	Collection & Storage	Transformation	Distribution & Retail
PULSE opportunity	**WATER PUMPS AND MILK EXRACTORS** • Water pumps to provide constant drinking water for dairy cows • Milk extractors to increase output and reduce labor time	**MILK CHILLERS** • Chillers reduce spoilage and contamination. Rate of contamination increases by 10% daily for unchilled milk	**SMALL PROCESSORS** • Processors provide value addition to the value chain, e.g. production of yoghurt, sour milk, etc.	**REFRIGERATION** • Fridges allow small-scale retailers to store fresh milk products for longer
Power capacity of sample products	 0.45-22kW 550W	 40-200W	 150-250W	 40-400W
Current small scale activity	• Most farmers use boreholes and surface water as a supply • Milking is carried out by hand • Women make up ~30% of producers	• Farmers store and transport milk in small plastic containers and deliver to MCCs (~10km away) • Aggregators have storage equipment on the grid	• A few on-grid processors produce yoghurt • There are a handful of small-scale traditional processors who make sour milk by exposing it to ambient temperature	• On-grid retailers will have household size fridges and off-grid retailers will purchase on a daily basis or boil the milk to preserve it

Sources: Dalberg analysis and interviews. 2018; GIZ. 2016. "Photovoltaics for productive use applications"; National Center for Biotechnology Information. 2018.

Milk chillers can help drive local dairy production by reducing milk loss and improving milk quality, both which increase farmer incomes

What are the incentives to invest?

- **Use of chillers can help increase farmer incomes by reducing spoilage** and making more milk available for commercial use
- **Improve quality so they can access a price premium from processors.** Preservation by chilling at an optimum temperature helps limit bacteria growth
- Chilling also provides farmers with an opportunity to **sell milk to both formal and informal markets**
- **Small-scale cooling can help smallholder farmers better link into MCCs.** A few smallholder dairy farmers are located near an MCCs which are a good aggregation point. The average MCC serves ~50 farmers

"Most farmers live too far from MCCs and don't produce enough (milk) to justify purchasing a cooler. There needs to be mobile cooling solutions targeting aggregated farmers and serving them at their point of production" – ***Red Dane, dairy producers***

What are the constraints to uptake?

Product cost

The smallest product in the market at $694 is expensive for the typical smallholder dairy farmer who currently has a monthly revenue of ~$115/month* from selling 6.4L/day

Distance

The majority of smallholder farmers are located away from MCCs. This **necessitates mobile solutions, which will address spoilage that occurs in transit**

Production volume

Smallholders produce ~8L/cow/day, nearly half of commercial farmers' production. **Farmers cannot fully utilize the smallest chillers (50 L) without aggregating**

Production cost

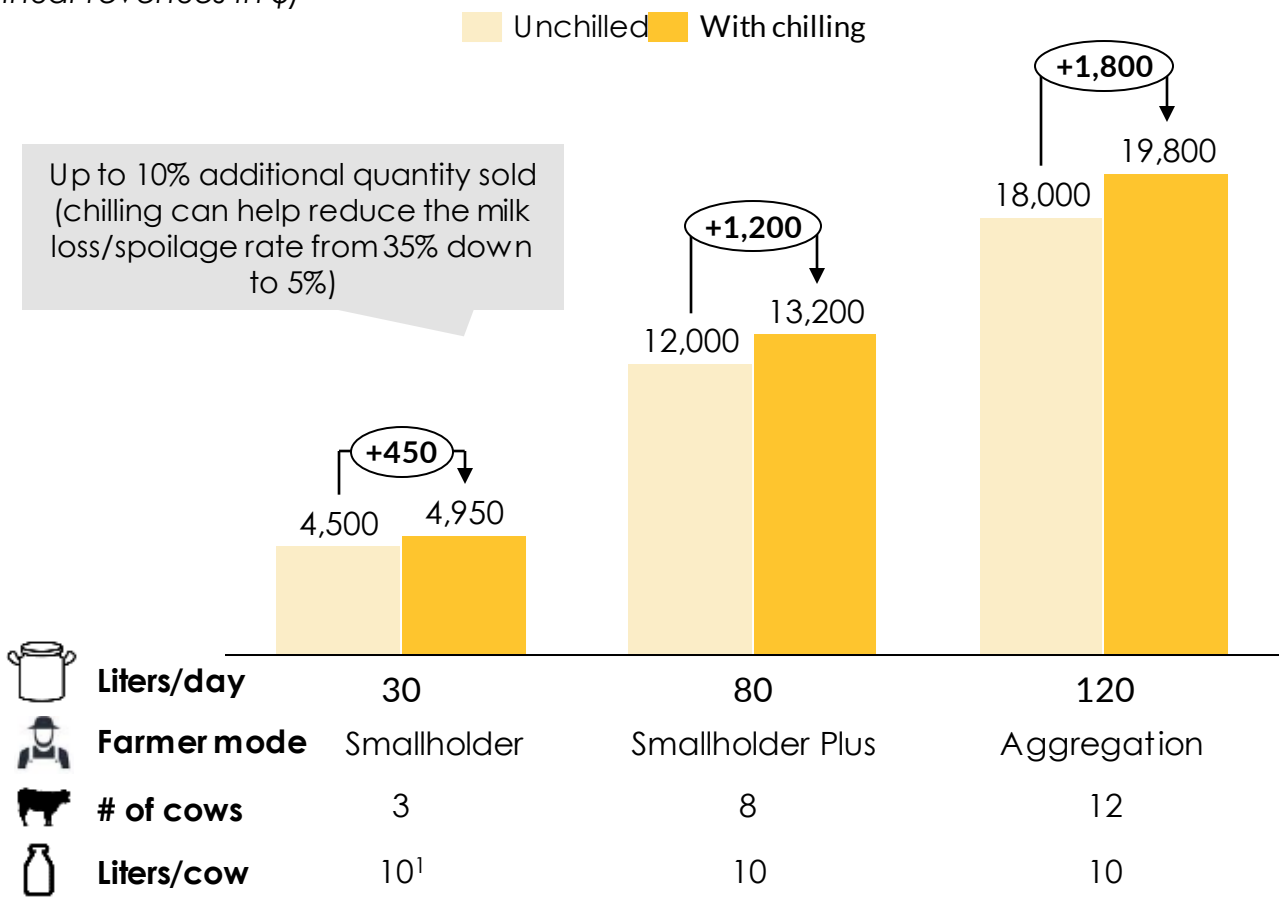
As SHF commercialize their production costs increase, including **improved feeds and animal health, which comes up to 70% of revenues.** This hinders smallholder participation

Sources: Dalberg analysis and interviews. 2018; SNV. 2012. "Zimbabwe's dairy subsector study"
Note: 1) Assumes farmer sells 6.4L/ day @ $ 0.6/ L for 30 days; assumes farmer sells 80% of milk produced

By chilling their milk, farmers can increase their annual revenue by up to 60% due to increased sales volumes and premium pricing

Annual revenue selling chilled vs. unchilled milk – across farmer profiles

(Annual revenues in $)

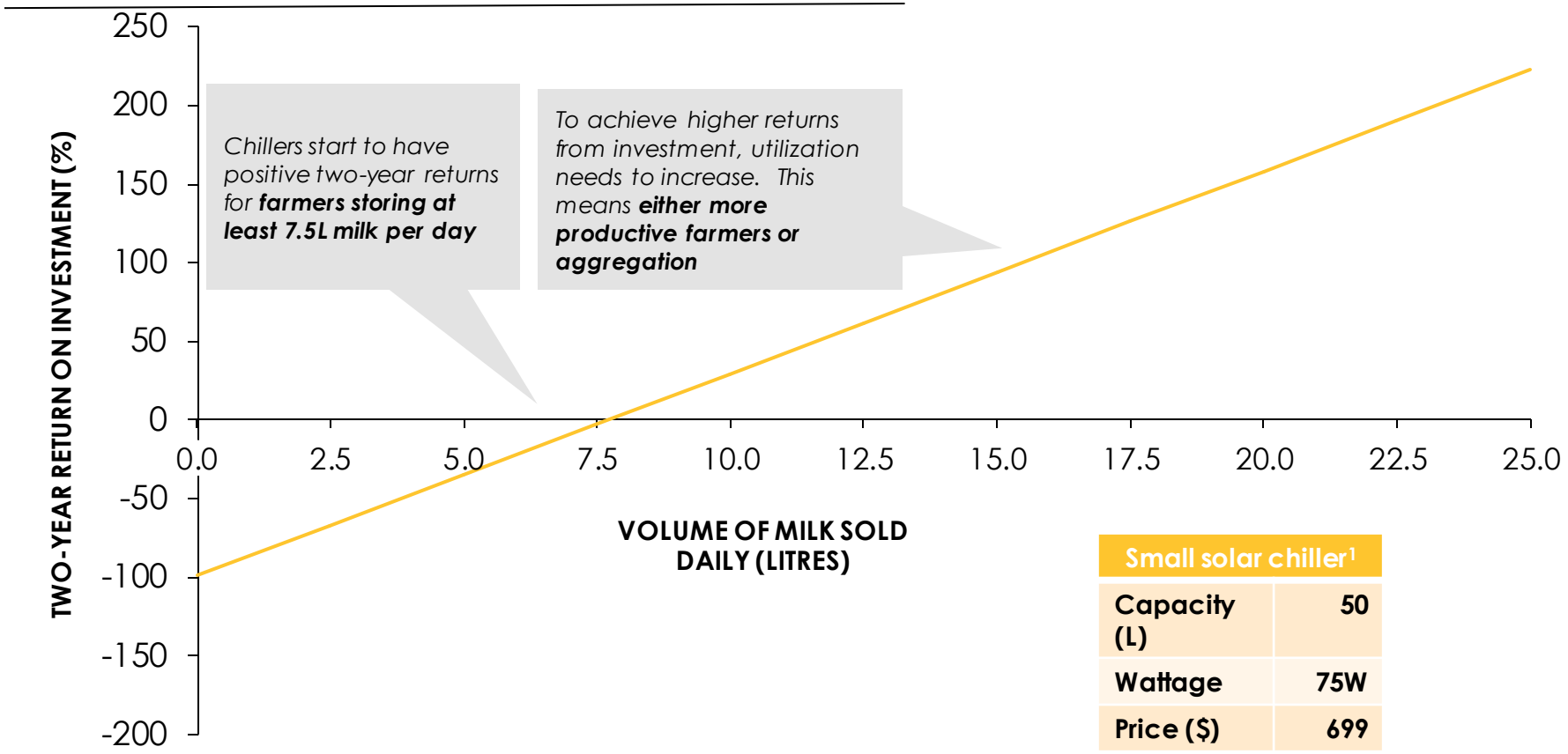


- Chilling solutions help **maximize the benefits from spoilage reduction and access to premium pricing***
- Even if no premium is possible, farmers can still **earn up to 40% more revenue based on the additional quantity sold**

Source: Dalberg analysis and interviews. 2018.
Note: 1) Volumes are up to figures presented; 2) Assumes at least 50% access to premium market

However, solar products on the market today only begin to make financial sense for farmers at the top end of the smallholder category

Minimum capacity level to achieve positive two-year ROI



Small solar chiller[1]	
Capacity (L)	50
Wattage	75W
Price ($)	699

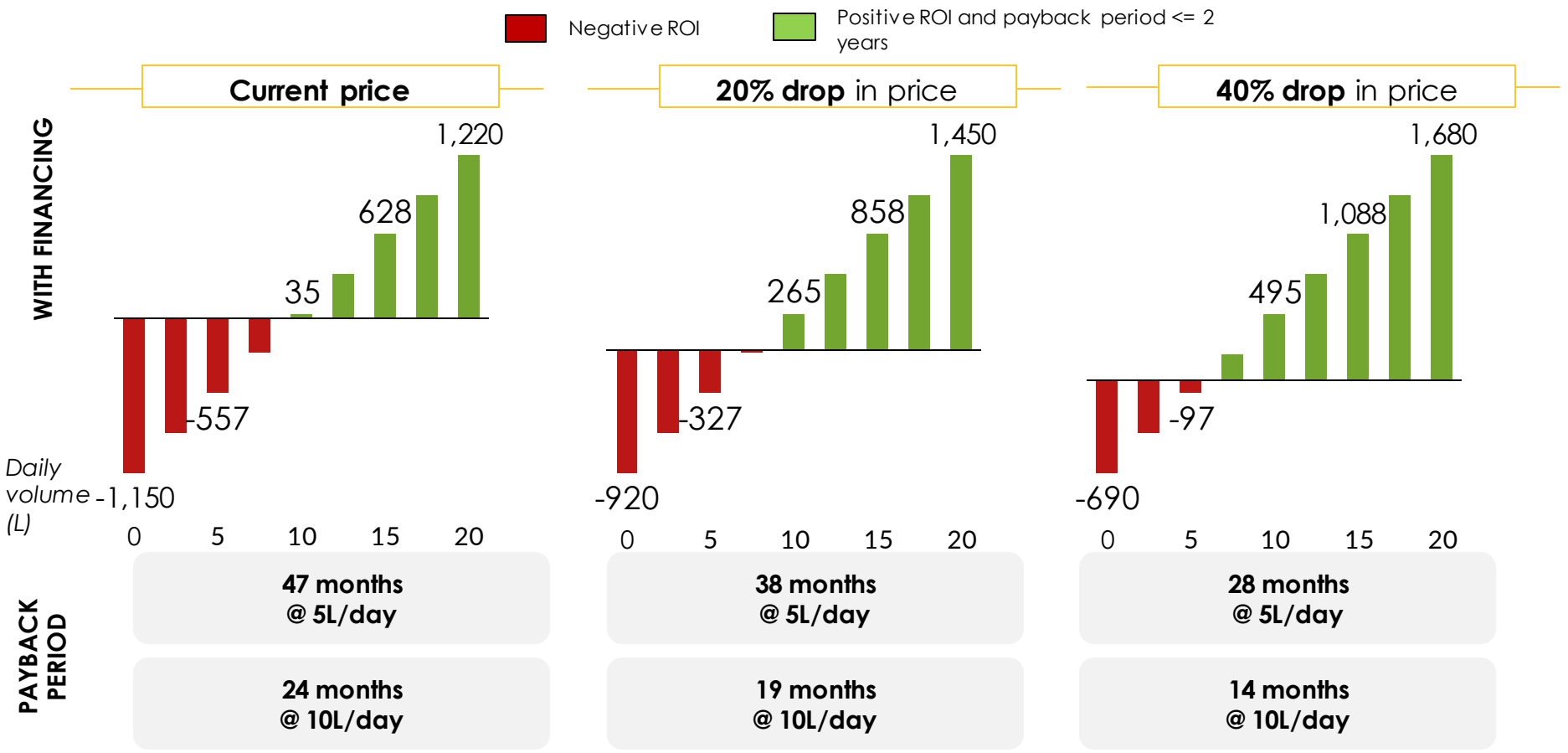
Based on current products and market prices, farmers marketing less than 7.5L per day will not earn enough to afford the smallest chiller in the market. However, **farmers may be successful in aggregating to make joint investment to be worthwhile**

Source: Dalberg analysis and interviews. 2018.
Note: 1. All chiller costs include financing costs over 24 months, at 24% compound interest.

Even if product price reduces by 40% SHFs selling 5L/day would not be able to pay back the product within 2 years

Two-year net operating income by product price: *(X-axis = Capacity util. %; Y-axis: operating income in $)*

Product price (including batteries) without financing = $804. Financing costs are 24% compound interest over 24 months



Source: Dalberg analysis and interviews. 2018.
Note: ROI is calculated from price of small solar chiller with financing, but assumes change in initial cost of product; no change to battery costs.

