Experiences from Deploying Solar PV Energy Businesses in Rural Malawi

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ABSTRACT

This paper draws out translational learning for off-grid energy access initiatives from a case study in Malawi. Deploying solar PV 'Charging Stations' in four rural communities, the Sustainable Off-Grid Electrification of Rural Villages (SOGERV) project set out to establish sustainable, community focussed, energy businesses. The market assessment that comprised a major stage of the project initiation is presented here. The financial performance of the SOGERV businesses is then summarised for comparison. It is found that market assessment recommendations for smaller, more affordable portable products were largely accurate. The established businesses tested this market with a range of products and analysis shows that sales are largely in line with market assessment product predictions. However, a larger market than predicted appears to exist and that there is more appetite for the larger 'household-scale' portable products than anticipated. Productive Use of Energy (PUE) customers were harder to establish and were limited to a small number of barber shop, cold-drink sales, video show and shop lighting customers. Stand-alone PV systems were not affordable for the majority and most PUE customers co-located with the charging infrastructure, suggesting a need to facilitate enhanced co-location opportunities or for electricity distribution infrastructure. The findings of the paper demonstrate the opportunity for community focussed energy businesses to support economic development (SDG6) and access to modern sustainable energy (SDG7), and are relevant for energy practitioners, decision makers and planners supporting SDG implementation in developing countries.

Keywords: Off-Grid, Solar PV, SDG7, Productive Use of Energy, Market Assessment

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1 Introduction and Background

Despite significant progress being made in the last decade, only around 35% of the 910 million people in Sub-Sahara African (SSA) has access to electricity (IEA, 2017). The national grid in Malawi serves 10% of the population with only 4.7% of the rural population being connected despite accounting for 83% of the population (GoM, 2018) (World Bank, 2016).

The current Malawi National Energy Policy (GoM, 2018), targets increased renewable energy deployment by 2030, including deployment of 50 'green' mini-grids (GoM, 2017). However, the sector is still young and learning on sustainable models for off-grid electrification in the Malawian context are yet to be well established. Rural energy projects in Malawi typically include aspects of community ownership and operation, and target a public facility such as a primary school or health centre (Dauenhauer & Frame, 2016a) (Dauenhauer & Frame, 2016b). Despite providing high short-term social impact, many of these projects have fallen short of sustainability expectations, typical of the historical experience with off-grid renewable energy projects in sub-Saharan Africa (Martinot, et al., 2002) (Chaurey & Kandpal, 2010). However, decentralised and renewable solutions are deemed essential to achieving 2030 'energy for all' targets (IEA, 2017). Supported by the dramatic decrease in technology costs in recent years, new options such as Solar PV energy kiosks and micro-grids are proving feasible for meeting lower tier electricity needs (ESMAP, 2014) (Roche & Blanchard, 2018). In addition, innovative 'social' business models that combine community based approaches with entrepreneurship are demonstrating improved sustainability (Chaurey, et al., 2012) (Munro, et al., 2015) (Katre, et al., 2018).

The Sustainable Off-Grid Electrification of Rural Villages (SOGERV) Project ran from 2015 – 2018. The project design was strongly influenced by an evaluation of PV project sustainability that took place in Malawi in two phases between 2015 and 2017 (Dauenhauer & Frame, 2016a) (Buckland, et al., 2017). Although all the classic sustainability factors (Ilskog & Kjellstrom, 2008) were considered, economic sustainability was a key target and is the focus of the remainder of this paper. Specifically, two contributions by the University of Strathclyde (as an academic partner in the project) are described: firstly, a market assessment undertaken during project initiation (Section 3), and secondly, collation and analysis of financial records from the businesses over the first 12-18 months of operation (Section 4). Key lessons for off-grid system deployment in Malawi and SSA are drawn out and discussed in Sections 5 & 6.

2 Methodology

The SOGERV market assessment aimed to estimate the demand for a range of renewables-based energy products in four rural locations in southern Malawi. The study implemented a custom survey at each location totalling 314 households and 46 businesses. Populations were estimated in each location through a minimum spanning tree solution and GIS data (Figure 1). The resulting maps allowed for the determination of number of households and their density in the surrounding region. Household sizes were determined at each location from the survey. With this statistic, an estimate of the village populations was calculated (Table 1).

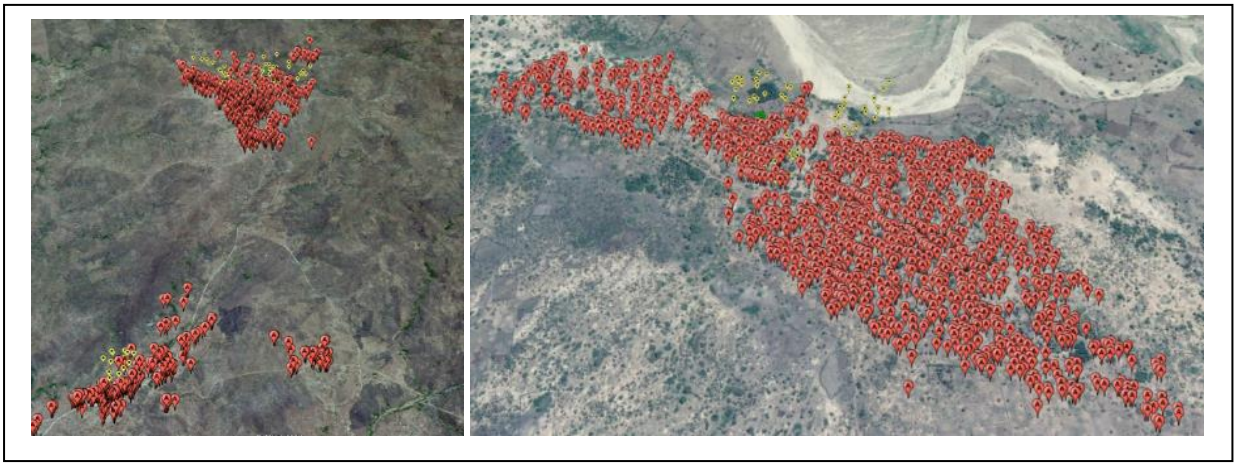

Figure 1: Kandeu and Mandrade Structures

All questionnaires were facilitated by a trained enumerator with prior experience in similar field work and piloted in a nearby village (not a SOGERV village) prior to deployment. Enumerators randomly selected households within the target village and heads of households were asked to respond on behalf the entire household. Target respondents for businesses were the owners, although employees were allowed to answer if the business owner was not available.

