

Productive use of off-grid solar: appliances and solar water pumps as drivers of growth

GOGLA

The Voice of the Off-Grid Solar Energy Industry



Introduction

The off-grid solar sector is increasingly enabling the productive use of off-grid solar appliances. This briefing note examines the potential impact of off-grid solar products on customers' economic productivity – and thus income and employment – with a focus on solar water pumps (SWPs). It gives an overview of the range of productive use of energy (PUE) applications of off-grid solar products and provides a deep dive into the potential application of SWPs across East Africa, West Africa, Central Africa and South Asia.

Productive use of energy can support livelihoods through income generation, employment opportunities, and diversification of economic activities. Off-grid solar products can increase productivity by providing more hours of light and offering a reliable electricity connection for small businesses in all stages of the production process¹. Raising productivity of existing work in, for example, the agriculture sector helps raise incomes among the rural poor, while new appliances can also create new value chains and generate new employment opportunities.

A range of PUE products are becoming increasingly common in emerging markets. These include the use of solar in shops and stalls, bars and restaurants and to power a whole range of appliances that support agri-business.

A key agricultural PUE appliance is the solar water pump. SWPs are increasingly becoming a viable alternative to diesel pumps and offer an attractive method of access to irrigation for smallholder farmers who currently lack access to electricity and are reliant on rainfed agriculture. SWPs can be cost-competitive with diesel alternatives², with significant savings created across the product lifetime, whilst pay-as-you-go (PAYGo) technology helps make them more affordable for smallholder farmers by avoiding the upfront costs³.

As the third note in a series of three, this briefing note expands on research which shows that with the right sector support and investment, the off-grid solar sector could employ 1.3 million full-time-equivalent workers – ranging from entry-level to highly skilled positions – across East Africa, West Africa, Central Africa and South Asia by 2022⁴.

1 GOGLA (2018), Powering Opportunity: The Economic Impact of Off-Grid Solar.
2 Open Capital Advisors & Shell Foundation (2017), Promoting Productive Uses of Energy in Uganda.
3 Guardian Labs (2018), Water From the Sun: How Solar Powered Pumps can Energise a Whole Community.
4 For the previous notes in this series, please see Vivid Economics (2018), Employment Opportunities in an Evolving Market. Off-Grid Solar: Creating High-Value Employment in Key Markets and Vivid Economics (2019), Energizing Job Creation: Employment Opportunities Along the Off-grid Solar Value Chain.

Putting off-grid solar products to productive use of energy (PUE)

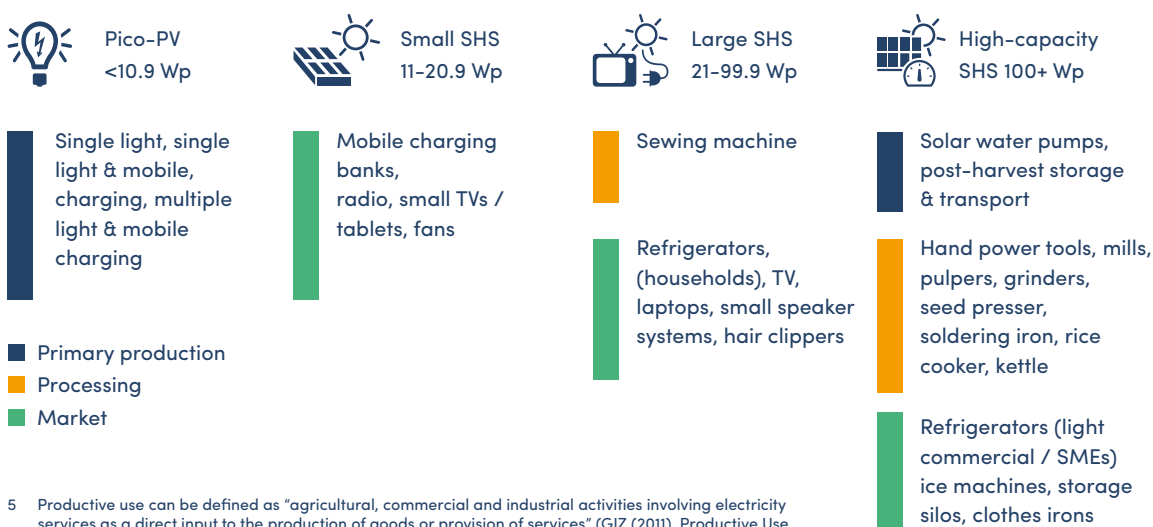
As the off-grid solar market expands, the range of products and applications is increasingly being put to productive use⁵. These range from use of small solar systems in households for mobile phone charging, to lighting, sound and television in bars and restaurants, refrigeration and cooling, to SWPs for irrigation, agri-processing, and various industries such as carpentry, tailoring, welding and looming (Figure 1)⁶. PUE provides another market for off-grid solar alongside domestic use, drives income increases through improved productivity, and supports job creation and economic diversification⁷.