Three levers could help strengthen the solar chiller product design and enhance the investment case for smallholders

FACTORS TO STRENGTHEN BUSINESS CASE			
			
	Improved cow productivity	**Pricing below $ 699* for a small solar chiller**	**Sustained access to formal markets**
	25% boost to the additional revenue	***Investment case for farmers at <10L***	***More consistent access to processing centers***
EPXLANATION	• **Improved cow productivity can boost both the overall volume of milk sold and its quality** • On quality, farmers can access premium pricing for milk with: (a) high fat content, (b) low bacterial count. Chilling helps only with the latter • **Improving fat content can add an additional 25% to the revenue boost already identified in this analysis**	• Farmers with production **below 50** L/day (which account for majority of small-scale farmer profiles)** are shut out of current chilling solutions – unless they aggregate • Such farmers would **be able to break even within 23 months on an investment for a small-scale solar chiller, costing no more than $ 699.** The case still stands even with added financing costs	• The **investment case rests in large part on the ability to sustainability access large-scale processors through larger volumes.** Smallholder farmers can also access premium prices by selling high quality milk to processors • **Smallholder farmers require support to aggregate and revitalize existing MCCs.** Industry players can also offer technical support and incentives to improve milk production quality

Source: Dalberg analysis and interviews. 2018.
Note: 1) Without financing 2) Smallest solar chiller capacity in the market

ZIMBABWE MARKET **DEEP DIVE**

AGRO-PROCESSING (MAIZE USE CASE)

Cereals make up the majority of the country's agro-processing demands, particularly maize and sorghum which are staple foods

State of play

Agro-processing in Zimbabwe is dominated by large scale processors as shown in the following value chains:

Cereals (maize, wheat, sorghum, barley, etc.)

- **Most cereals consumed go through the process of husking, threshing, and milling.** In rural areas, >50% of processing is carried out by hand
- **Milling is carried out by larger processors** while, threshing and husking are mainly carried out by small- to mid-range processors

Tubers (potatoes, cassava, etc.)

- **Processing of tubers is still a nascent industry in the country**
- Processing is mainly carried out by two companies, i.e. Selby and Interfresh. **Producers tend to be smallholder farmers who sell their produce to larger wholesalers and sometimes processors**

Oilseed crops (soya, cotton etc.)

- **Almost all oilseed crops are processed in country. 95% of all soya for example is processed** to produce animal feed and oil
- **Processing is capital-intensive,** requiring specialized technology, and is dominated by large scale processors (97%)

Characteristics of the small- and micro-scale agro-processing market

Ownership structure	• **Owned by mid-scale farmers** in the locality who have > 10ha and process ~15 tonne/day • **Very minimal ownership by small-scale farmers,** because current technologies are expensive
Business model	• **Offer processing as a service** • **Due to currency restrictions in the country, payment for services,** especially in rural areas, is usually in kind, i.e. goods in exchange for a service
Opportunity for solar	• Offer a **cheaper alternative** to current processing • **Increase market** for processing by driving entrepreneurship at micro level

Agro-processing applications are commercially geared and more developed within the cereals value chain

Source: Dalberg analysis and interviews. 2018.

Across crops, large scale grid processing applications are widespread, while solar solutions are currently not available

	Medium-scale applications	Small-scale applications	Very small-scale applications
Typical products & capacity	 N/A	 N/A	 N/A
	>2 MT/day	*1-2 MT/day*	*<1 MT/day*
Degree of uptake	Grid: **High**; Solar: **None**	Grid: **Medium**; Solar: **None**	Grid: **Low**; Solar: **None**
State of play	• Threshers and huskers are mobile and tend to be diesel-powered combine harvesters • Mills, grinders, and pressers are grid- or diesel-powered • There are **no solar products for large-scale processing** in the market	• For oilseed processing, **small- and mid-scale processors frequently use screw presses** • There is some **uptake of small-scale threshers and mills,** predominantly in cereal value chains, these are either imported or locally manufactured	• There are currently **no solar solutions for micro-scale processors in the market** • There are a few micro-scale screw presses in the market • There are almost **no grinders, millers, and threshers at a micro-scale**

Source: Dalberg analysis and interviews. 2018;
Note: 1) MT– Metric Ton

The biggest suppliers in the market only provide grid and diesel-powered processing solutions, interest in solar is limited

Organization	Stage	PULSE products & services	Outlook
Farmec	Distributor	**Product:** brand combined harvesters of ~40-60 such as Massey Ferguson, Falcon **Services:** provide warranty and maintenance	Target large-scale producers as well as those in rural areas; have multiple branches across the country
Bain	Integrated	**Product:** combined harvester, millers **Services:** provide maintenance support	Target large-scale farmers and looking to grow distribution across the country
Agricon	Integrated	**Products:** harvesters, shellers, tractors **Services:** have maintenance contract and extended warranty. Provide a loyalty program which includes on site training, visits from equipment specialist	Serve large-scale commercial producers Integrating technology solutions into their equipment
Appropriate Technology Africa	Integrated	**Products:** Vegetable oil mills, cereal grinding mills, dehullers, manual and motorised peanut butter mills, motorised juice extractor	Also provide some solar products, e.g. solar pumps, hence would be interested in exploring other PULSE products

Sources: Dalberg analysis and interviews. 2018; Company websites. 2018.

Maize offers a large market for agro-processing – it is farmed by 80% of smallholder farmers, with significant small-scale processing needs

2.2M MT

Annual production, 2017

80%

% of smallholders engaged in maize farming

9%

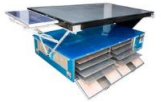
Contribution to agricultural GDP

Maize - Overview

- **Maize is a staple crop in Zimbabwe and 80% of the maize produced is for consumption**, while the rest is processed into maize meal and other by- products e.g. stock-feed. Maize contributes up to 43% of the dietary energy supply in Zimbabwe
- **There was a 300% increase in maize production from 2016-2017 (up to 2.2. million MT).** This is attributed to the 'Command Programme', which began in 2016 and was aimed at making Zimbabwe self-sufficient in production
- **Majority of the maize produced passes through the formal value chain.** ~40,554 (50%) SHFs are contracted to sell directly to the Grain Marketing Board, who offer the highest prices in Southern Africa, at $ 390/MT
- **Most farmers thresh their maize on the farm** and then sell the processed crop to large-scale off-takers and millers. **Threshing is a labor-intensive activity**, requiring >2-3 people per machine to feed cobs into the processor

Sources: Tinashe et al. 2010. "The grain industry value chain in Zimbabwe"; GAIN. 2017. "Grain and feed annual report"; Reserve Bank of Zimbabwe. 2017. "Quarterly economic review"; GAIN. 2015. "Zimbabwe Agricultural Economic Fact Sheet"; Dalberg analysis and interviews. 2018.

PULSE products can address gaps at production and processing, specifically saving costs and time in on-farm transformation

	Production	Collection & Storage	Transformation	Distribution & Retail
PULSE opportunity	**WATER PUMPS** • Pumps to increase yield and allow farmers to plant multiple cereal crops in a year	**DRYERS AND SILOS** • Sun-dryers to cut down on time spent drying • Dryers and silos to retain appropriate moisture content more efficiently and prevent contamination	**THRESHERS AND MILLERS** • Threshers to reduce time spent manually threshing prior to milling and save on fuel cost • Solar millers to save fuel and transportation costs to large processors	**N/A** • No real opportunity in transportation as spoilage largely occurs during storage*
Power capacity of sample products	 0.45-22kW	  10 kW	 1.2 kW	
Current small scale activity	• A few mid-scale farmers use diesel pumps, while most small-scale farmers rely on rain-fed farming for one season of maize • Land is tilled manually	• Most farmers sun-dry their maize, a process which takes ~2 weeks • Famers store their produce in bags and keep them in reusable sacks	• Threshing is mainly carried out mainly manually. Some farmers pay for threshing via combined harvester or diesel processor • Maize grain is sold to large-scale processors for milling	• Collection of maize grain by brokers is usually done using trucks

Source: Dalberg analysis and interviews. 2018;

Solar threshers could be a cheaper solution than diesel incumbents, and open up more efficient threshing services to remote producers

What are the incentives to invest?

- **For smallholder farmers threshing is typically delivered as a service at or near farm**
- **Smallholder farmers either thresh their maize using** a large-scale combined harvesters (~35%), mid-scale diesel-powered threshers (~15%) or by manual farm labor (50%)
- Alternative solar-powered products could both: **a) reduce costs of mid-scale threshing** when compared with diesel alternatives, **b) increase the efficiency and quality** of processing when compared with manual threshing, which could **help SHF to access downstream commercial mills**

> *"I sometimes spend at least 25 dollars a day on fuel when I use my diesel thresher –* ***maize farmer and micro-processor***

What are the constraints to uptake?

Limited incumbency

Currently 50% of farmers thresh by hand, therefore technologies will need to reach customers with no incumbent technology

Seasonality

Threshing is a seasonal activity and within the maize value chain, a bespoke threshing product would only be operational for a 3 month period

Mobility

SHFs typically rely on near-farm or on-farm threshing, but available solar solutions are not yet mobile. Transporting unthreshed cobs in bulk is expensive, costing around $0.38/MT per km travelled to a processor

Source: Dalberg analysis and interviews. 2018.
Note: 1) MT– Metric Ton

A solar threshing solution will need to show commercial viability compared with both manual and diesel-powered incumbents

	Manual - Incumbent	Diesel - Incumbent	Solar - Alternative
Summary	Local labourers use manual techniques such as beating	Typically owned by a mid-scale farmer with (10 ha+), who then threshes for neighboring farms	One of the smallest solar threshers (100W) in the market, targeted at micro-processors
Capacity	Two labourers typically thresh a volume of 50kg tonnes/day	The smallest products available process up to 1MT/hour, but seldom reach full capacity, 960MT	Can process a maximum of 0.25MT/hour, with a typical annual output of 240MT
Mobility	**Mobile** – labour is either from the household or paid workers from the nearby village	**Partially mobile** - such machines tend to be mobile, being both pulled and powered by a tractor	**Not mobile** - current models in the market are not mobile, a recognised disadvantage from manufacturers
Product Cost	-	$ 420	$ 950
Charge Rate	Typically family labour or $15/MT for hired labour which can be paid in bags of maize ($20/MT)	Typically $10/MT	$7-10/MT (depending on distance)

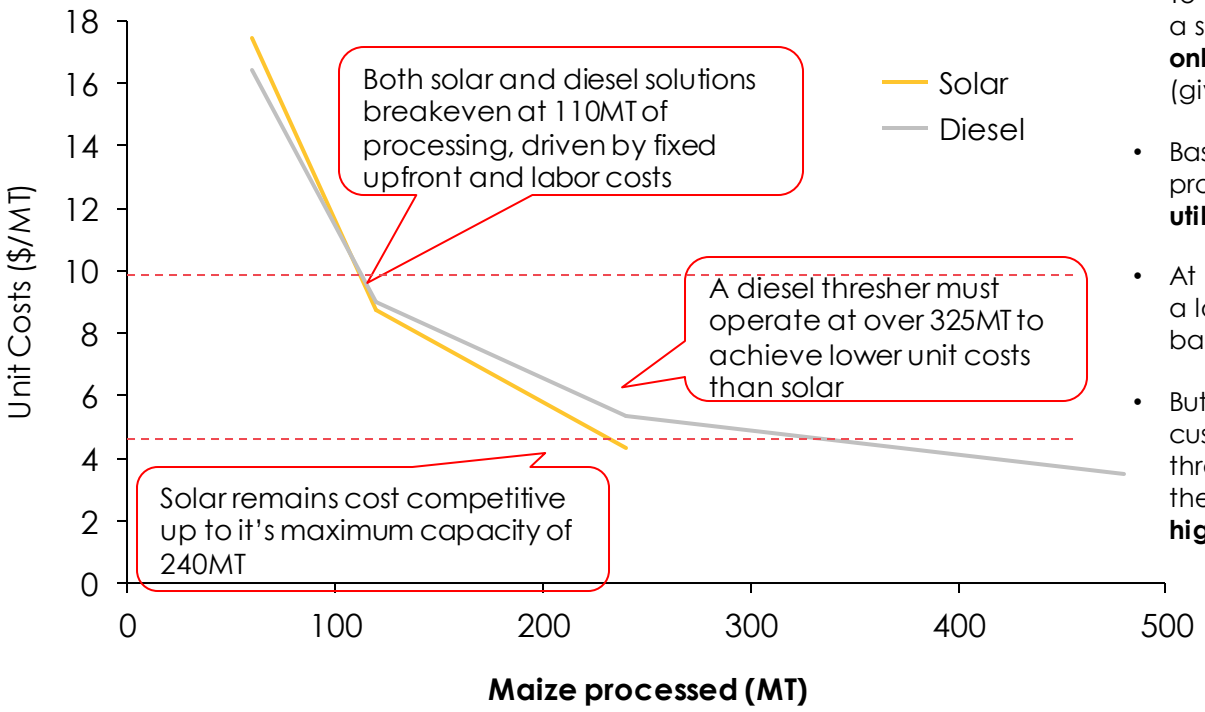
Available solar solutions have lower capacity than diesel and are also not mobile. Prices will need to be adjusted to account for costs of transport

Source: Dalberg analysis and interviews. 2018.
Note: 1) MT– Metric Ton

Between 120-240MT (max capacity) solar threshers have lower costs than diesel, but the unit economics shift towards diesel after 325MT

Unit cost analysis of solar vs. diesel (averaged over 5 years of operation)

In $/MT, for a typical current price of $ 10/MT



The economics of solar vs. diesel

- To match the processing capacity of a solar mill of 240MT a **diesel solution only needs to utilize 25% capacity** (given overall capacity of 960MT)
- Based on current prices a solar product appears **viable where utilization is greater than 50%**
- At these scales, the solar solution has a lower unit processing cost and pays back after the first year of operation
- But when processors can reach more customers, increasing processing throughput above 325MT/annum, they have **incentives to invest in higher-rate diesel-powered products**

Key assumptions

- **Product price**: $ 950 (solar); 420 (diesel)
- **Financing:** 24% per annum over 2Y, after 20% upfront
- **Annual operating days:** 120 days for single purpose use
- **Operating costs:** Solar (battery, labor, maintenance) $ 690; Diesel (fuel, labor, maintenance) $ 1,136
- **Revenue/MT:** $ 10

Source: Dalberg analysis and interviews. 2018.
Note: 1) Maximum sunlight days in Zimbabwe

To be profitable a solar thresher must reach at least 44 households, but transporting maize will reduce potential charge rates

How many households need to be serviced? Over what catchment area?

Processing capacity, 110 - 240 MT of maize/season

÷

2.5 MT/ household/season

=

44 – 96 households serviced per year

÷

10 households/km^2

=

Typical catchment area: 4.4 – 9.6km2

If a static off-farm solution, how could travel costs affect customer willingness to pay?

Service fee when threshed on farm, $10/MT

–

Typical travel based on catchment : 2.2 -3.5 km

÷

Approximate travel costs, 0.38 $/km/MT

=

Additional total cost of travel: $1 – 1.5/MT

=

Potentially need to offer remote rates of $8.5 – 9/MT

Static solar solutions will need to offer a lower price to compensate customers for their travel costs to be more attractive than mobile diesel ($10/MT) and manual processing

Sources: Dalberg analysis and interviews. 2018; Zimstat Census. 2012.
Note: 1) Population density, 42 people per sq km, 2) Household size 4.2 ppl/hh 3) Typical travel distance assumed to be half of the catchment radius 4) Avg household production of 0.6MT; Assuming $ 12/MT/32 Km = $ .38 per km.

