Productive Use of Solar PV in Rural Malawi: Feasibility Studies

University of Strathclyde and Community Energy Malawi

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Executive Summary

Productive Uses of Energy are agricultural, commercial and industrial activities involving energy services as a direct input to the production of goods or provision of services. Productive uses include home businesses, non-monetary income, excludes social infrastructure and cuts across different sectors, energy sources, and types of enterprises.

This study focusses on the economic feasibility of a range of businesses in Malawi powered by solar PV. The overall objective is to identify a set of businesses that have the potential to be progressed to pilot projects.

Surveys were carried out on existing electricity using businesses in Dedza, Malawi to determine CAPEX, OPEX and monthly income figures for agricultural, sales and services, and repair and manufacture businesses. Solar PV systems were designed to supply the business loads and then priced using component costs obtained from suppliers. 10 year cash flow forecasts were conducted for 3 business scenarios (strong, stable and weak). Using the modelled profit and loss, the viability of the different businesses powered by solar PV was evaluated.

As shown in the table below, the study has found that irrigation and small sales and services (specifically barber shop and phone charging) businesses powered by standalone PV systems look likely to succeed, with most paying back initial investment under 3 years over all scenarios. Maize milling and tailoring businesses give paybacks of 5 and 8 years for strong and stable scenarios respectively, indicating grant funding would be required to contribute to CAPEX to be affordable for most entrepreneurs in Malawi. A metal workshop business doesn't recover initial investment within 10 years for any of the scenarios modelled.

The results indicate solar PV has potential to reduce poverty through income generation in Malawi. Recommendations have been given for implementing pilot projects based on the feasibility studies, along with suggestions for future research to inform wider scale dissemination of Solar PV productive use initiatives.

Summary of Economic Feasibility Evaluation

	Scenario 1		Scenario 2		Scenario 3		Viability
Businesses	**Payback (years)**	**10 year profit (MWK)**	**Payback (years)**	**10 year profit (MWK)**	**Payback (years)**	**10 year profit (MWK)**	
Irrigation	2	6,201,000	3	5,591,000	5	12,981,000	HIGH
Barbershop and Phone Charging	2	2,002,500	2	1,342,500	>10	0	HIGH
Maize mill	5	5,000,000	8	1,548,000	>10	0	MEDIUM
Tailoring	5	602,750	8	122,750	>10	0	MEDIUM
Metal workshops	>10	0	>10	0	>10	0	LOW

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1. Introduction

1.1. Energy Access in Malawi

Malawi has one of the most rapidly growing populations in Africa, which has increased from 4 million in 1966 to 17 million today and is expected to reach 26 million by 2030 (NSO 2012). About 85% of Malawians live in rural areas, deriving their livelihoods from natural resources and agriculture. The remaining 15% of the population resides in urban areas and is mainly concentrated in the four cities of Blantyre, Lilongwe, Mzuzu and Zomba (NSO, 2008). Malawi has a high population of young people with about 48% of the population below 15 years of age.

Malawi is one of the least developed countries in the world with a purchasing-power-party (PPP) based Gross Domestic Product (GDP) per capita of about USD 780 in 2013. Agriculture is the mainstay of Malawi's economy and supports 84.7% of the rural population. It contributes 90% of export earnings and 46% of wage employment and it employees over 80% of the labour force. Agriculture accounts for 27% of the GDP. Other sectors such as Industry and Services account for 18% and 54.2% of the GDP respectively (NEP, 2016).

Malawi has one of the lowest electricity access rates in the Southern African Development Community (SADC) with an average consumption rate of 111 kWh per capita per annum. Access to modern energy services is approximately 8% and comprised of mostly urban households (Zalangera, 2014), while only 1% of the rural population have access to electricity. Electricity in Malawi is faced with various challenges such as inadequate generation capacity and outdated transmission and distribution lines resulting in frequent black-outs and load shedding.

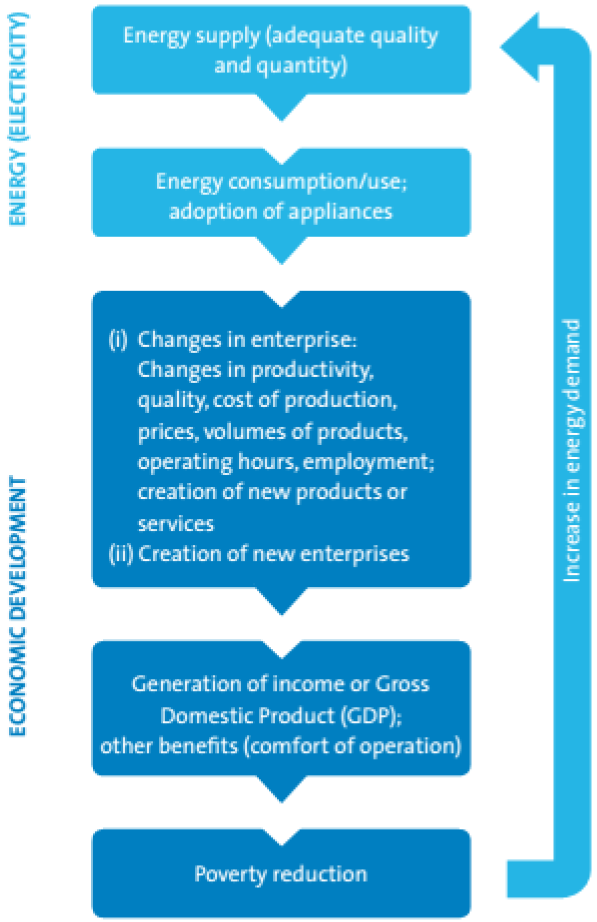
Access to modern energy is widely considered an important ingredient in the strategy towards alleviating poverty and achieving sustainable development goals, specifically Sustainable Development Goal 7. It is recognised that electrification removes bottlenecks for enterprise development and enables new potentials for income generation.

1.2. Productive Uses of Energy as an Economic and Developmental Driver

Productive Uses of Energy (PUE) are defined as agricultural, commercial and industrial activities involving energy services as a direct input to the production of goods or provision of services (GIZ, 2016). PUE can be a significant driver of economic growth and social progress in developing countries like Malawi, as they can underpin the creation and upgrading of value chain and facilitate diversification of economic structures. They can also reduce livelihood vulnerability to multiple stresses and external shocks and enhance the commercial viability and financial sustainability of infrastructure investments. PUE can convert into additional sources of income for end-users, increase their ability to pay bills and recoup investment in grid connection/standalone systems as well as increase economic viability of mini-grids through higher load factors (particularly during daytime) and hence offer a baseload and higher revenues for operators. This increases the technical durability of energy infrastructure through an improved operator ability to cover O&M costs and ultimately enhance impact of (rural) electrification.

Error! Reference source not found. below show how electricity provision can stimulate economic development through increased productivity and an increase in enterprises, which in turn increases electricity demand and further economic development, which results in poverty reduction at each iterative step.

FIGURE 1 STEPS FROM PUE TO POVERTY REDUCTION (ADAPTED FROM KOOLIJMAN-VAN DIJK (2008)



2. Methodology

2.1. Scope and Overview of this Study

The study has been carried out by the University of Strathclyde (UoS) and Community Energy Malawi (CEM) and draws on the practical experiences of selected rural communities which have benefited from electricity supply and utilised it for running businesses. It is expected that the results of the PUE study will contribute to clear understanding of the socio-economic dynamics of rural communities in Malawi in terms of PUE. Such knowledge will inform CEM on how to transfer solar PV technologies for PUE to rural communities and the strategies/methodologies therein.

The feasibility studies in this PUE are based on cross-sectional data and try to compare businesses from grid electrified areas to businesses from non-electrified (off grid) areas. Ideally the survey would cover a variety of different village types in order to assess different levels of community characteristics or geographic conditions. Instead, resource constraints allowed surveys of two villages, which it is intended will capture enough variation of village characteristics for useful output. A focus has been put on the economics of the business, specifically CAPEX, OPEX and Income, however not included in the study is other social-economic parameters such as market size and population.

2.2. Literature Review

The literature review (Section 3) comprises previous case studies of PUE in Malawi, drawing out relevant experiences of businesses being powered by solar PV in rural areas. It goes on to summarise previous market assessment work completed by UoS and CEM determining which businesses are most desired by rural communities, and finishes with a brief overview of challenges faced by businesses in Malawi examining influencing parameter on a national and local scale.

2.3. Surveys on Existing Electricity Using Businesses

Surveys based on structured questionnaires covering all areas of business activities have been conducted in the target villages. Quantitative data was collected through the structured questionnaires complemented by qualitative information gathered by open interviews with key informants and resource persons in the survey areas. Such additional insights are indispensable to understand the business environment in the villages and to complement the quantitative data. Interviews and surveys were conducted by CEM researchers during field work in September 2016.

The CEM enumerators were responsible for quality control, including consistency and completeness checks, as well as reporting fieldwork observations, methodological problems and pitfalls back to the central study team at UoS. The surveys were conducted in the digital data collection platform kobo collect, with data analysed in Microsoft Excel. The surveys have informed system design and business planning for specific off-grid business scenario planning.

