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

JULY 2019
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viii. What Next for the PULSE Market?
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 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 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).

- **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.

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

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...given complexity, PULSE for agriculture requires coordination, market building, and patient capital...
## Insights and Findings (3/10)
### Country nuances

**Kenya (KEN)**

- **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 relatively high
- **At micro scale, there is limited productive use of energy** (solar or otherwise), but with notably higher penetration of water pumps relative to other product groups

**Zimbabwe (ZIM)**

- **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)

**Côte d’Ivoire (CIV)**

- **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)

### Agriculture-Energy Nexus Overview

- VAT on all solar appliances was removed in 2014 but the Treasury have indicated they may reintroduce 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

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**Kenya (KEN)**

- **Agriculture**
- **Energy**

**Zimbabwe (ZIM)**

- **Agriculture**
- **Energy**

**Côte d’Ivoire (CIV)**

- **Agriculture**
- **Energy**
Insights and Findings (4/10)

Country nuances

<table>
<thead>
<tr>
<th>Kenya (KEN)</th>
<th>Zimbabwe (ZIM)</th>
<th>Côte d’Ivoire (CIV)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Irrigation</strong></td>
<td>Uptake is growing rapidly; specialist providers / distributors and (now) larger OEMs are starting to enter segment using Kenya as entry point.</td>
<td>Solar pumps are available but uptake is limited; there are several distributors targeting smallholders, but affordability is a major constraint.</td>
</tr>
<tr>
<td><strong>Cold storage</strong></td>
<td>Nascent but growing market; to date suppliers have intentionally targeted aggregators in high value crops.</td>
<td>Opportunity for horticulture cold storage is limited, post-harvest losses are largely driven by poor handling practices and a lack of market access.</td>
</tr>
<tr>
<td><strong>Milling/threshing</strong></td>
<td>Pilot activity only; current actors are exploring segments where distance to existing processors is prohibitive but technologies are untested.</td>
<td>No activity; there is potential to displace incumbent micro-scale milling, but services are usually compensated in a % of produce not money.</td>
</tr>
<tr>
<td><strong>Milk chilling</strong></td>
<td>Pilot activity only; potential for farmers in both formal and informal channels but prices need to come down to be viable for smallholders.</td>
<td>Pilot activity only; there is an opportunity to help boost smallholder incentives to utilize the government’s milk collection centers.</td>
</tr>
<tr>
<td><strong>Drying</strong></td>
<td>There is some latent demand across several value chains, but no incumbent commercial equipment is currently being utilized.</td>
<td>Farmers voiced some need for maize drying technologies, but returns are low and no incumbent technologies exist.</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td></td>
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</tr>
</tbody>
</table>

Note: 1) OEM - Original equipment manufacturer
## Insights and Findings (5/10)
### Summary of use cases - KENYA

<table>
<thead>
<tr>
<th>Use case</th>
<th>Direct incumbent</th>
<th>Farm size</th>
<th>Break even versus incumbent</th>
<th>Two-year return on investment (ROI)</th>
<th>Full payback period</th>
<th>Summary of viability</th>
</tr>
</thead>
</table>
| 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 months²                          |                     | • 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 |

<table>
<thead>
<tr>
<th>Key</th>
<th>Viability</th>
<th>Break even versus incumbent</th>
<th>Two-year ROI</th>
<th>Typical payback</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green</td>
<td>High</td>
<td>&lt; Year 1</td>
<td>&gt;100%</td>
<td>&lt; 1 Year</td>
</tr>
<tr>
<td>Yellow</td>
<td>Medium</td>
<td>Year 1 - Year 2</td>
<td>&lt;50%</td>
<td>&lt; 2 Years</td>
</tr>
<tr>
<td>Red</td>
<td>Low</td>
<td>&gt; Year 2</td>
<td>&lt;0%</td>
<td>&gt; 2 Years</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Use case</th>
<th>Direct incumbent</th>
<th>Farm size</th>
<th>Break even versus incumbent</th>
<th>Two-year return on investment (ROI)</th>
<th>Full payback period</th>
<th>Summary of viability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horticulture irrigation</td>
<td>Diesel</td>
<td>1 ha</td>
<td>Year 1</td>
<td>140%</td>
<td>&lt; 1 Year</td>
<td>• High viability - payback in &lt;1 year across multiple crops</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>• Returns can be improved through market linkages with off-takers, and tailored financing options</td>
</tr>
<tr>
<td>Dairy chilling</td>
<td>N/A</td>
<td>50L</td>
<td>N/A</td>
<td>30%</td>
<td>19 months</td>
<td>• Medium viability, highly dependent on increasing productivity, and sustained access to formal markets</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Returns are boosted by premium price offered for higher quality</td>
</tr>
<tr>
<td>Maize threshing</td>
<td>Diesel</td>
<td>0.25MT/h</td>
<td>Year 2</td>
<td>29%</td>
<td>14 months¹</td>
<td>• Medium viability driven by reduced long-term costs of threshing</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td>• Can be increased by improving mobility of the product and ability of the technology to be multi-purpose</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Key</th>
<th>Viability</th>
<th>Break even versus incumbent</th>
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<th>Typical payback</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
<td>&lt; Year 1</td>
<td>&gt;100%</td>
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</tr>
<tr>
<td></td>
<td>Medium</td>
<td>Year 1 - Year 2</td>
<td>&lt;50%</td>
<td>&lt; 2 Years</td>
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<tr>
<td></td>
<td>Low</td>
<td>&gt; Year 2</td>
<td>&lt;0%</td>
<td>&gt; 2 Years</td>
</tr>
</tbody>
</table>

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.

**Note:**
## Insights and Findings (7/10)

### Summary of use cases – CÔTE D’IVOIRE

<table>
<thead>
<tr>
<th>Use case</th>
<th>Direct incumbent</th>
<th>Farm size</th>
<th>Break even versus incumbent</th>
<th>Two-year return on investment (ROI)</th>
<th>Full payback period</th>
<th>Summary of viability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cassava grating</td>
<td>Diesel</td>
<td>50kg/h</td>
<td>Year 3</td>
<td>-34%</td>
<td>37 months</td>
<td>• 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</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Viability more probable for cooperatives given high volumes processed</td>
</tr>
<tr>
<td>Rice hulling</td>
<td>Diesel</td>
<td>60kg/h</td>
<td>Year 5</td>
<td>16%</td>
<td>21 months</td>
<td>• Viability low/medium even at max capacity of 68MT/year and ~75 farmers in a year</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• 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</td>
</tr>
<tr>
<td>Fish freezing / chilling</td>
<td>Grid</td>
<td>20L</td>
<td>Year 4</td>
<td>101%</td>
<td>12 months</td>
<td>• High viability (payback in &lt;1 year) driven by high spoilage and value loss, but incumbent ice usage is cheaper</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>• Highest value proposition for traders further inland where access to ice is lower</td>
</tr>
</tbody>
</table>

### 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).
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.

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.

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
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

<table>
<thead>
<tr>
<th></th>
<th><strong>Demand generation/aggregation</strong></th>
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<tbody>
<tr>
<td>1</td>
<td>Support to selected value chain aggregators through TA and finance to extend PULSE products to farmer groups</td>
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<table>
<thead>
<tr>
<th></th>
<th><strong>Access to finance</strong></th>
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<tr>
<td>3</td>
<td>Patient capital, seed capital, working capital and grants to support set-up, growth and scaling</td>
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<table>
<thead>
<tr>
<th></th>
<th><strong>Technology &amp; innovation</strong></th>
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<tr>
<td>2</td>
<td>Technical assistance and investment to support technology upgrading and skills transfer</td>
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<table>
<thead>
<tr>
<th></th>
<th><strong>Business development support</strong></th>
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<tbody>
<tr>
<td>4</td>
<td>Work alongside PULSE innovators to provide business management, market entry and growth strategy advice</td>
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<thead>
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<th></th>
<th><strong>Quality assurance</strong></th>
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<tr>
<td>5</td>
<td>Develop minimum product standards, especially for emerging DC appliances and service levels for post-sales support</td>
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<th></th>
<th><strong>Market intelligence</strong></th>
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<tbody>
<tr>
<td>6</td>
<td>Develop detailed use cases across a range of products, provide annual PULSE surveys and market analysis</td>
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<table>
<thead>
<tr>
<th></th>
<th><strong>Consumer education</strong></th>
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<tbody>
<tr>
<td>7</td>
<td>Work with existing value chain actors and donors to expand the awareness of solar product, focused on emergent products</td>
</tr>
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<table>
<thead>
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<th></th>
<th><strong>Policy development</strong></th>
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<tbody>
<tr>
<td>8</td>
<td>Policy papers, research and lobbying to enhance regulatory environment at interface between off-grid and agriculture</td>
</tr>
</tbody>
</table>
SECTION TWO

INTRODUCTION: WHY IS PULSE CRITICAL FOR AGRICULTURE?
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**

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.

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

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

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.

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

<table>
<thead>
<tr>
<th>AGRICULTURAL</th>
<th>INDUSTRIAL</th>
<th>COMMERCIAL</th>
<th>SOCIAL/PUBLIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation</td>
<td>Clothing</td>
<td>Hairdressing</td>
<td>Education</td>
</tr>
<tr>
<td>Threshers</td>
<td>Land preparation</td>
<td>Cooking</td>
<td></td>
</tr>
<tr>
<td>Mills</td>
<td>Chilling</td>
<td>Retail cooling</td>
<td>Health devices</td>
</tr>
<tr>
<td>Drying</td>
<td>Carpentry</td>
<td>Phone charging</td>
<td></td>
</tr>
<tr>
<td>Cold storage</td>
<td>Construction</td>
<td>Transport</td>
<td></td>
</tr>
<tr>
<td>Night fishing</td>
<td>Cinema</td>
<td>Handcrafts</td>
<td></td>
</tr>
<tr>
<td>Oil presses</td>
<td>Electronic/auto repair</td>
<td>ICT</td>
<td></td>
</tr>
<tr>
<td>Egg incubators</td>
<td>Electric fences</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.

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

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 contribution to sub-Saharan Africa’s GDP, despite the sector employing 50%+ of its population.