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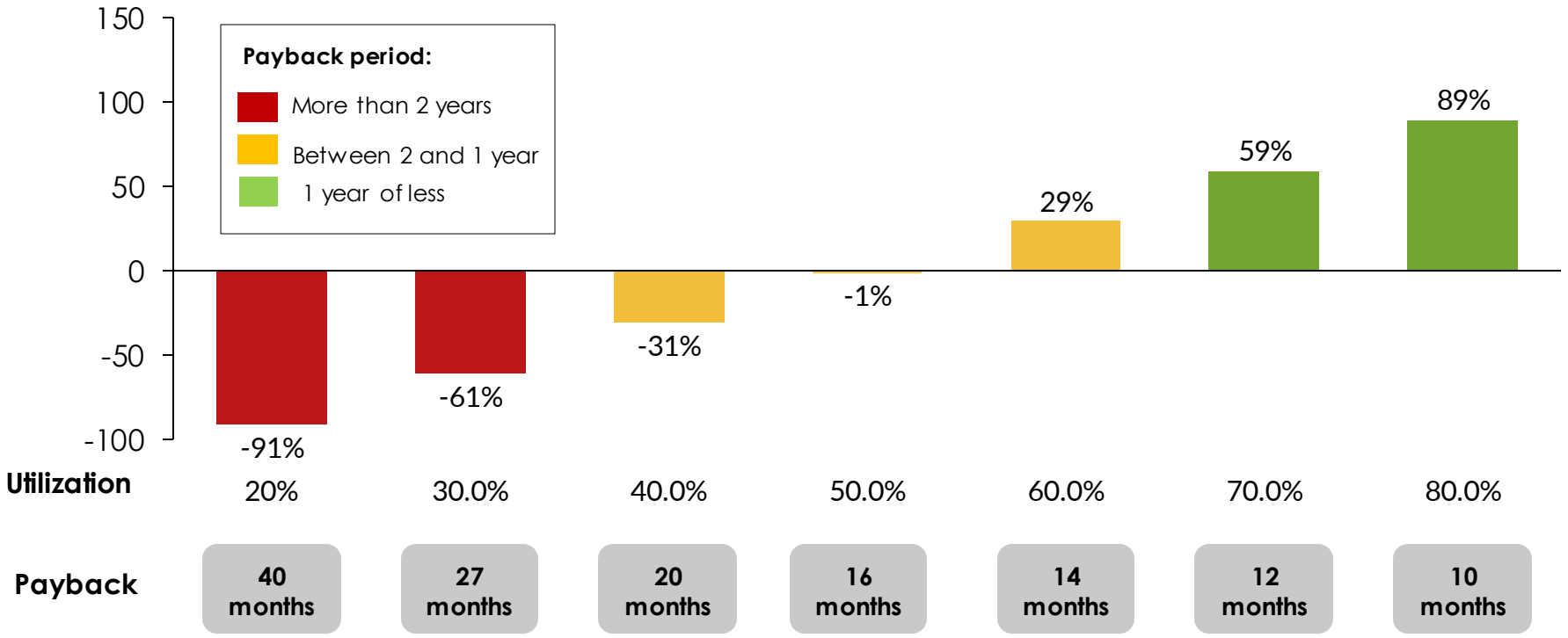
A processor needs to maintain more than 50% utilization to see positive ROI within the first 2 years

Two-year ROI and payback periods at different utilization points

X-axis: Utilization: Y-axis: Two-year ROI in %. Service fees = $8.5 per MT



The ROI assumes operations of 8h/day and 240 kg per hour for 120 days in a year. However, due to competition from mobile diesel threshers, utilization is likely to vary. A processor can charge $8.50, below the current market rate of $10, to undercut competition from mobile diesel processors

Source: Dalberg analysis and interviews. 2018.
Note: 1) Analysis assumes financing costs of 24% over a 2 year period with 20% paid upfront. 2) Assuming each smallholder produces approximately 1.6MT.

Two levers could help strengthen the product design and hence the investment case for smallholder farmers

FACTORS TO STRENGTHEN BUSINESS CASE

EPXLANATION

Increased mobility

Provide mobile solar threshing services to match current alternatives and ensure catchment

- **Smallholder farms in Zimbabwe are sparsely distributed**
- Compared with diesel solutions, **solar threshers have better cost effectiveness at lower volumes** which could make remote applications more viable
- However, as solutions are currently not mobile, any **enterprise will need to carefully consider its position and viable catchment**
- The development of **mobile solar threshers would reduce the transactions costs** associated with reaching remote smallholders
- In the mean time, processors might need to **include bulk transport of maize** in their services, along with the associated costs

Multi-purpose machinery

Utilize multi-purpose products (which include threshing) to maximize year-round PV utilization

- **Solar threshers would only be operational for 3 months of the year**, as Zimbabwe has one maize season per annum. Threshing, and processing, takes place after harvesting. However, most smallholder farmers rotate production of maize with other crops (e.g. soya, wheat) throughout the year
- **Customizing the thresher to process a minimum of 3 crops** by providing modular spare parts to process specific crop. Solar threshers with customized heads can process a range of pulse and cereals e.g. Agsol's multipurpose equipment
- **A multi-purpose thresher could triple the ROI of the machine.** With fuller year-round utilization, a threshing device could double annual revenues and half the repayment period

Source: Dalberg analysis and interviews. 2018.

ZIMBABWE MARKET **DEEP DIVE**

POLICY ENVIRONMENT

The government reduced taxes on solar products which could increase PULSE uptake, however, existing policy limits growth of the sector

TAXES, DUTIES & SUBSIDIES

- **Excise duty of 40% was removed on all imports of solar products,** however, VAT is still applicable
- Due to inconsistent classification of solar products, **some items (e.g. batteries, chillers) are not included in tax exemptions**
- Aside from tax exemptions, **there are no other incentives and subsidies on solar products**
- The government developed, but is yet to implement the renewable energy feed in tariff (REFIT) scheme which **mandates ZERA to buy power from renewable energy sources (up to 10MW) at a pre-determined price**

Parameter	Solar Products	Diesel/Grid Products	Agriculture Equipment
Import Duty	No	5%	No
VAT	15%	15%	No
Surtax	No	25%	No
Subsidies	No	No	No
Incentives	No	No	No

BROADER POLICY ISSUES

Energy & Solar

- **The government is soon going to approve a Renewable Energy policy** to establish market oriented measures and define regulatory instruments to promote the use of renewable energy as well as establish a Renewable Energy Fund
- **ZESA's immediate priority is to electrify urban areas,** which presents an opportunity to develop alternative energy for rural communities; < 20% of the rural population has access to electricity

Agriculture

- **Strong government push to increase agricultural production:** all agricultural equipment is exempt of excise duty, VAT, surtax, and farmers can access low-interest financing through the state-owned Agribank

Co-ordination/Cross-sector

- **PULSE product use is overseen by multiple players:** various ministries (Energy, Agriculture, Water and Environment), Electrification agencies (ZERA), non-government players (REA), and private sector
- **Inter-stakeholder coordination is limited,** e.g. policy on classification and regulation of renewable energy is required to unlock opportunities around solar energy

Sources: ZIMRA. 2018; ZERA. 2016. "Energy Regulation in Zimbabwe"; Dalberg analysis and interviews. 2018.
Note: VAT– Value Added Tax; Excise duty – paid at customs; Surtax – tax levied on top of another tax

CÔTE D’ IVOIRE MARKET **DEEP DIVE**

SECTION SEVEN

CÔTE D' IVOIRE MARKET **DEEP DIVE**

AGRO-PROCESSING (WITH CASSAVA USE CASE)

The government aims to increase local value addition, providing an opportunity for off-grid agro-processing across multiple value chains

State of play

- Agro-processing accounts for **6.5% of GDP**, 31% of the industrial sector in Côte d'Ivoire
- High processing activity is concentrated within a few value chains, including, cassava, rice, cocoa, cashew, and palm seeds
- **Processing for exports is low overall, (e.g. 31% in cocoa and 6.5% for cashew**, two of the leading cash crops in the country)
- Recognizing the opportunity to increase SHF incomes and retain value locally, the government aims to increase agro-processing particularly in cocoa and cashew **(aiming to process 50% of produce locally by 2020)**
- Agro-processing is divided into industrial, semi-industrial and small-scale processing

Characteristics of the domestic agro-processing market

Industrial processing	• **Ownership:** run by large scale private entities • **Business model:** purchase produce from commercial farmers or SHF cooperatives; process and sell higher value finished product (often export crops)
Semi - industrial processing	• **Ownership:** run by a SHF association or cooperative • **Business model:** buy produce, process and sell finished product. May offer processing as a service and on-sell the product on behalf of the farmer
Small scale processing	• **Ownership:** run by a small cooperative or an entrepreneur • **Business model:** process produce charging a processing fee or against payment in kind. May also purchase produce and sell the finished product

Source: CIV. 2017. "PNIA II"; CIV. 2018. "Cashew : The Ivorian government aims to process 50% of production by 2020" ; AbidjanNet. 2016. "Agro-processing, a vital lever to becoming an emerging economy "; WB National Accounts. 2018; Dalberg analysis and interviews. 2018.

Across scales, incumbent technologies are well established while uptake of solar is low, despite a growing interest

	Large-scale applications	Small-scale applications	Micro-scale applications
Typical products & capacity	 *No solar products operating at >2MT/day*	 *No solar products operating at 1-2MT/day*	 
	>2 MT/day	**1-2 MT/day**	**<1 MT/day**
Degree of uptake	Grid/Diesel: **High**; Solar: **Low**	Grid/Diesel: **High**; Solar: **Low**	Grid/Diesel: **High**; Solar: **Low**
State of play	• Common at the industrial level where high volumes are processed to meet demand in the **export market and the formal retail market** • There are no solar products in the market operating at >5MT/day, but alternative energy plants, e.g. biomass are under development	• Current grid/diesel-powered solutions are based in **cities, towns, and peri-urban areas** where demand is high • There are no solar products in market operating at 2-5MT/day, but there is interest in using solar energy to power processors to reduce operational costs	• Grid- and diesel-powered solutions are common in **small towns and villages** where demand is lower than in small towns • Market-ready solar products are rare on the market, though a few suppliers have some in pilot

Sources: Jeune Afrique. 2018.; RTI. 2018.; Dalberg analysis and interviews. 2018.

Yandalux is an early mover while other existing equipment providers are yet to start supplying solar products

Suppliers of solar products

Organization	Operating model	PULSE products & services	Outlook
Yandalux	Integrated (Manufacturer + distributor)	**Product:** Cassava mill; 50kg/h, price TBD after testing	Targeting women's groups whose main economic activity is processing cassava
		Services: Direct sales to women's groups/co-ops	Looking to move into other products, e.g. rice hullers

Suppliers of grid and diesel-powered products

- Solar processing equipment is rarely used on the Ivorian market despite significant agro-processing activity
- Suppliers of grid-/diesel-powered equipment may be interested in supplying solar equipment, but market demand and affordability of solar equipment needs to be demonstrated to generate buy-in
- Examples of other suppliers are highlighted below:

Imports and sells a range of agro-processing equipment, e.g. oil presses, maize and rice mills, coffee grinders, etc.

Supplies equipment for processors of export crops

Imports and supplies processing equipment for cashew

Local artisans manufacture small scale equipment, which are usually cheaper than imports

Sources: Company websites. 2018; Dalberg analysis and interviews. 2018.

Cassava is a key market for agro-processing actors, as it is one of the main staples in CIV supporting the livelihoods of 1.7M smallholders

1.7M *Smallholder farmers*

3.1M *Annual production in tons*

5.9% *5-year average annual production growth rate*

Cassava - Overview

- At production levels of 3.1 million MT per annum, Côte d'Ivoire is **self-sufficient in cassava production**
- **Smallholders produce over 90%** of this, typically grown on 0.5ha of land or less
- **Over 55% of cassava production is processed,** with attiéké – fermented, granulated cassava – being the most common one
- **Cassava is mostly transformed by small-scale processors**; 70% (~1 million) are traditional village units (family or informal associations), 25% are semi-industrial (~357 140), and 5% industrial (~71 430)
- The high small-scale processing activity provides opportunity for solar products to compete with incumbents

Source: FAOSTAT. 2018; FHB University & CIRAD. 2018. "La chaîne de valeur du manioc en Côte d'Ivoire, 2017; Dalberg analysis and interviews. 2018."
Note: 1) Consumptions varies based on different sources; CIV refers to Côte d'Ivoire

Transformation is the most energy-demanding process in the cassava value chain; a few solar processing options are available in the market

	Production	Transport	Transformation	Distribution & Retail
PULSE opportunity	**IRRIGATION AND MECHANIZATION** • Irrigation to increase production/yields • Solar tractors to improve efficiency of production	**CHILLED TRANSPORT** • Chilled storage to keep raw, unprocessed cassava fresher for longer - this is uncommon in Côte d'Ivoire	**GRINDERS, PRESSERS, GRANULATORS, STOVES** • Grinders to turn it into paste – **grinding is a pre-requisite for all other processes** • Pressers to remove water and granulators convert into grains • Dryers to further remove water	**DRYERS** • Dryers to dehydrate the granules/ground cassava to prolong shelf life
Power capacity of sample products	 0.45-22kW  30-45kW	 1-5kW	 450W  11-15 W	 100-200W
Current small scale activity	• Cassava is drought tolerant and is rain-fed, so **irrigation is uncommon** • **Production usually done by women** who are given a share of farmland by their husbands	• Mini vans and trucks are used for transportation; **transporters are mainly hired by collectors/traders** • Traders often get together to negotiate a transport cost	• Mostly transformed by traditional village units • Grinders use diesel/grid. Pressing and granulating are done manually • **Processing is dominated by women, and often done in groups/co-operatives**	• Traders sell fresh attiéké or other processed products that are bought for same-day consumption or frozen for later use (**due to high spoilage)**

Sources: YesFoodCan. 2014. "Producteurs de manioc livrant l'unité DADTCO; Espaceagro. 2018; FHB University & CIRAD. 2017 "La chaîne de valeur du manioc en Côte d'Ivoire"; Dalberg analysis and interviews. 2018.

Grinding could provide an opportunity for entrepreneurs to address a large market, while minimizing their operational costs

What are the incentives to invest?

- **Cassava needs to be transformed or consumed almost immediately post-harvest** to avoid spoilage, and **demand for processed forms is high**
- Grinding is usually provided as a service, and **costs $10.7/MT**
- In rural areas, mobile diesel-run grinders are common, **they process ~2.5T/week** and use 1L of diesel ($1.1) for ~150-500kg of cassava
- End users, often women/women's groups in remote areas who use ground cassava to make attiéké or placali for sale and for consumption
- Solar could provide benefits to customers by enabling **more accessible services, with lower time and transport costs**

*"We spend a lot of money on electricity. We could save a lot if we are able to cut that out of our costs" – **Leader of cassava processing co-operative***

What are the constraints to uptake?