Table 1: Numbers of households and associated surveys for each community

Location	No. Households	Surveys completed	% of HH
Kandeu	473	52	11.0%
Mandrade	604	32	5.3%
Thendo	841	99	11.2%
Gola	1334	131	9.8%

The study makes the assumption that customer reported and itemised energy expenditures would be spent on replacement products. All financial values are reported in Malawi Kwacha (MWK) with the exchange rate to GBP at the time being 900:1.

3 Market Assessment

3.1 Incomes and Energy Expenditures of Households

The distributions for self-reported yearly incomes for households are shown for all locations in

Figure 2 and energy expenses in Figure 3 as density plots. Overall, household annual incomes and energy expenditures are extremely low, though Kandeu and Mandrade are significantly lower on average than Gola and Thendo.

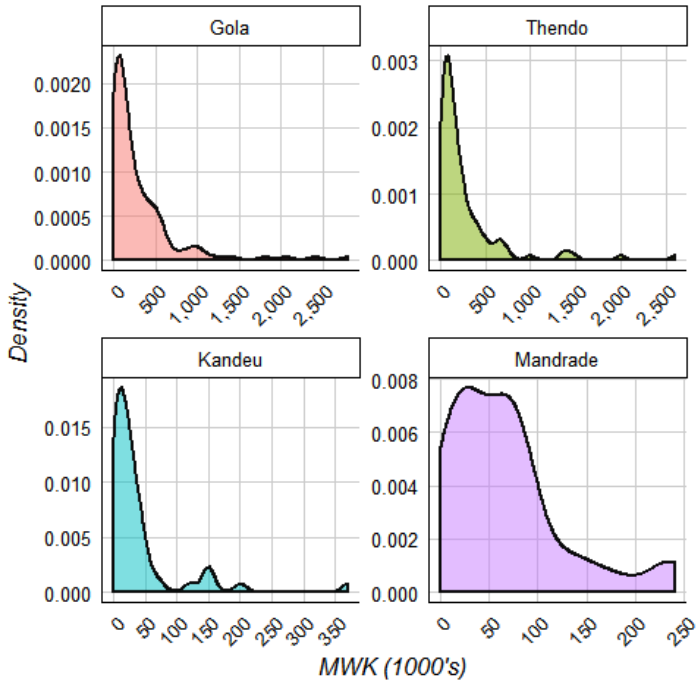

Figure 2: Yearly Income Density for Households in all Locations

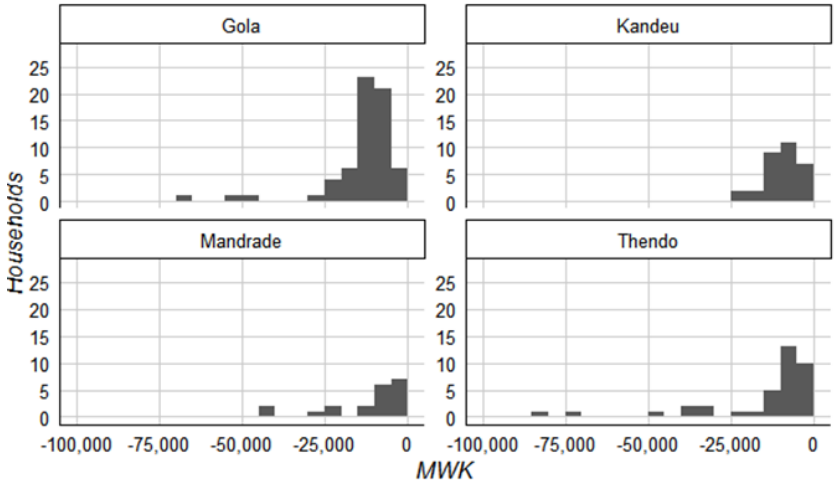

Figure 3: Annual Energy Expenses Distributions for all Locations

Households and businesses were also surveyed on their interest levels in various productive uses if they were to be established at each location. Households were asked whether they would be willing to pay for the services from each business. Businesses were asked a slightly different question: how well a business doing said activity would fare if it were established (or expanded) at the location, specifically in terms of its likelihood to be profitable. The results are shown in

Figure 4 below. The squares represent the average response from businesses; the circle is the average response from households. The highest scoring productive uses were mobile phone charging, cold drinks, battery charging, entertainment, barbershop, metal shop and shop lighting.