**Shifting from manual to mechanized** 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%.


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

<table>
<thead>
<tr>
<th>Cross-value chain use cases</th>
<th>Production</th>
<th>(Near-farm) processing</th>
<th>Storage and transport</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprayers (pesticide/fertilizer)</td>
<td>Mills</td>
<td>Freezers/Refrigerators</td>
<td></td>
</tr>
<tr>
<td>Irrigation pumps</td>
<td>Driers</td>
<td>Ice makers</td>
<td></td>
</tr>
<tr>
<td>Tractors</td>
<td></td>
<td>Cold rooms/coolers</td>
<td></td>
</tr>
<tr>
<td>Electric fences</td>
<td></td>
<td>Siloes</td>
<td></td>
</tr>
<tr>
<td>Greenhouses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Animal feed mixer</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value chain-specific use cases</th>
<th>Product</th>
<th>Product</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg incubators</td>
<td>Butter makers</td>
<td>Milk Chillers</td>
<td></td>
</tr>
<tr>
<td>Cow milkers</td>
<td>Maize threshers</td>
<td>Fish freezers</td>
<td></td>
</tr>
<tr>
<td>Night fishing lights</td>
<td>Cassava graters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fishing boats</td>
<td>Coffee pulpers</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Oil presses</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


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

<table>
<thead>
<tr>
<th>Irrigation Pumps</th>
<th>Cooling/Drying</th>
<th>Agro-processing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Surface water pumps</strong></td>
<td><strong>Cooling systems</strong></td>
<td><strong>Flour Milling</strong></td>
</tr>
<tr>
<td>• Wattage: 75w – 1.5kW</td>
<td>• Wattage: 40-200W</td>
<td>• Wattage: 500-750W</td>
</tr>
<tr>
<td>• Suction head: &lt;7m</td>
<td>• Capacity: Up to 45l of milk/day</td>
<td>• Capacity: 25-160kg/h</td>
</tr>
<tr>
<td><strong>Submersible pumps</strong></td>
<td><strong>Refrigeration</strong></td>
<td><strong>Husking/Threshing/Hulling</strong></td>
</tr>
<tr>
<td>• Wattage: 0.45-22kW+</td>
<td>• Wattage: 40-400W</td>
<td>• Wattage: 100-375W</td>
</tr>
<tr>
<td>• Head: 4-310m</td>
<td>• Capacity: 50-400l</td>
<td>• Rice Capacity: 35 -70kg/h</td>
</tr>
<tr>
<td><strong>Other - Livestock</strong></td>
<td><strong>Freezing/ice making</strong></td>
<td>• Maize Capacity: 250kg/h</td>
</tr>
<tr>
<td><strong>Poultry incubators</strong></td>
<td>• Wattage: 95W</td>
<td><strong>Grating</strong></td>
</tr>
<tr>
<td>• Wattage: 75w – 100W</td>
<td>• Capacity: 1.2kg/day</td>
<td>• Wattage: 250W</td>
</tr>
<tr>
<td>• Capacity: 48-1000 eggs</td>
<td></td>
<td>• Capacity: 100kg/hr</td>
</tr>
<tr>
<td><strong>Milk machines</strong></td>
<td><strong>Walk-in cooling units</strong></td>
<td><strong>Oil &amp; nut presses</strong></td>
</tr>
<tr>
<td>• Wattage: 1.1kW</td>
<td>• Wattage: 2kW+</td>
<td>• Wattage: 1.5kW</td>
</tr>
<tr>
<td>• Head: 20 cows/day</td>
<td>• Capacity: 9 tonnes+</td>
<td>• Capacity: 20kg/h</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

### Cross-value chain products

<table>
<thead>
<tr>
<th>Product</th>
<th>Capacity (Watts)</th>
<th>Key: The length of the boxes represents the power requirement for the range of products in the relevant category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprayers</td>
<td>50W</td>
<td></td>
</tr>
<tr>
<td>Driers</td>
<td>50W</td>
<td></td>
</tr>
<tr>
<td>Silos</td>
<td>50W</td>
<td></td>
</tr>
<tr>
<td>Irrigation Pumps</td>
<td>0 – 7m suction capacity</td>
<td></td>
</tr>
<tr>
<td>Mills/Threshers/Hullers</td>
<td>25-160 kg/hr</td>
<td></td>
</tr>
<tr>
<td>Tractors</td>
<td>1500W</td>
<td></td>
</tr>
<tr>
<td>Freezers/Refrigerators</td>
<td>501 – 400l</td>
<td></td>
</tr>
<tr>
<td>Electric Fences</td>
<td>10 – 30 Miles</td>
<td></td>
</tr>
<tr>
<td>Ice Makers</td>
<td>250 kg/day</td>
<td></td>
</tr>
<tr>
<td>Cold Rooms/Coolers</td>
<td>1000L – 23m²</td>
<td></td>
</tr>
<tr>
<td>Fan Cooling</td>
<td>25 kg/day</td>
<td></td>
</tr>
<tr>
<td>Night Fishing Lights</td>
<td>25 kg/day</td>
<td></td>
</tr>
<tr>
<td>Coffee Pulpers</td>
<td>200-300 kg/hr</td>
<td></td>
</tr>
<tr>
<td>Egg Incubators</td>
<td>40-250 Eggs</td>
<td></td>
</tr>
<tr>
<td>Butter Makers</td>
<td>15l</td>
<td></td>
</tr>
<tr>
<td>Maize Thresher</td>
<td>250 kg/hr</td>
<td></td>
</tr>
<tr>
<td>Coffee Pulpers</td>
<td>200-300 kg/hr</td>
<td></td>
</tr>
<tr>
<td>Egg Incubators</td>
<td>40-250 Eggs</td>
<td></td>
</tr>
<tr>
<td>Coffee Pulpers</td>
<td>200-300 kg/hr</td>
<td></td>
</tr>
<tr>
<td>Night Fishing Lights</td>
<td>25 kg/day</td>
<td></td>
</tr>
<tr>
<td>Coffee Pulpers</td>
<td>200-300 kg/hr</td>
<td></td>
</tr>
<tr>
<td>Egg Incubators</td>
<td>40-250 Eggs</td>
<td></td>
</tr>
<tr>
<td>Coffee Pulpers</td>
<td>200-300 kg/hr</td>
<td></td>
</tr>
<tr>
<td>Night Fishing Lights</td>
<td>25 kg/day</td>
<td></td>
</tr>
</tbody>
</table>


---

**Note:** The table above provides a snapshot of the range of products and their capacities in watts. The key explains the importance of these capacities in the context of various agricultural value chains.
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

<table>
<thead>
<tr>
<th>Units Sold Range</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 1,000</td>
<td>29%</td>
</tr>
<tr>
<td>1,001 to 10,000</td>
<td>29%</td>
</tr>
<tr>
<td>50,001 to 100,000</td>
<td>13%</td>
</tr>
<tr>
<td>10,001 to 50,000</td>
<td>4%</td>
</tr>
<tr>
<td>More than 100,000</td>
<td>25%</td>
</tr>
</tbody>
</table>

### African countries in each firms’ top 5 by sales

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of Firms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kenya</td>
<td>17</td>
</tr>
<tr>
<td>Nigeria</td>
<td>10</td>
</tr>
<tr>
<td>Uganda</td>
<td>9</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>8</td>
</tr>
<tr>
<td>Tanzania</td>
<td>6</td>
</tr>
<tr>
<td>Rwanda</td>
<td>6</td>
</tr>
<tr>
<td>South Africa</td>
<td>4</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Category</th>
<th>PULSE as secondary business</th>
<th>PULSE as core business</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar water pumps</td>
<td>9</td>
<td>17</td>
</tr>
<tr>
<td>Entertainment</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td>Agro-processing</td>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td>Cooling / refrigeration</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>Heating</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Communications</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Small manufacturing</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Livestock related</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Other services</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Category</th>
<th>PULSE as core business</th>
<th>PULSE as secondary business</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communications</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Agro-processing</td>
<td>11</td>
<td>4</td>
</tr>
<tr>
<td>Cooling / refrigeration</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td>Small manufacturing</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>Heating</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Livestock related</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Solar water pumps</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Other services</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Entertainment</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Irrigation Pumps</th>
<th>Cooling</th>
<th>Agro-processing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Large</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 5 Ha</td>
<td>&gt;10,000 L</td>
<td>&gt; 10 MT/day</td>
</tr>
<tr>
<td>While technologies exist there are limited large scale applications in practice</td>
<td>Typically applied as walk-in cooling, technologies are available at an aggregated scale, but uptake remains low</td>
<td>The main examples that exist are mini-grid applications as like-for-like replacement of grid-based processing</td>
</tr>
</tbody>
</table>

| 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            |         |                 |
| < 2 Ha           | 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)

<table>
<thead>
<tr>
<th>Use Case</th>
<th>Distribution presence</th>
<th>Firms</th>
<th>State of play</th>
</tr>
</thead>
</table>
| Solar water pumps | Kenya, Zimbabwe, Côte d’Ivoire, Nigeria, Ghana, Sierra Leone, Tanzania, Malawi, Botswana, and majority African markets | Grundfos, SunCulture, Solartech, Jain, Solar, Dayliff, Yangchun, Futurepump, 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                                       | LifeCycle, 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)

<table>
<thead>
<tr>
<th>Use Case</th>
<th>Distribution presence</th>
<th>Firms</th>
<th>State of play</th>
</tr>
</thead>
</table>
| 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](#) ![ColdHubs](#)  | • 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-pan](#)  | • 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

<table>
<thead>
<tr>
<th><strong>PULSE innovators</strong></th>
<th><strong>International manufacturers</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Some still require R&amp;D and piloting support, while others are ready to scale</td>
<td></td>
</tr>
<tr>
<td>• Typically vertically integrated; often subsidized with grant funding</td>
<td></td>
</tr>
<tr>
<td><strong>SHS/PAYGO leaders</strong></td>
<td><strong>Portfolio distributors</strong></td>
</tr>
<tr>
<td>• Could start moving to smaller scale PULSE applications, but price point and quality are concerns</td>
<td></td>
</tr>
<tr>
<td>• Have the potential to scale quickly after market entry, if they can find the right distribution partners</td>
<td></td>
</tr>
<tr>
<td><strong>Mini-grid operators</strong></td>
<td><strong>Prime archetype example</strong></td>
</tr>
<tr>
<td>• Can leverage their customer profiles and credit histories to target PULSE buyers</td>
<td></td>
</tr>
<tr>
<td>• Will need to adapt to longer term financing and more complicated technologies</td>
<td></td>
</tr>
<tr>
<td><strong>Portfolio distributors</strong></td>
<td><strong>Mini-grid operators</strong></td>
</tr>
<tr>
<td>• Have the best view of take-up vs non-solar alternatives – up to 25% of sales in East Africa</td>
<td></td>
</tr>
<tr>
<td>• Have traditionally focused on mid-size farms based on limited affordability of smallholder farmers</td>
<td></td>
</tr>
<tr>
<td><strong>Mini-grid operators</strong></td>
<td><strong>Prime archetype example</strong></td>
</tr>
<tr>
<td>• PULSE is incorporated at a larger scale, often as anchor clients for mini-grids given consistency/level of demand</td>
<td></td>
</tr>
<tr>
<td>• Ownership and operations can be tailored to boost mini-grid operator incomes</td>
<td></td>
</tr>
</tbody>
</table>

**Prime archetype example**

- **AgSol** is trying to build market for solar-powered milling equipment, pilot testing product and building awareness
- **Lorentz** is planning to launch a smaller scale solar water product and looking to partner with SHS players in East Africa
- **FENIX International** has the intention to add PULSE products, currently deciding whether to manufacture or buy to meet demand from customers
- **Davis & Shirtliff** is an existing partner of PULSE focused firms with significant distribution networks ready to leverage
- **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