	Upfront costs	At a cost of **~$1,750**, solar grinders are double the cost of diesel ones **(~$890)**, posing an affordability barrier
Mobile Grinder	**Limited battery running time**	**Mobile solar-powered grinders use a battery that can run for 4 hours post-charge**, limiting grinding activities and therefore total revenues
Stationary Grinder	**Mobility**	**Mobile diesel-run grinders are common in rural areas**, so stationary solar grinders may struggle to be competitive in remote areas
Stationary Grinder	**Higher operational costs**	**Stationary grinders could increase operational costs** for the service provider if customers expect them to collect/deliver produce to compete with the mobile diesel grinders

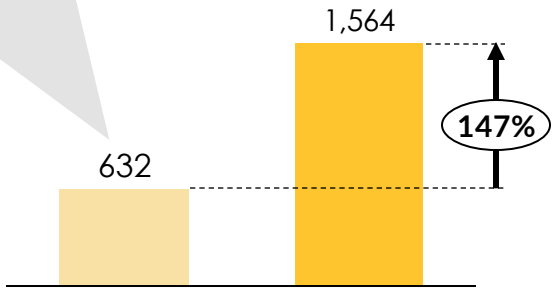
Source: FHB University & CIRAD. 2017 "La chaîne de valeur du manioc en Côte d'Ivoire"; Dalberg analysis and interviews. 2018.
Note: 1) Assumes that most people in rural areas are in the lowest quintile (20%)

Solar grinders have lower capacity & revenue potential than diesel, output for mobile grinders is further constrained by battery run time

Annual revenue from solar vs diesel (both mobile)

(annual revenues in $)

- The mobile solar grinder could also operate as a stationary device, but is **limited to 4h/day when mobile due to battery life**
- With a second battery, the mobile grinder could match revenues of the stationary one, or surpass them as mobility allows it to capture additional market

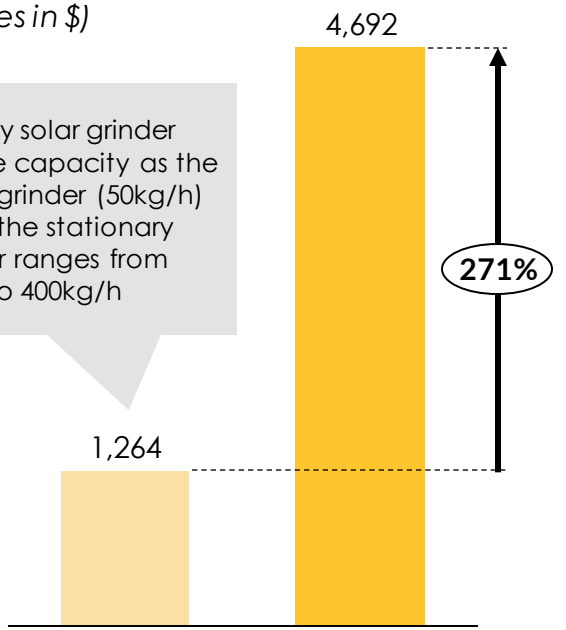


	Mobile solar grinder	Mobile diesel grinder
Max capacity (MT/year)	**59**	**146**
Product type	Mobile solar grinder	Mobile diesel grinder
Hourly capacity	50kg/h	50kg/h
Hours/day	4	8

Annual revenue from solar vs diesel both stationary

(annual revenues in $)

- The stationary solar grinder has the same capacity as the mobile solar grinder (50kg/h)
- Capacity of the stationary diesel grinder ranges from 150kg/h up to 400kg/h



	Stationary solar grinder	Stationary diesel grinder
	118	**438**
Product type	Stationary solar grinder	Stationary diesel grinder
Hourly capacity	50kg/h	150kg/h
	8	8

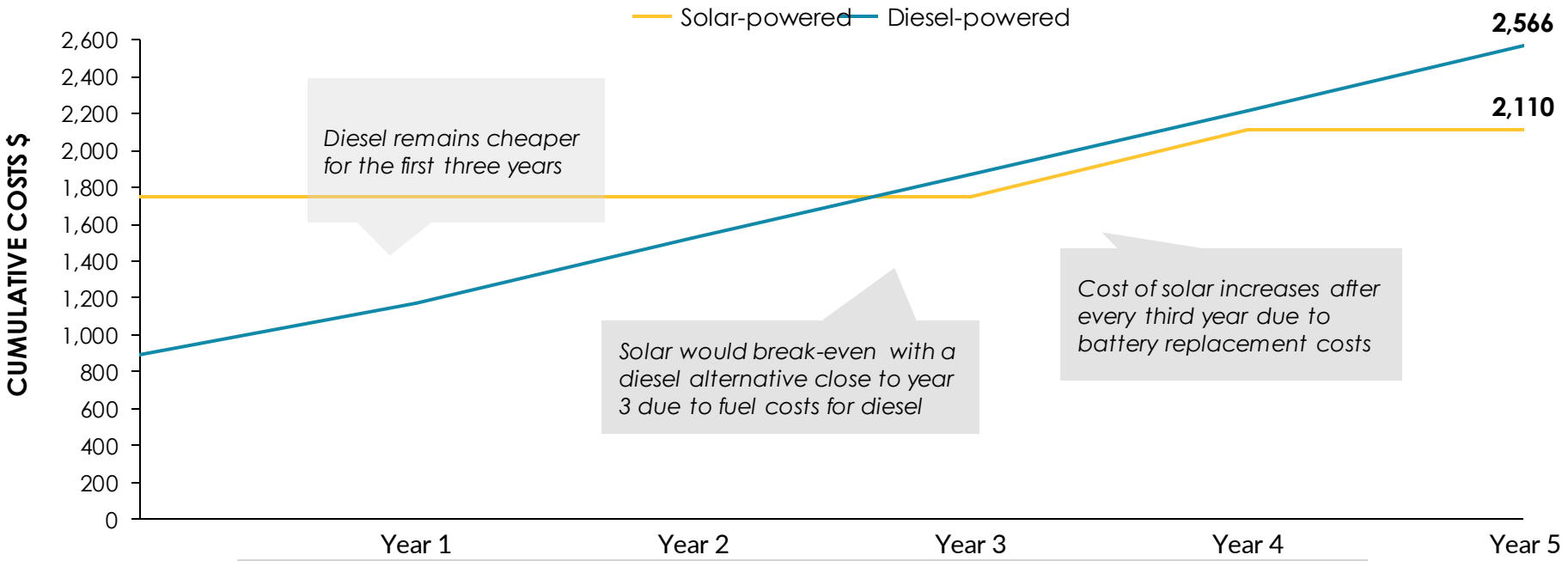
Note: subsequent analyses use the mobile solar grinder and factor in the cost of a second battery for maximum utilization

Source: Dalberg analysis and interviews. 2018.
Note: Charges for grinding are $10.71/MT

The upfront cost of solar is twice that of diesel, but solar becomes slightly cheaper than diesel within approximately 3 years

Cumulative annual expenses over five years: solar vs. diesel (mobile)

US dollars ($)



Key assumptions:

Mobile solar-powered grinder
- Capacity: 50kg/h
- Product cost: $ 1,750 (2,366 if incl. financing)
- Maintenance: $ 360 every three years*
- Annual operating days: 294
- Utilization: 80%

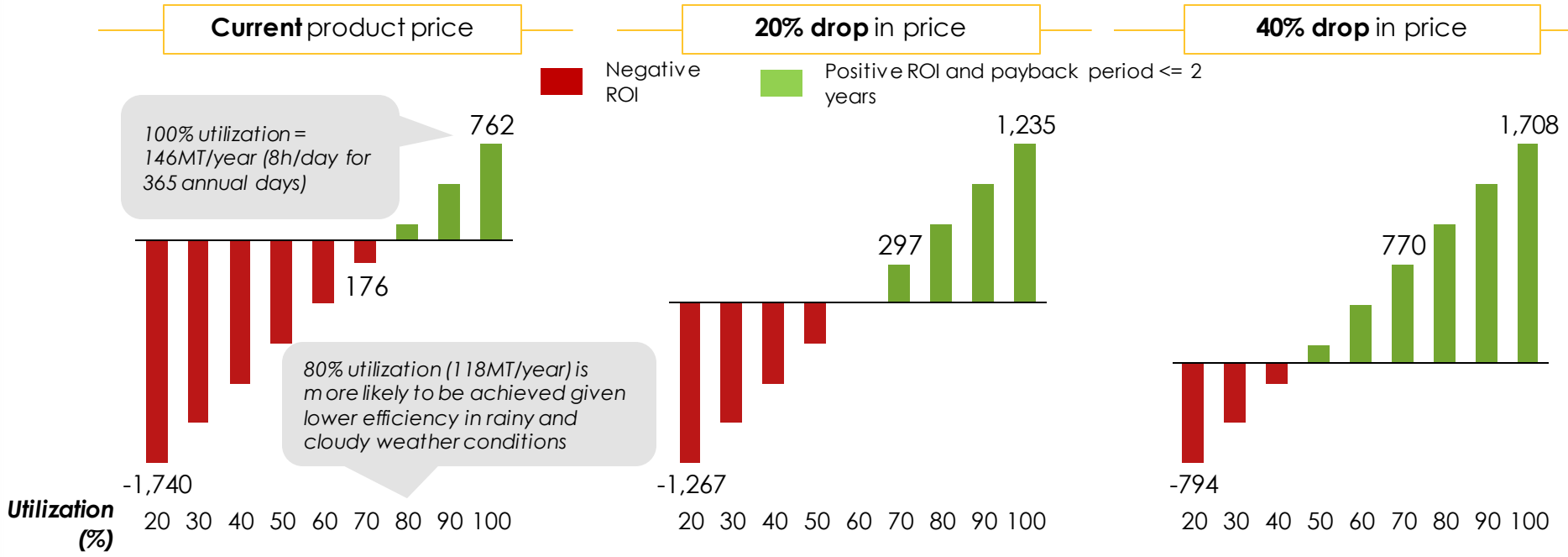
Mobile diesel-powered grinder:
- Capacity: 50kg/h
- Product cost: $ 893, (1,029 if incl. financing)
- Fuel costs: $ 1.1 per liter; 1 liter per 0.5T
- Annual operating days: 365
- Utilization: 80%

Source: Dalberg analysis and interviews. 2018.
Note: Assumes use of two batteries to be able to operate at maximum capacity.

Utilization rate is key for returns, the cost of a solar grinder would need to drop ~40% to achieve two-year payback at 50% utilization

Two-year net operating income by demand (MT/year):

X-axis = MT/year %; Y-axis: operating income in US dollars



PAYBACK PERIOD	Current product price	20% drop in price	40% drop in price
	19 months @ 100% utilization	15 months @ 100% utilization	11 months @ 100% utilization
	37 months @ 50% utilization	30 months @ 50% utilization	22 months @ 50% utilization

Source: Dalberg analysis and interviews. 2018.
Note: Product price ($1750, without financing, $2366 with financing). Assumes the current/initial total cost of the grinder (including panel and battery) is $1750

Achieving a high but realistic utilization of 80% (118MT/year) would require serving 284 households (approximately an area of 4.5 sq. km)

Minimum number of households to serve per year

118 MT of cassava/year

÷

0.077MT/ person/year[1]

=

1,532 people/year

÷

5.4 people/household[2]

=

284 households

Coverage (area) required for commercial viability

1,532 people/year

÷

339 people/sq. km[3]

=

~4.5 sq km

The coverage area could further be reduced if the grinder serves an area with a high concentration of women's co-operatives involved in processing cassava - that can provide high demand within a short radius

Note: 1) Annual per capita consumption is 140kg, of which at least 55% is processed forms. 2) Average household size in Côte D'Ivoire (ArcGIS). 3) Rural population density per sq. km of arable land (ArcGIS).
Source: FHB University & CIRAD. 2017 "La chaîne de valeur du manioc en Côte d'Ivoire"; Dalberg analysis and interviews. 2018.

Aside from lowering price, uptake can be boosted by targeting mobile grinders to entrepreneurs & stationary ones to small women's co-ops

FACTORS TO STRENGTHEN BUSINESS CASE

Improve battery life of the grinder

Maximize daily revenue generating capacity

EXPLANATION

- Currently, the mobile grinder is limited in processing capacity due to the **short discharge time of the battery**
- Improving battery life would **increase the amount of revenue** that can be earned daily, making it more economically viable
- It would further **reduce the need to buy an additional battery,** considering that product cost may already be a barrier to purchase

Target small women's co-operatives and informal associations

High processing activity and demand for grinders

- Women's groups process up to **300-600 MT of cassava/year**, (3-5x the maximum capacity of a solar grinder 118MT/per year)
- Smaller groups in more **remote areas with lower market access likely process smaller volumes**, and may be willing to invest in stationary grinders (some groups already own diesel/grid-run grinders)
- **Solar mobile grinders can be used by micro-entrepreneurs** to serve individuals or multiple dispersed women's groups

Sources: USAID Investment Support Programme. 2017. "Cassava Value Chain Financing Analysis in Côte D'Ivoire"; Dalberg analysis and interviews. 2018.

CÔTE D' IVOIRE MARKET **DEEP DIVE**

AGRO-PROCESSING (WITH RICE USE CASE)

Rice is an important crop for the agro-processing market – it makes up more than 60% of cereal production and 4% of agro-processing GDP

2 M *Rice farmers*

1.9 M *Annual production in MT*

3% *5-year average annual production growth rate*

64% *Share of rice in total cereal production*

Rice - Overview

- Rice is the most consumed cereal, and **the 3rd most consumed food crop** after yams and cassava
- Local production does not meet **demand; annual imports total 1.2 MT** to cover the deficit
- Rice production consists of **80% rain-fed rice**, 15% irrigated rice, and 5% deepwater rice
- Majority of rice production is processed by mills with capacities of **at most 1MT/hour:**

Mill capacity/h	# of mills	% of rice milled
<= 500kg	1,672	47.9%
500kg - 1T	380	35.6%
1T - 5T	98	16.3%
5T	2	0.2%

- In an effort to improve rice processing and marketing, the government has installed 12 high capacity processors (5T/h), with 18 to be added
- Small-scale solar hullers/mills can bring processing activities closer to farmers in remote areas

Sources: FAOSTAT. 2018; Dalberg analysis and interviews. 2018; National Rice Office. 2018; Presse Côte d'Ivoire 2018. "Rice Self-sufficiency: 30 industrial rice processing plants will be used"
Note: Determined by the value of rice milling services recorded by mills over the value of agro-processing as a share of GDP (6.5% of GDP).

There are opportunities for increased mechanization across the value chain, with transformation being the most energy intensive stage

	Production	Harvesting and Transport	Transformation	Distribution & Retail
	IRRIGATION PUMPS	**THRESHERS AND DRYERS**	**HULLING AND POLISHING MILL**	**N/A**
PULSE opportunity	• Irrigation to increase production – due to communal irrigation using dams and high volumes of water used, pumps would need high power capacity	• Thresher to remove rice from stalks cleanly and efficiently • Dryers to reduce moisture content before milling	• Mills to hull and whiten rice with minimal to no breakage and impurities	• No strong PULSE opportunity in distribution
Power capacity of sample products	  0.45-22kW 30-45kW	 100-200W	 250-375W	N/A
Current small scale activity	• Gravity-fed irrigation is the most common system used for irrigated rice • Irrigated rice has the highest yields, but it is at least 2 times more expensive to grow than rain-fed rice	• **Non-mechanised methods are used in threshing**, causing losses from rice falling to the ground and mixing with dirt • Rice is laid out and dried directly under the sun	• Grid-powered mills are used in peri-urban and urban areas while diesel-powered ones with capacities of **250-400 kg/hour** are used in areas with limited access to the grid • Manual labour may be used to de-husk, but this is rare	• Mills either buy paddy (unmilled) or white (milled) rice from famers and on sell milled rice to wholesalers, retailers or consumers • Sale of rice in the local markets (outside of mills) is dominated by women

Source: Dalberg analysis and interviews. 2018; CAPEC. 2009. "Evolution of Rice Production and Imports in CIV from 1965 to 2008".

Solar mills can bring processing services closer to rice farmers who would normally travel 2-7 km to mill their rice

What are the incentives to invest?

- **Rice needs to be transformed or consumed almost immediately post-harvest** before it ferments and spoils
- Demand for processing services is high – **95-98% of farmers take their rice to a mill for processing** and travel **2-7km** to access a mill. A minority hull it manually but this is rare due to the tediousness of the process
- In some cases a co-op will transport the rice and charge the farmer **$9-12/MT for transport** (average farmer yield is 0.5-1T)
- Entrepreneurs in remote, off-grid areas can acquire solar mills and generate revenue by offering processing services closer to home **(market rate for milling is ~$ 53/MT)**
- **Mills also earn money from selling white rice** (a role played by many rice processors)
- While not the direct investor in a mill, farmers would benefit from reduced transport and time costs

What are the constraints to uptake?