Off-grid solar products can increase productivity by providing more hours of light and offering a reliable electricity connection for small businesses in all stages of the production process. The study *Powering Opportunity: The Economic Impact of Off-Grid Solar* found that 58% of households undertake more economic activity due to their purchase of a solar home system (SHS), either by unlocking additional work hours, using the system in a new or existing businesses or enabling SHS-owners to get a new job⁸. A recent study reviewing the impacts of small-scale PUE applications in emerging economies found that 38% of the evaluation sample

generated additional employment opportunities, while other users reported income or productivity increase¹⁰. Off-grid solar products have the potential to create and upgrade agricultural value chains, for example by increasing production volume or providing storage of products. Moreover, they allow for diversification of economic opportunities and increase communities' resilience to economic shocks¹¹, for example through reducing dependency on fluctuating fuel prices or by making farmers less dependent on unreliable rainfall and frequent episodes of drought¹². Of the larger off-grid solar products, household and commercial/ small to medium enterprise (SME) refrigeration, televisions and fans are highest in demand, while SWPs, agriculture cold chain refrigeration, and commercial/ SME refrigeration are ranked highest in terms of their potential short-term contribution to socioeconomic development and poverty reduction¹³.

The uptake of off-grid solar for productive use also boosts direct job creation across the off-grid solar supply chain itself both from increased sales and from the growth of a more extensive product support sector.

Figure 1: Productive use of off-grid solar appliances ranges from mobile phone charging in households to large-scale industrial applications – Vivid Economics analysis of GOGLA (2018), Global LEAP (2017) and Terrapon-Pfaff et al. (2018)⁸



5 Productive use can be defined as "agricultural, commercial and industrial activities involving electricity services as a direct input to the production of goods or provision of services" (GIZ (2011), Productive Use of Energy – PRODUCE: A Manual for Electrification Practitioners). Off-grid solar energy supports wider welfare benefits like improving health and opportunities for education, but this briefing note focuses on productivity benefits only.

6 GIZ (2011), Productive Use of Energy – PRODUCE: A Manual for Electrification Practitioners.

7 GIZ (2011), Productive Use of Energy – PRODUCE: A Manual for Electrification Practitioners.

8 Appliances for productive use and categorisation derived from: GOGLA (2018), Standardised impact metrics for the Off-Grid Solar Energy Sector; Global LEAP (2017), Off-Grid Appliance Survey Summary; and Terrapon-Pfaff et al. (2018), Productive use of energy – Pathway to development? Reviewing the outcomes and impacts of small-scale energy projects in the global south.

9 GOGLA (2018), Powering Opportunity: The Economic Impact of Off-Grid Solar. The research focuses on the impact of SHS, from multi-light and phone charging kits (3-10.99 Wp) to larger SHS (11-200 Wp). Of these 58% of households undertaking more economic activity, 36% of households generate additional income of, on average, \$35/month once they purchase an off-grid solar device.