<table>
<thead>
<tr>
<th>Business model</th>
<th>Activities</th>
<th>Implications for PULSE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>END-TO-END INTEGRATION</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-sale</td>
<td>Post-sale</td>
<td></td>
</tr>
<tr>
<td>Manufacture</td>
<td>Financing</td>
<td>- Helping to build market and customer awareness</td>
</tr>
<tr>
<td>Assembly</td>
<td>Installation</td>
<td>- Allow for better quality control, customer targeting and support. The implications of poor product use/malfunction are high</td>
</tr>
<tr>
<td>Distribution</td>
<td>Customer service</td>
<td>- But can create burdensome overhead costs that can reduce profitability</td>
</tr>
<tr>
<td>Customer acquisition</td>
<td>Maintenance/repair</td>
<td></td>
</tr>
<tr>
<td>Pre-sale support</td>
<td>Control/monitoring</td>
<td></td>
</tr>
<tr>
<td>Sales/retail</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| HARDWARE MANUFACTURER   |            |                        |
| Pre-sale                | Post-sale  |                        |
| Manufacture             | Financing  | - Will have difficulty leveraging existing distribution without active agriculture sector partners |
| Assembly                | Installation | - Established players are looking to partner to overcome customer awareness challenges |
| Distribution            | Customer service | - Product design can be improved by working closely with existing agriculture value chain actors |
| Customer acquisition    | Maintenance/repair |                        |
| Pre-sale support        | Control/monitoring |                        |
| Sales/retail            |                       |                        |

| DISTRIBUTION SPECIALIST |            |                        |
| Pre-sale                | Post-sale  |                        |
| Manufacture             | Financing  | - SHS providers are looking to join traditional distributors in this PULSE sub-sector |
| Assembly                | Installation | - The need for more hands-on customer service and higher financing costs mean **business models may need to adapt** |
| Distribution            | Customer service | - May require additional collaboration with agriculture players to ensure effective customer engagement |
| Customer acquisition    | Maintenance/repair |                        |
| Pre-sale support        | Control/monitoring |                        |
| Sales/retail            |                       |                        |

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.

**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

<table>
<thead>
<tr>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Began operations and launched first prototype in Kenya</td>
<td>Research and development</td>
<td>Prototyping</td>
<td>In-field testing</td>
<td>Marketing and distribution testing</td>
<td>RainMaker 1 launch in 2017</td>
</tr>
<tr>
<td>Grant/donor funding</td>
<td>RainMaker2 product testing and launch (Jan 2019)</td>
<td>Advanced its commercialization strategy (including PAYG financing options) &amp; AgOptimized data</td>
<td>Operations scaling across Africa</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 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
- *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 ClimateSmartTM 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

#### Productivity ladder
- Use water to increase yield and incomes

#### Use water to increase yield and incomes

#### Moving water

#### Other productive assets

#### 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 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

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

**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.

SunDanzer

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

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

African Energy

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

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

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

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

**Product development** – Initially **SunDanzer** did not target SSA markets. Then starting in 2010 SunDanzer supported several donor funded projects to adapt its 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 its 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, cooperatives 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 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

<table>
<thead>
<tr>
<th>Micro-PULSE applications</th>
<th>Units</th>
<th>Unit price</th>
<th>Market value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar water pumps</td>
<td>5,398 K</td>
<td>$650(^2)</td>
<td>$3,509 M</td>
</tr>
<tr>
<td></td>
<td>701 K</td>
<td>$650(^2)</td>
<td>$456 M</td>
</tr>
<tr>
<td>Agro-processing</td>
<td>941 K</td>
<td>$1,625(^3)</td>
<td>$1,529 M</td>
</tr>
<tr>
<td></td>
<td>54 K</td>
<td>$1,625(^3)</td>
<td>$87 M</td>
</tr>
<tr>
<td>Cooling &amp; refrigeration</td>
<td>6,480 K</td>
<td>$825(^4)</td>
<td>$6,250 M</td>
</tr>
<tr>
<td></td>
<td>225 K</td>
<td>$825(^4)</td>
<td>$191 M</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>$11,288 M</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>$734 M</strong></td>
</tr>
</tbody>
</table>

**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 products 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.

<table>
<thead>
<tr>
<th>2018 country markets</th>
<th>KEN Market</th>
<th>ZIM Market</th>
<th>CIV Market</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Micro-PULSE applications</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solar irrigation pumps</td>
<td>$157 M</td>
<td>$115 M</td>
<td>$56 M</td>
</tr>
<tr>
<td></td>
<td>$25.3 M</td>
<td>$7.3 M</td>
<td>$8.0 M</td>
</tr>
<tr>
<td>Agro-processing</td>
<td>$68 M</td>
<td>$15 M</td>
<td>$65 M</td>
</tr>
<tr>
<td></td>
<td>$1.2 M</td>
<td>$0.1 M</td>
<td>$3.7 M</td>
</tr>
<tr>
<td>Cooling &amp; Refrigeration</td>
<td>$125 M</td>
<td>$53 M</td>
<td>$96 M</td>
</tr>
<tr>
<td></td>
<td>$9.1 M</td>
<td>$0.7 M</td>
<td>$12.5 M</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$350 M</td>
<td>$183</td>
<td>$217 M</td>
</tr>
<tr>
<td></td>
<td>$35.6 M</td>
<td>$8.1 M</td>
<td>$24.2 M</td>
</tr>
</tbody>
</table>

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)

<table>
<thead>
<tr>
<th>Crops</th>
<th>Rural households</th>
<th>Smallholder households</th>
<th>Non-subsistence SHF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total subsistence</td>
<td>121M</td>
<td>95M</td>
<td>38M</td>
</tr>
</tbody>
</table>

**Sub-Saharan Africa market assumptions (2018)**

Serviceable market waterfall

<table>
<thead>
<tr>
<th>Smallholder farmers (millions)</th>
<th>Total subsistence</th>
<th>Grid connected</th>
<th>No water access</th>
<th>Can't Afford</th>
<th>Serviceable market</th>
</tr>
</thead>
<tbody>
<tr>
<td>37.99M</td>
<td>100%</td>
<td>-36%</td>
<td>-50%</td>
<td>-12%</td>
<td>2%</td>
</tr>
<tr>
<td>13.69M</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18.90M</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.70M</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.70M</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

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: 701 K
- 2030: 2,832 K

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

Product cost:
- 2018: $650
- 2030: $577

Affordability (% who can afford):
- 2018: 10%
- 2030: 51%

No. of customers:
- 2018: 0.70M
- 2030: 2.83M

Market size ($):
- 2018: $456M
- 2030: $1,633M

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 waterfall**
  - MT of produce:
    - Total: 120.45M
    - Large processors: 50.59M
    - Grid connected: 18.32M
    - Can’t afford: 48.60M
    - Serviceable Market: 2.95M

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)

<table>
<thead>
<tr>
<th>Serviceable market projection (2018-2030)</th>
<th>Potential number of units</th>
</tr>
</thead>
<tbody>
<tr>
<td>54 K</td>
<td>257 K</td>
</tr>
<tr>
<td>+13.9%</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>2018</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product cost</td>
<td>$1625</td>
</tr>
<tr>
<td>Affordability (% who can afford)</td>
<td>6%</td>
</tr>
<tr>
<td>No. of customers</td>
<td>54K</td>
</tr>
<tr>
<td>Market size ($)</td>
<td>$87M</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Crop</th>
<th>Total Production</th>
<th>SHF production</th>
<th>SHF small-scale traders*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dairy</td>
<td>160M MT</td>
<td>51M MT</td>
<td>21M</td>
</tr>
<tr>
<td>Fisheries</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horticulture</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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 waterfall

<table>
<thead>
<tr>
<th>Serviceable market</th>
<th>Total</th>
<th>Non-stored produce</th>
<th>Grid connected</th>
<th>Can’t afford</th>
<th>Serviceable Market</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>21.57M</td>
<td>11.48M</td>
<td>3.60M</td>
<td>6.26M</td>
<td>0.23M</td>
</tr>
</tbody>
</table>

A proportion of traders do not need direct storage and produce is traded immediately, across dairy, 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)**

<table>
<thead>
<tr>
<th>Serviceable market projection (2018-2030)</th>
<th>Potential number of units</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>2018</td>
<td>225K</td>
</tr>
<tr>
<td>2030</td>
<td>1,550K</td>
</tr>
</tbody>
</table>

+17.4% increase from 2018 to 2030

- **Product cost**
  - 2018: $825
  - 2030: $743 (10% decrease)

- **Affordability** (% who can afford)
  - 2018: 5%
  - 2030: 50%

- **No. of customers**
  - 2018: 225k
  - 2030: 1,550k

- **Market size ($)**
  - 2018: $191M
  - 2030: $1,318M

**Market size values based on current prices.**

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

- 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

Component costs will continue to reduce, and system sizes optimized

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

<table>
<thead>
<tr>
<th>Interest rates</th>
<th>Loan terms</th>
<th>Affordability threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>15% per annum</td>
<td>36 months repayment</td>
<td>15% of monthly incomes</td>
</tr>
</tbody>
</table>

- 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 individual's 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

**Energy – oriented**

*Constraints that may need energy sector expertise to solve*

- **A** Upfront investment costs
- **B** VC structure and aggregation points
- **C** Lack of precedents
- **D** Insufficient investment in R&D activities/ quality of products
- **E** Distribution challenges
- **F** Limited tailored product design in PULSE use cases
- **G** Limited post-sales support
- **H** Limited post-sales support
- **J** Lack of policy support targeting PULSE
- **L** Lack of co-ordination at Country-level
- **M** Limited financing for users especially SHF

**Agriculture – oriented**

*Constraints that may need agriculture sector expertise to solve*

- **K** Limited financing for local PULSE innovators
- **I** Poor market linkages for SHF

**Severity of constraint:**

- High
- Medium
- Low

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)

<table>
<thead>
<tr>
<th>Description &amp; Gap</th>
<th>Ease to unlock</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Focus:</strong> Energy</td>
<td><strong>Severity:</strong> High</td>
</tr>
<tr>
<td>Upfront investment costs</td>
<td></td>
</tr>
<tr>
<td>• PULSE products are out of the affordability range of most SHF/rural microenterprises</td>
<td></td>
</tr>
<tr>
<td>• 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</td>
<td></td>
</tr>
<tr>
<td><strong>Focus:</strong> Agriculture</td>
<td><strong>Severity:</strong> Medium</td>
</tr>
<tr>
<td>Limited financing for users, especially SHF</td>
<td></td>
</tr>
<tr>
<td>• SHF financing needs are dictated by existing obligations: school/education fees, milestone life events (weddings), and purchases of other agricultural inputs</td>
<td></td>
</tr>
<tr>
<td>• 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</td>
<td></td>
</tr>
<tr>
<td>• 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</td>
<td></td>
</tr>
<tr>
<td><strong>Focus:</strong> Both Agri and Energy</td>
<td><strong>Severity:</strong> Low</td>
</tr>
<tr>
<td>Distribution challenges</td>
<td></td>
</tr>
<tr>
<td>• Logistics chains in many places are not developed and demand not aggregated enough to make nodal manufacturing and investment in distribution viable</td>
<td></td>
</tr>
<tr>
<td>• 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</td>
<td></td>
</tr>
</tbody>
</table>