Upfront costs	**High cost of solar mills presents a significant barrier**. At $ 2,000-3,000, solar mills are ~4-6 times more costly than small diesel mills
Milling capacity	**Solar mills (40-70 kg/h) are slower** than the small diesel ones (200-400kg/h), As a result, **less revenue can be generated daily**, and **waiting times will be longer** and could result in loss of customers, e.g. a farmer with 0.5T would wait **7-12h**
Perceptions of quality of rice from small mills	**Small diesel mills produce rice with** high debris/stone content as they **lack the cleaning compartment that larger mills have.** Due to their small size, solar mills may be perceived as low quality, and need to produce rice of similar quality to that of small diesel mills to be competitive

Sources: Dalberg analysis and interviews. 2018; Aloko-Nguessan J. 2015. "The informal commercialisation of local rice in Gagnoa".

Mills have two revenue sources, subsequent analysis anchors on milling as a service as this is where discrepancies with alternatives arise

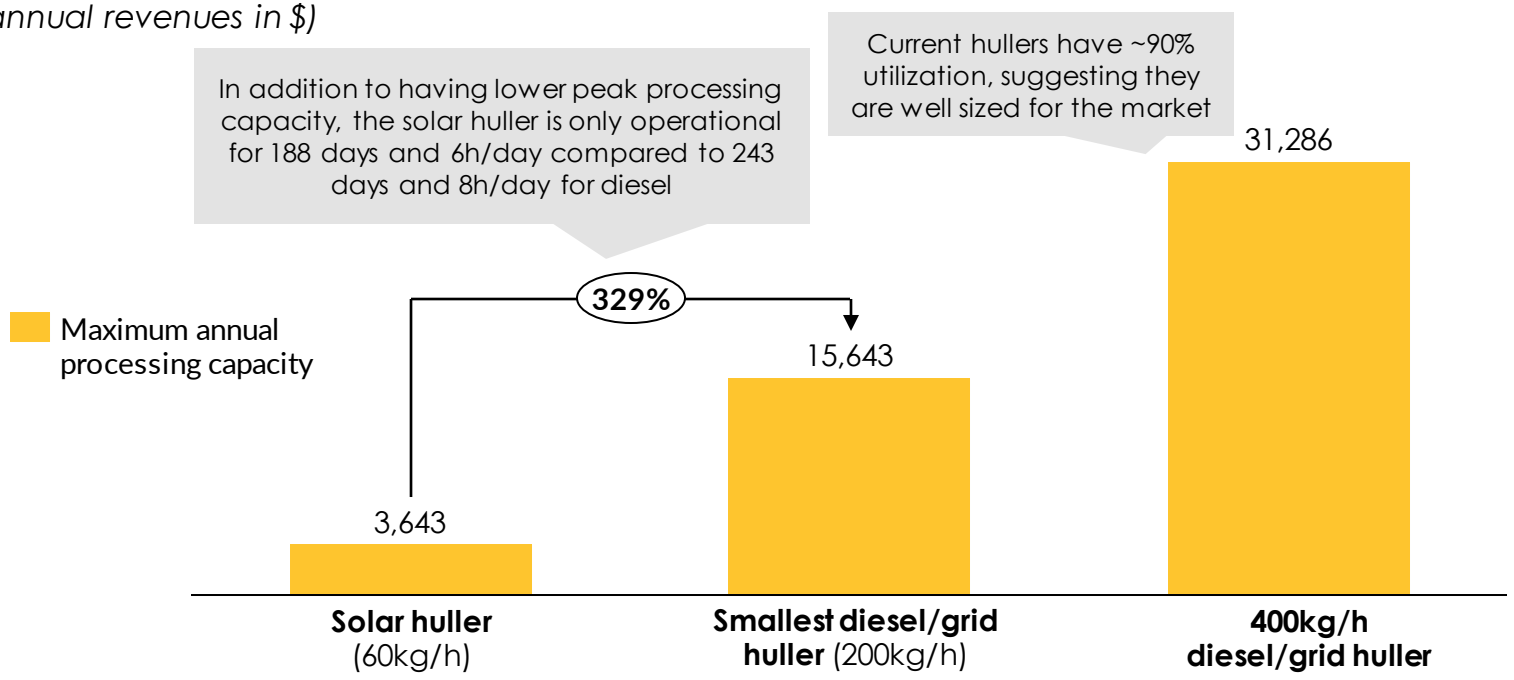
Revenue source	Operational dynamics	Business implications for a solar product
Milling as a service	• The processor mills the farmer's rice at $53.5/MT • If the farmer doesn't have the money to pay for the service, **the processor keeps a share of the milled rice as payment**	• A solar mill's main value proposition for the customer (farmer) would be shorter travel distance and lower transport costs • If the mill is closer to the farmers, it can capture some market share from diesel mills, but would be **further from wholesalers and retailers, increasing the cost of reaching better priced markets** • While the mill makes a higher margin per MT from selling rice than hulling, subsequent analyses on commercial viability focus on the provision of hulling as a service as **operational costs when compared with diesel largely arise out of the hulling services**
Sale of milled rice	• The farmer **sells ~85-90% of the processed rice to the mill** and takes the rest home for consumption, and may sell some on the local market • The processor sells the milled rice to wholesalers and retailers, making a margin of ~$180/MT • Buyers may come to the mills, or mills may transport rice to neighbouring towns/clients	

Source: Dalberg analysis and interviews. 2018.

Solar hullers have lower revenue potential than diesel ones due to lower processing capacity

Annual revenue using a solar huller vs diesel

(annual revenues in $)



	Solar huller (60kg/h)	Smallest diesel/grid huller (200kg/h)	400kg/h diesel/grid huller
Maximum MT/year	68	292	584
Maximum farmers served annually	75	294	648

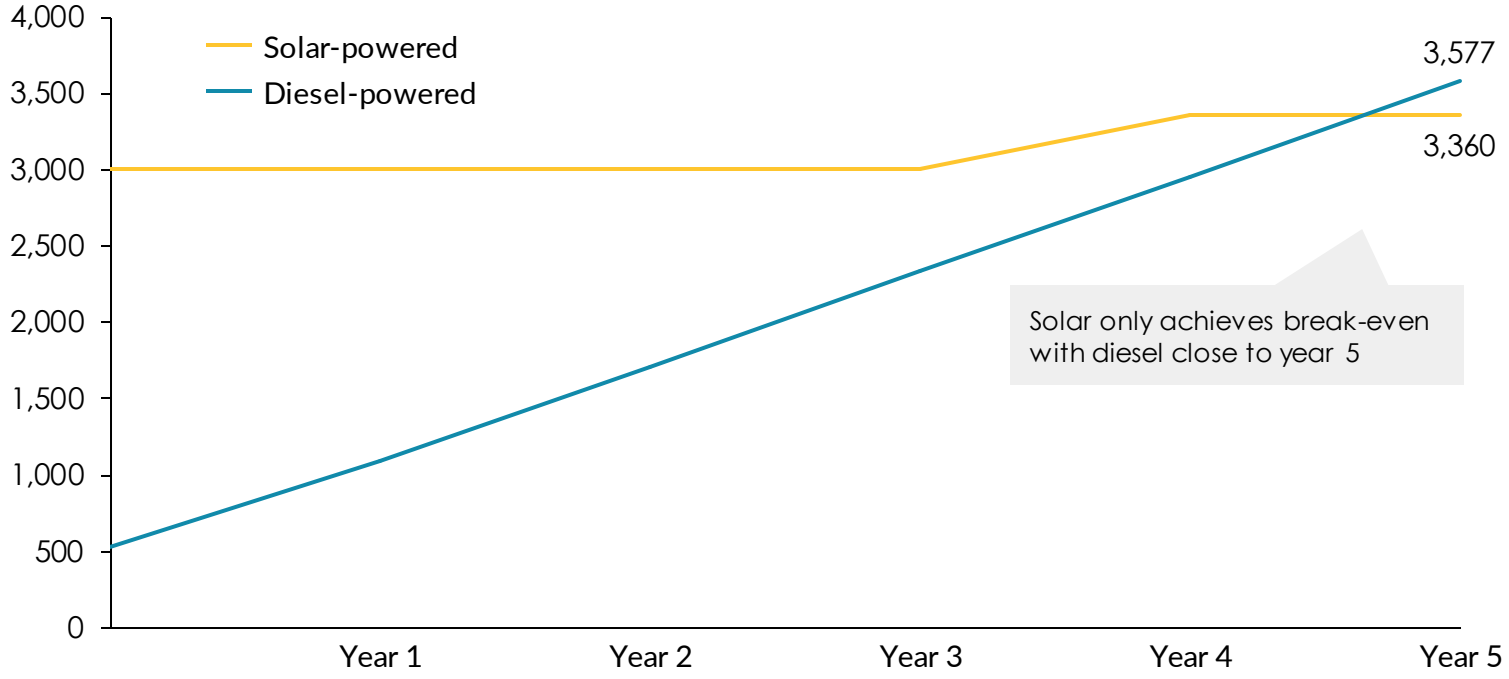
- Maximum capacity is based on 8 month operations (number of months when hulling activity is high)
- Hulling is usually done a few days or weeks after harvest as hulled rice has lower spoilage rates when stored; high processing performance is important after harvest when demand is high

Source: Dalberg analysis and interviews. 2018.
Note: *Annual demand for small mills = % of market share mills of <500kg/h (47.9%*1.87MT) divided by number of mills with capacity of <500kg/h (1672mills). Number of farmers is based on average yield of 0.9T/farmer.

Even if the diesel huller serves the same demand as solar (68MT/year), solar only breaks even with diesel at ~year 5

Cumulative expenses over five years: Solar vs. diesel

($, both machines operating at capacity of 68MT/year, Revenue/MT: $ 53.57 (market price)



Key assumptions:

Solar huller
- Maximum annual capacity = 68MT
- Product cost: $3,000 (4,056 with financing)
- Maintenance: $360 every three years*
- Annual operating days: 188

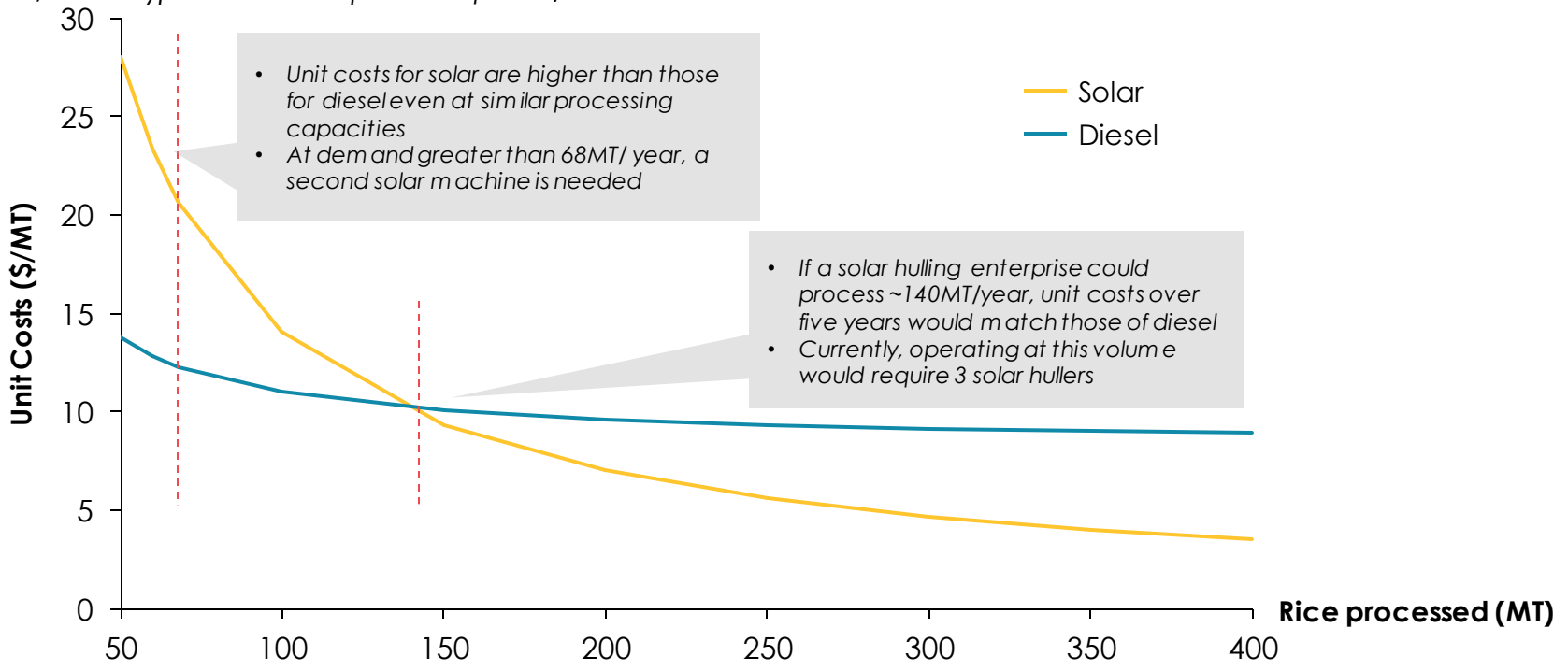
Diesel huller
- Maximum annual capacity = 584MT
- Product cost: $536, (724 with financing)
- Fuel costs: $1.1 per liter; 1 liter per 0.13T
- Annual operating days: 243

Source: Dalberg analysis and interviews. 2018.
Note: Maintenance cost is due to battery replacement

A solar huller would need to increase annual processing capacity from 68MT to 140MT to match viability of a diesel machine over five years

Unit cost analysis of solar vs. diesel (averaged over 5 years)

$/MT, for a typical current price of $ 53.5/MT



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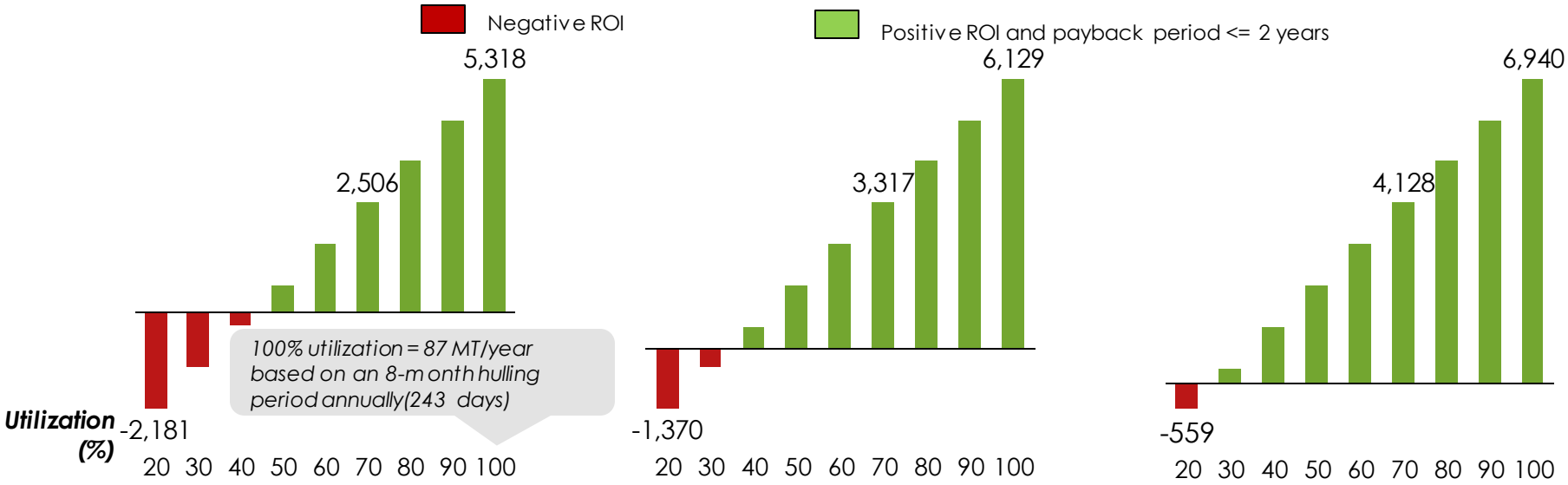
- Annual operating days: 243

Source: Dalberg analysis and interviews. 2018.