10 Terrapon-Pfaff et al. (2018), Productive use of energy – Pathway to development? Reviewing the outcomes and impacts of small-scale energy projects in the global south.

11 GIZ (2011), Productive Use of Energy – PRODUCE: A Manual for Electrification Practitioners.

12 FAO (2018), The Benefits and Risks of Solar Powered Irrigation.

13 Global LEAP (2017), Global LEAP Off-Grid Appliance Market Survey.

A closer look at solar water pumps, productivity and livelihoods

Agriculture continues to be the world's largest employer, sustaining the livelihoods of 40% of the world's population¹⁴. Improved irrigation is an important mechanism in generating increased income, employment and rural development¹⁵. Moving from rainfed irrigation to SWPs for irrigation can lead to significantly higher agricultural productivity and increased or diversified harvest, which in turn leads to higher income for farmers. Alongside income improvements, access to SWPs makes communities more resilient to variable climate conditions by enabling production of a wider range of crop types or by allowing farmers to diversify their income sources, for example by selling excess water to their neighbors or surplus energy to the grid¹⁶. A recent study in India reports that 45% of farmers saw an increase of 50% or more in their annual incomes compared to rainfed irrigation¹⁷. This is corroborated by recent global research by FAO, where 90% of the respondents agreed or strongly agreed that changes in income were significant after the installation of SWPs for irrigation¹⁸. Moreover, study in Zimbabwe reports an increase in income of 47% for middle income groups, and substantially higher increases for lower income farmers due to the use of SWPs¹⁹.

As well as their potential to improve irrigation on rainfed farms, solar water pumps represent a clean, reliable alternative to diesel-based pumping systems²⁰, and to grid-based electricity where this is not available or is of poor quality. The life cycle costs of a solar water pump are 22–56% of the life cycle costs of diesel pumps, enabling a payback period of 2 years²¹. Replacing conventional pumps with solar water pumps reduces daily fuel costs and operation and maintenance costs. Diesel-powered pumps are typically characterized by a lower initial cost but high operation and maintenance costs, while solar water pumps are the opposite, with a higher initial cost but very low ongoing operation and maintenance costs²². On average, the life cycle costs of a solar water pump are 22–56% of that of diesel pumps,

which means a payback period of 2 years is possible. As the price of petroleum products increases and the cost of SWPs has rapidly fallen in recent years, it is likely the life cycle cost for SWPs compared to diesel pumps will decrease further. Furthermore, SWPs generally have a longer operational life than diesel-powered pumps as they require less maintenance²³.

SWPs have the potential to stimulate labor demand by promoting the use of modern agricultural techniques, which can increase the number of seasonal harvests and crop area coverage. Using SWPs for irrigation can stimulate jobs in the agricultural sector through 'within-crop' and 'across-crop' effects²⁴. The first effect is directly due to the introduction of a second harvest which raises labor demand relative to the benchmark of one harvest. The second effect is due to the expansion of crops over areas previously dedicated to less-labor intensive activities, which also tends to increase labor demand. For example, by switching from soy (one of the least labor-intensive agricultural activities), to other cereals like rice, wheat or maize, or to seasonal crops²⁵. Furthermore, as set out in Section 4, off-grid solar products like SWPs create jobs directly as well. Recently, a 3-year program in Rwanda was launched with the aim to provide energy access to 77,000 people in rural communities through mini-grids and solar-powered irrigation. Altogether, it is expected to create 7,000 jobs, especially for women and youth²⁶.

SWP significantly boost broader welfare gains. Welfare gains range from individual benefits such as reducing time needed for water collection and higher food security, to societal benefits like reduction of CO₂ emissions. Furthermore, SWPs can have significant benefits for women, since women produce two-thirds of the food in most developing countries and are predominantly responsible for fetching water for food production²⁷.

14 United Nations (2015), Food security and nutrition and sustainable agriculture, Sustainable Development Knowledge Platform.