Source: Dalberg analysis. 2018.
The most severe of these challenges are potential focus areas for interventions and many require agriculture sector expertise (2/3)

<table>
<thead>
<tr>
<th>Description &amp; Gap</th>
<th>Ease to unlock</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Focus</strong></td>
<td><strong>Energy</strong></td>
</tr>
<tr>
<td><strong>Limited financing for local PULSE innovators</strong></td>
<td></td>
</tr>
<tr>
<td>• 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)</td>
<td></td>
</tr>
<tr>
<td>• Some local firms are wary of international investment given business or proprietary risk, this limits scaling product trials and expanding once proven</td>
<td></td>
</tr>
<tr>
<td><strong>Value chain structure &amp; aggregation points</strong></td>
<td></td>
</tr>
<tr>
<td>• 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</td>
<td></td>
</tr>
<tr>
<td>• 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.)</td>
<td></td>
</tr>
<tr>
<td><strong>Lack of precedents (little incumbency)</strong></td>
<td></td>
</tr>
<tr>
<td>• There are PULSE-enabled value chain activities, where existing technologies have high operating costs or fuel-access makes activities prohibitive</td>
<td></td>
</tr>
<tr>
<td>• So, despite underlying commercial viability many use cases do not have incumbent technologies or currently have very low uptake</td>
<td></td>
</tr>
<tr>
<td>• This presents potential untapped opportunities for PULSE providers, but awareness raising and market development are required alongside products</td>
<td></td>
</tr>
</tbody>
</table>

**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)

<table>
<thead>
<tr>
<th>Description &amp; Gap</th>
<th>Ease to unlock</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Focus</strong></td>
<td><strong>Energy</strong></td>
</tr>
<tr>
<td><strong>Limited tailored product design in PULSE use cases</strong></td>
<td></td>
</tr>
<tr>
<td>• In some cases, existing products have <strong>not targeted small or micro</strong> segments predominantly due to the limited affordability for SHF and cost of technology</td>
<td></td>
</tr>
<tr>
<td>• There is also a <strong>mismatch on scale and value chain targeting</strong>, e.g. value chain activity may require higher mobility or higher performance than the product is built for</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Focus</strong></th>
<th><strong>Energy</strong></th>
<th><strong>Severity</strong></th>
<th><strong>Difficulty</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Insufficient investment into R&amp;D funding (quality of products)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• 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</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• As a result R&amp;D is being carried out in a fragmented way by smaller firms with less experience in manufacturing at scale</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Focus</strong></th>
<th><strong>Both Agri and Energy</strong></th>
<th><strong>Severity</strong></th>
<th><strong>Difficulty</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lack of policy support targeting PULSE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Limited policy support for PULSE versus traditional approaches or energy sources</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Some markets have reduced import tariffs and taxes for solar panels, but benefits do not extend to all PULSE equipment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• 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</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Severity of constraint:</th>
<th>PULSE use cases / product groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Irrigation</td>
</tr>
<tr>
<td>A</td>
<td></td>
</tr>
<tr>
<td>Upfront investment costs*</td>
<td><img src="https://example.com" alt="High" /></td>
</tr>
<tr>
<td>M</td>
<td><img src="https://example.com" alt="High" /></td>
</tr>
<tr>
<td>Limited financing for users especially SHF</td>
<td><img src="https://example.com" alt="High" /></td>
</tr>
<tr>
<td>E</td>
<td><img src="https://example.com" alt="Medium" /></td>
</tr>
<tr>
<td>Distribution challenges</td>
<td><img src="https://example.com" alt="Medium" /></td>
</tr>
<tr>
<td>K</td>
<td><img src="https://example.com" alt="High" /></td>
</tr>
<tr>
<td>Limited financing for local PULSE innovators</td>
<td><img src="https://example.com" alt="High" /></td>
</tr>
<tr>
<td>B</td>
<td><img src="https://example.com" alt="Medium" /></td>
</tr>
<tr>
<td>VC structure &amp; aggregation points*</td>
<td><img src="https://example.com" alt="Medium" /></td>
</tr>
<tr>
<td>C</td>
<td><img src="https://example.com" alt="Medium" /></td>
</tr>
<tr>
<td>Lack of precedents*</td>
<td><img src="https://example.com" alt="Low" /></td>
</tr>
<tr>
<td>G</td>
<td><img src="https://example.com" alt="Medium" /></td>
</tr>
<tr>
<td>Limited tailored product design in PULSE use cases*</td>
<td><img src="https://example.com" alt="Medium" /></td>
</tr>
<tr>
<td>D</td>
<td><img src="https://example.com" alt="High" /></td>
</tr>
<tr>
<td>Insufficient investment in R&amp;D activities / quality</td>
<td><img src="https://example.com" alt="High" /></td>
</tr>
<tr>
<td>J</td>
<td><img src="https://example.com" alt="Medium" /></td>
</tr>
<tr>
<td>Lack of policy support targeting PULSE</td>
<td><img src="https://example.com" alt="Medium" /></td>
</tr>
<tr>
<td>H</td>
<td><img src="https://example.com" alt="High" /></td>
</tr>
<tr>
<td>Limited post-sales support</td>
<td><img src="https://example.com" alt="High" /></td>
</tr>
<tr>
<td>I</td>
<td><img src="https://example.com" alt="Medium" /></td>
</tr>
<tr>
<td>Poor market linkages for SHF</td>
<td><img src="https://example.com" alt="Medium" /></td>
</tr>
<tr>
<td>L</td>
<td><img src="https://example.com" alt="Medium" /></td>
</tr>
<tr>
<td>Lack of co-ordination at country level programming</td>
<td><img src="https://example.com" alt="Medium" /></td>
</tr>
<tr>
<td>F</td>
<td><img src="https://example.com" alt="Low" /></td>
</tr>
<tr>
<td>Capacity building of SHF/microenterprises*</td>
<td><img src="https://example.com" alt="Low" /></td>
</tr>
</tbody>
</table>

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 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

<table>
<thead>
<tr>
<th>Land area under agriculture</th>
<th>Value of marketed crop produce</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigated</td>
<td>$2.88</td>
</tr>
<tr>
<td>Not irrigated</td>
<td>72.0%</td>
</tr>
<tr>
<td>2.9M ha</td>
<td>7%</td>
</tr>
<tr>
<td>93%</td>
<td>18.0%</td>
</tr>
</tbody>
</table>

### Projected evolution of irrigation capacity by scheme typology

- **Private**
  - 2010: 75,000 hectares
  - 2030 projection: 330,000 hectares
  - Increase: 340%

- **Small scale govt. projects**
  - 2010: 75,000 hectares
  - 2030 projection: 300,000 hectares
  - Increase: 300%

- **Large scale govt. projects**
  - 2010: 10,000 hectares
  - 2030 projection: 340,000 hectares
  - Increase: 3,300%

### 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**

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**

<table>
<thead>
<tr>
<th>Crops</th>
<th>Annual Production (MT)</th>
<th>Best Case Yield Increase</th>
<th>Water Required (m3/MT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>3,339,000</td>
<td>2x</td>
<td>2,703</td>
</tr>
<tr>
<td>Potatoes</td>
<td>1,335,883</td>
<td>2x</td>
<td>191</td>
</tr>
<tr>
<td>Bananas</td>
<td>1,288,588</td>
<td>4x</td>
<td>545</td>
</tr>
<tr>
<td>Cabbages</td>
<td>775,994</td>
<td>4.5x</td>
<td>218</td>
</tr>
<tr>
<td>Beans</td>
<td>728,160</td>
<td>8x</td>
<td>8,319</td>
</tr>
<tr>
<td>Kales</td>
<td>647,342</td>
<td>2x</td>
<td>218</td>
</tr>
<tr>
<td>Tea</td>
<td>473,000</td>
<td>4x</td>
<td>4,061</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>410,033</td>
<td>4x</td>
<td>206</td>
</tr>
<tr>
<td>Rice</td>
<td>118,150</td>
<td>1.6</td>
<td>1,065</td>
</tr>
<tr>
<td>Capsicum</td>
<td>4,140</td>
<td>4x</td>
<td>4,779</td>
</tr>
</tbody>
</table>

- 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.**


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
- **Typical products & capacity:** 2->5ha
- **Degree of uptake:** Grid/Diesel High, Solar Low
- **State of play:** Limited large scale applications for solar at >5ha

### Small-scale applications
- **Typical products & capacity:** 1->2ha
- **Degree of uptake:** Grid/Diesel High, Solar Medium
- **State of play:** 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.

### Very small-scale applications
- **Typical products & capacity:** <1ha
- **Degree of uptake:** Grid/Diesel Medium, Solar Low
- **State of play:** 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.

<table>
<thead>
<tr>
<th>Organization</th>
<th>Stage</th>
<th>PULSE products &amp; services</th>
<th>Outlook</th>
</tr>
</thead>
</table>
| 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 |
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)**

- **Solelaby**
  - Offers a range of solar products including solar pumps
  - Provides large and small scale irrigation systems. Also offers a broad range of agri-support services including input supply, and training
  - Provide pumps along with complimentary equipment e.g. water tanks, greenhouses etc.

- **Amiran**
  - Provides human-powered (treadle) pumps, building a solar prototype due to demand from customers

- **Suntech**
  - Provides irrigation system design and installation, maintenance & consultancy for both solar and diesel pumps
  - In addition to pumps, supply seed, agro-chemicals, and packaging materials

- **FineTouch**
  - 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**
- **KOSHI**
- **SHURFLO**
- **PEDRULLO**
- **MARQUIS**
- **GRUNDFOS**
- **BRIGGS & STRATTON**
- **DAISHIN**
- **JIANGDONG**
- **JAIN Irrigation Systems Ltd.**

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

- **2M**: Number of people employed in the sector
- **80%**: % of producers that are smallholders
- **1.5%**: 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.


Note: 1) MT – Metric Ton
In horticulture, various PULSE products could add value by increasing production, enhancing quality, and reducing post harvest losses

**Production**

- **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

**Transportation & Storage**

**Transformation**

**Distribution & Retail**

**Note:** Women provide ~80% of the French bean industry labour

Sources: Dalberg interviews. 2018’ GIZ. 2016. “Photovoltaics for productive use applications”;

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

<table>
<thead>
<tr>
<th>What are the incentives to invest?</th>
<th>What constraints are there to uptake?</th>
</tr>
</thead>
<tbody>
<tr>
<td>There are four interrelated incentives to invest:</td>
<td>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</td>
</tr>
<tr>
<td>• <strong>Increasing total incomes</strong> by having higher yields and sales per hectare</td>
<td><strong>Upfront costs</strong></td>
</tr>
<tr>
<td>• <strong>Providing flexibility to produce out of peak season</strong> to capture higher market prices, boosting overall yields and having higher volumes to sell</td>
<td><strong>Require access to ground or surface water</strong></td>
</tr>
<tr>
<td>• <strong>Improving certainty of income</strong> and resilience to cushion against climate fluctuations</td>
<td><strong>Technical capacity</strong></td>
</tr>
<tr>
<td>• For those currently irrigating (a minority of SHFs), <strong>reduce operational costs of diesel pumps or time-burden of manual labour</strong></td>
<td><strong>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.</strong></td>
</tr>
</tbody>
</table>

“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**

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.