However, at current product costs, solar hullers operating at 50% utilization would still be able to pay back the product in two years

Two-year net operating income by demand (MT/year):

(X-axis = MT/year %; Y-axis: operating income in $). Product price ($3000, without financing costs)



PAYBACK PERIOD	Current product price	20% drop in price	40% drop in price
	11 months @ 100% utilization	10 months @ 100% utilization	7 months @ 100% utilization
	21 months @ 50% utilization	17 months @ 50% utilization	13 months @ 50% utilization

Source: Dalberg analysis and interviews. 2018.
Note: Assumes the current/initial total cost of the grinder (including panel and battery) is $3000

Aside from lowering the cost of the product, improving performance and quality of output could help increase uptake

FACTORS TO STRENGTHEN BUSINESS CASE

Increase processing capacity

Maximize daily revenue-generating capacity

- Currently, revenues from the solar huller are limited due to the **low peak processing capacity**
- Increasing capacity would **increase the amount of revenue that can be earned daily**, making it more economically viable
- It would also **reduce loss of customers who may choose to travel further** for faster services, especially if they would have to process their rice over multiple days at a solar processor

Target rice co-operatives to support distribution

High farmer aggregation capacity

- The government aims to increase commercialization of rice to meet the high and growing national demand
- This includes **increasing processing capacity** and **improving farmer mobilization through co-operatives**
- These co-ops could play a key role in **aggregating farmers to support product roll-out**, but improving processing capacity is crucial for buy-in

Refined product to ensure high quality rice

High value proposition for better quality rice

- Small mills usually lack the cleaning compartment that removes impurities – incorporating this into a solar product would help **boost the reputation of solar mills**
- Since mills are **directly involved in marketing rice**, a processor that provides higher quality would have better **market access and prices**
- Higher quality is also **more likely to incentivize support from co-operatives**

Source: Dalberg analysis and interviews. 2018.

CÔTE D' IVOIRE MARKET **DEEP DIVE**

COLD STORAGE (WITH FISHERIES USE CASE)

Post-harvest losses in Côte d'Ivoire are mainly due to lack of adequate cold storage facilities/cold chain

Cold storage needs in Côte d'Ivoire

- **Lack of adequate transport, storage, and preservation facilities** in production regions are the main reason for post-harvest loss
- Cold storage could help reduce losses in **fishery and horticulture where major post-harvest losses** are registered*:
  - Fish: **30-50%** of produce lost
  - Fruit: **20-40%** of produce lost
- Many formal and informal suppliers meet the urban household demand for cold storage, however agribusiness demand is met mainly for formal retailers, importers and exporters
- The majority of small-scale producers serving local markets lack access to cold storage facilities, particularly in rural areas

Current supply & coverage

An overview of cold storage across four value chains with highly perishable produce is provided below:

Fish	• Players in the formal value chain use large scale cold rooms and refrigeration facilities • In informal channels, **vendors with ice machines** supply ice to fishermen & traders
Horticulture	• High need, particularly for SHFs at farm level • However, uptake is low, and some development partners are starting to **target small-scale actors with technologies on a shared basis**
Cassava	• Raw cassava is processed quickly before it spoils, and processed forms are frozen in urban households to prolong the shelf life and are **consumed immediately in rural households**
Dairy	• Spoilage is **poorly quantified** and likely receives little attention due to high imports (**88% of milk is imported**) through formal channels (with cold storage) & transformed

Source: CNRA. 2018. "Programme conservation et transformation des produits agricoles"; CTA and ISF. 2016. "Cassava production and processing"; Koffi Y. F. 2018. "Ananas: Alterations et Moyens de Lutte"; Dalberg analysis and interviews. 2018.
Note: These are overall losses. There is limited research on the exact contribution of cold storage to losses

Small- and micro-scale solar cold storage solutions are gaining traction in rural areas, but costs remain prohibitive

	Medium-scale applications	Small-scale applications	Very small-scale applications
Typical products & capacity	 		 
	>2000 L	*201 – 2000 L*	*<200 L*
Degree of uptake	Grid: **Medium** Solar: **Low**	Grid: **Medium** Solar: **Low**	Grid: **Medium** Solar: **Low**
State of play	• Large-scale grid systems, such as cold rooms, are in use, but are limited to commercial fish and meat importers and fruit exporters • There are **no large-scale solar players**, but development partners are exploring solar options for agriculture VCs	• Commercial retailers and wholesalers use small-scale grid solutions. In the fish sector, bulk traders rent out freezer space to smaller traders • There are a limited number of small-scale, solar cold solution suppliers, they largely target rural small-scale retailers & households, though **affordability is a challenge**	• Many formal and informal electronic appliance suppliers **offer household fridges/freezers** that are not specifically designed for the agriculture space • Solar household cold storage and retail solutions have started to penetrate the SHS market, with suppliers offering a range of solar products as opposed to specializing in solar cold storage

Sources: IFAD. 2017 "PADFA"; AMSCO. 2018; Dalberg analysis and interviews. 2018.

There are a growing number of suppliers in the market, often including cooling alongside other consumptive/productive use products

Organization	Operating model	PULSE products & services	Outlook
Yandalux	Integrated (Manufacturer + Distributor)	**Product:** Fridges, <200L, ~$2,300 **Services:** Sell household products, designing and testing market-relevant PULSE products	Supplied small scale cold storage solutions but halted imports after experiencing quality challenges Also supply other solar products: pumps, grinders, and tricycles
Ledak	Distributor	**Product:** Fridges, <200L, ~$4,800 **Services:** Sell and install household, retail, and agriculture products	Target rural communities to provide both household and retail fridges and freezers Also supply SHSs and pumps; work with farmers to provide input finance and market access, so as to promote uptake of pumps
HACH /HICOM	Integrated (Manufacturer + Distributor)	**Product:** Freezers/ fridges, 50L – 500L, ~$895 - 8950 **Services:** Sell household and business solar solutions; convert energy for households and businesses from electricity to solar	Currently supporting government efforts and seeking to expand to other renewable energies

Other solar players

APHELION ENERGY — Provides household, business and industrial solar solutions, including household and medical refrigeration

STATIONENERGY WWW.STATION-ENERGY.COM — Offers a range of household and business products for remote, off-grid populations. Solar solutions include SHS, kiosks, pumps, cold storage

Sources: Dalberg analysis and interviews. 2018; Company websites. 2018.

The fishing sector is attractive to suppliers due to the high spoilage rates (+30%) and potential consumer base (70,000 directly engaged)

82,800 MT — *Annual local production*

70 000 — *Number of people employed directly*

2% — *Share of population supported by the fishing sector*

Fisheries - Overview

- **Annual consumption is 388,700 MT (i.e. 17 kg per capita)**, of which 12% is satisfied by local production and 88% is imported
- **The 82,800 MT of annual local fish production** comprises 73% artisanal fishing, 22% industrial fishing, and 5% aquaculture. Inland and lagoon fishers, and sea fishers contribute equally to the national production
- **The sector directly employs 70 000 people, of whom ~32,000 are fishermen and the rest are traders and processors**
- **98%** of domestic and imported fish are traded on the **informal market**; **39% of total fish is consumed fresh**
- The sector has spoilage rates of **30-50%, largely driven by a lack of cold storage facilities**; smoking is the most common method of preservation used to reduce losses

Sources: CIV & UEMOA. 2016. "Inland and Lagoon Fishing in Côte d'Ivoire"; CIV & UEMOA. 2016. "Offshore Fishing in Côte d'Ivoire"; CIV. 2017. "Fishery Division"; FAO. 2008. "General Overview of Fishery Sector in Côte d'Ivoire"; Dalberg analysis and interviews. 2018.

While there is an array of opportunities for PULSE products across the value chain, cooling addresses the most pressing challenges

	Production	Collection & Transport	Transformation	Distribution & Retail
PULSE opportunity	**FISHING LIGHTS AND SOLAR AERATORS** • Fishing lights to increase visibility while at sea • Solar aerators to transfer and circulate oxygen in fish ponds	**COLD TRANSPORT** • Cold chain transport to reduce spoilage in transit, e.g. when being transported from coastal areas further inland	**OVENS** • Ovens to smoke fish – current approaches use wood/charcoal to heat, and a solar-powered motor to distribute heat evenly	**REFRIGERATION, FREEZING, ICE MAKER** • Freezers/fridges and ice makers to allow bulk traders and market vendors to store fresh and smoked fish
Power capacity of sample products	  0.8-1W 1.5-17W	 1-5kW	  100-200W	 40-200W
Current small scale activity	• Little night fishing, but fishers may use **torches** • Fish farmers use electric/diesel aerators to circulate air in ponds • Fishing is dominated by men, but their **trips are at times financed by bulk traders (mostly women)**	• Commercial traders have **refrigerated trucks** to transport cross-country • **Smaller bulk traders** distributing inland use **non-refrigerated vehicles** from major towns to more rural areas	• Traders smoke fish using charcoal and firewood. A few **solar-coal hybrid ovens are being tested by a local supplier** • Smoking is dominated by women, and poses serious health risks for them	• Bulk traders of fresh fish use old, non-functional freezers, which they **fill with crushed ice** • Smaller market traders use **coolers filled with ice** at trading points

Source: Dalberg analysis and interviews. 2018.

Cooling can increase fish traders' incomes by reducing quality losses and allowing them to capitalize on the demand for fresh fish

What are the incentives to invest?

- Fresh fish, once captured, spoils easily and **needs to be kept in cold storage until consumed or processed**
- Fishermen store their catch in boxes with ice while out at sea and offload fish as soon as they land; bulk traders are often located at coastal and inland landing sites and have easier access to ice than market vendors
- **Market vendors are prioritized as a target segment**; they have the fish the longest, and experience the highest losses. Value add is:
  - **Increasing volume of fish available for sale** by eliminating spoilage
  - **Reducing proportion of fish sold at lower prices** due to fear of spoilage
  - **Decreasing operational costs** of daily ice
  - **Serving latent/unmet demand** for fresh fish

What are the constraints to uptake?

Upfront costs

The smallest (~20L) solar coolers sufficient for market trader volumes cost **~$400**, compared to the cooler boxes currently used by traders which cost **~$45**

Product design (mobility)

Current solutions have not been specifically designed for the realities of market traders; who need portable cold storage that **can be carried to and from the market daily.** Existing products are bulky, or if mobile, are designed largely to be transported by car and not carried by hand

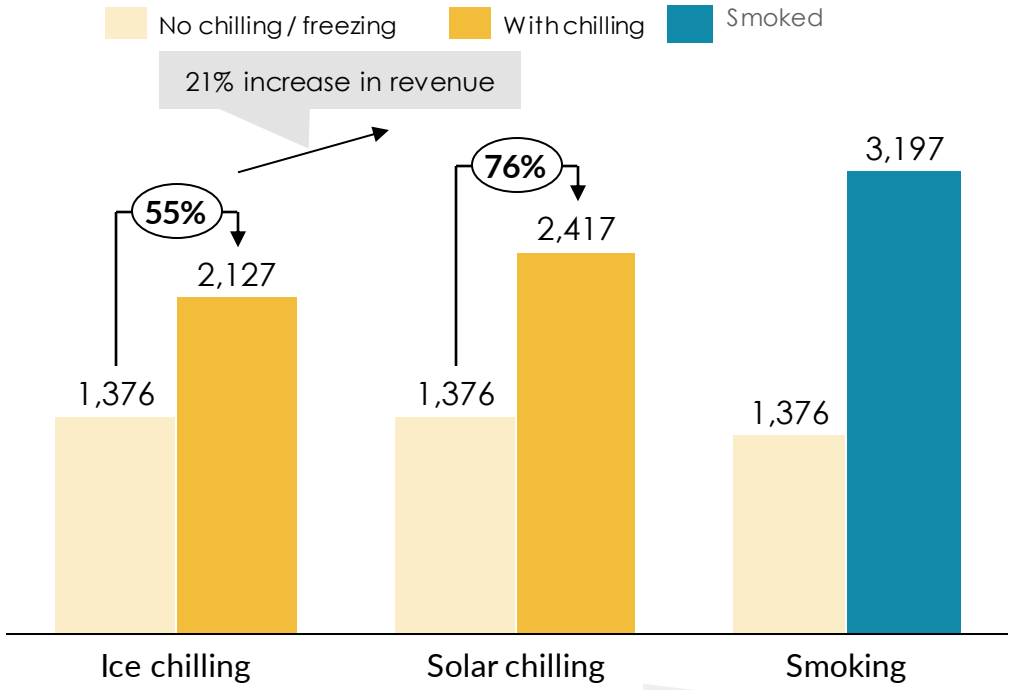
"Some people prefer smoked fish to fresh fish. Often smoking happens because people can't keep the fish fresh for a long time. Some will buy ice, but in rural areas even ice is scarce" ***– Fish trader***

Source: Dalberg analysis and interviews. 2018.

Fish traders using purchased ice could achieve up to a 21% boost by switching to solar; being highest for those with low access to ice

Annual revenue selling chilled vs. unchilled fresh fish – for a sample trader @ 15kg/week

(annual revenues in $)



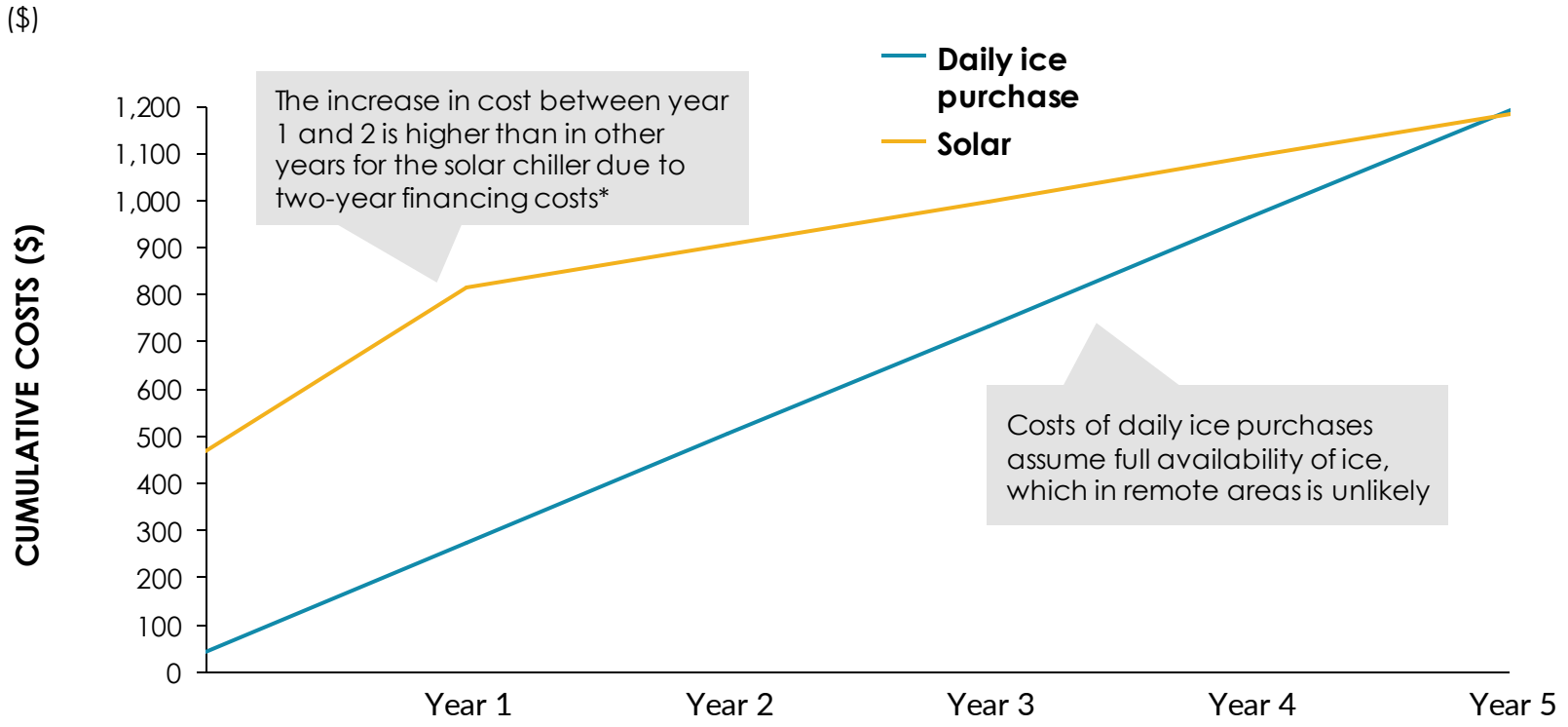
- Revenues from using ice are lower compared to solar freezing, as with ice a proportion of the fish is sold at lower prices due to inability to chill overnight[1]
- Solar chilling would be most attractive in remote areas where access to ice is low **(no grid power for ice vendors to produce ice)**