15 While supporting SWPs for irrigation at scale, adequate efforts for water conservation measures would be essential to reach sustainable rural development, particularly in areas with constrained ground water resources. Apart from economic incentives, some technical knowledge or service infrastructure to ensure systems are run and maintained effectively is crucial to avoid unsustainable water use, as low energy costs can lead to wasteful water use, over-abstraction of groundwater, and low field application. Furthermore, SWPs are a high risk investment, especially if the roll-out programs do not adequately address onsite ownership, making them inaccessible for smallholders (FAO (2018), The benefits and risks of solar powered irrigation). Recognizing these risks and addressing those from the beginning will be crucial to ensure the sustainable use of SWPs.

16 FAO (2018), The Benefits and Risks of Solar Powered Irrigation.

17 SSAEL (2018), Evaluation and Impact Assessment of the Solar Irrigation Pumps Program in Andhra Pradesh and Chhattisgarh.

18 FAO (2018), The Benefits and Risks of Solar Powered Irrigation.

19 IRENA (2016), Solar pumping for irrigation: Improving livelihoods and sustainability; Burney et al. (2009), Solar-powered drip irrigation enhances food security in the Sudano-Sahel. The UK Aid funded Low Energy Inclusive Appliances program (LEIA) and Acumen will publish an SWP impacts report early 2019, which will include more insightful data on income and yield increases through the use of SWPs, change on spending on irrigation, and the occurrence of loan-out of SWPs to friends/neighbors for money.

20 FAO (2018), The Benefits and Risks of Solar Powered Irrigation. Beyond increasing productivity, welfare gains include CO₂ reduction, reducing time needed to fetch water (mostly by women) and reducing farmers' vulnerability to changing rainfall patterns and fuel price fluctuations.

21 Open Capital Advisors & Shell Foundation (2017), Promoting Productive Uses of Energy in Uganda. Payback period depends on: (i) initial capital costs (type and size of system, cost of shipping and installation); (ii) recurring costs (costs relating to operation and maintenance, labor and fuel); (iii) ensuing economic benefits (fuel savings, yield increases); and (iv) current energy expenditure.

22 Solar Electric Light Fund (2018), A cost and reliability comparison between solar and diesel powered pumps; Open Capital Advisors & Shell Foundation (2017), Promoting Productive Uses of Energy in Uganda.

23 IRENA (2016), Solar pumping for irrigation: Improving livelihoods and sustainability; Solar Electric Light Fund (2018), A cost and reliability comparison between solar and diesel powered pumps.

24 FAO (2018), The Benefits and Risks of Solar Powered Irrigation.

25 Bustos et al. (2015), Agricultural Productivity and Structural Transformation. Evidence from Brazil.

26 IRENA (2017), Renewable Energy and Jobs – Annual Review 2017, International Renewable Energy Agency.

27 IRENA (2016), Solar pumping for irrigation: Improving livelihoods and sustainability.

A Solar Water Pump Customer – Vincent Onyango, Kenya

Vincent started Kolik tree nursery in 2014 together with his brother. To irrigate the farm, they tried everything; buckets from the nearby swamp, a treadle pump, a petrol pump but each came with unpredictable costs of temporary laborers and fuel. In August 2016, to overcome these volatile costs, Vincent purchased a Futurepump solar pump using financing.

Since then, the brothers have expanded their nursery and also started growing kale and local vegetables. They keep 5% of the vegetables for themselves and sell the other 95% on the local market. With their extra income they have been able to become farmers on a full-time basis and have brought on a permanent employee.

To expand their income even further, they also lend and rent the solar pump – either for farming (at \$4 a day) or construction (at \$10 a day), which has enabled Vincent to pay off the loan on the solar pump in less than a year. With these additional funds Vincent has improved life for his family, while at the same time, the pump is bringing benefits to friends and neighbors.