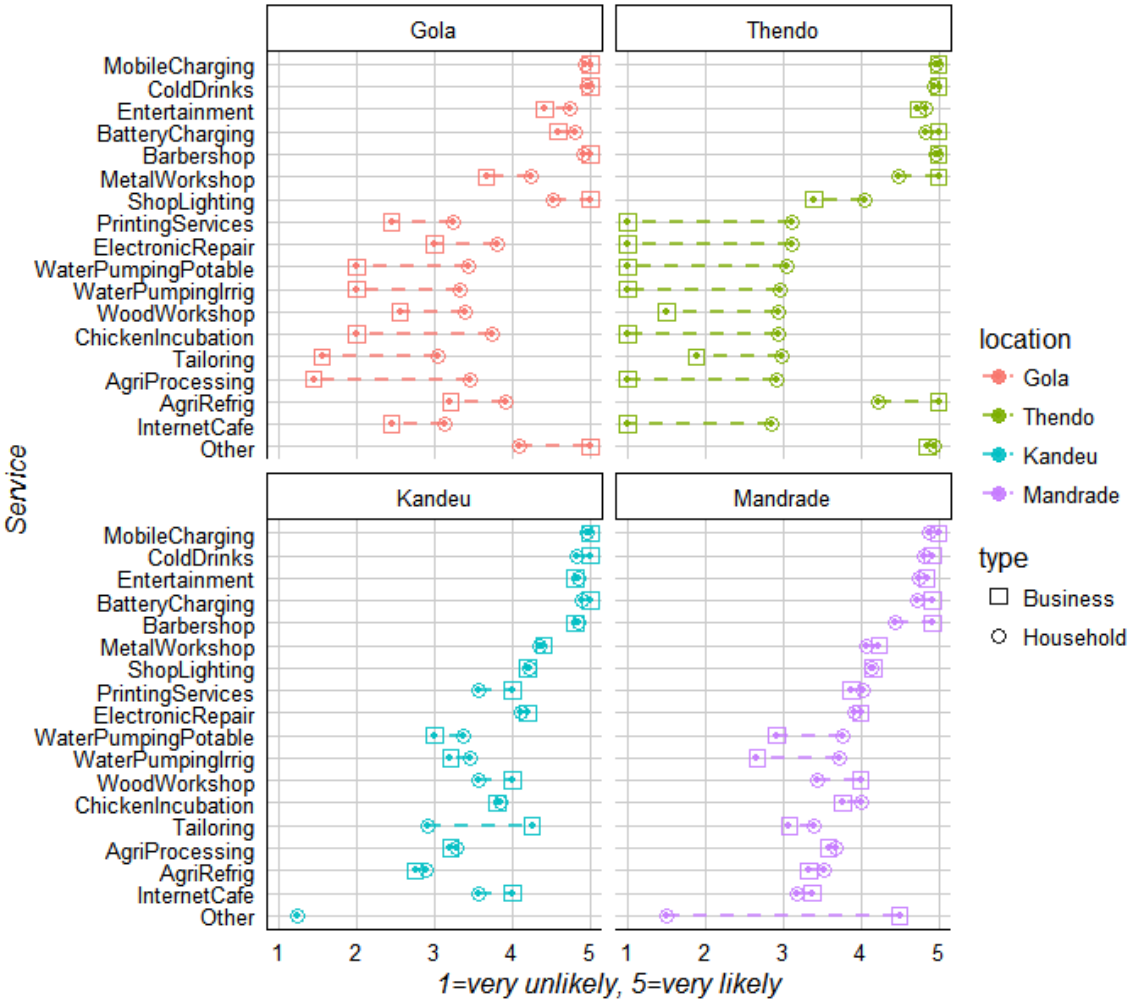

Figure 4: Interest in Energy Services for both Households and Businesses

3.2 Market Size Estimation

At all locations, it was established that the majority of consumers have very low yearly energy expenses and since the likely prices can be estimated using the products available to be deployed, the number of products and likely pricing mechanisms for this market could thus be estimated. To do this, a full population was estimated using the actual village size and the distributions of energy expenses in the village. The assumption was made that old products and fuel sources will be substituted for the new products introduced by the project, and hence, future energy expense would be equal to or greater than current expense.

The project identified four consumer products with well-established supply chains in Malawi (Table 2). Expected prices are given for each product, competitive with the local markets at the time. Although the intention was to offer 'rent to buy' arrangements, the analysis was simplified such that only the cash price and the yearly price for renting the products were considered.

Table 2: Locally Available Consumer Products and Prices

Product and Description	Cash Price, MWK	Rental Price (per year), MWK
1 - Small Solar Lantern	8,000	4,800
2 - Small Solar Lantern with Mobile Charger	21,000	13,200
3 - Portable battery kit (PBK) with 2 lights and mobile phone charger	96,000	38,400
4 - DC Solar Home System (SHS) with 4 lights, mobile phone charging, radio, and task light	134,000	78,200

In Figure 5, these thresholds are drawn in as horizontal lines and labelled. In the graph, each dot represents one (simulated) household's energy expenses over the course of one year. These are drawn from the income distributions and scaled to the number of households in the village. The cash price is shown as red with the rental price in blue. The y-axis has been limited to a maximum of MWK80,000. As is clear, the higher priced goods are not affordable at a cash price. The rental price for Product 4 appears to be the maximum any one household would be able to afford.

Given these thresholds, the number of households who would purchase or rent the products can be estimated simply by summing those that fall between the thresholds. This is done on the cash purchase only scale and a renting only scale on the table below. The assumption used is that each household will purchase one product which is immediately at or below their budget. As is expected, the use of a financing arrangement (rental) means that considerably more households gain access to the products.