- Some traders specialize in either fresh or smoked fish, **others sell both, to serve demand for both types**
- **Prices for smoked fish are higher** than for fresh fish, (~$4.1/kg, vs $~3.1/kg) but margins are similar (~$1/kg)[2]
- While more available solar chilling will incentivise traders to store fish to sell fresh, **a large segment of the market prefers smoked fish**, which traders will continue to supply, in part because the prices for smoked fish are higher

Source: Fishery Division, Côte D'Ivoire; Dalberg analysis and interviews. 2018
Note: 1) Throw away prices for fish can be as much as 50% lower due to decreasing quality and market saturation. This analysis assumes that under ice chilling ~40% of the fish stock is sold at 30% lower prices). 2) Margins are similar when smoked fish is purchased smoked from wholesalers for retail, but could be higher for smoked fish when an individual retailers purchase fresh fish, and then smoke it themselves

However, at more than 10x the initial cost of traditional cooler boxes, use of the solar freezer only breaks even with ice at five years

Cumulative product and operating costs for solar freezer vs. a cooler box + daily ice purchase



Key assumptions:

Solar powered freezer
- Capacity: 20L
- Product cost: $ 603 (with financing costs)
- Maintenance: $ 92/year (batteries)

Plastic cooler box
- Capacity: 25L (current product used in the market)
- Product cost: $ 45 (no financing)

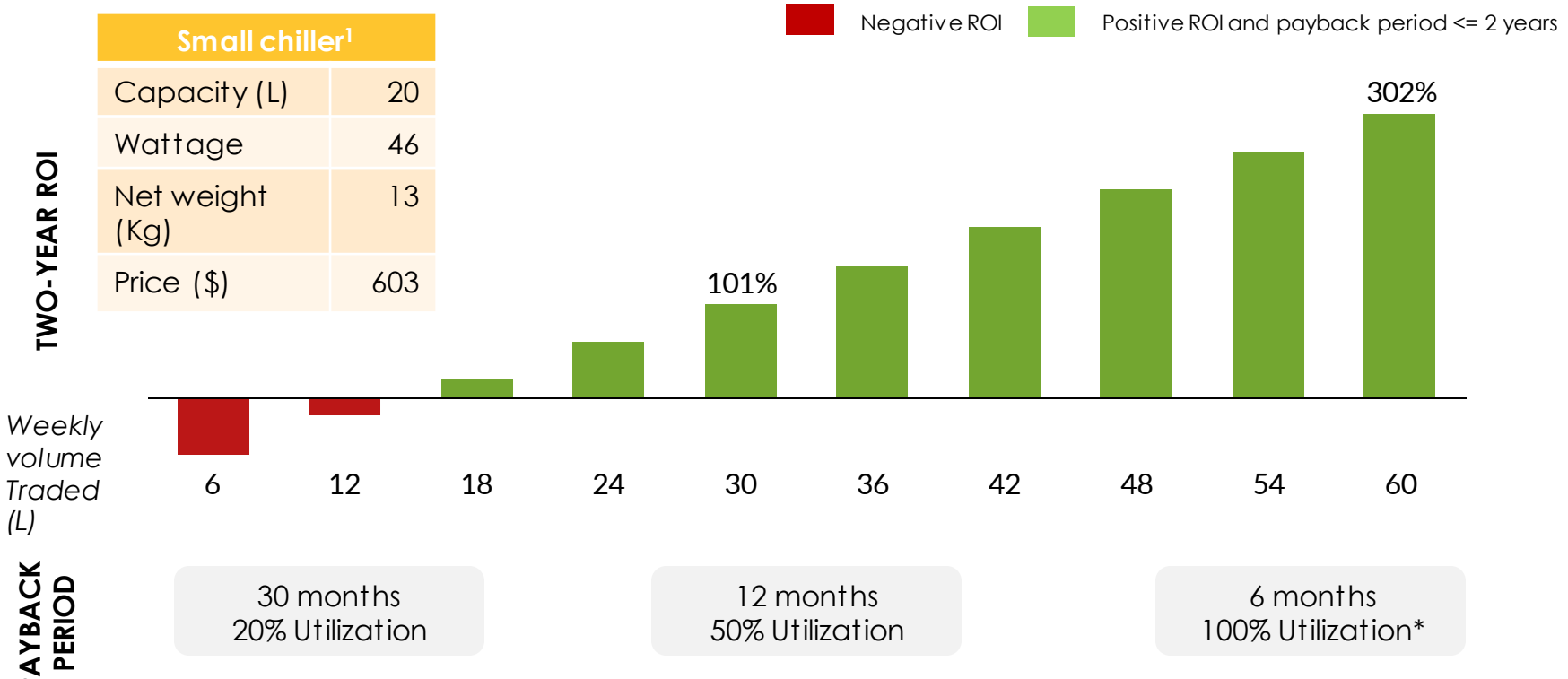
Source: Dalberg analysis and interviews. 2018.
Note: 1) The reference product is currently not available in the market. 2) Traders will likely need financing to afford chillers, calculations used assume A 20% upfront payment and two year loan term at an interest rate of 20% per annum, based on terms on MFIs in Côte D'Ivoire.

A trader would need at least 50% utilization (30kg/week stored fish) to pay back within a year, assuming some spoilage remains

Two-year return on investment small solar chiller with varying utilization

X-axis = Volume traded (L); Y-axis: operating income in $, current product price = $603 ($815 with financing costs)

Small chiller[1]	
Capacity (L)	20
Wattage	46
Net weight (Kg)	13
Price ($)	603



Solar freezers pose mobility challenges due to their weight. At 13kg, the small freezer is still bulky – a smaller/lighter product would better suit more mobile traders dealing in small volumes

Source: Dalberg analysis and interviews. 2018.
Note: 100% utilization = 60kg per week, based on freezer capacity of 20kg and 3 trading days a week, assume conservative assumption that chilling halves losses (16% losses remain) and same priced sales as chilling with ice

Product uptake could be improved by targeting traders with higher spoilage, higher financial losses, and by making the product lighter

FACTORS TO STRENGTHEN THE BUSINESS CASE

Target traders in rural, inland areas

Inland traders experience higher losses

EPXLANATION

- **Coastal areas have higher access to ice** due to accessible grid power, and **strong incentive for ice vendors to invest** since the volume of fish per given area is higher
- Access to ice in rural areas further inland is lower than coastal areas, due to the limited grid power
- **Traders inland may be more willing to invest** in a solar chiller as ice is not an option

Target fish traders trading in higher value fish

Certain fish types provide higher income per kg

- Traders supplying high value fish experience **higher financial losses per kg** when fish spoils, compared to one dealing in lower value fish
- These traders have higher incentive to invest in cold storage to reduce their losses

Refine the product for lighter weight

Improve portability of the product

- Cooler boxes that traders use to carry their catch to and from the market daily weigh **1-3kg**, while the smallest freezer weighs **13kg**
- This makes it difficult to transport by foot, and would require **higher transport costs** to use a taxi, motorbike/bicycle
- A lighter product could increase the value proposition as it wouldn't increase operational costs

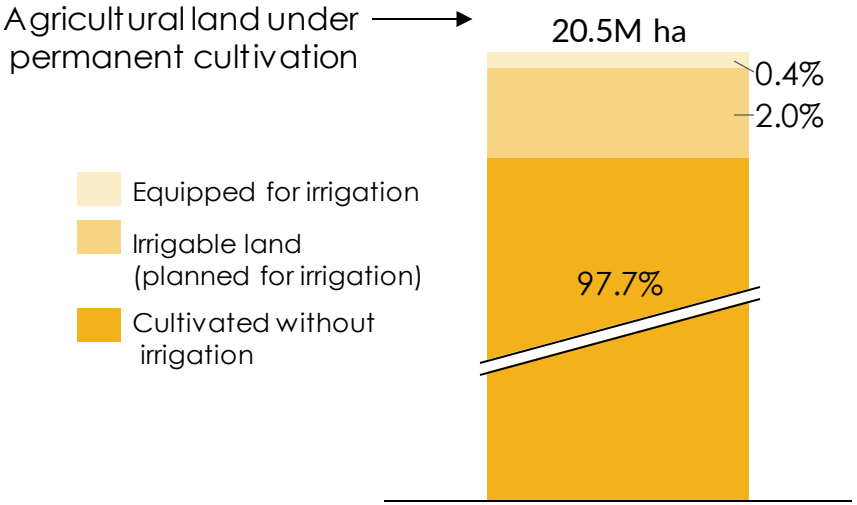
Source: Dalberg analysis and interviews. 2018.

CÔTE D’ IVOIRE MARKET **DEEP DIVE**

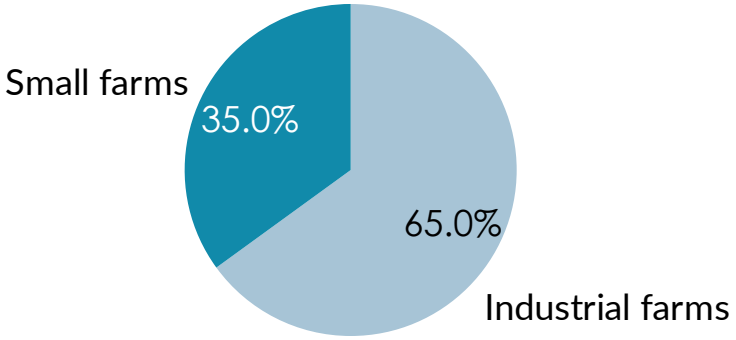
IRRIGATION (SNAPSHOT)

98% of Côte d'Ivoire's cultivated land is not irrigated, but use of irrigation is increasing, especially in horticulture

Agricultural land under irrigation



Share of irrigated land use



State of irrigation in Côte d'Ivoire

- Due to fairly constant rainfall (1,300mm annually), pressure for irrigation is reduced and **almost all cultivation is rain-fed only**, which limits yields
- However, **irrigation usage is increasing, particularly in horticulture**, to facilitate year-long production and to **manage timing of water supply**
- Côte d'Ivoire's irrigable land stands at 475,000 ha of which 72,750 ha are equipped for irrigation under **ten large dam-fed schemes**
- 65% of irrigated land is used by industrial farmers, comprising mostly of **rice, sugar cane, and industrial banana and pineapple farms**
- The government is piloting the development of 10,000 ha of land for lowland irrigation. It also acknowledges the importance of climate change impacts on water resources and agriculture

Sources: FAO Aquastat. 2015. "2005 Survey Irrigation Figures in Africa"; IWMI. 2010. "Irrigation in West Africa (Workshop report)"; Dalberg analysis and interviews. 2018.

A range of solar water pump suppliers has emerged to meet the growing demand and compete with existing diesel pump suppliers

Organization	Operating Model	PULSE Products & Services	Approach & Outlook
Conergies Group	Distributor	**Product:** Solar pumping kits and spare parts **Services:** Design, size, and install integrated irrigation solar pumping systems	Supplying households and businesses across West Africa with energy efficiency solutions
Hydrausolar	Distributor	**Product:** Solar panels, regulators, batteries, lamps, kits, pumps **Services:** Evaluations, and installations of solar and non-solar irrigation systems	Works with agricultural cooperatives, local communities, NGOs, and international organizations to increase access to drinking water, electricity, sanitation
AD Solar	Distributor	**Product:** Lorentz solar pumps **Services:** Evaluation and installation of solar pump systems	Working with development partners to install water pump solutions
LEDAK	Distributor	**Product:** Solar pumps ranging from $ 530-1430. Also supply SHS and solar cold storage **Services:** Installing pumps and training of apprentices to become solar technicians	Support SHF with input finance and training on farming techniques, to increase their income up so they can afford solar pumps. Aims to be a solar product manufacturer
APB-Energy	Distributor	**Product**: Solar pumps for household and irrigation purposes **Service**: A wide range of solar electrification installations for remote areas	Works in Africa and France, provides solar pumps for a range of household and agricultural uses
Yandalux	Distributor	**Product**: Solar pumps for SHF with 1-2 ha farms; pumps cost ~$ 360-9000 **Services**: Supplying and installing a range of solar-powered solutions	Innovator looking to supply products tailored for the local market. Currently targeting horticulture farmers for irrigation

Sources: Company websites. 2018; Dalberg analysis and interviews. 2018.