An outline of the surveys can be found in Appendix 1, the data collected in spreadsheet form can be found in Appendix 2. Table 1 outlines the types of businesses targeted for the surveys.

TABLE 1 TYPES OF BUSINESSES SURVEYS WERE CONDUCTED ON

Agriculture	**Small Sales and Services**	**Repair and Manufacture**
Maize Milling	Barbershop	Wood Workshop
Irrigation	Entertainment	Metal Workshop
	Cold Drinks	Electronic Repair
	Phone Charging	Tailoring

2.4. Selection of Appropriate Areas

Following the success of the PUE pre testing CEM conducted on 12th December 2016 at Bowe trading centre in Dowa district, CEM identified two communities namely: Njonja located south east of Dedza and Chiluzi trading centre located on north east of Dedza.

The comparability of Chiluzi's non-electrified and Njonja electrified communities has proved to be best during the selection of these communities. Njonja is a big trading centre with a very small area being electrified and a large area non-electrified. Very few businesses are connected using off grid Solar PV systems. Trading centre and village level parameters like size, demography, political importance and access to roads, transport services or telecommunication have already been checked in both areas. Actual aerial Maps have been attached in Appendix 3.

FIGURE 2 CHILUZI TRADING CENTRE

2.5. Survey Analysis

The results from the surveys were segregated into separate businesses for analysis. Useful anecdotal information has been noted, with key information analysed being Capital start-up costs (CAPEX), monthly operational expenditure (OPEX), and monthly income. Load profiles were gathered and used to inform the system designs.

Where appropriate, box and whisker plots are included which indicate the mean, median and 25 percentiles either side of the mean, with outliers plotted. This gives a clear indication of the spread of answers. Where key average information is required, the Mean is stated with maximum and minimum values.

2.6. System Design

Following information gained from the surveys on energy use, off grid solar PV systems were designed to supply the loads identified in the business surveys. A system was then specified with a component list to determine the cost of the energy system to run the businesses. More information specific parameters required for system design (load profiles and solar resource) can be found below.

Costs for solar PV systems to power the agricultural loads, specifically Solar Irrigation and Maize Milling were found from the Foundation for Irrigation and Sustainable Development. FISD are a social enterprise with both an NGO and ltd company arms who supply, design and offer consultancy on all matters relating to irrigation (FISD, 2017). FISD offer “ready to go” irrigation and maize milling packages which include solar PV and controls. Costs were obtained during a visit to FISDs offices with CEM and UoS in February 2017.

Small Service and Sales and Repair and Manufacture Systems were designed, specified and costed by CEM who are accredited by the Malawi Energy Regulatory Authority (MERA) to be installers of all types of renewable energy. The following assumptions are included:

- 30% labour costs on top of capital expenditure for installation. This will depend on transport costs from Lilongwe, where CEM are based, but is assumed to be accurate for the business modelling.
- Maintenance cost as 20% of CAPEX, monthly. Again, accurate costs will depend on the distance of the installation from where the service technician exists.
- 5.1 Sunshine hours per day in Malawi (see resource section) below.
- Costs of equipment were found from Solair Corporation and Sonlite, two local suppliers in Lilongwe considered to be reputable, and providing good quality equipment (contact details included in the Appendix 4)
- The specific assumptions and parameters for system designs are outlined in Appendix 5
- Equipment costs can be found in Appendix 6

2.6.1. Resource Assessment

For the purpose of the study, 5.8 kw/m^2/day was used which equates to 5 sunshine hours. This is the case because it is good engineering practice to put lowest average monthly sunshine hours to become the design month of the solar system to avoid under-sizing the system. In this case Malawi on average the lowest sunshine recorded is approximately equal to 5 sunshine hours. According to the Malawi Energy Policy of 2003, the annual average solar radiation for Malawi is 21.1 MJ/m^2/day which is equivalent to 5.8 kWh/m^2/day. This is equivalent energy required to power a total of three hundred and sixty two 16 watt energy saver bulbs for one hour. A solar resource map of Malawi can be found in Appendix 8.

2.6.2. Load Profiles

A load profile is a graph of the variation in the electrical load versus time. A load profile will vary according to customer type, and different load profiles and energy use throughout the day can inform the size of energy system needed to run the business.

Load profiles were determined by asking the businesses at what time of the day they used specific appliances, multiplying this probability with power rating of the appliances to plot the final load profile. These graphs are plotted for each business to represent how energy use changes for different businesses. The load profile graphs were then matched to appropriate systems to deliver that load.

2.7. Business Economics

The surveys were used to find information of key business parameters, namely CAPEX Start-up costs (tools, materials, registration fees etc.), OPEX (on going monthly costs such as rent and tax) and monthly income. As answers varied significantly across the spread of businesses, average (MEAN) were taken were appropriate, with box and whisker graphs used to display the spread of the results. A higher spread indicated less confidence on the result, whereas a low spread indicated that most businesses gave a similar answer and that the mean is likely to be an accurate figure to use for business planning.

To model the businesses in an off grid scenario, the energy OPEX costs were removed from the total, and solar PV OPEX cost were added. The solar PV were assumed to by 20 of initial solar PV annual costs.

2.8. Business Finance/cash flow

A simple 10 year cash flow forecast was used, utilising the "Productive Use of Energy Mini Business Plan Calculator", an open source spreadsheet available online GIZ (GIZ, 2016). The tool take inputs from the parameters outlined above to output a profit or loss graph over a 10 year period to give an accurate representation of payback period, and cumulative profit or loss at the end of the 10 year period. Different scenarios were devised using ranges of capex, OPEX and income to derive strong, stable and weak case scenarios to determine the relative likelihood of the business being viable.

3. Literature Review

3.1. PUE Case studies in Malawi

3.1.1 Case Study: Video show and phone charging in Thete, Dedza,

With a solar PV system, the family of Mr and Mrs Kapolois is operating a video show room and phone charging station at Kachule village. The idea of buying and installing solar PV came after harvesting maize in 2014, the family saved $ 210 for solar PV and TV. On average the business recouped the initial cost of solar PV in 10 months. After this, the family saves $1700 a year from video show and phone charging—around 44% of the total annual income generation. Mrs Kapolo further said that, the family is spending nothing on lighting at all which means they're able to spend their money on other things. Mrs Kapolo said that 14% of the household proportion of income they were spending on lighting was significant and so having access to a solar PV is life changing. He emphasized that they spend their savings from the business on food, clothing, soap, school fees and cooking oil. They also save money from reduced spending on lighting alternatives like kerosene, candles, and battery torches they were using before solar PV.

3.1.2 Case study: Impact of Solar PV Light on Mr Chinkhwita shops in Ntchisi, Malawi.

"The accessibility of solar PV has enabled my small business to extend the trading hours well into the night."

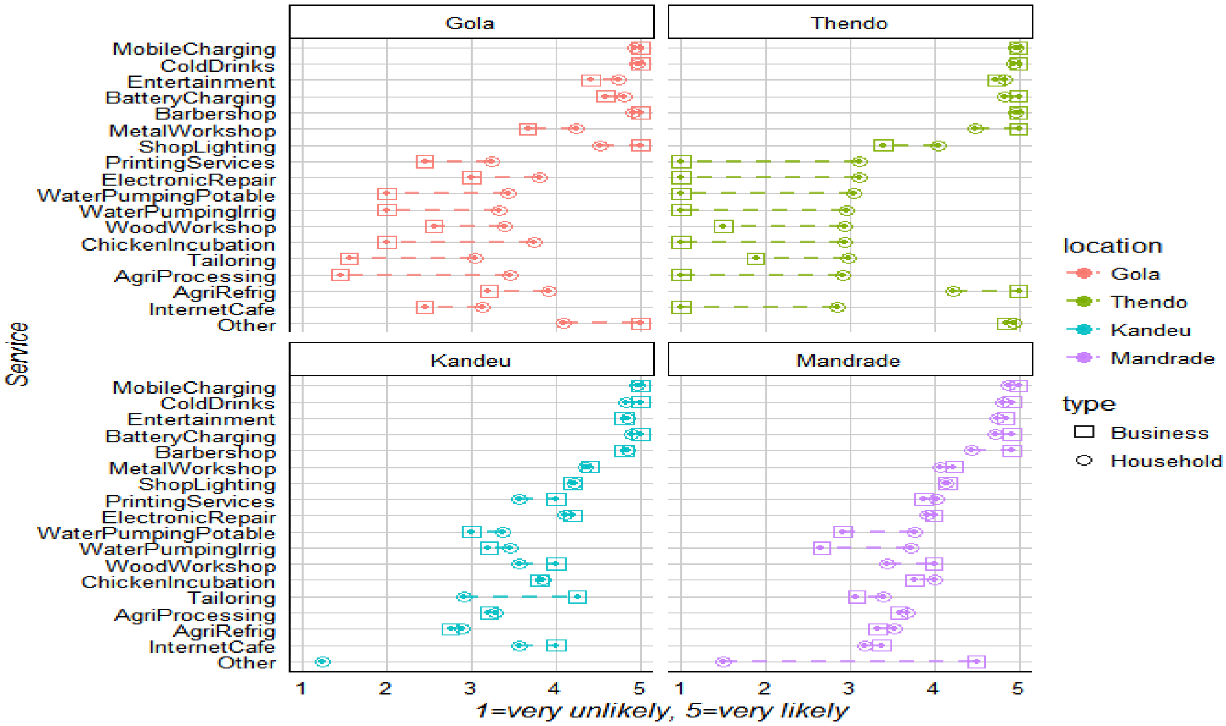
Mr. Chinkhwita runs a small groceries shop, tearoom and restaurant in Sopani village. Previously, he was using kerosene lamp and candles for lighting in his trading sites. He said that the lighting was of poor quality as a result visibility of his shop was limited hence less customers weren't able to buy things from him. He further emphasized kerosene lamps were contributing to business losses in the tea room and restaurant business because it was difficult to handle since it diffuses fast and contaminated the foods. With the solar PV light system now he is able to extend the business operation hours up to around 21:30 in the evening. He said that before the Solar PV light he could sell 9% of the total daily sells and closed the shop around 18:30 and now with solar PV light system they are able increase sales from 9% to 40% of the total daily sales.