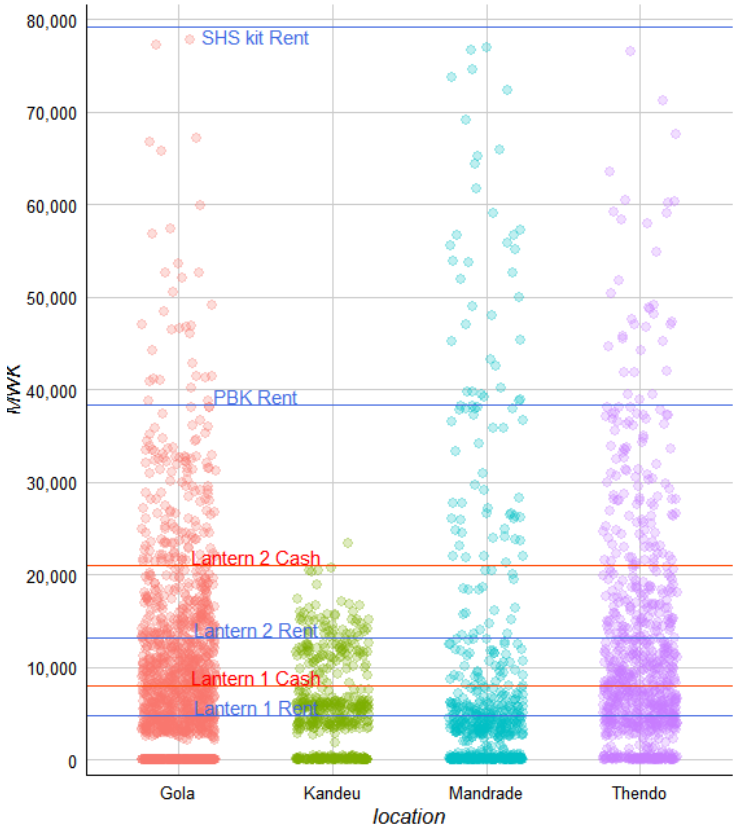

Figure 5: Yearly Energy Expenditure and Product Cost Thresholds

3.3 Market Assessment Key Findings

The market assessment made the following recommendations to the project based on the analysis conducted above.

Household market:

- Product selection should err towards smaller systems which are less costly.
- Limited cash sales will be possible and in order to provide access to more functional products, a financing arrangement will need to be offered by the installed business which allows either for a rent-to-own or fee-for-service.
- As there was a preference and familiarity for cash sales, the less expensive products may be more appropriate for a rent-to-own arrangement with repayment terms that sufficiently lower the entry point.
- Although there were a few outliers, it is unexpected that many families will be able to purchase larger portable solar products (PSP) and solar home system (SHS) products outright.
- With the low level of competition, lack of existing renewable energy products, and willingness to pay, products targeted at the right entry point should be in high demand.

Productive use of energy:

- There was a 'high' willingness to pay for businesses offering mobile phone charging, cold drinks, battery charging, entertainment, barbershop, metal shop and shop lighting.
- Existing business owners predicted that businesses offering these services would be profitable.

4 Actual Business Outcomes

In this section, the recorded sales performance of the community energy businesses is set out for comparison with the market assessment forecast.

Following the project design stage, and building on the recommendations of the market assessment, each business implemented a 'Charging Station' powered by a 4kW PV array that providing the following services: PSP sales, mobile phone charging, battery charging. The business also provides stand-alone solar PV systems and 'wired connections' for monthly fees to a small number of nearby PUE businesses.

Figure 6 provides a summary of the total revenues for each business, categorized by the main product groups. The trading periods for each business are not uniform as the businesses commenced operating at different times; however, the cut-off date for collection of the data is the same in all cases: September 2018. The total revenues and trading period for each business is shown in Table 3.

Table 3: Trading period and total revenues for each business

Business Location	Date Started Trading	Total Revenues Recorded (MWK)
Mandrade	June 2017	9,013,212
Kandeu	April 2017	2,219,288
Gola	November 2017	2,815,395
Thendo	November 2017	2,935,648

It is immediately notable that for all businesses the majority of revenues realized has been through PSP sales. However, the best performing business (Mandrade) has also recorded high revenues related to portable batteries. The following sections will present further detail on the sale revenues, focussing on PSP sales and services for PUE businesses as the two main themes.

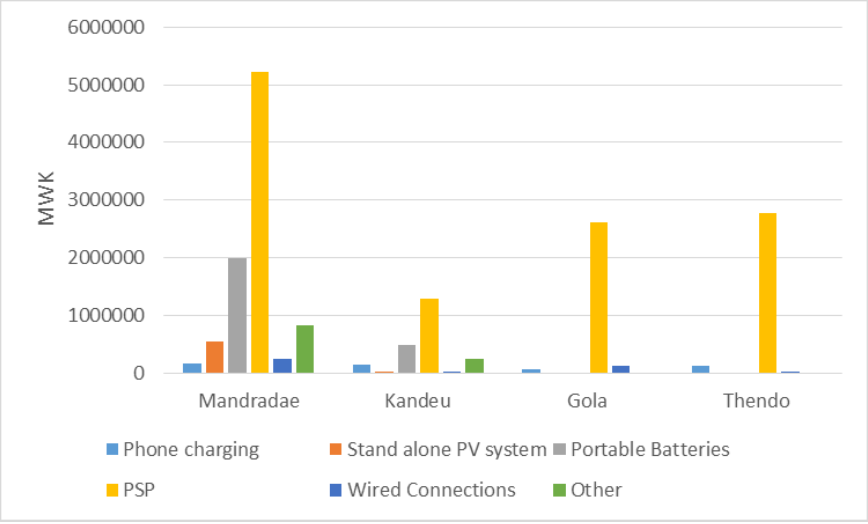

Figure 6: Total Sales Revenues per Product Type for All Businesses

4.1 PSP Business

Portable solar products are a major component of the business turnover. The products relate to the four market assessment categories as follows. Product Type 1: SM100, Velux, Sunking Pico. Product Type 2: D-Light, Sunking Boom, OV Pilot. Product Type 3: Sunking Home. Product Type 4: OV Camp.

4.1.1 Mandrade Community Energy Business

The numbers of each product sold and the associated sales revenues are shown in Figure 7 and Figure 8.