Case Study: Futurepump; Photo Credit: Martin Wright, Ashden

The future role of SWPs across emerging regions

The potential size and impact of the solar irrigation market depends on a number of characteristics. For example, the share of agriculture in employment and GDP, weather conditions, existing modern irrigation, and the extent to which farms are in areas not well served by a reliable national grid.

Agriculture remains of significant importance across emerging regions in terms of GDP and employment. In Sub-Saharan Africa, more than 95% of farmed land relies on seasonal rains to meet irrigation needs. West Africa's access to modern irrigation is especially low, at only 1%. As a result, almost 700 million ha of agricultural land is not equipped with modern irrigation. Currently, 62% of the farms are smaller than 1 hectare (ha) and make up close to 19% of total farmland²⁸. Enabling more smallholders to access solar irrigation would be transformative for agriculture and economic opportunities across the continent. Of the customers currently benefitting from an off-grid solar device, about a third report agriculture as their main source of income²⁹.

While supporting solar water pumps for irrigation at scale, adequate efforts for water conservation measures would be essential to reach sustainable rural development, particularly in areas with constrained ground water resources. Apart from economic incentives, some technical knowledge or service infrastructure to ensure systems are run and maintained effectively is crucial to avoid unsustainable water use, as low energy costs can lead to wasteful water use, over-abstraction of groundwater, and low field application.

The technical potential for SWPs on smallholder farms (<1 ha) is at least 130 million across West, Central and East Africa, and 33 million in South Asia³⁰. As the world's population rises and supplies of freshwater decrease in the context of climate change, the demand for irrigation due to the need for higher food production increases rapidly³¹. The potential for SWPs to meet this need is determined by the proportion of currently non-irrigated agricultural land farmed by small-holder farmers (<1 ha land). The actual potential for SWPs will be higher as this takes only the market potential for new pumps into account, whereas SWPs can also replace existing diesel or grid-connected pumps.

In South-Asia, the current potential for SWPs is 33 million units. In South Asia, there has been a fast development of irrigation infrastructure in recent years, resulting in 33% of agricultural land using modern irrigation³². However, this has contributed to the agricultural sector consuming 23% of India's power from the over 20 million grid-powered irrigation pumps³³ and driven up emissions, as nearly nine million water pumps in the country are powered by diesel generators. To address the overconsumption of grid-based energy for irrigation and polluting diesel pumps, as well as to create more opportunities for the 67% of farmers without modern irrigation, India's Ministry of New and Renewable Energy has issued supportive policies for SWPs. It aims to grow the use of SWPs by a minimum of 100,000 per year, to reach a total of 1,000,000 pumps by 2020-21³⁴ and has recently announced the introduction of the KUSUM scheme, which aims to install a further 2.75 million SWPs through the use of capital subsidies³⁵. Alongside environmental and agricultural benefits, this will help to create thousands of jobs in the SWP supply chain.

28 FAO (2016), The Number, Size, and Distribution of Farms, Smallholder Farms, and Family Farms Worldwide.

29 GOGLA (2018), Powering Opportunity: The Economic Impact of Off-Grid Solar.

30 The technical potential for SWPs is determined by the proportion of currently non-irrigated (rainfed) agricultural land and the irrigable area a SWP can cover, which is typically only a small garden area of 0.3 to 1 ha (FAO (2014), Irrigation Techniques for Small-scale Farmers). This is only the market potential for pumps to connect farmers who are not currently using modern irrigation, i.e. supplying SWPs where currently only rainfed irrigation is used. In general, grid-based irrigation is much cheaper than SWPs or diesel-powered irrigation, which is why farmers that have a reliable grid connection are assumed to not be potential customers for SWPs. Calculations are based on country-level World Bank development indicators. The analysis further assumes that all currently non-irrigated agricultural land of <1 ha can be irrigated by SWPs, and that all small-holder farmers will have only 1 SWP per farm.