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

<table>
<thead>
<tr>
<th>Crop</th>
<th>Without Irrigation</th>
<th>With Irrigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>89</td>
<td>147</td>
</tr>
<tr>
<td>Kales</td>
<td>1,232</td>
<td>2,217</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>7,503</td>
<td>15,006</td>
</tr>
<tr>
<td>Capsicum</td>
<td>8,470</td>
<td>16,940</td>
</tr>
</tbody>
</table>

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


**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**

*Figures in $*

![Graph showing cumulative costs over five years with and without solar pumps.]

**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)**

**PAYBACK PERIOD**

- 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**
  - Incentive for farmers with guaranteed market
  - 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

- **Select suitable scale of water pump**
  - Appropriate product selection maximizes benefits
  - 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

- **Pre-sale support to help identify irrigation and technical needs**
  - Technical training improves viability
  - 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.
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

<table>
<thead>
<tr>
<th>Cold storage equipment supplier</th>
<th>Sells or leases to farmer (nascent model)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregator</td>
<td>Sells to aggregator (dominant model)</td>
</tr>
<tr>
<td>Farmer/retailer</td>
<td></td>
</tr>
</tbody>
</table>

- **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.

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

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

**Typical products & capacity**

- **Medium-scale applications**
  - Grid: Medium
  - Solar: Medium
  - Capacity: >2000 L

- **Small-scale applications**
  - Grid: Low
  - Solar: Low
  - Capacity: 201 – 2000 L

- **Very small-scale applications**
  - Grid: Medium
  - Solar: Low
  - Capacity: <200 L

**Degree of uptake**

- 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

**State of play**

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

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

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.

**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.

**Number of dairy cattle**: 4.3M

**Number of smallholders**: 800K - 1M

**Contribution to national GDP**: 6 – 8%

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

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.

**Sources:** Dalberg analysis and interviews, 2018; GIZ, 2016. “Photovoltaics for productive use applications”

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**Collection & Storage**

**WATER PUMPS AND MILK EXTRACTORS**
- 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

**Distribution & Retail**

**WATER PUMPS AND MILK EXTRACTORS**
- 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

**MILK CHILLERS AND COLD TRANSPORT**
- Farmers transport in plastic containers by foot or motorbike
- Cooperatives collect in non-refrigerated pick-up trucks

**SOLAR-POWERED PLANTS & SMALL PROCESSORS**
- 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

**REFRIGERATION**
- Traders who are off-grid buy milk daily, only those with grid access buy for overnight storage and chill at point of sale
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?**

- 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
- 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
- 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
- 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.

- % 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.

### Annual revenue selling chilled vs. unchilled milk

<table>
<thead>
<tr>
<th></th>
<th>Unchilled</th>
<th>With chilling</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of SHF</td>
<td>25%</td>
<td>75%</td>
</tr>
<tr>
<td>Liters sold /day</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Sold to the formal market</th>
<th>Sold to the informal market</th>
</tr>
</thead>
<tbody>
<tr>
<td>+141 (39%)</td>
<td>365</td>
<td>506</td>
</tr>
<tr>
<td>+236 (39%)</td>
<td>608</td>
<td>844</td>
</tr>
</tbody>
</table>

Note: Farmers sell at $0.3/L to cooperatives, and 0.5/L to the informal market.


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.

For 96% of SHFs who sell 1-8L per day, it is impossible to achieve positive ROI in two years.

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**

*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 co-operative and 75% sales to the informal market. In reality, those selling to co-operatives will have lower costs.

**PAYBACK PERIOD**

- **72 months**
  - @ 5L/day
- **58 months**
  - @ 5L/day
- **43 months**
  - @ 5L/day
- **36 months**
  - @ 10L/day
- **29 months**
  - @ 10L/day
- **22 months**
  - @ 10L/day
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**
- 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.

**Help boost milk quality and introduce premium pricing**
- 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.

**Target dairy farmers in hot regions**
- 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.

**Explanation**

- **Cost-sharing to improve product viability**
  - Lower rejection rates in formal markets
  - Compelling value prop. around spoilage reduction

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


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.

<table>
<thead>
<tr>
<th>Medium-scale applications</th>
<th>Small-scale applications</th>
<th>Very small-scale applications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Typical products &amp; capacity</strong></td>
<td><strong>Degree of uptake</strong></td>
<td><strong>State of play</strong></td>
</tr>
<tr>
<td>&gt;2 MT/day</td>
<td>Grid/Diesel</td>
<td>High</td>
</tr>
<tr>
<td>Solar</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>1-2 MT/day</td>
<td>Grid/Diesel</td>
<td>High</td>
</tr>
<tr>
<td>Solar</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>&lt;1 MT/day</td>
<td>Grid/Diesel</td>
<td>High</td>
</tr>
<tr>
<td>Solar</td>
<td>Low</td>
<td></td>
</tr>
</tbody>
</table>

- 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**

<table>
<thead>
<tr>
<th>Organization</th>
<th>Size</th>
<th>Stage</th>
<th>PULSE products &amp; services</th>
<th>Outlook</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agsol</td>
<td>&gt;200 units in other markets, pilot in Kenya</td>
<td>Manufacturer</td>
<td><strong>Product:</strong> Maize mill, 50kg/h, $1800</td>
<td>Working with SHS companies with strong retail networks &amp; customer base Not aiming to replace diesel mills but to reduce distance to mills for smaller villages (300-500 HH)</td>
</tr>
</tbody>
</table>

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

- **Number of smallholders**: 3.5M
- **Average acreage under maize for a smallholder**: 70%
- **Annual per capita consumption**: 90kg
- **% of maize produced by SHFs consumed at home**: 58%

**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

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

### 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.

#### Production

<table>
<thead>
<tr>
<th>PULSE opportunity</th>
<th>Power capacity of sample products</th>
<th>Current small scale activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation pumps and tractors</td>
<td>0.45-22kW 30-45kW</td>
<td>Most farmers grow maize once a year, <strong>planting during the long rainy season</strong>. In drier areas some farmers irrigate maize</td>
</tr>
<tr>
<td>Driers and siloes</td>
<td>100-200W Varies based on size up to~350kW</td>
<td>Drying is done under direct sunlight. Short rains season occurs during harvest or drying, causing spoilage</td>
</tr>
<tr>
<td>Threshers, mills and driers</td>
<td>100W 0.75-2.4kW</td>
<td>Brokers offer <strong>lower prices when moisture content is high</strong>, as they have to incur additional drying costs</td>
</tr>
</tbody>
</table>

---

**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
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.
- 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.

> 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?

<table>
<thead>
<tr>
<th><strong>What are the constraints to uptake?</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Upfront costs</strong></td>
</tr>
<tr>
<td>Solar mills are ~2x or more the cost of diesel mills. <strong>Minimum price</strong> of a solar mill is $1,800 and could go up to $3,300.</td>
</tr>
<tr>
<td><strong>Efficiency of solar</strong></td>
</tr>
<tr>
<td>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 &amp; rainy weather. A small diesel mill can do ~1100 MT annually at 8h/day, but <strong>solar can only do ~110MT</strong>.</td>
</tr>
<tr>
<td><strong>Low farmer aggregation</strong></td>
</tr>
<tr>
<td>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.</td>
</tr>
</tbody>
</table>
A solar mill may be the more attractive option for remote customers, and become cheaper than a diesel mill after two years.

**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.
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

<table>
<thead>
<tr>
<th></th>
<th>Milling costs</th>
<th>Travel costs</th>
<th>Total $ costs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Annual milling costs ($)</strong></td>
<td>36</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td><strong>Annual time costs (hours)</strong></td>
<td>39</td>
<td>30</td>
<td>69</td>
</tr>
</tbody>
</table>

- **Milling costs**: 15kg weekly @ $0.05/kg
- **Travel costs**: 52 trips (weekly) @ $0.7/trip
- **Per kg spend**: $75/780kg = 0.097/kg
- **Travel time**: 52 trips @ ~45min/trip
- **Waiting time at mill**: 52 trips @ ~30min/trip
- **Total time cost**: 69 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. **Fineness 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

Weather conditions are one factor that limits full year-round utilization, **80% utilization is a reasonable estimate of maximum viable usage** …

... additionally utilization is further limited by the number of customers within a given catchment area (rural population density) and the relative proximity of a diesel mill

<table>
<thead>
<tr>
<th>Utilization</th>
<th>Payback period</th>
</tr>
</thead>
<tbody>
<tr>
<td>90%</td>
<td>13 months</td>
</tr>
<tr>
<td>80%</td>
<td>15 months</td>
</tr>
<tr>
<td>70%</td>
<td>18 months</td>
</tr>
<tr>
<td>60%</td>
<td>21 months</td>
</tr>
<tr>
<td>50%</td>
<td>27 months</td>
</tr>
<tr>
<td>40%</td>
<td>38 months</td>
</tr>
<tr>
<td>30%</td>
<td>61 months</td>
</tr>
<tr>
<td>20%</td>
<td>-</td>
</tr>
</tbody>
</table>

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/year¹
- 0.9 MT/farmer² (average yield of 1.6MT per year of which 58% is consumed at home)
- 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

---


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
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.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Solar Products</th>
<th>Diesel/Grid Products</th>
<th>Agriculture Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Import Duty</td>
<td>0%</td>
<td>~25%</td>
<td>0 (I) 25%(L)</td>
</tr>
<tr>
<td>VAT</td>
<td>0%</td>
<td>16%</td>
<td>0 (I) 16%(L)</td>
</tr>
<tr>
<td>Other levies</td>
<td>2.25% (IDF)</td>
<td>2.25% (IDF)</td>
<td>2.25% (IDF)</td>
</tr>
<tr>
<td>Subsidies</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Incentives</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

**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.


Note: 0% for imports but 16% (exempt) for local manufacturers. 2. IDF = Import Declaration Fee.
Land reforms and a changing agricultural landscape has opened up smallholder production opportunities in Zimbabwe, which solar irrigation could help to fill.

- 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.

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.

- 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; Zimbabwe land, 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

<table>
<thead>
<tr>
<th>Scheme Typology</th>
<th>Irrigated</th>
<th>Not Irrigated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large scale</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td>A1</td>
<td>20%</td>
<td>80%</td>
</tr>
<tr>
<td>A2</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td>Communal</td>
<td>28%</td>
<td>72%</td>
</tr>
</tbody>
</table>

Types of irrigation practiced in Zimbabwe

- **Sprinkler**: 75%
- **Surface/flood**: 18%
- **Drip**: 7%

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

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.