3.2. Previous studies on PUE in Malawi

3.2.1. SOGERV market assessment

The Sustainable Off-Grid Electrification of Rural Villages (SOGERV) project in Malawi is aims to reduce energy poverty in rural Chikhwawa district through the electrification of households, businesses and community energy infrastructure via the deployment of sustainable renewable energy technologies. Part of the project research included a market assessment for energy services in Mandrade, Kandeu, and Gola, Chikwawa District. Households and businesses were 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 on the plot below, for each location. The squares represent the average response from businesses; the circle is the average response from households.

FIGURE 3 COMPARISON OF INTEREST IN SERVICES BOTH HOUSEHOLDS AND BUSINESSES RESPONDING



While there were some variations in the lower scored activities, the higher scored activities were remarkably similar at all locations: Mobile phone charging, cold drinks sales, entertainment provision, battery charging, barbershop, metal workshops and shop lighting. There was near agreement between business owners and households in their responses, except in the case of Gola and Thendo's lower scored items where consumers consistently rated these higher than businesses. There is no obvious explanation for this so it has to be assumed either that local businesses are not yet aware of a market for these services or that consumers are unaware of the business constraints for establishing the service. The high scoring uses were passed on to the technical design team for consideration for standalone solar PV system design.

3.2.2. CEM Market Assessment

Community Energy Malawi conducted market assessments for a variety of renewable energy technologies in 2015. A standard questionnaire was performed within a number of different remote communities within Malawi by CEM. There were two versions of the questionnaire: one for households and one for businesses/entrepreneurs, both were asked to score a business with regards to how viable they felt the business would be in their community. Results are shown below.

FIGURE 4 PRODUCTIVE USE "CHOOSE TOP 3" QUESTION FOR HOUSEHOLDS. SURVEY RESULTS FROM 115 HOUSEHOLDS.

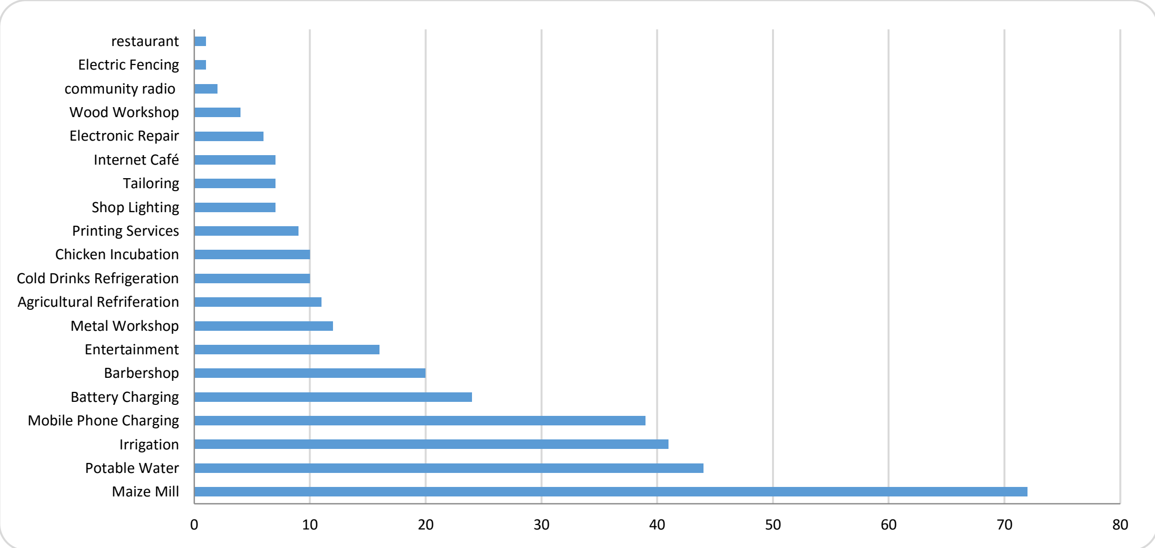
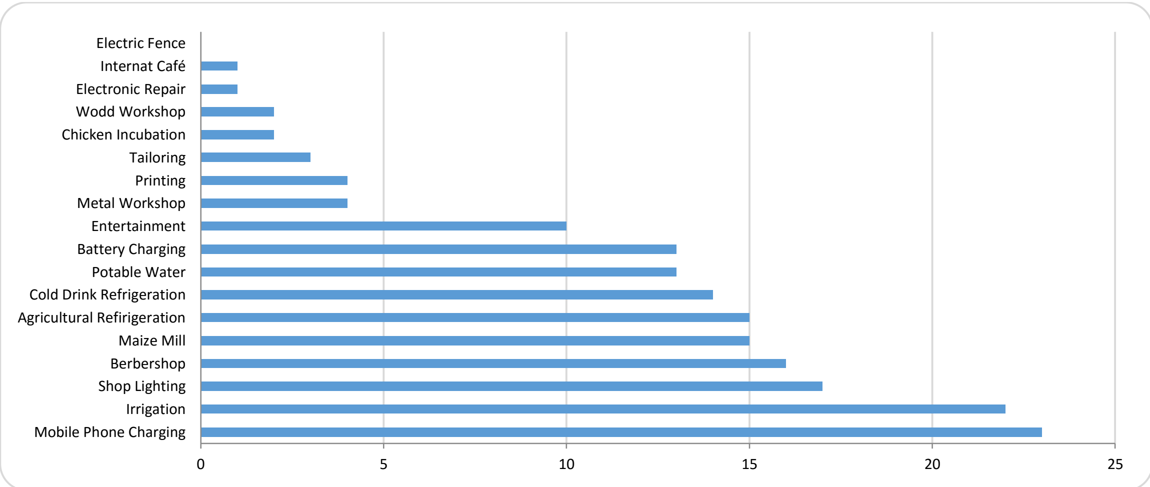


FIGURE 5 PRODUCTIVE USE "CHOOSE TOP 3" QUESTION FOR BUSINESSES. SURVEY RESULTS FROM 62 BUSINESSES.



It can be seen that the most desirable PUE in the village's surveys were Maize Mill, Potable Water, and Irrigation. In the "choose top 3" questions, Mobile phone charging, Irrigation and shop lighting came out top. Potable water, although possible to be run as an enterprise, was deemed to have other complicating factors such as accessibility to water sources, borehole pumps and often covered by government schemes, so not considered in this study. The other PUE are similar to the results found in the SOGERV study so have been selected for consideration in this study.

3.3. Challenges to Business Start Up in Malawi

3.3.1. Capacity

Lack of entrepreneurship skills is a basic challenge faced by business start-ups. Business training is needed to assist business owners in keeping track of business costs, as they are often not being recorded. Accounting skills can help the business operator to mitigate losses and track the progress of the business. It also strengthens the business processes, systems and rules that influence collective and individual behaviour and performance in business endeavours. It also allows to enhance the business owner's ability and willingness to play new developmental roles and adapt to new demands and situations in business.

3.3.2. Standards and Regulations

In general there is a lack of regulation which is limiting factor of the Solar PV market where currently few standards exist, causing an influx of cheap counterfeit products. This is being addressed in part by the Malawi Bureau of Standards and Malawi Energy Regulatory Authority (MERA), as standards are in place for both large and small solar systems mainly on the installations and the products.

According to MERA, any commercial energy undertaking (buying and selling of renewable energy products on a commercial level) needs a licence. For home use (for example a SHS) the installer needs to obtain the Renewable Energy Permit or licence. In case the owner of a SHS wanted to sell some power to other households then they need to obtain the distribution code from MERA.

3.3.3. Funding Businesses

Interest rates in Malawi are staggeringly high (43%). Additionally, to get a loan from a bank one is required to have proof of address, utility bills and other paperwork which will be unobtainable for many rural Malawians. Some Micro Finance Institutions exist such as CUMO, similarly FISD offer the FISD Fund, which offers 7% interest with a 1 year payback (however most payback periods are above this). Village savings and loans also offer options for start-up capital, however the maximum available is usually MWK 200,000 and the loan often needs to be paid back within 6 months, which makes it unsuitable for many of the businesses proposed.