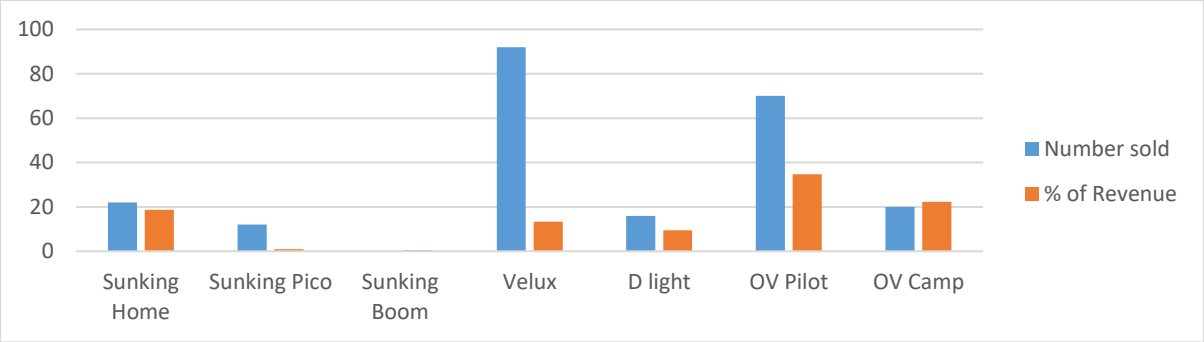

Figure 7: Business 1- PSP total sales

In terms of units sold, the smallest product dominates. However, the slightly more advanced OV pilot has also sold well and returns a greater revenue due to its higher price. Although sold in smaller quantities, the higher functionality, higher price 'home' systems (Sunking Home and OV Camp) account for a significant proportion of total sales revenue.

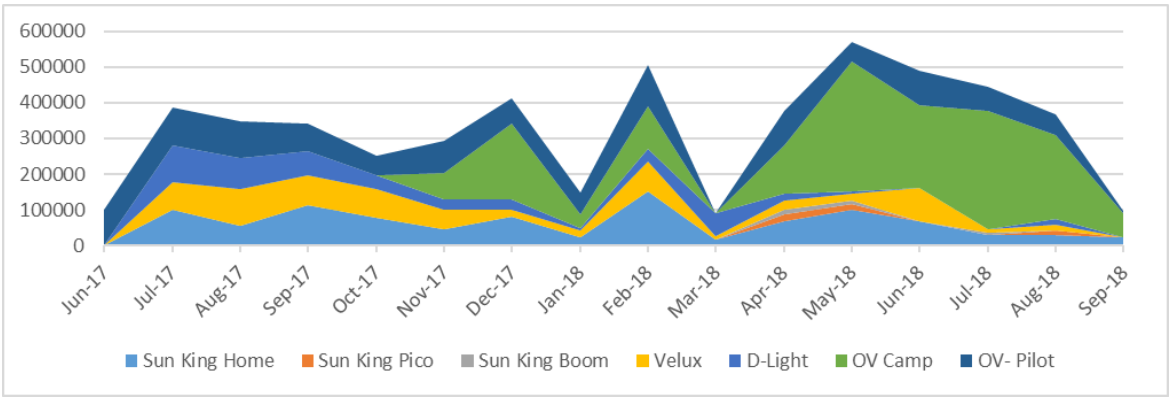

Figure 8: Business 1 - PSP sales revenues

4.1.2 Kandeu Community Energy Business

Portable solar products are a major component of the business turnover. The numbers of each product sold and the associated sales revenues are shown in Figure 9 and Figure 10.

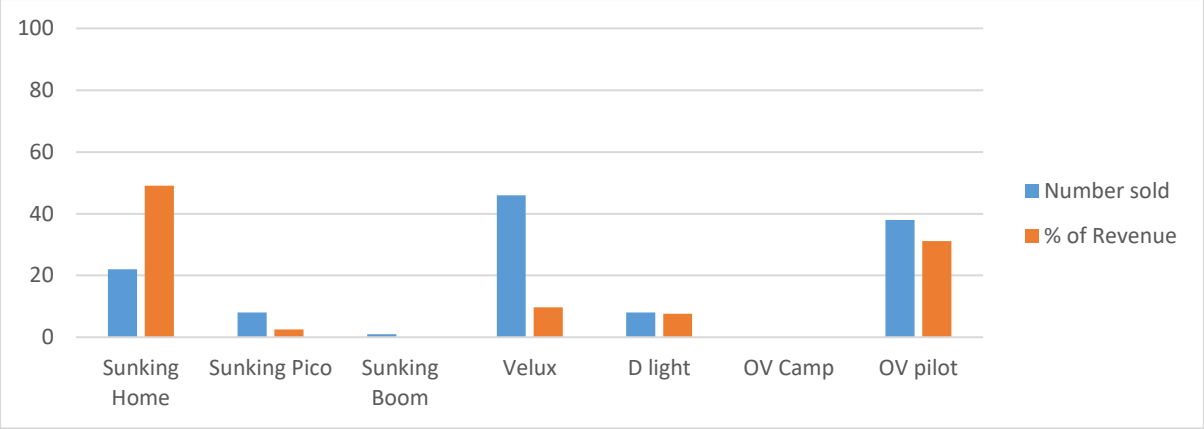

Figure 9: Business 2- PSP total sales

Again, in terms of units sold the smaller product dominates, with the OV pilot also selling well and returning a greater revenue due to its higher price. Although sold in smaller quantities, the higher functionality, higher price 'home' systems (Sunking Home) account for a significant proportion of total sales revenue.

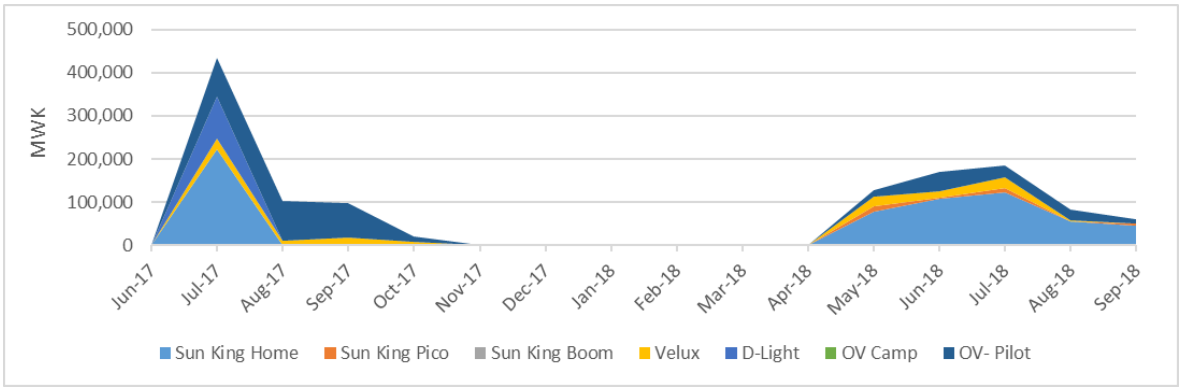

Figure 10: Business 2 - PSP sales revenues

4.1.3 Gola Community Energy Business

The numbers of each product sold and the associated sales revenues are shown in Figure 11 and Figure 12.