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.**

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

<table>
<thead>
<tr>
<th>Crop</th>
<th>Annual Production (MT)</th>
<th>Best Case Yield Increase</th>
<th>Water Required (m³/MT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar cane</td>
<td>3,483,000</td>
<td>1.5x</td>
<td>41</td>
</tr>
<tr>
<td>Maize</td>
<td>852,909</td>
<td>2x</td>
<td>232</td>
</tr>
<tr>
<td>Cotton</td>
<td>110,000</td>
<td>2x</td>
<td>2,555</td>
</tr>
<tr>
<td>Bananas</td>
<td>104,032</td>
<td>2x</td>
<td>1,173</td>
</tr>
<tr>
<td>Soya beans</td>
<td>70,000</td>
<td>4x</td>
<td>2,391</td>
</tr>
<tr>
<td>Sorghum</td>
<td>65,017</td>
<td>2x</td>
<td>6,242</td>
</tr>
<tr>
<td>Potatoes</td>
<td>64,127</td>
<td>2x</td>
<td>250</td>
</tr>
<tr>
<td>Wheat</td>
<td>43,294</td>
<td>4x</td>
<td>4,260</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>24,863</td>
<td>4x</td>
<td>423</td>
</tr>
<tr>
<td>Onions</td>
<td>3,569</td>
<td>4.5x</td>
<td>353</td>
</tr>
<tr>
<td>Cabbages</td>
<td>462</td>
<td>4x</td>
<td>496</td>
</tr>
</tbody>
</table>

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

### State of play

<table>
<thead>
<tr>
<th>State of play</th>
<th>Medium-scale applications</th>
<th>Small-scale applications</th>
<th>Very small-scale applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>2-5ha</td>
<td>1-2ha</td>
<td>&lt;1ha</td>
</tr>
<tr>
<td>Typical products &amp; capacity</td>
<td>Grid/Diesel</td>
<td>Solar</td>
<td>Grid/Diesel</td>
</tr>
<tr>
<td>Degree of uptake</td>
<td>Medium</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Source</td>
<td>Dalberg analysis and interviews. 2018.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

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

Source: Dalberg analysis and interviews. 2018.
Zimbabwe has a number of solar pump importers and distributors in the market (2/2)

<table>
<thead>
<tr>
<th>Organization</th>
<th>Type</th>
<th>PULSE products &amp; services</th>
<th>Outlook</th>
</tr>
</thead>
</table>
| 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.


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**
- Pumped water and tractors
  - Pumps to irrigate produce
  - Tractors to increase efficiency by powering planters, sprayers and combine harvesters

**Transportation & Storage**
- Cold storage
  - Cold storage facilities to reduce spoilage at farm/first collection point
  - Cold chain transport to reduce spoilage in transit

**Transformation**
- Driers and small processors
  - Driers to convert produce into higher value dried forms
  - Solar-powered juicing/pulping processors

**Distribution & Retail**
- Refrigeration
  - Commercial refrigeration units to allow vendors in remote areas to stock products for longer periods

---

**Pulse opportunity**

**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 practices to till land
- Grow a variety of crops in a year as part of good soil management practices
- 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?**

<table>
<thead>
<tr>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>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</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Solar product reputation</th>
</tr>
</thead>
<tbody>
<tr>
<td>There is an influx of low quality imported pumps and panels which can negatively skew the experience of first-time solar pump users</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Technical support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most small-scale farmers have limited understanding of best irrigation practices, nor have incumbent diesel pumps to know about pumping systems (solar or diesel)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Familiarity</th>
</tr>
</thead>
<tbody>
<tr>
<td>There is limited knowledge on the long-term cost-benefits of solar pumps vs diesel pumps</td>
</tr>
</tbody>
</table>

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.


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.

- **Without irrigation**
  - $500/MT
  - Assuming 40% of production is sold (reminder is spoilage and domestic consumption)

- **With irrigation**
  - $330/MT
  - Assuming 50% of production is sold (reminder is spoilage and domestic consumption)

- **With irrigation**
  - $500/MT
  - Assuming 50% of production sold (reminder is spoilage and domestic consumption)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Without Irrigation</th>
<th>With Irrigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomatoes</td>
<td>$1,141</td>
<td>$2,852</td>
</tr>
<tr>
<td>Cabbages</td>
<td>$1,848</td>
<td>$3,696</td>
</tr>
<tr>
<td>Onions</td>
<td>$4,000</td>
<td>$8,000</td>
</tr>
</tbody>
</table>

**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 $

With solar pump

With diesel pump

While the upfront cost of the diesel is less than solar, the cost over time rises, whereas solar stays relatively flat.

- 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 ($)*

#### 0.4 Ha irrigated land

<table>
<thead>
<tr>
<th></th>
<th>Solar</th>
<th>Diesel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payback</td>
<td>2 seasons</td>
<td>&gt;2 seasons</td>
</tr>
<tr>
<td>Two-year ROI</td>
<td>22%</td>
<td>-9%</td>
</tr>
</tbody>
</table>

#### 1 Ha irrigated land

<table>
<thead>
<tr>
<th></th>
<th>Solar</th>
<th>Diesel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payback</td>
<td>1 Season</td>
<td>1 Season</td>
</tr>
<tr>
<td>Two-year ROI</td>
<td>166%</td>
<td>106%</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>FACTORS TO STRENGTHEN BUSINESS CASE</th>
<th>EXPLANATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market linkages with guaranteed off-takers</td>
<td>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.</td>
</tr>
<tr>
<td>Tailored financing options for potential customers</td>
<td>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 &lt;$50 per month, and current interest rates are ~24% pa.</td>
</tr>
<tr>
<td>Pre- and post-sales support</td>
<td>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.</td>
</tr>
</tbody>
</table>

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 practices, 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**

<table>
<thead>
<tr>
<th>Horticulture (Tomatoes)</th>
<th>Dairy</th>
<th>Livestock (Fisheries and Poultry)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40% of losses due to spoilage</td>
<td>50% of losses due to spoilage</td>
<td>10% of losses due to spoilage in fisheries</td>
</tr>
<tr>
<td>~77% of commercial produce passes through cooling facilities</td>
<td>32% of milk sold passes through chilling facilities</td>
<td>~30% of poultry is transported in cooling systems</td>
</tr>
</tbody>
</table>

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

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

### State of play

<table>
<thead>
<tr>
<th>Type of Application</th>
<th>Large-Scale Applications</th>
<th>Small-Scale Applications</th>
<th>Micro-Scale Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical products &amp; capacity</td>
<td>Grid</td>
<td>Solar</td>
<td>Grid</td>
</tr>
<tr>
<td>Degree of uptake</td>
<td>Medium</td>
<td>None</td>
<td>Low</td>
</tr>
<tr>
<td>State of play</td>
<td>Large refrigeration solutions are usually grid-powered and used by industrial processors.</td>
<td>Grid walk-in cold room solutions are increasingly being used in horticulture by large aggregators and exporters.</td>
<td>There are currently no solar solutions that meet large-scale demand for cooling.</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Organization</th>
<th>Type</th>
<th>Stage</th>
<th>PULSE products &amp; services</th>
<th>Outlook</th>
</tr>
</thead>
</table>
| 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 |
| 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 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 |
| 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.

### Dairy - Overview

- **Number of dairy cattle**: 3.5M
- **Number of smallholders**: 300K
- **Contribution to agriculture GDP**: 9%
- **Level of spoilage at small-scale**: 50%


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

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

- **WATER PUMPS AND MILK EXTRACTORS**
  - 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.

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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 $)

<table>
<thead>
<tr>
<th>Farmer mode</th>
<th>Liters/cow</th>
<th># of cows</th>
<th>Liters/day</th>
<th>Unchilled</th>
<th>With chilling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smallholder</td>
<td>10¹</td>
<td>3</td>
<td>30</td>
<td>4,500</td>
<td>4,950</td>
</tr>
<tr>
<td>Smallholder Plus</td>
<td>10</td>
<td>8</td>
<td>80</td>
<td>12,000</td>
<td>13,200</td>
</tr>
<tr>
<td>Aggregation</td>
<td>10</td>
<td>12</td>
<td>120</td>
<td>18,000</td>
<td>19,800</td>
</tr>
</tbody>
</table>

*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*

**Note**: 1) Volumes are up to figures presented; 2) Assumes at least 50% access to premium market.

Source: Dalberg analysis and interviews, 2018.
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

Chillers start to have positive two-year returns for farmers storing at least 7.5L milk per day.

To achieve higher returns from investment, utilization needs to increase. This means either more productive farmers or aggregation.

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

Table:

<table>
<thead>
<tr>
<th>Daily volume (L)</th>
<th>With financing</th>
<th>Current price</th>
<th>20% drop in price</th>
<th>40% drop in price</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WITH FINANCING</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>47 months @ 5L/day</td>
<td>47 months @ 10L/day</td>
<td>28 months @ 5L/day</td>
<td>14 months @ 10L/day</td>
</tr>
<tr>
<td>5</td>
<td>38 months @ 5L/day</td>
<td>38 months @ 10L/day</td>
<td>19 months @ 5L/day</td>
<td>14 months @ 10L/day</td>
</tr>
<tr>
<td>10</td>
<td>24 months @ 10L/day</td>
<td>24 months @ 20L/day</td>
<td>12 months @ 10L/day</td>
<td>8 months @ 20L/day</td>
</tr>
<tr>
<td>15</td>
<td>20 months @ 20L/day</td>
<td>20 months @ 30L/day</td>
<td>10 months @ 20L/day</td>
<td>6 months @ 30L/day</td>
</tr>
<tr>
<td>20</td>
<td>16 months @ 30L/day</td>
<td>16 months @ 40L/day</td>
<td>8 months @ 30L/day</td>
<td>4 months @ 40L/day</td>
</tr>
</tbody>
</table>

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**
  - 25% boost to the additional revenue
  - 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

- **Pricing below $699* for a small solar chiller**
  - Investment case for farmers at <10L
  - 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

- **Sustained access to formal markets**
  - More consistent access to processing centers
  - 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

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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.

---

Source: Dalberg analysis and interviews. 2018.
Across crops, large scale grid processing applications are widespread, while solar solutions are currently not available.

<table>
<thead>
<tr>
<th>State of play</th>
<th>Degree of uptake</th>
<th>Typical products &amp; capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Medium-scale applications</strong></td>
<td>Grid</td>
<td>&gt;2 MT/day</td>
</tr>
<tr>
<td></td>
<td>Solar</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td></td>
</tr>
<tr>
<td><strong>Small-scale applications</strong></td>
<td>Grid</td>
<td>1-2 MT/day</td>
</tr>
<tr>
<td></td>
<td>Solar</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td></td>
</tr>
<tr>
<td><strong>Very small-scale applications</strong></td>
<td>Grid</td>
<td>&lt;1 MT/day</td>
</tr>
<tr>
<td></td>
<td>Solar</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Organization</th>
<th>Stage</th>
<th>PULSE products &amp; services</th>
<th>Outlook</th>
</tr>
</thead>
</table>
| 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.