3.3.4. Supply Chain

The availability of solar PV materials can be a limiting factor. Transportation costs for solar goods are high as shipping from China to Europe is $600, whereas in Malawi it is 6 – 8 times more. Road access has been noted as a challenge in rural locations of Malawi, as apart from the main carriageways most road are dirt tracks and difficult to travel on during the raining season.

Solar PV modules, batteries, charge controllers and inverters are becoming more available in trading centres, normally purchased from South Africa, however there have been concerns over quality of the goods supplied.

3.3.5. Policy

It is also clear that the policy does not much protect the small businesses in the communities and it only favours the big businesses. The market channel for small business operators is narrower than the high scale business operators, which limits the profits they get from the business.

It is encouraged to register any new business to city assembly if operating within the city or district. The business operator needs to pay the registration fee depending on the size of the business. But if the business will be operating in any district then it will need to be registered in registry general and a business licence obtained. The business is also required to register with Malawi regulatory Authority (MRA) which will issue a Taxpayer Identification Number (TPIN) on registration that should be used on any correspondence with the Authority. With any business involving production, the Malawi Bureau of standards (MBS) regularly inspects the products if they all meet the standards and it is obliged to close the business if it does not meet the requirements.

3.3.6. Availability and Affordability of Energy

The concern here is the role of the diffusion agencies (NGOs). The onus is on them to make the innovation widely available in off grid communities. The simple logic here is that if there is no system to take the innovation to the market as it is the case of energy in Malawi, be it new technology or service, then the potential adopters will not adopt it in their respective business.

This question on affordability of energy to start a business in Malawi regards the purchasing power of business energy users and their access to credit, and notes that even competitive innovations can remain unaffordable to the majority in emerging markets. This question is particularly crucial in the diffusion of solar PV systems, which are quite expensive relative to the low incomes in the rural areas, where they are more relevant.

3.3.7. The Market Infrastructure

The market infrastructure perspective integrates entrepreneurs in the innovation diffusion process. It is built on the simple fact that "unless some government, entrepreneurial or non-profit organisation makes business innovation available at or near the location of the potential adopter in the community, that person or household will not have the option to adopt it in the first place". This perspective focuses on the supply side of innovation diffusion like Solar PV or solar Mini grids in off grid communities. It is concerned with the process through which innovation is taken to the people who are supposed to benefit from it in his/ her business. This is where the role of the agencies is crucial. The agencies are "public or private entities through which an innovation is distributed or made available to society at large". Diffusion agencies can be commercial entities, such as shops run by dealers and distributors of an innovation, or government entities, such as local agricultural extension offices, or non-profit entities. Market infrastructure becomes more of an issue for innovations that must be serviced regularly or where access to maintenance and repair services is critical. This is exactly the case with solar technologies in Malawian communities.

4. Fieldwork Observations

In both communities, CEM team discovered similar income generation activities (IGAs). Productive uses in these communities were recognised as a means of offering a sustainable source of income for people which then adds weight to the economic business case. Contrary to this, the two communities are struggling to find energy services. In the face of energy services being insufficient, the two communities have number of productive uses offered in the areas that are powered by fossil fuel and very small solar systems.

Some of PUE activities CEM noted in the communities are; maize milling, irrigation, refrigeration, welding, carpentry, tailoring, hardware shops, electrical repair shops, bar, and barbershops. The enumerator team collected data from appropriate business services taking a selection of appropriate communities to meet the aim of this study, and established cases/ stories out of the current energy situations in communities. The interviews were also segregated by gender (both men and women were interviewed in their respective business services).

Both trading centres are scattered but have carefully located key resources for community development that are meant to serve their surrounding farm populations. Chiluzi is reasonably small compared to Njonga which has two segments. One segment (lower area) is partly electrified and approximately has more than 170 shops with different businesses activities. The upper section is completely not electrified but it's almost equal to lower section and also it registered more different business activities. Both trading centres offer services to surrounding communities and businesses activities increases during the market days where people from other districts conduct trade with the communities. Of those who live in trading centres/communities, approximately 70 per cent live and work on farms as primary source of their income. This is because many businesses are seasonal and the business activities increased especially during harvesting period. Maize is the staple crop of the communities. Irish, beans, tobacco, sweet potato, fruits are some of examples of cash crops.

The team noted the following general observations during the surveys, mostly related to unavailability of energy;

4.1. Njonja

- Persistent lack of energy in their areas have underrated the efforts in Chimoto Health centre as a woman in health centre has died due to lack of electricity.
- The customer's confidence in local welders has reduced because they don't supply products at the agreed time (due intermittent grid supply).
- Despite some owners of maize mills re-introducing diesel powered maize mills alongside the electricity ones, frequent blackouts leaves many households without food because many maize mills run out of service.
- Some businesses operate through the night because this is time when electricity is available hence quality of work is compromised.
- Monthly income generation for most businesses have gone down and expressed worry that they are not affording to meet some basic needs due to power cut. Even school fees were coming from business income and most business men have withdrawal their children in expensive schools.
- Electricity is not available to everyone who applied for it. Some customers applied for electricity 3 years back but are still waiting a connection.
- Business men disclosed that they are now spending more on fuel for their genset to supply power to crucial facilities.
- There is a lack of access to information about solar energy. Most people believe that solar energy can only be used for lighting and power small radios.

4.2. Chiluzi

- Lack of electricity in the area limits the operation hours of their businesses and also limit the business activities.
- Women and girls travel long distances to working maize mills and the services are also very expensive, community members also travel long distances to access health services because the community failed to attain health works because of lack of electricity.
- It was noted that the area depends on both rain fed and irrigation agriculture but unavailability of energy limits farmer's productions. Very few farms use a motor pump and expressed that motor pump running costs are expensive.
- It was noted only one phone charging unit powered by a small PV system but still the community is not aware that solar can proved sufficient energy sources for different income activities.

4.3. General Observations

- Shortage/ lack of energy services in the communities' hits social economic activities in both households level and institutional. Absence of electricity from any source is an obstacle to growing their businesses
- In grid connected trading centres, very few people are connected and there are several unreliable connections within.
- People realise the importance of electricity to business activities, and all businesses are affected when there are power cuts.

- From the survey, it shows many people who participated have applied for an electricity connection four years before but ESCOM declined giving them a quotation to pay for the connection claiming there is no transformer to supply their households with electricity power.
- Only few customers who were given a quotation by ESCOM and are in the process of paying for the connection but claimed that they have used back doors for them to be processed fast.
- Many people in both communities evaluated ESCOM's effort to connect households as total failure. The participants seem to be emotional and aggressive when talk about national electricity. This was the case because they claim ESCOM has failed them in any way and it was time for them to hint hard on ESCOM in order to be heard.

5. Business Plans

5.1. Maize Mills

Maize is a staple crop grown and eaten in Malawi and the main ingredient of Nsima. 96% of maize consumed in Malawi is grown in Malawi (Jaicaf 2008), and maize consumption in Malawi averages 130kg/person/year (Derlangen 2012). Maize is stored whole in woven basket silos, which allows the maize to be stored for longer periods of time than milled maize. Maize grains are hulled then milled into flour. Maize milling is a year-round activity, with maize planted in rainy season, Nov-April and harvested in July-September, however maize mills will generally have more customers in harvest season. 11 maize mill owners were surveyed. It was found that the amount of maize milled depends on the availability of electricity, with some maize millers operating at night when the grid electricity is available which affects the quality of the product.

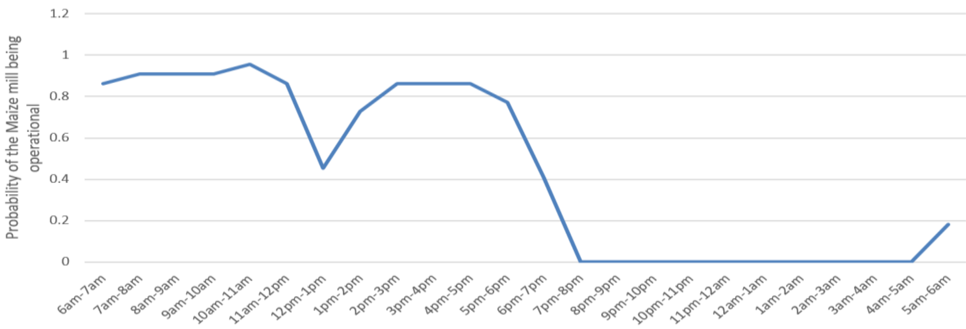
OPEX costs for a maize mill is driven by electricity use and therefore number of operating hours for the Maize mill. The cost of a normal maize mill that uses electricity from the grid or a diesel generator is between 800,000 MWK and 1,200,000 MWK (correct December 2016).

FIGURE 6 SOLAR MAIZE MILL (SOLARMILLING, 2017)

5.1.1. Maize Mill Load Profiles

Most of the interviewees didn't know the maize mill power rating. There were only 4 systems where the rating was known; the maize milling power rating ranges from 2kW to 120kW (22kW; 2kW; 120kW; and 36kW). Considering the maize mill responses from the survey, the probability of the maize mill running is given in Figure 7, indicating a standard working day from 6am to 7pm with a break for lunch.