CÔTE D’ IVOIRE MARKET **DEEP DIVE**

POLICY ENVIRONMENT

Few incentives for solar products exist, with suppliers awaiting government clarification on broader policy issues on solar equipment

TAXES, DUTIES & SUBSIDIES

- The only existing fiscal incentive specifically geared at solar products is a reduction in VAT from **18% to 9% on solar panels in 2008**
- **Agriculture equipment can be exempted from import duty**, but approval from the Ministry of Agriculture must be obtained before importation
- AfDB is helping the government to clarify its solar policies – the **opaque regulations have caused confusion among developers and product suppliers** alike on the government's position on certain taxes, as well as other factors such as geographical restrictions

Parameter	Solar Equipment	Diesel/Grid Products	Agriculture Equipment
Import duty	0%[1] (0-35%)	0-35%	0%[2] (0-35%)
	1% statistical levies		
	0.5% community levy		
VAT	9% (panels)	18%	18%
Subsidies	None	None	None
Incentives	None	None	None

BROADER POLICY ISSUES

Energy & Solar

- In 2014, the government adopted a new Electricity Code that recognises the role of renewable energy in the energy mix
- The Code requires developers to sell excess power to the CIE, but forbids direct sales to consumers, and **restricts mini-grid development by private actors to limited areas**
- Additionally, a policy under discussion seeks to **restrict geographical distribution of SHS by suppliers,** in a bid to push them to address needs in underserved regions
- These **restrictions will limit the potential of SHS suppliers and mini-grid developers to scale PULSE solutions**

Agriculture

- The revised National Program for Agricultural Investment (PNIA) recognizes the role of renewable energy for storage to reduce post-harvest loss and for small-scale processing
- The PNIA is supported by several agriculture related ministries, providing multiple channels to elevate PULSE in government

Co-ordination/Cross-sector

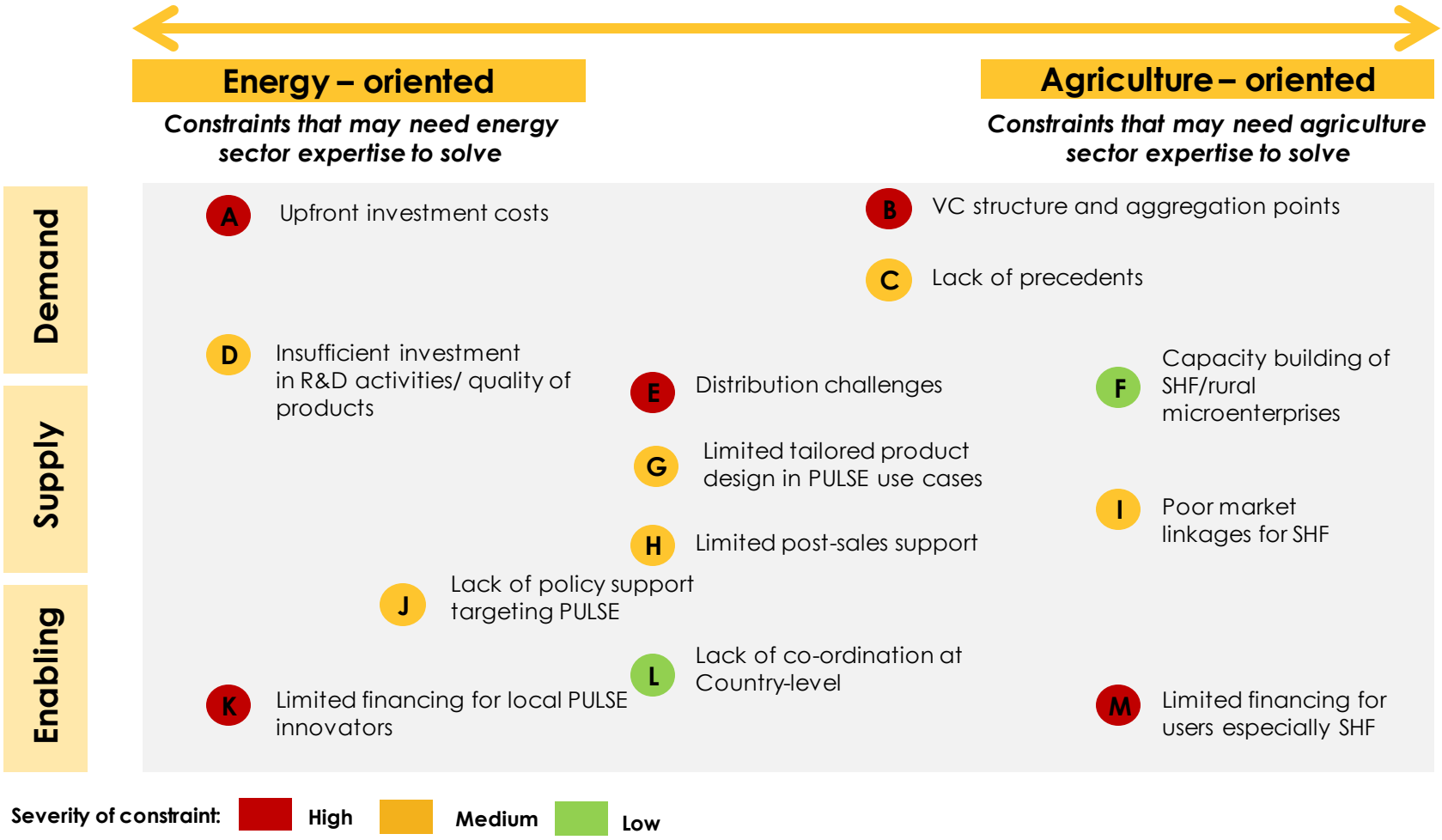
- The ECOWAS Centre for Renewable Energy and Energy Efficiency supports ECOWAS countries to align on a regional renewable energy policy as well as developing national policies
- It also organizes renewable energy forum for actors from different sectors; **these forums are a potential avenue to raise the profile of the PULSE agenda in agriculture regionally**

Sources: PWC. 2018. "Côte d'Ivoire Corporate – Other taxes"; OBG. 2018. "Côte d'Ivoire Energy"; Tax Division, General Tax Code. 2018; Dalberg analysis and interviews. 2018.
Note: 1) 0% duty on solar panels. 2) The Ministry of Agriculture provides exemptions on imports of agricultural equipment, the exemption letter must be sought before importation, otherwise duty is charged.

WHAT NEXT FOR **THE PULSE MARKET?**

SECTION EIGHT

Across SSA several constraints to scaling PULSE exist, they are likely to need a range of energy and agricultural expertise to unlock



Note: SHF refers to Smallholder farmers; VC refers to Value chain

There are two fundamental challenges that are likely to be persistent in the medium term, which will constrain pico-PULSE uptake

Economies of scale driving productive use interventions to larger scales

- Agricultural value chains have **differing value chain dynamics around aggregation**
- This affects the **underlying need for labor-saving machinery at a rural level,** and hence the viability of small-scale PULSE. Three scenarios exist:
- **Scenario 1 – PULSE products have the potential to add value at an individual level.** Example: Solar water pumps for horticulture in Kenya
- **Scenario 2 – To be cost effective, PULSE products require further aggregation that it not yet present in the market.** Example: milk chillers in Zimbabwe
- **Scenario 3 – The optimal value addition is at a much larger scale than a micro-PULSE solution.** Example: rice hulling/milling in Côte d'Ivoire

Demand load profiles not suited to standalone solar applications

- **Where there is potential demand for off-grid productive use activities, PULSE products must out compete diesel alternatives.** This hinges on utilization rates, system sizing, and the nature of power demand
- **Dynamic 1 – Non time-critical, regular energy demand. Example: irrigation** economics tend to outstrip diesel where pumping can be used at any time through the day and the daily load curve is flat
- **Dynamic 2 – Non time-critical, lumpy energy demand. Example: agro-processing** where energy is needed in sharp short bursts. In these cases diesel continues to provide optimal solutions
- **Dynamic 2 – Time-critical, lumpy energy demand. Example: cooling & refrigeration** where surges in power are needed to bring temperatures down that then increase the size of panels/batteries, but benefits of diesel are less clear

There are 8 areas in which governments, development partners, and private sector can partner to help build the market for PULSE products

1 **Demand generation/aggregation**

Support to selected value chain aggregators through technical assistance (TA) and finance to extend PULSE products to farmer groups

2 **Technology & innovation**

Technical assistance and investment to support technology upgrading and skills transfer

3 **Access to finance**

Patient capital, seed capital, working capital and grants to support set-up, growth and scaling

4 **Business development support**

Work alongside PULSE innovators to provide business management, market entry and growth strategy advice

5 **Quality assurance**

Develop minimum product standards, especially for emerging DC appliances and service levels for post-sales support

6 **Market intelligence**

Develop detailed use cases across a range of products, provide annual PULSE surveys and market analysis

7 **Consumer education**

Work with existing value chain actors and donors to expand the awareness of solar products, focused on emergent products

8 **Policy development**

Policy papers, research, and lobbying to enhance regulatory environment at interface between off-grid and agriculture

Note: VC refers to Value chain; Areas 1-4 are expanded upon in the following section, given the specificity of the needs presented from the PULSE product use cases

Demand generation/aggregation: unlike household energy use, PULSE in agriculture will require value chain engagement to scale

Types of interventions which can move the needle

- **Alignment with ag partners** - Partnerships with value chain actors and donors who have detailed value chain knowledge and active programs to help target potential users at different stages (input provision, extension services/training, and market access/point of sale)
- **System and business model piloting** - Proof of concepts must highlight the incentives and value added of PULSE products in terms of 1) helping achieve intended impact but, also, 2) improving SHF purchasing power for their inputs/other products, etc., 3) ability of solutions to scale
- **Target commercial off-taker** - Collaborate with off-takers who aggregate produce, e.g. dairy co-operatives, horticultural exporters at point of purchase to leverage the network of SHFs they have for distribution. They have an interest in improving farmer productivity to meet market demand for produce and so would make natural partners
- **Co-operative capacity building** - Building capacity of co-operatives and farmer organizations to offer training on use of PULSE products

What is required

Success factors

- Off-takers and other value chain actors must receive commensurate value to engage with suppliers e.g. reduced burden of post sales support, clear pathway for higher revenues etc.
- Ensure localization of PULSE through establishment of service capabilities, parts and skills training

Risks and mitigations

- **Key risks include** role definition in partnerships (workload) and branding – the co-op, off-taker, other org can be negatively affected if product is sold under their brand/endorsement and malfunctions or has poor post-sales support
- **Mitigation strategies include** clear delineation of responsibilities, alignment on branding and who bears cost of what

Technology & innovation: given the low levels of maturity, there is still need for soft capital/technology transfer to make products viable

Types of interventions which can move the needle

- **Technical assistance** - Technical assistance and direct support to PULSE innovators to refine products and test in selected value chains
- **Distribution linkages** - Linking PULSE innovators and existing PAYG/SHS providers with agricultural value chain expertise/partners to co-create solutions and business models
- **Technology and innovation grants** - Grant windows and competitions to address particular sector/agricultural value chain limitations, e.g. dairy spoilage at pico-scale. Based on initial country-level use cases
- **Technology transfer** - encouraging collaboration between organizations. Noting that this may be challenging when navigating commercial interests and intellectual property (IP) protections
- **Product design support** - As seen in the use case analysis, products are not always tailored for particular crop/value chain applications. Recurring design issues include a) system sizing and modularity, b) mobility and weight, c) processing quality and capacity requirements

What is required

Success factors

- **Targeting/additionality:** Critical will be in basing technology and innovation in sectors that will not move, without intervention, i.e. the most immature markets/PULSE products
- **Product launch:** Research and piloting will need to be geared to product launch and sustainable commercially-driven scale up

Risks and mitigations

- **Key risks include:** Challenge to maintain incentives to invest while considering commercial interests and IP protections
- **Partner appetite:** There are several market dynamics that push larger NMCs to focus on higher value, easier-to-reach segments within existing manufacturing capacities

Access to finance: given relatively higher costs of PULSE assets (vs. SHS), the financing challenge is even greater and needs new models

Types of interventions which can move the needle

- **User targeting** – Instruments will need to be designed to target particular user types to increase their ability to afford PULSE products, these could include: 1) individual producers, 2) co-operatives purchasing for shared use, and 3) micro-enterprise purchase to operate as a service
- **Models supported** - Interventions could support several models including scaling up a) PAYG models into the PULSE space, which will require higher levels of credit per sale and longer dated repayment and b) leasing models, for example for pumps, because farmers don't irrigate year round
- **Risk instruments** - Risk mitigation for domestic FIs - guarantees and sub-ordinated debt to help reduce risks for commercial banks and MFIs as technologies prove at scale. Guarantees could include third-party actors such as off-takers who will stand to gain from PULSE interventions
- **Debt instruments** - Credit lines for domestic FIs to start productive energy use windows. Support financing from impact investors (SHF loans), e.g. Kiva – suppliers will likely need to work with value chain actors to meet reporting requirements

What is required

Success factors

- **Additionality:** interventions need to be sure to target products, user groups or crops where financing is not already fully available, or where partially available will have the effect of crowding in further capital

Risks and mitigations

- **Key risks include:** Guarantees don't always result in increased lending once they end, banks just use them to cover risks but not willing to take the risk on the borrower after that
- **Mitigation strategies include** Off-taker arrangements – better long-term solution than guarantees because farmer income is guaranteed

Business support: PULSE innovators require support in developing business models while micro-enterprises need basic business skills

Types of interventions which can move the needle

- **Market-entry/growth strategies** – Supporting early-stage companies to refine their business models as they grow, including a) market analysis, b) business planning, c) financial analysis, and d) tax/legal support to set them up to receive additional investment for domestic or foreign investors
- **Distribution strategies** – Specifically, PULSE providers face distribution challenges as they scale and need support in a) identifying channel partners, b) defining logistical needs, c) where there is a need to adapt distribution strategies, d) defining pre and post-sale services, and e) commercial & operational terms
- **Delivery approach** – The above interventions could be delivered through a) institutional/education partners, b) standalone targeted business incubators/accelerators, c) components within agriculture sector donor programs
- **Micro-enterprise support** – Basic financial mgmt. and business mgmt. support for rural entrepreneurs purchasing PULSE products to start operations as micro-enterprises

What is required

Success factors

- Targeted activity to support where private sector organization cannot allocate their own resources
- If functioning as an incubator, the platform is used to take a commercial position and recover costs from enterprises
- Clear exit strategy for firms (and investments where made)

Risks and mitigations

- **Key risks:** 1) BDS support does not lead to organization growth or further investment, 2) support crowds out private sector intervention or resources
- **Mitigation strategies:** 1) Very targeted application process, 2) regular engagement with potential investors, 3) skin in the game from applicants

The intervention mix will vary depending on the PULSE use case, though some aspects will be the same across use cases*

	1 Demand generation & aggregation	2 Technology & innovation	3 Consumer awareness & education
Irrigation 	• Demand generation and aggregation mainly needed to **secure investment cases and reduce perceived credit risk**. Working with off-takers will be key to ensure additional produce sale	• Progress has already been made, but future R&D should prioritize quality improvement & **system modularity to improve farmer ability to expand** land under irrigation progressively	• Prioritize training on **technical requirements needed to maximize returns** e.g. on good agricultural practices, appropriate pump selection, downstream market access etc.
Cold storage 	• Highest impact likely to be in supporting off-taker/processor aggregation models **given technology limitations for small scale solutions**	• Focus should be on **reducing costs** to improve uptake by medium scale aggregators. And **product design to overcome VC-specific requirements**	• **Needs to focus on availability of solutions where present**, and involve aggregators in education on premium pricing for quality where they offer this
Milling/threshing 	• Aggregation already occurs at mid-scale agro-processors. However, further work is required to establish **business models to disrupt more remote non-aggregated systems**	• Improvements needed **on increasing peak processing capacity and mobility** to increase viability by allowing solar products to better compete with incumbents	• Little role for education to SHFs as they **choose based on pricing and convenience**, education can be focused on potential entrepreneurs and communicate long term savings
Milk chilling 	• **Co-ops/milk collection hubs act as natural aggregation points**, but innovative models targeting e.g. villages where farmers continue to market milk informally	• Focus on **developing and optimizing technology on micro scale operations** (<10-15L/day) where the bulk of SHF fall	• **Value proposition is already quite clear on reducing spoilage** – likely needed on price premium where available and more **marketing to accompanying product roll-out**
Drying 	• **Largely done individually but opportunity to aggregate** based on proximity to other farmers, if not, products are likely to have too low utilization	• Few affordable commercial models in the market; future development should look to **reduce costs and commercialize/scale existing solutions** to serve SHF	• Value proposition is already quite clear on reducing spoilage, whether for household consumption or for sale. Education likely needs to focus more on marketing

Source: Dalberg analysis and interviews. 2018.
Note: Aspects where interventions are likely to be similar across use cases include access to finance, business development support, quality assurance, market intelligence, and policy development

Two success factors for PULSE interventions are i) engaging both energy and agriculture actors and ii) seeing the solution space as a spectrum

Energy and Agriculture collaboration

- Constraints are concentrated around either **supply-side energy sector expertise** and demand side **agricultural sector expertise**
- Agricultural value chain issues intertwine with energy access issues
- Energy and energy **practitioners need to work together** to break these constraints down

Seeing solutions space as a spectrum

- Use cases have highlighted that PULSE product **maturity, uptake and operational requirements vary** at different scales
- They have also shown that optimal energy demand will need to match the aggregation dynamics of a given agricultural value chain
- In many cases the **most commercially viable/optimal PULSE product is a larger unit** with either shared or aggregated use

These issues will require integrated programming and organizational collaborations to identify where small-scale solutions are most applicable or where larger investments are needed to boost productivity

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