- **Annual production, 2017**: 2.2M MT
- **% of smallholders engaged in maize farming**: 80%
- **Contribution to agricultural GDP**: 9%

### 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.

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

<table>
<thead>
<tr>
<th>Production</th>
<th>Collection &amp; Storage</th>
<th>Transformation</th>
<th>Distribution &amp; Retail</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WATER PUMPS</strong></td>
<td><strong>DRYERS AND SILOS</strong></td>
<td><strong>THRESHERS AND MILLERS</strong></td>
<td><strong>N/A</strong></td>
</tr>
<tr>
<td>• Pumps to increase yield and allow farmers to plant multiple cereal crops in a year</td>
<td>• Sun-dryers to cut down on time spent drying</td>
<td>• Threshers to reduce time spent manually threshing prior to milling and save on fuel cost</td>
<td>• No real opportunity in transportation as spoilage largely occurs during storage*</td>
</tr>
<tr>
<td><strong>Power capacity of sample products</strong></td>
<td><strong>Current small scale activity</strong></td>
<td><strong>Source</strong>: Dalberg analysis and interviews. 2018;</td>
<td><strong>Source</strong>: Dalberg analysis and interviews. 2018;</td>
</tr>
<tr>
<td>0.45-22kW</td>
<td>10 kW</td>
<td>1.2 kW</td>
<td></td>
</tr>
<tr>
<td>• A few mid-scale farmers use diesel pumps, while most small-scale farmers rely on rain-fed farming for one season of maize</td>
<td>• Most farmers sun-dry their maize, a process which takes ~2 weeks</td>
<td>• Threshing is mainly carried out mainly manually. Some farmers pay for threshing via combined harvester or diesel processor</td>
<td>• Collection of maize grain by brokers is usually done using trucks</td>
</tr>
<tr>
<td>• Land is tilled manually</td>
<td>• Farmers store their produce in bags and keep them in reusable sacks</td>
<td>• Maize grain is sold to large-scale processors for milling</td>
<td></td>
</tr>
</tbody>
</table>

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.

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

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

- **Both solar and diesel solutions breakeven at 110MT of processing, driven by fixed upfront and labor costs.**
- **A diesel thresher must operate at over 325MT to achieve lower unit costs than solar.**
- **Solar remains cost competitive up to its maximum capacity of 240MT.**

**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.

<table>
<thead>
<tr>
<th>How many households need to be serviced? Over what catchment area?</th>
<th>If a static off-farm solution, how could travel costs affect customer willingness to pay?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processing capacity, 110 - 240 MT of maize/season</td>
<td>Service fee when threshed on farm, $10/MT</td>
</tr>
<tr>
<td>2.5 MT/ household/season</td>
<td>Typical travel based on catchment: 2.2 - 3.5 km</td>
</tr>
<tr>
<td>44 – 96 households serviced per year</td>
<td>Approximate travel costs, $0.38/km/MT</td>
</tr>
<tr>
<td>10 households/km²</td>
<td>Additional total cost of travel: $1 – 1.5/MT</td>
</tr>
</tbody>
</table>

Typical catchment area: 4.4 – 9.6 km²

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.
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.

<table>
<thead>
<tr>
<th>Utilization</th>
<th>Payback period:</th>
<th>Payback period</th>
</tr>
</thead>
<tbody>
<tr>
<td>20%</td>
<td>-91%</td>
<td>40 months</td>
</tr>
<tr>
<td>30%</td>
<td>-61%</td>
<td>27 months</td>
</tr>
<tr>
<td>40%</td>
<td>-31%</td>
<td>20 months</td>
</tr>
<tr>
<td>50%</td>
<td>-1%</td>
<td>16 months</td>
</tr>
<tr>
<td>60%</td>
<td>29%</td>
<td>14 months</td>
</tr>
<tr>
<td>70%</td>
<td>59%</td>
<td>12 months</td>
</tr>
<tr>
<td>80%</td>
<td>89%</td>
<td>10 months</td>
</tr>
</tbody>
</table>

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 thresher, 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

**Increased mobility**

- 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**

- 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

**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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Solar Products</th>
<th>Diesel/Grid Products</th>
<th>Agriculture Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Import Duty</td>
<td>No</td>
<td>5%</td>
<td>No</td>
</tr>
<tr>
<td>VAT</td>
<td>15%</td>
<td>15%</td>
<td>No</td>
</tr>
<tr>
<td>Surtax</td>
<td>No</td>
<td>25%</td>
<td>No</td>
</tr>
<tr>
<td>Subsidies</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Incentives</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>


Note: VAT – Value Added Tax; Excise duty – paid at customs; Surtax – tax levied on top of another tax.
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

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

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

<table>
<thead>
<tr>
<th>State of play</th>
<th>Large-scale applications</th>
<th>Small-scale applications</th>
<th>Micro-scale applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree of uptake</td>
<td>&gt;2 MT/day</td>
<td>1-2 MT/day</td>
<td>&lt;1 MT/day</td>
</tr>
<tr>
<td>Typical products &amp; capacity</td>
<td>Grid/Diesel</td>
<td>Solar</td>
<td>Grid/Diesel</td>
</tr>
<tr>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>

- 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.

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

### Suppliers of solar products

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

### 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:

- LET: Imports and sells a range of agro-processing equipment, e.g. oil presses, maize and rice mills, coffee grinders, etc.
- SOTIC: Imports and supplies processing equipment for cashew
- Bouchard Export: Supplies equipment for processors of export crops
- 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.

- **Smallholder farmers**: 1.7M
- **Annual production in tons**: 3.1M
- **5-year average annual production growth rate**: 5.9%

**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.


Note: 1) Consumption vary 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.

**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**
- **IRRIGATION AND MECHANIZATION**: 0.45-22kW, 30-45kW
- **CHILLED TRANSPORT**: 1-5kW
- **GRINDERS, PRESSERS, GRANULATORS, STOVES**: 450W, 11-15 W
- **DRYERS**: 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:
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.

**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.

**Mobility**

Mobile diesel-run grinders are common in rural areas, so stationary solar grinders may struggle to be competitive in remote areas.

**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: INH University & CIRAD. 2017 “La chaîne de valeur du manioc en Côte d’Ivoire”; Dalberg analysis and interviews s. 2018.

Note: 1) Assumes that most people in rural areas are in the lower 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)

<table>
<thead>
<tr>
<th>Product type</th>
<th>Max capacity (MT/year)</th>
<th>Hourly capacity</th>
<th>Hours/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobile solar grinder</td>
<td>59</td>
<td>50kg/h</td>
<td>4</td>
</tr>
<tr>
<td>Mobile diesel grinder</td>
<td>146</td>
<td>50kg/h</td>
<td>8</td>
</tr>
</tbody>
</table>

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

### Annual revenue from solar vs diesel both stationary

<table>
<thead>
<tr>
<th>Product type</th>
<th>Max capacity (MT/year)</th>
<th>Hourly capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stationary solar grinder</td>
<td>118</td>
<td>50kg/h</td>
</tr>
<tr>
<td>Stationary diesel grinder</td>
<td>438</td>
<td>150kg/h</td>
</tr>
</tbody>
</table>

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)

<table>
<thead>
<tr>
<th>Year</th>
<th>Solar-powered</th>
<th>Diesel-powered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 1</td>
<td>2,110</td>
<td>2,566</td>
</tr>
<tr>
<td>Year 2</td>
<td>2,210</td>
<td>2,566</td>
</tr>
<tr>
<td>Year 3</td>
<td>2,310</td>
<td>2,566</td>
</tr>
<tr>
<td>Year 4</td>
<td>2,410</td>
<td>2,566</td>
</tr>
<tr>
<td>Year 5</td>
<td>2,510</td>
<td>2,566</td>
</tr>
</tbody>
</table>

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*

**Current product price**

100% utilization = 146MT/year (8h/day for 365 annual days)

**20% drop in price**

negative ROI

Positive ROI and payback period <= 2 years

**40% drop in price**

80% utilization (118MT/year) is more likely to be achieved given lower efficiency in rainy and cloudy weather conditions

PAYBACK PERIOD

- **19 months @ 100% utilization**
- **37 months @ 50% utilization**

- **15 months @ 100% utilization**
- **30 months @ 50% utilization**

- **11 months @ 100% 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)

<table>
<thead>
<tr>
<th>Minimum number of households to serve per year</th>
<th>Coverage (area) required for commercial viability</th>
</tr>
</thead>
<tbody>
<tr>
<td>118 MT of cassava/year</td>
<td>1,532 people/year</td>
</tr>
<tr>
<td>0.077MT/ person/year¹</td>
<td>339 people/sq. km³</td>
</tr>
<tr>
<td>1,532 people/year</td>
<td>~4.5 sq km</td>
</tr>
<tr>
<td>5.4 people/household²</td>
<td></td>
</tr>
<tr>
<td>284 households</td>
<td></td>
</tr>
</tbody>
</table>

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).

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**

**Explanations**

**Maximize daily revenue generating capacity**

- 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**

- 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.

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.

### Rice farmers

| 2 M |

### Annual production in MT

| 1.9 M |

### 5-year average annual production growth rate

| 3% |

### Share of rice in total cereal production

| 64% |

#### 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.

<table>
<thead>
<tr>
<th>Mill capacity/h</th>
<th># of mills</th>
<th>% of rice milled</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;= 500kg</td>
<td>1,672</td>
<td>47.9%</td>
</tr>
<tr>
<td>500kg - 1T</td>
<td>380</td>
<td>35.6%</td>
</tr>
<tr>
<td>1T - 5T</td>
<td>98</td>
<td>16.3%</td>
</tr>
<tr>
<td>5T</td>
<td>2</td>
<td>0.2%</td>
</tr>
</tbody>
</table>

- 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: 50 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**
- Irrigation to increase production – due to communal irrigation using dams and high volumes of water used, pumps would need high power capacity
- 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

**Harvesting and Transport**
- Thresher to remove rice from stalks cleanly and efficiently
- Dryers to reduce moisture content before milling
- 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

**Transformation**
- Mills to hull and whiten rice with minimal to no breakage and impurities
- 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

**Distribution & Retail**
- No strong PULSE opportunity in distribution
- 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

**Power capacity of sample products**
- **IRRIGATION PUMPS**
  - 0.45-22kW
  - 30-45kW
- **THRESHERS AND DRYERS**
  - 100-200W
- **HULLING AND POLISHING MILL**
  - 250-375W
- **N/A**