FIGURE 7 PROBABILITY (BETWEEN 0 AND 1) OF THE MAIZE MILL BEING OPERATIONAL THROUGH EACH HOUR OF THE DAY



5.1.2. Solar Maize Mill System Design and Costs

Prices as obtained from FISD, Lilongwe are outlined below. Systems come complete with solar PV array, an inverter and an AC motor powering the maize mill. Very few solar maize mills have been installed in Malawi, with only a few projects in pilot stage. Products come from a Spanish company, SolarMilling.com. A summary of prices and specification for the two system sizes offered can be found in Table 1Table 2 below. For this study, the lower cost of maize mill was considered (1.1kW).

TABLE 2 COST OF SOLAR POWERED MAIZE MILLS (FISD, 2017)

Size (kW)	PV	Yield	Cost (MWK)
7.5kW	40 x 250W	6 hours – 50 bags (1 tonne)	23,000,000
1.1 kW	12 x 160W	8 hours – 10 bags (50kg)	7,000,000

5.1.3. Maize mill CAPEX

6 maize mill owners gave information on CAPEX, broken down into the sub-categories below:

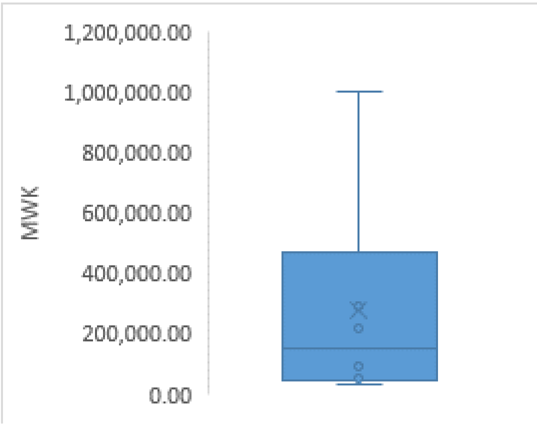
TABLE 3 SUMMARY OF MAIZE MILL CAPEX

Item	No of Maize mills	Cost
Initial materials and machinery	4	MWK 12,000,000 /220,000/280,000/1,000,000
Registration fees	3	MWK 5000/15,000/35,000
Renovation of the building	3	MWK 40,000/1,500/60,000
Bringing energy supply to the building	2	MWK 100,000/9000
Training staff	2	MWK 15,000/ 5,000
Purchase of building	1	MWK 50,000
Legal fees	0	

It is noticed there is an order of magnitude difference in CAPEX response between individual maize mill businesses. Most noticeably, there is 1 major outlier due to very high initial material costs of 12,000,000 MWK. The enumerators conducting the survey noted this business had several maize mills and was therefore exceptionally large. Conclusions are outlined below, the spread of total CAPEX is shown below in Figure 8 Maize Mill CAPEX spread and summaryFigure 8.

- Large variation in registration fees, and ssually no legal fees are paid.
- Purchase or renovation of the building may be a small cost at 1,500 MWK or may be a large cost c. 50,000 MWK if the whole building needs changing.
- Staff training is usually not done but may cost 5,000 MWK to 15,000 MWK.
- Initial materials and machinery is the most expensive CAPEX item for a Maize mill (which is an intuitive result). CAPEX is usually between MWK 300,000 and MWK 1,000,000 (noting this cost may be much larger for a larger maize mill).

FIGURE 8 MAIZE MILL CAPEX SPREAD AND SUMMARY



For the purposes of business planning, analysis was conducted to see what the average CAPEX costs are excluding initial machinery and for bringing energy supply to the building. This is assuming these costs will not be required when getting set up with a solar PV maize. The Max, Min and Mean results for CAPEX excluding energy connection and machinery costs are shown in Table 4.

TABLE 4 MAIZE MILL CAPEX WITHOUT ENERGY CONNECTION AND MACHINERY COSTS

MAX	90,000 MWK
MIN	1,500 MWK
MEAN	44,300 MWK

5.1.4. Maize mill OPEX

RUNNING COSTS WERE CONSIDERED IN TERMS OF GOOD MONTHS (WITH HIGHER RUNNING COSTS), AVERAGE MONTHS AND BAD MONTHS (WITH PRESUMABLY LOWER RUNNING COSTS). THERE IS AN UNREALISTICALLY HIGH OUTLIER FOR AN AVERAGE MONTH RUNNING COST AND THE MEDIAN IS CONSIDERED AS A BETTER ESTIMATION OF RUNNING COSTS IN THIS CASE. GRAPHS SHOWING MAIZE MILL OPEX FOR AVERAGE, GOOD AND BAD MONTHS IS SHOWN BELOW, BOTH WITH AND WITHOUT THE UNREALISTIC OUTLIER. IN

Table 5 the mean, max and min values are shown.

Figure 9 Maize Mill OPEX costs

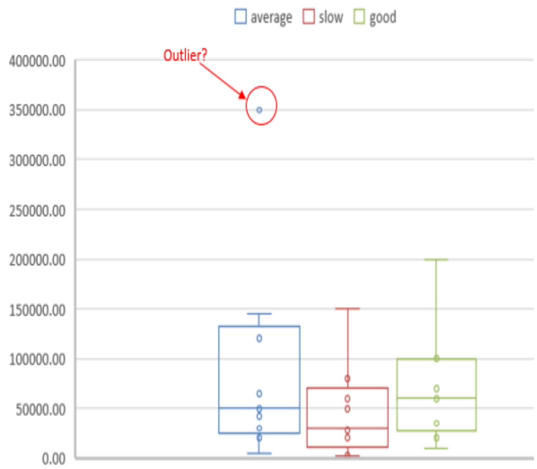


Figure 10 Maize Mill OPEX with outlier removed

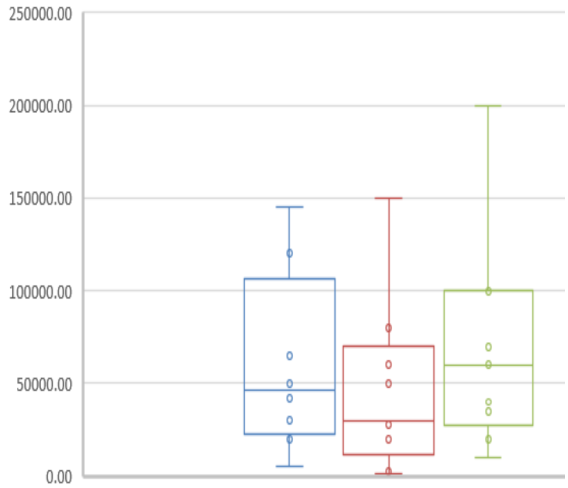
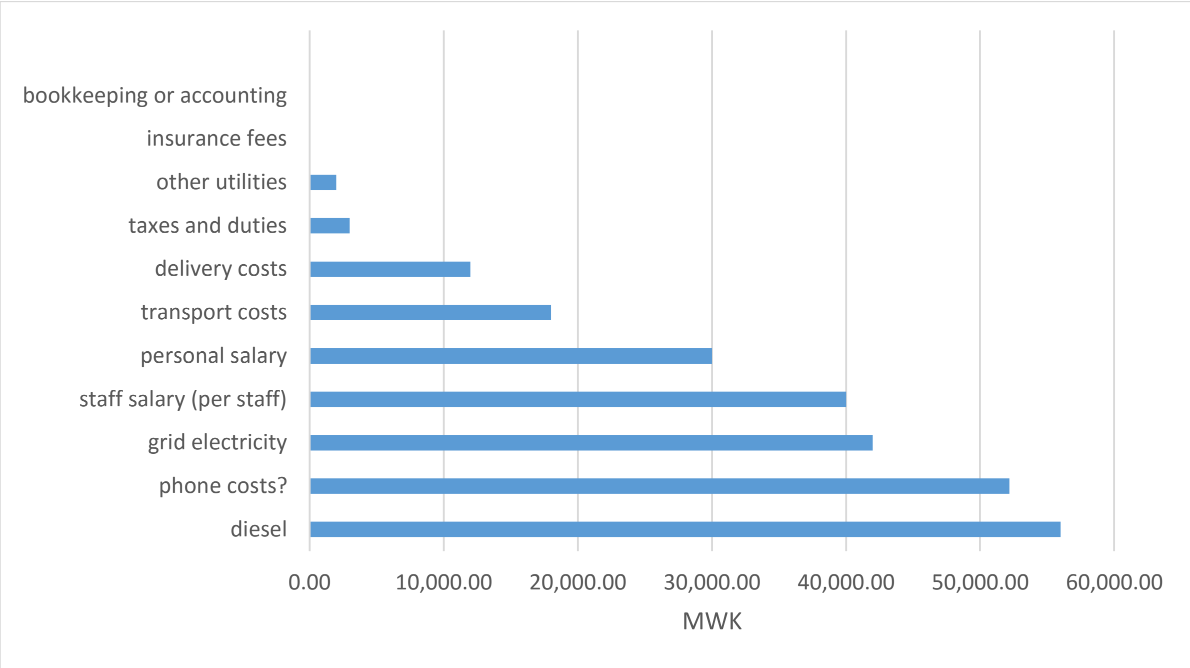


Table 5 Summary of MEAN, MAX and MIN OPEX for estimated running costs

	Average (MWK)	Slow (MWK)	Good (MWK)
MEAN	59,625	46,889	70,556
MAX	145,000	150,000	200,000
MIN	5,000	1,500	10,000

Individual OPEX cost by type were also surveyed and can be cross-referenced with the response above. Each category was averaged and the results displayed in Figure 11. Staff costs were multiplied by the number of staff employed. It can be seen that energy costs dominate the OPEX for maize mills, with diesel and grid electricity making two out of the top three monthly expenses.