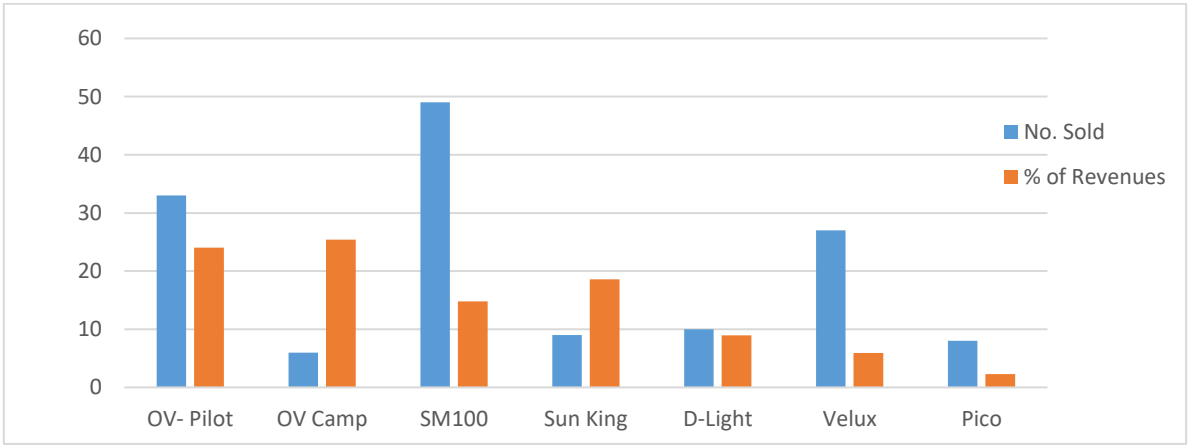

Figure 11: Business 3 - PSP total sales

The SM100 and the Velux dominate here in terms of units sold, due to being smaller and cheaper products. The OV pilot again sells well with its higher price returning a greater revenue. The higher price home systems (OV Camp and Sunking Home) offering higher functionality account for a significant proportion of total sales revenue despite being sold in smaller quantities.

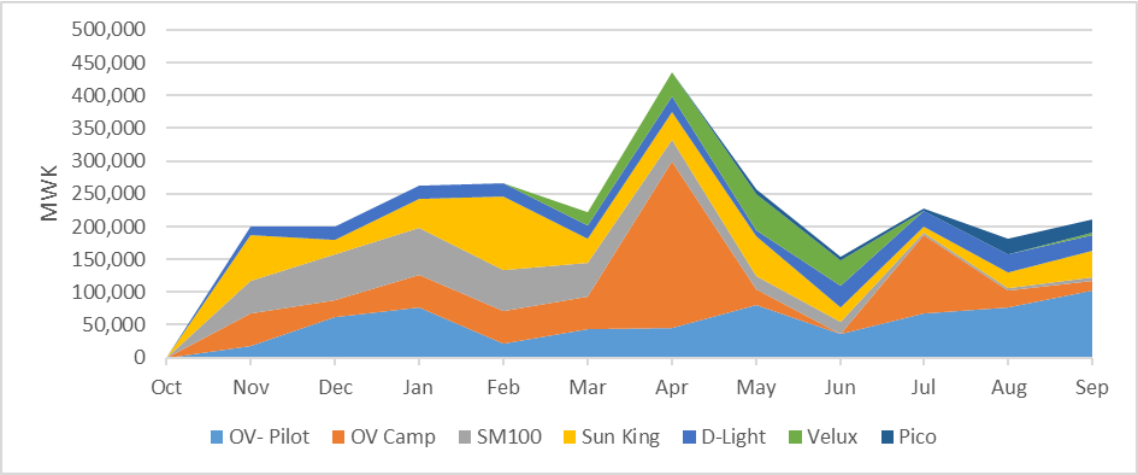

Figure 12: Business 3 - PSP sales revenues

4.1.4 Thendo Community Energy Business

The numbers of each product sold and the associated % of sales revenues are shown in Figure 13 and Figure 14.

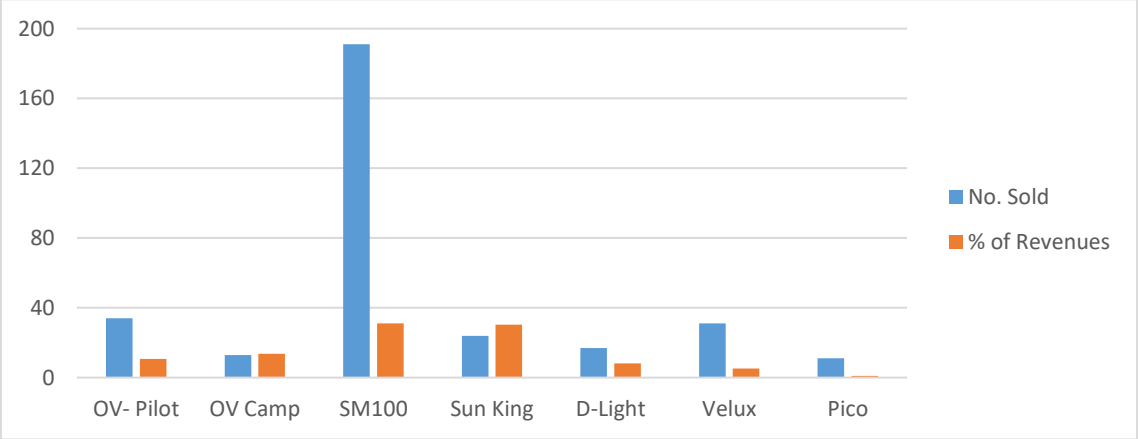

Figure 13: Business 4 - PSP total sales

As with the other businesses, the low cost smaller products dominate, in this case the SM100, with higher price home systems (OV Camp and Sunking Home) accounting for a significant proportion of total sales revenue.