31 FAO (2018), The Benefits and Risks of Solar Powered Irrigation.

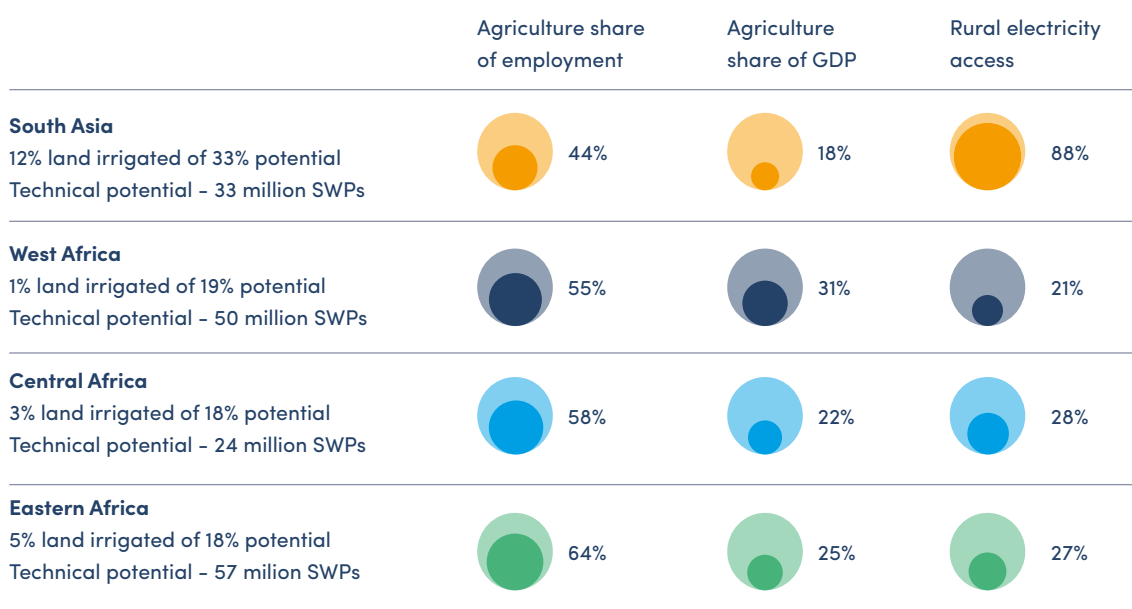
32 Vivid Economics calculations based on country-level World Bank development indicators.

33 Energy Efficiency Services Limited, a Joint Venture of public sector undertakings under the Indian Ministry of Power.

34 SHAKTI (2018), Impact assessment of the National Solar Pumps Programme.

35 CEEW (2018), Solar for Irrigation: A Comparative Assessment of Deployment Strategies.

Figure 2: Agriculture remains of significant importance across emerging regions, with a substantial contribution to national GDP and a large proportion of the population employed in agriculture - Source: Vivid Economics³⁶



NOTE Agricultural share of employment, agricultural share of GDP and rural electricity access percentages are averaged across regions based on World Bank country-level data.

The employment opportunities resulting from the use of modern irrigation services are huge and remain largely untapped or informal. In emerging economies, only a fraction of agricultural land is irrigated, while the agricultural sector remains the main sector of employment across sub-Saharan Africa (Figure 2). Similarly, across the three African regions in this study, grid connectivity is low, and off-grid solutions for small scale agriculture could play an important role in improving employment and livelihoods for off-grid communities.

In South Asia, grid connectivity is much higher, but nonetheless off-grid solar appliances for PUE have become widely used, and there is a large potential to expand this market. PUE appliances and SWPs present a huge and emerging opportunity for employment and the off-grid sector. An opportunity that, if supported, will also boost employment opportunities and welfare for millions of the world's poorest people.

³⁶ Based on World Bank World Development Indicators. Values are averaged across regions from available country-level data. For Central Africa there was no data available for irrigated land (as a percentage of agricultural land), so an average of the percentages of West and Eastern Africa was used.



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