Figure 11 Maize Mill OPEX by type

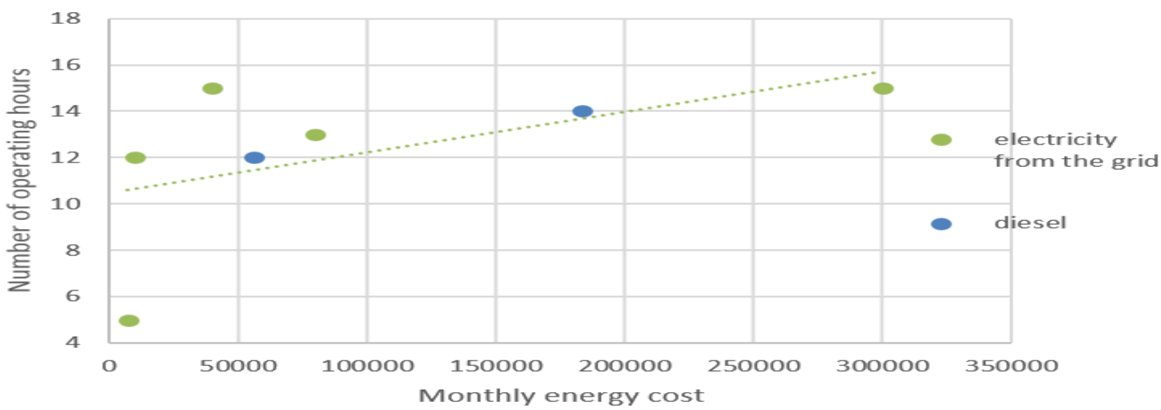


5.1.4.1. Maize Mill Energy OPEX

Maize mill profit and income is directly linked to spend on energy use, i.e. the maize mill operation is completely dependent on energy provision. Of the maize millers surveyed, 7 got their electricity form the grid, 4 from diesel and one used both. Other comments of note included a miller using Airtel money to buy energy which occasionally resulted in a delay from the agent. Most respondents indicated it was not normally a problem to pay for grid energy, however access to energy and Intermittent energy was stated as either a problem or a major problem for all. Many said that PV system are not available.

Spend on energy per operating hour per month ranges from 800 MWK to 20,000 MWK. The total energy spend per month varies massively between 7,000 MWK and 300,000 MWK with an expected energy spend of 50,000 MWK (over half of the total monthly spend). The graphs below show the relationship between monthly OPEX and number of operating hours, showing a positive correlation.

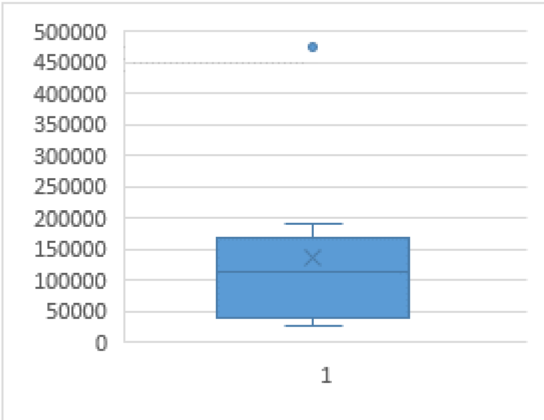
Figure 12 Number of operating hours against energy cost and OPEX



5.1.4.2. Maize Mill OPEX for Business Planning

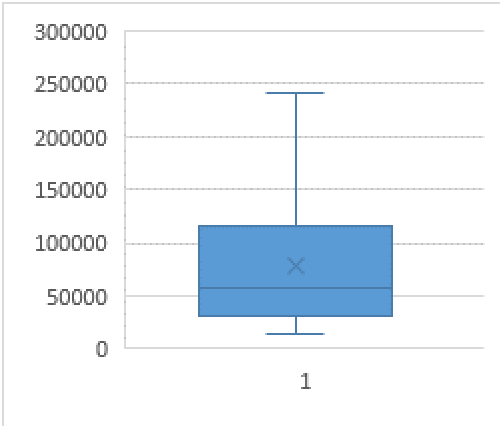
To calculate the business model cash flow, total OPEX costs were calculated by summing the individual monthly costs as shown above, this is shown in Figure 13. Energy costs (diesel and grid electricity) were then removed from the total OPEX removed, assuming that a PV powered maize mill will not have to spend on grid or diesel costs. The OPEX costs excluding energy, used for the business cash flow modelling calculations is shown below in Figure 14.

FIGURE 13 MAIZE MILL TOTAL OPEX



AVERAGE	129,600 MWK
MAX	476,000 MWK
MIN	26,000 MWK

FIGURE 14 MAIZE MILL OPEX WITHOUT ENERGY COSTS (USED FOR BUSINESS PLANNING)

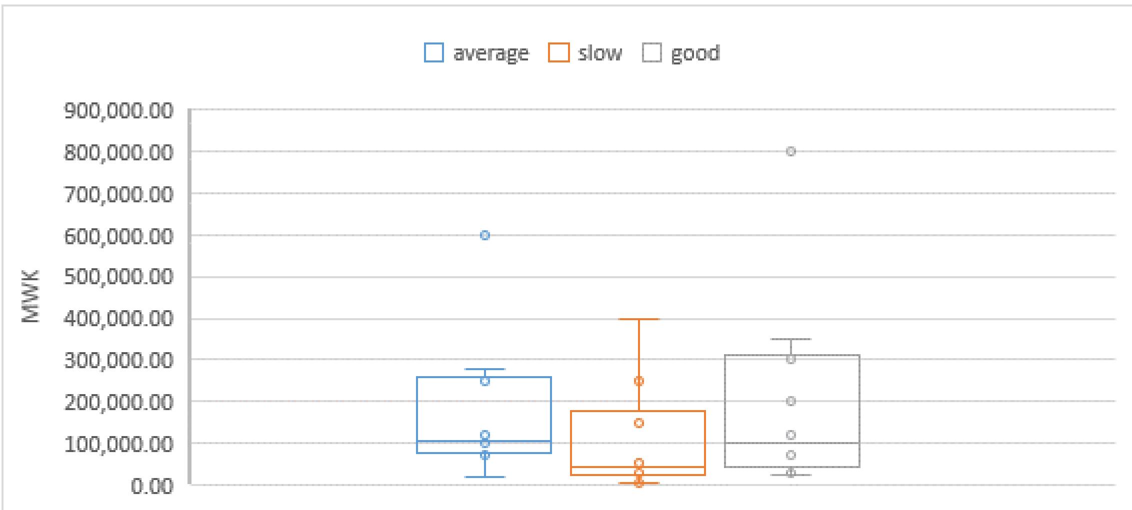


AVERAGE	722,00 MWK
MAX	241,000 MWK
MIN	13,000 MWK

5.1.5. Maize Mill Income

The survey participants were asked to estimate the income for the owner per month. Figure 15 shows the given responses in terms of a box and whisker plot. The cross is the mean and the middle bar is the median. A summary of the mean, max and min values for each monthly scenario is also given.

FIGURE 15 THE ESTIMATION OF MAIZE MILL INCOME FOR IN AN AVERAGE, GOOD AND SLOW MONTH



	Average month (MWK)	**Bad month (MWK)**	**Good month (MWK)**
MEAN	173,000	103,300	202,000
MAX	600,000	400,000	800,000
MIN	20,000	5,000	25,000

Considering the amount charged per kg of maize, the amount of maize milled per customer and the number of customers in an average/slow/good month, the income per month can be profiled. The result is an average income per month of 9,000,000 MWK assuming 15 days operating (best case income of 17,000,000 MWK and a worst case income of 4,000,000 MWK).

This is unrealistic which indicated that the maize miller misunderstood the question. For example, surveyed responses indicated 250kg per customer, which is a quarter of a tonne**.** Due to the lack of reliability of this part of the data, the business forecasting has used the initial estimates in Figure 15.

5.1.6. Maize Mill Cash Flow Forecast

Given the wide ranges of responses, different scenarios are modelled using figures from different parts of the responses. The scenario parameters are outlined below with the corresponding graphs following.

As the OPEX is dominated by energy, to model a solar maize mill business model, the energy OPEX has been subtracted from the total OPEX, as outlined above. Maintenance costs of the solar system are assumed as 5% of the capex (yearly) so are added on, calculated for monthly. The maintenance costs are considered lower than the other systems, as batteries are not part of the system, which are normally a high maintenance cost of a solar PV system.