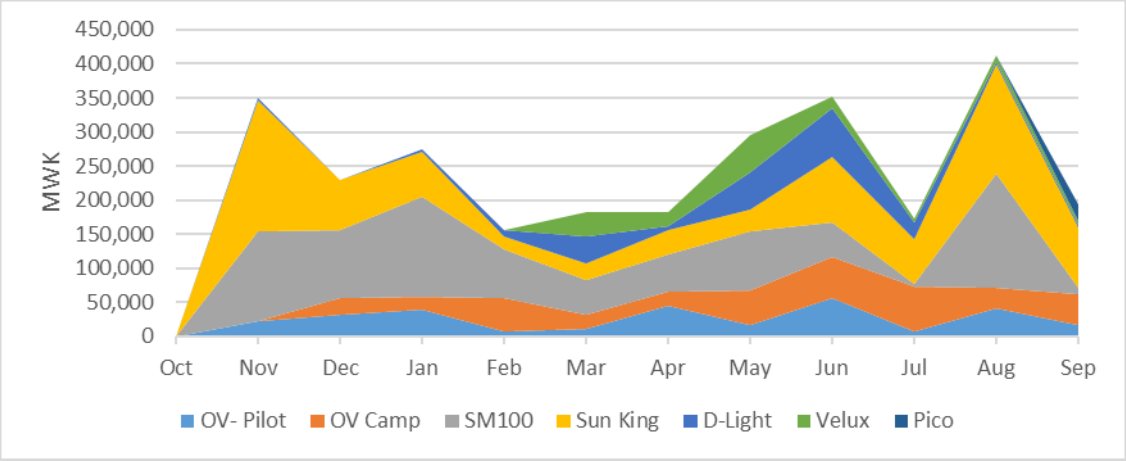

Figure 14: Business 4 - PSP sales revenues

4.2 PUE Businesses

Mandrade initially offered the rental of 'large' or 'small' stand-alone solar PV systems to local businesses priced at MWK15,000 and MWK20,000 respectively. Three businesses signed up for systems but one failed to maintain payments, others complained that pricing was too high. By Sept 2018 two 'small' systems were remaining, each paying MWK13,000, one hardware shop and one barber/cold drinks shop. After establishing the businesses in the village, entrepreneurs started to co-locate with the Charging Station and request a wired connection. This was offered and three PUE businesses connected paying a flat rate fee of MWK10,000 per month: a barbershop, a video show and a cold drinks kiosk.

Kandeu also offered the rental of 'large' or 'small' stand-alone solar PV systems to local businesses priced at MWK15,000 and MWK 20,000 each. Two businesses signed up for systems but both failed to maintain payments, complaining that pricing was too high. By Sept 2018, both systems had been removed. Wired connections proved more attractive and two PUE businesses connected, paying a flat rate fee of MWK10,000 per month: a barber shop and a video show.

Based on experiences in Kandeu and Mandrade, neither Gola nor Thendo opted for stand-alone solar PV system options, finding wired connections more attractive. In Gola, four PUE businesses connected, paying a flat rate fee of MWK10,000 per month: a barber shop, a grocery, a cold drinks kiosk and a video show. In Thendo two PUE businesses connected, paying a flat rate fee of MWK10,000 per month – a barber shop, and a cold drinks kiosk.

5 Comparing MA Predictions with Actual Sales Figures

5.1 PSP Sales

The market assessment predicted that smaller products would be most attractive. This has been proven to be correct, evidenced by the dominance of portable solar products in the actual sales data. The figures are compared in Table 4 below. The most notable points are firstly the lower costs achieved for product cash price (reflecting the dynamically moving sector), and secondly that a 'rent to buy' option was implemented with approximately 10% price premium. It is noted that the business operators report almost 90% of sales are 'rent to buy'. There is an exception with the largest product as operators reported that customers were often unable to afford the three-month repayment and usually instalments were paid over 6 months totalling the cash price with no premium.

Table 4: Comparison of market assessment predictions and implemented sales for PSP

	Market Assessment		Implemented	
Product and Description	**Cash Price, MWK**	**Rental Price (per year), MWK**	**Cash Price, MWK**	**Monthly installments (3 of) MWK**
1 - Small Solar Lantern	8,000	4,800	5,000 -6,500	1,840-2,400
2 - Small Solar Lantern with Mobile Charger	21,000	13,200	19,000 – 25,000	7,200 – 9,200
3 - Portable Solar Product with panel, battery, 2 lights and mobile phone charger	96,000	38,400	58,000	21,000
4 - DC Solar Home System (SHS) with 4 lights, mobile phone charging, radio, and task light	134,000	78,200	140,000	46,700

The market assessment effectively predicted the maximum number of cash sales or rentals for each product type in each location. These are compared with actual sales in Table 5 (market assessment figures are shown as (cash/rent). Actual sales are recognised to be mostly 'rent to buy' monthly instalment sales, so the comparison is not exactly like for like. It could be argued that the actual sales figures should therefore be somewhere between the two, approaching the rental prediction.