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

<table>
<thead>
<tr>
<th>What are the incentives to invest?</th>
<th>What are the constraints to uptake?</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Rice needs to be transformed or consumed almost immediately post-harvest before it ferments and spoils</td>
<td>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</td>
</tr>
<tr>
<td>• 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</td>
<td>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</td>
</tr>
<tr>
<td>• In some cases a co-op will transport the rice and charge the farmer $9-12/MT for transport (average farmer yield is 0.5-1T)</td>
<td>Small diesel mills produce rice with high debris/stone content as they lack the cleaning compartment that larger mills have. Due to their small size, solar mills may be perceived as low quality, and need to produce rice of similar quality to that of small diesel mills to be competitive</td>
</tr>
<tr>
<td>• Entrepreneurs in remote, off-grid areas can acquire solar mills and generate revenue by offering processing services closer to home (market rate for milling is ~$ 53/MT)</td>
<td></td>
</tr>
<tr>
<td>• Mills also earn money from selling white rice (a role played by many rice processors)</td>
<td></td>
</tr>
<tr>
<td>• While not the direct investor in a mill, farmers would benefit from reduced transport and time costs</td>
<td></td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Revenue source</th>
<th>Operational dynamics</th>
<th>Business implications for a solar product</th>
</tr>
</thead>
</table>
| **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**

<table>
<thead>
<tr>
<th></th>
<th>Solar huller (60kg/h)</th>
<th>Smallest diesel/grid huller (200kg/h)</th>
<th>400kg/h diesel/grid huller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum MT/year</td>
<td>68</td>
<td>292</td>
<td>584</td>
</tr>
<tr>
<td>Maximum farmers served annually</td>
<td>75</td>
<td>294</td>
<td>648</td>
</tr>
<tr>
<td>Maximum annual processing capacity</td>
<td>3,643</td>
<td>15,643</td>
<td>31,286</td>
</tr>
</tbody>
</table>

- **In addition to having lower peak processing capacity, the solar huller is only operational for 188 days and 6h/day compared to 243 days and 8h/day for diesel.**
- Current hullers have ~90% utilization, suggesting they are well sized for the market.

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

- Unit costs for solar are higher than those for diesel even at similar processing capacities
- At demand greater than 68MT/year, a second solar machine is needed
- If a solar hulling enterprise could process ~140MT/year, unit costs over five years would match those of diesel
- Currently, operating at this volume would require 3 solar hullers

**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.
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)

<table>
<thead>
<tr>
<th>Utilization (%)</th>
<th>Current product price</th>
<th>20% drop in price</th>
<th>40% drop in price</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Negative ROI</td>
<td>Positive ROI and payback period &lt;= 2 years</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>2,181</td>
<td>1,370</td>
<td>-559</td>
</tr>
<tr>
<td>30</td>
<td>5318</td>
<td>3,317</td>
<td>4,128</td>
</tr>
<tr>
<td>40</td>
<td>2,506</td>
<td>6,129</td>
<td>6,940</td>
</tr>
<tr>
<td>50</td>
<td>5318</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>2,506</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>80</td>
<td>2,506</td>
<td></td>
<td></td>
</tr>
<tr>
<td>90</td>
<td>5318</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>2,506</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**PAYBACK PERIOD**

- **100% utilization**
  - 11 months @ 100% utilization
  - 10 months @ 100% utilization
  - 7 months @ 100% utilization

- **50% 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.

**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

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

### State of play
- **Medium-scale applications**
  - Grid: Medium
  - Solar: Low
- **Small-scale applications**
  - Grid: Medium
  - Solar: Low
- **Very small-scale applications**
  - Grid: Medium
  - Solar: Low

### Degree of uptake
- **Medium**: Large-scale grid systems, such as cold rooms, are in use, but are limited to commercial fish and meat importers and fruit exporters.
- **Low**: Commercial retailers and wholesalers use small-scale grid solutions. In the fish sector, bulk traders rent out freezer space to smaller traders.
- **Medium**: There are no large-scale solar players, but development partners are exploring solar options for agriculture VCs.
- **Low**: 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.
- **Medium**: Many formal and informal electronic appliance suppliers offer household fridges/freezers that are not specifically designed for the agriculture space.
- **Low**: 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.

<table>
<thead>
<tr>
<th>Organization</th>
<th>Operating model</th>
<th>PULSE products &amp; services</th>
<th>Outlook</th>
</tr>
</thead>
</table>
| 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 |
| **YANDALUX**     |                                  |                                                                                           |                                                                         |
| 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 |
| **LEDAK**        |                                  |                                                                                           |                                                                         |
| 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 |
| **HACH/HICOM**   |                                  |                                                                                           |                                                                         |

**Other solar players**

**Aphelion Energy**
Provides household, business and industrial solar solutions, including household and medical refrigeration

**Station Energy**
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).

**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.**

---

**82,800 MT**

- **Annual local production**

**70,000**

- **Number of people employed directly**

**2%**

- **Share of population supported by the fishing sector**

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

**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**
- **FISHING LIGHTS AND SOLAR AERATORS**
  - 0.8-1W
  - 1.5-17W
- **COLD TRANSPORT**
  - 1-5kW
- **OVENS**
  - 100-200W
- **REFRIGERATION, FREEZING, ICE MAKER**
  - 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 $)

<table>
<thead>
<tr>
<th></th>
<th>No chilling / freezing</th>
<th>With chilling</th>
<th>Smoked</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ice chilling</td>
<td>1,376</td>
<td>1,376</td>
<td>1,376</td>
</tr>
<tr>
<td>Solar chilling</td>
<td>2,127</td>
<td>2,417</td>
<td></td>
</tr>
<tr>
<td>Smoking</td>
<td></td>
<td></td>
<td>3,197</td>
</tr>
</tbody>
</table>

- 21% increase in revenue

### 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

### 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)

### 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

The increase in cost between year 1 and 2 is higher than in other years for the solar chiller due to two-year financing costs*

Costs of daily ice purchases assume full availability of ice, which in remote areas is unlikely

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 MRs 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)

<table>
<thead>
<tr>
<th>Small chiller¹</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity (L)</td>
<td>20</td>
</tr>
<tr>
<td>Wattage</td>
<td>46</td>
</tr>
<tr>
<td>Net weight (Kg)</td>
<td>13</td>
</tr>
<tr>
<td>Price ($)</td>
<td>603</td>
</tr>
</tbody>
</table>

**TWO-YEAR ROI**

<table>
<thead>
<tr>
<th>Weekly volume traded (L)</th>
<th>PAYBACK PERIOD</th>
<th>TWO-YEAR ROI</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>30 months</td>
<td>101%</td>
</tr>
<tr>
<td>12</td>
<td>12 months</td>
<td>302%</td>
</tr>
<tr>
<td>18</td>
<td>6 months</td>
<td>302%</td>
</tr>
<tr>
<td>24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td></td>
<td></td>
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<tr>
<td>36</td>
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<td>48</td>
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<tr>
<td>54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Negative ROI
- Positive ROI and payback period <= 2 years

**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.

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

**Target traders in rural, inland areas**

- *Inland traders experience higher losses*

**Target fish traders trading in higher value fish**

- *Certain fish types provide higher income per kg*

**Refine the product for lighter weight**

- *Improve portability of the product*

**FACTORS TO STRENGTHEN THE BUSINESS CASE**

**EXPLANATION**

- 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.

- 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.

- 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**

- **Agricultural land under permanent cultivation**: 20.5M ha
- **Equipped for irrigation**: 0.4%
- **Irrigable land (planned for irrigation)**: 2.0%
- **Cultivated without irrigation**: 97.7%

**Share of irrigated land use**

- **Small farms**: 35.0%
- **Industrial farms**: 65.0%

**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**.

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

<table>
<thead>
<tr>
<th>Organization</th>
<th>Operating Model</th>
<th>PULSE Products &amp; Services</th>
<th>Approach &amp; Outlook</th>
</tr>
</thead>
</table>
| 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                                                                                                                                 |
| Hydraulosolar       | 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.
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**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Solar Equipment</th>
<th>Diesel/Grid Products</th>
<th>Agriculture Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Import duty</td>
<td>0% (0-35%)</td>
<td>0-35%</td>
<td>0% (0-35%)</td>
</tr>
<tr>
<td>VAT</td>
<td>9% (panels)</td>
<td>18%</td>
<td>18%</td>
</tr>
<tr>
<td>Subsidies</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Incentives</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

**BROADER POLICY ISSUES**

**Energy & Solar**
- In 2014, the government adopted a new Electricity Code that recognizes 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**
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

<table>
<thead>
<tr>
<th>Energy – oriented</th>
<th>Agriculture – oriented</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Constraints that may need energy sector expertise to solve</strong></td>
<td><strong>Constraints that may need agriculture sector expertise to solve</strong></td>
</tr>
<tr>
<td><strong>A</strong> Upfront investment costs</td>
<td><strong>B</strong> VC structure and aggregation points</td>
</tr>
<tr>
<td><strong>D</strong> Insufficient investment in R&amp;D activities/ quality of products</td>
<td><strong>C</strong> Lack of precedents</td>
</tr>
<tr>
<td><strong>E</strong> Distribution challenges</td>
<td><strong>F</strong> Capacity building of SHF/rural microenterprises</td>
</tr>
<tr>
<td><strong>G</strong> Limited tailored product design in PULSE use cases</td>
<td><strong>I</strong> Poor market linkages for SHF</td>
</tr>
<tr>
<td><strong>H</strong> Limited post-sales support</td>
<td><strong>J</strong> Lack of policy support targeting PULSE</td>
</tr>
<tr>
<td><strong>L</strong> Lack of co-ordination at Country-level</td>
<td><strong>M</strong> Limited financing for users especially SHF</td>
</tr>
<tr>
<td><strong>K</strong> Limited financing for local PULSE innovators</td>
<td></td>
</tr>
</tbody>
</table>

**Severity of constraint:**
- High
- Medium
- Low

---

*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 is 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 outcompete 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

- **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

**Types of interventions which can move the needle**

**What is required**

- 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

**Success factors**

**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

- **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

### Types of interventions which can move the needle

<table>
<thead>
<tr>
<th>What is required</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Targeting/additionality</strong>: Critical will be in basing technology and innovation in sectors that will not move, without intervention, i.e. the most immature markets/PULSE products</td>
</tr>
<tr>
<td><strong>Product launch</strong>: Research and piloting will need to be geared to product launch and sustainable commercially-driven scale up</td>
</tr>
</tbody>
</table>

### Success factors

- **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

- **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.

**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

- **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.

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**Types of interventions which can move the needle**

- 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).

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**Success factors**

**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.

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**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**
   - 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.
   - Highest impact likely to be in supporting off-taker/processor aggregation models given technology limitations for small scale solutions.

2. **Technology & innovation**
   - 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.
   - Focus should be on reducing costs to improve uptake by medium scale aggregators. And product design to overcome VC-specific requirements.

3. **Consumer awareness & education**
   - Prioritize training on technical requirements needed to maximize returns e.g. on good agricultural practices, appropriate pump selection, downstream market access etc.
   - Needs to focus on availability of solutions where present, and involve aggregators in education on premium pricing for quality where they offer this.

### 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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