TABLE 6 SUMMARY OF MAIZE MILL SCENARIOS

Scenario	Description	CAPEX non maize mill (MWK)	OPEX non energy (MWK)	Solar OPEX (MWK)	Total OPEX (MWK)	Income (MWK)	Cost of Solar Maize Mill (MWK)
1	HIGH	44,300	72,200	29,200	101,400	202,000	7,000,000
2	AVERAGE	44,300	72,200	29,200	101,400	173,000	7,000,000
3	LOW	44,300	72,200	29,200	101,400	103,300	7,000,000

FIGURE 16 SCENARIO 1 – PAYBACK IN YEAR 5, MWK 5,000,000 PROFIT AT YEAR10

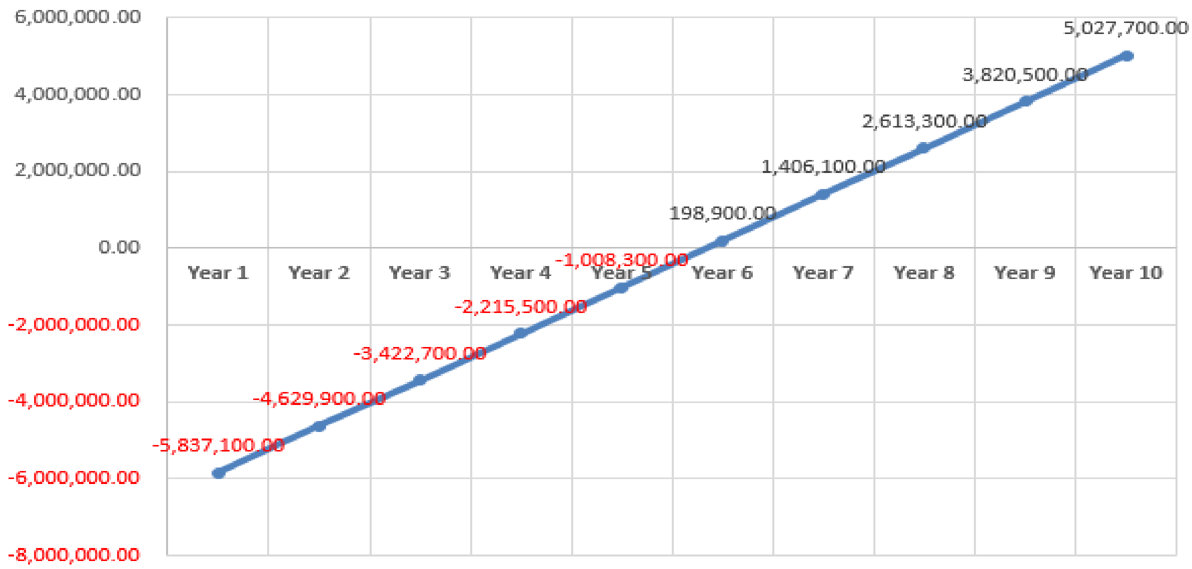


FIGURE 17 SCENARIO 2 – PAYBACK IN YEAR 8, MWK 1,548,000 PROFIT AT YEAR 10

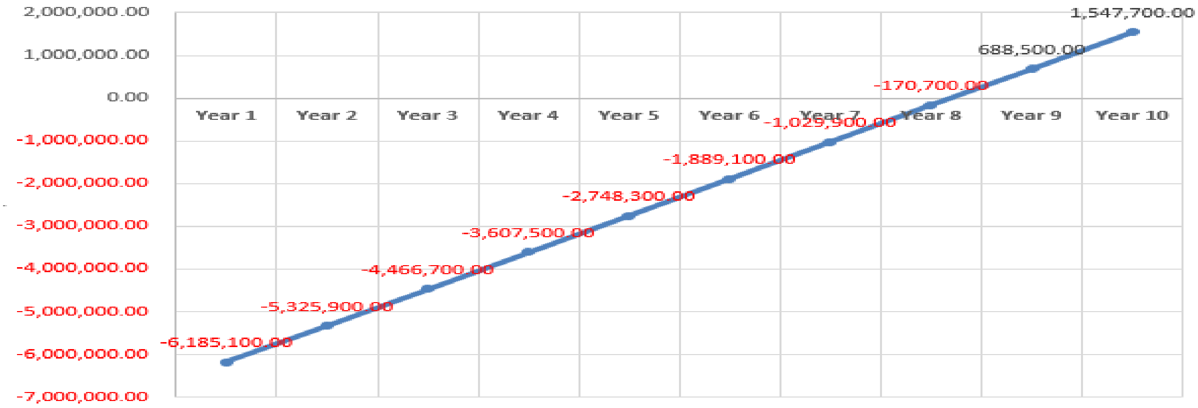
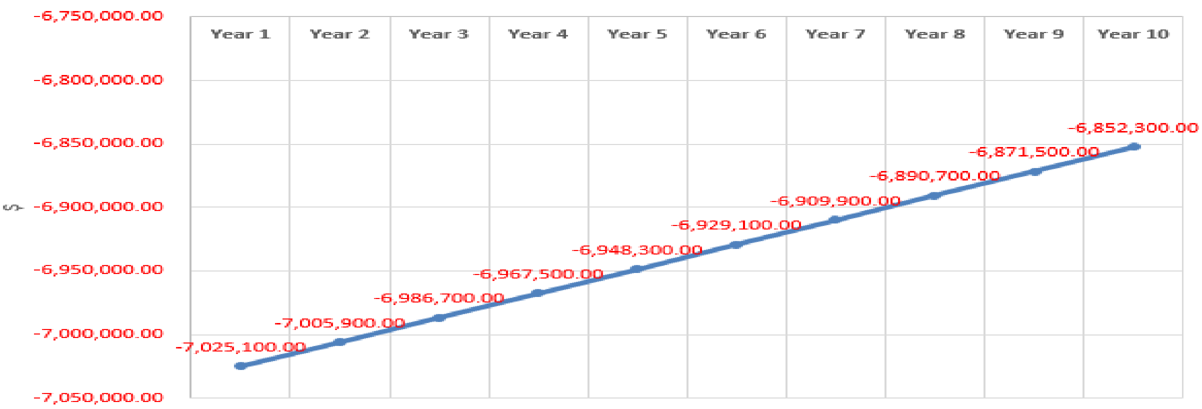


FIGURE 18 SCENARIO 3 NO PAYBACK IN 10 YEARS



5.1.7. Maize Mill Conclusions

If a business model can prove to be profitable, there is high potential for solar PV maize mills as maize is the staple crop and there is a high customer base in most areas of Malawi. Given that most existing maize mills are found in trading centres with grid electricity, customers currently travelling a long distance to get their maize milled may be willing to pay a higher price, which would increase income and make the cash flow forecasts listed above more profitable and viable.

The best case scenario gives a payback of 5 years, the middle option 8 years, and the worst case doesn't break even after 10 years. It must be noted that these are modelled on the cheaper solar maize mill (1.1kW), meaning that that 7.5kW maize mill would be an order of magnitude less profitable.

The high CAPEX for a new maize mill are likely to be too expensive for an average farmer, and even a 5 year payback is too long for most current financing mechanisms in Malawi. Solar maize mills are still in early stages of piloting in Malawi, which has implications of risk in terms of technological failure, and cultural resistance to new technology. There are no recorded maintenance costs, an uncertainty which adds further risk to a pilot project.

Given the above observations, it is likely initial maize mill projects will need to be funded by an NGO in an aid model until the performance of the systems and accurate maintenance costs are known. A cooperative model might work where several farmers can contribute to the upfront purchasing costs. Only once the costs of solar maize mills have come down will the option be a viable business in Malawi.

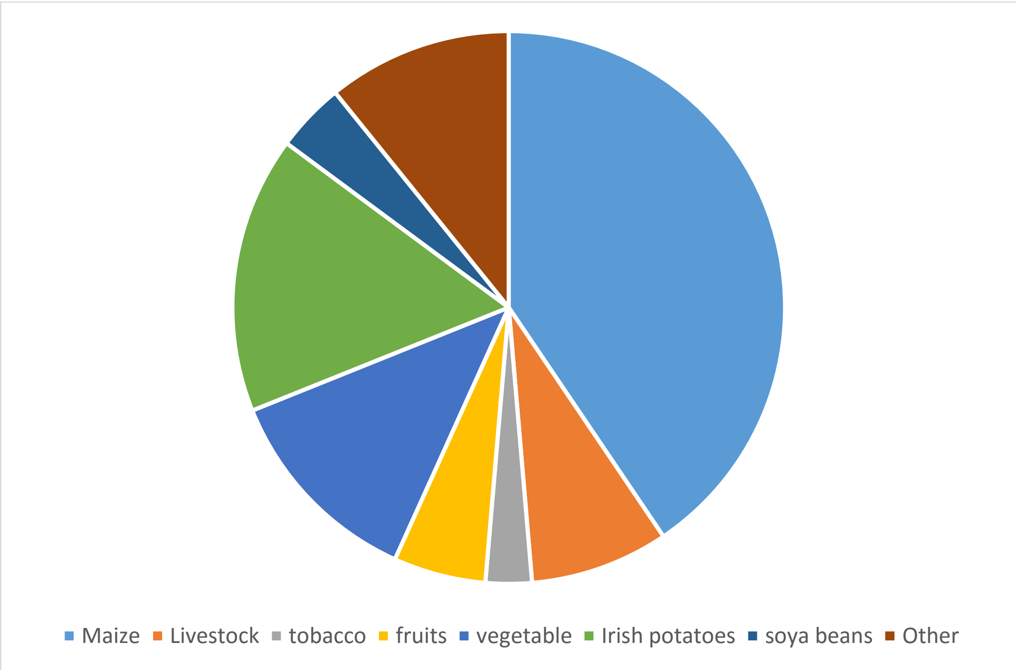
5.2. Irrigation farming

Irrigation is the controlled application of water for agricultural purposes through man-made systems to supply water requirements not satisfied by rainfall. Crop irrigation is vital in Malawi in order to provide the ever-growing population with enough food. Solar powered irrigation means that farmers can grow crops when outwith the rainy season, meaning they can extend the growing season and bring in a greater income. Farmers using irrigation as part of their business use mostly diesel, due to the need to power irrigation pumps in rural locations. None of the enterprises surveyed use electricity from the grid.