It appears that for the smallest product type, the market in Mandrade was well estimated and is approaching saturation (this matches well with verbal reports from the operator that he has been travelling outside the village to maintain sales). The Gola Product 1 market appears significantly overestimated. Sales have been prolific in Thendo and are also approaching the top end of the predicted market. For Product 2, Kandeu and Mandrade appear well estimated and approaching saturation, while Gola and Thendo seem underestimated. The market for Product 3 has been underestimated in Kandeu. Mandrade and Thendo are achieving reasonable sales in line with predictions, but Gola is under performing. The market for Product 4 has been largely underestimated with Mandrade and Thendo performing well above expectation and Gola also achieving sales near the maximum predicted.

Table 5 Comparison of market assessment predictions and implemented rental income for PSP

	Kandeu		Mandrade		Gola		Thendo	
Product Type	MA	Actual	MA	Actual	MA	Actual	MA	Actual
1 - Small Solar Lantern	142/206	55	66/126	104	440/ 458	84	270/ 327	233
2 - Small Solar Lantern with Mobile Charger/radio	5/62	46	63/103	86	170/3 25	43	134/ 208	51
3 – Medium Portable Solar Kit	0	22	0/54	22	6/36	9	0/41	24
4 – Large Portable Solar Kit	0	0	0/9	20	0/10	6	0/4	13

It is noteworthy that the numbers of units reported as sold do not align fully with the sales revenues reported. Namely, although Mandrade has reported approximately twice the PSP income of Thendo,

the sales numbers are: 104/233, 86/51, 22/24, 20/13 for the respective products 1 through 4. These sales figures would imply similar total revenues; however, the data does not allow this to be fully explored. A possible explanation is that Mandrade has achieved more cash sales and/or recovered instalment payments more successfully, banking more income from units 'sold'.

5.2 Productive Uses of Energy

The market assessment highlighted a 'top eight' of PUE prospects, which are discussed in turn below:

5.2.1 Mobile phone charging

The business is selling products that enable phone charging to be undertaken by households and other businesses; however, the extent of this activity is not being tracked formally by the project. Each charging station has averaged about 200 'charges' per month. However, the low fee for a charge (MWK 70) means that mobile phone charging has provided a minimal income stream to the Charging Stations. The continued presence of customers for the charging station does imply that there is still a significant market for other entrepreneurs to target (with a larger PSP product for example).

5.2.2 Entertainment, cold drinks and barbershops

These three PUE businesses make up the bulk of the entrepreneurs paying for services: four cold drink shops and five barbershops. Only one of those uses a stand-alone PV system. Three video show customers have been established by the Charging Stations.

5.2.3 Charging batteries

This service has been exclusive to the Mandrade and Kandeu Charging Stations. This is reported to be primarily due to delay in supply of appropriate battery kits and charger units. The sales at Mandrade are dominated by battery rental and sales rather than charging. The business operator identified that there was demand for the flexibility of a simple battery instead of PSP and sourced these for retail. There appears to be a potentially significant market for this service.

5.2.4 Metal workshops

No metal workshops were established as neither the Charging Station or stand-alone PV systems are able to meet the massive power requirements.

5.2.5 Providing shop lighting

Only one shop has maintained the rental of PV system for shop lighting. There is a perception from the business operators that many small entrepreneurs are using portable PSP for their basic shop lighting which is deemed a more economical solution.

5.2.6 Agricultural refrigeration

No agricultural refrigeration has been established. Determining the reasons for this are outside the scope of this work; however, it can be speculated that this would require input from an agricultural development initiative to establish a new farming mind-set and route to market.

6 Conclusions

The market assessment described in this paper provided a clear direction towards smaller, more affordable products that are portable and provide simple lighting, phone charging and perhaps radio services. The established businesses have tested this market with a range of products and have found that sales are largely in line with market assessment product predictions. However, a larger market than predicted appears to exist and there is more appetite for the larger 'household-scale' portable products than previously thought. In addition, the market assessment indicated an opportunity for PUE services in the community. There has been a small uptake on the offered energy provisions from local

entrepreneurs with cold drink sales, barbershops, video shows and shop lighting. The maximum monthly fee the entrepreneurs will sustain is MWK13,000 and only two entrepreneurs have sustained payment for a stand-alone PV system, while the others sought 'ad-hoc' wired connections. Battery charging at the Charging Stations has been popular where the service is available, suggesting that further households are meeting basic electricity service needs via this method instead of purchasing PSP.

With the large majority of revenues being obtained through PSP sales and battery sales and rental, the value or need for the 4kW Charging Station is questionable. The income streams that require on-site power production could be estimated at best as MWK40,000 per month from four wired connections and MWK4,000 per month for battery charging. To fully utilise the potential of the on-site generation it appears that further effort to initiate a range of co-located PUE is required, or alternatively, inclusion of some localised distribution networks to connect the charging stations with nearby household and business lighting and basic energy service demand, suggesting a solar micro-grid approach would be the logical next step.

The findings of the paper demonstrate the opportunity for community focussed energy businesses to support economic development (SDG6) and access to modern sustainable energy (SDG7), and are relevant for energy practitioners, decision makers and planners supporting SDG implementation in developing countries. The value of in-depth market assessment has been shown, with the recommendations of particular import to practitioners looking to conduct similar projects within Malawi and similar contexts in SSA. In such locations, a light touch market assessment could be sufficient to confirm an appropriate product offering and pricing models, allowing more efficient and rapid implementation. Additionally, the results presented here provide a foundation for organisations developing strategies for scale up of their SDG7 response. For example, planning widespread deployment of a 'fleet' of community energy businesses in SSA. More generally, many developing countries with large, rural, subsistence farming populations will face similar energy access challenges and such communities could be expected to have analogous household demand for lighting, communications and entertainment, plus demand for local business PUE. A similar market assessment and business design approach would allow an appropriate selection of products and solutions for the chosen locations. Finally, the importance of economic sustainability of off-grid solar PV businesses has been highlighted as a key priority for achieving SDG7.

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