FIGURE 19 SOLAR IRRIGATION

33 farmers interviewed indicated that they use irrigation, the type of farming is shown below. It can be seen that maize is mostly used, followed by irish potatoes (which is a common crop in Dedza). Other responses included ground nuts and tree seedlings.

FIGURE 20 TYPE OF FARMER USING IRRIGATION



5.2.1. Irrigation Load Profiles

None of the farmers knew the loading of their irrigation systems therefore load profiles for irrigation farming could not be made in the same way as the other businesses. The load profiles for irrigation have therefore been derived from the specifications of available equipment from FISD, which includes the pumping capacity and the areas of land that can be irrigated.

5.2.2. Irrigation CAPEX

The CAPEX costs segregated by type are shown in Figure 21, it is clear that initial materials and machinery are highest, with land and bringing an energy supply the next highest. The mean, max, min and median of the total capex is also shown in Table 7.

FIGURE 21 IRRIGATION CAPEX BY TYPE, AND SUMMARY OF AVERAGES, MAX AND MIN

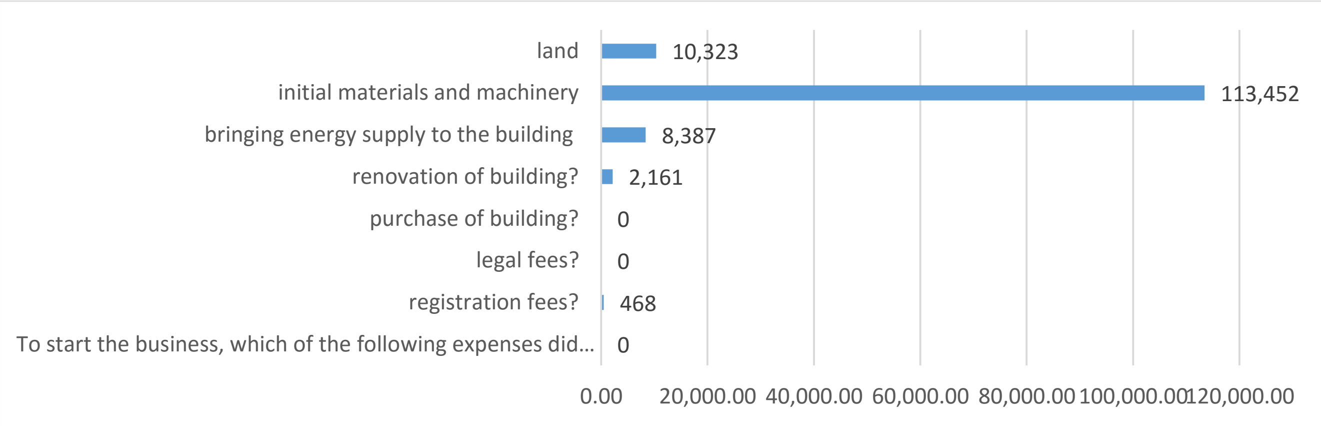


TABLE 7 SUMMARY OF IRRIGATION CAPEX PARAMETERS

Parameter	Value (MWK)
MEAN	198,976
MAX	1,859,000
MIN	500
MEDIAN	50,000

It is noticed there is an order of magnitude difference in CAPEX response between individual in irrigation farming businesses. Most noticeably, there is 1 Major outlier due to very high initial material and machinery costs of 1,559,000 MWK.

Other findings to note:

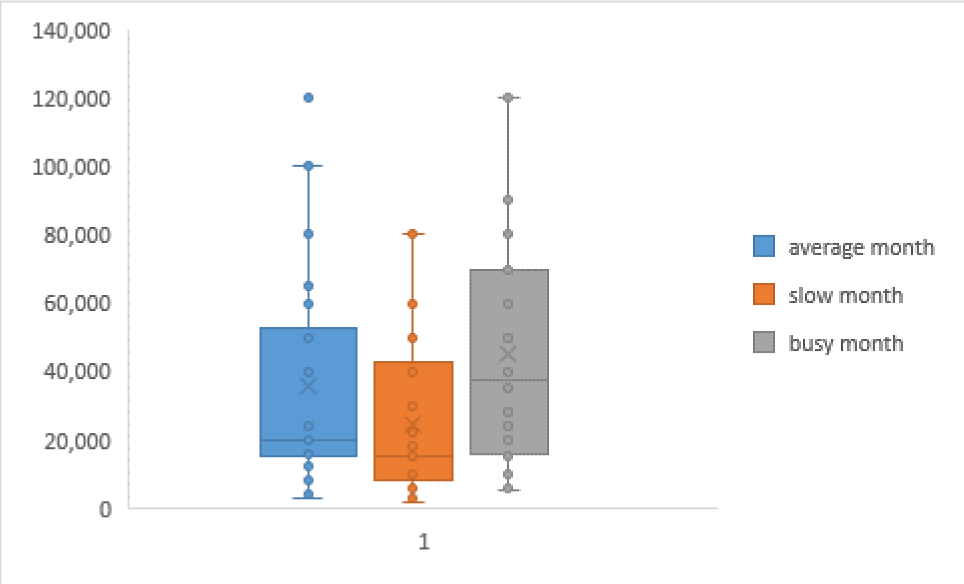
- Small variation in registration fees;
- Usually no legal fees are paid;
- No Purchase of the building but renovation of the irrigation lands may be a small which may cost 67,000 MWK for a very small irrigation land. This means for big irrigation schemes this cost is expected to be much higher;
- Staff training is usually not done but may cost 5,000 MWK to 15,000 MWK;
- Initial materials and machinery is the most expensive CAPEX cost.

The CAPEX used for business planning is the mean of the totals, which is 199,000 MWK (rounded to the nearest 500 MWK).

5.2.3. Irrigation OPEX

The farmers interviewed were asked to estimate their monthly OPEX costs for an average, busy and slow month. 7 businesses didn't know their OPEX cost, so these were taken out. The results are shown in Figure 22 Irrigation OPEX, along with the Mean, Max and Min values for each type of month.

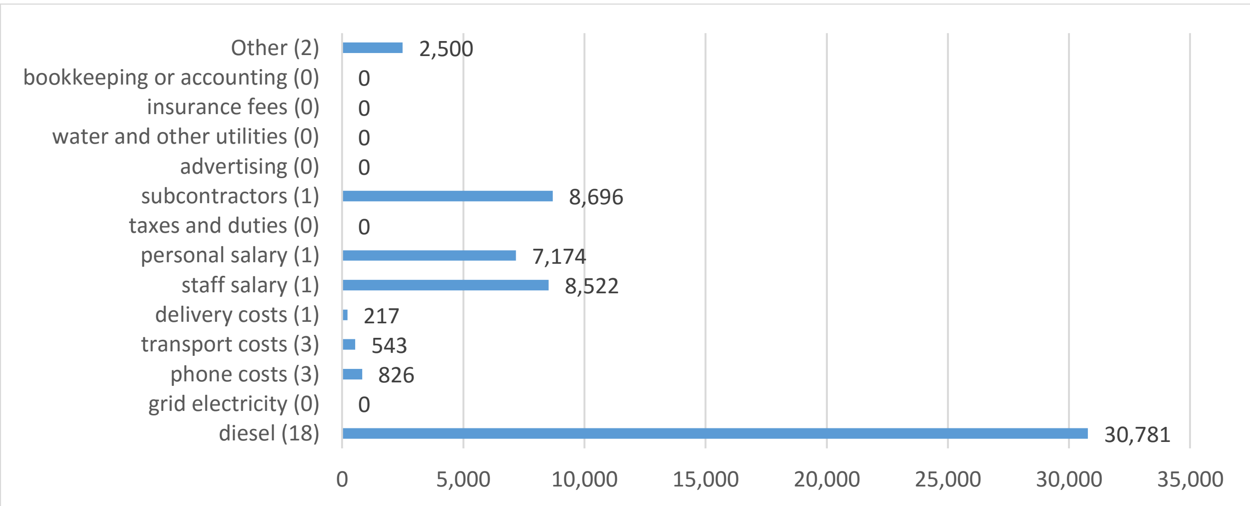
FIGURE 22 IRRIGATION OPEX



	Average month (MWK)	Slow Month (MWK)	Busy Month (MWK)
MEAN	35,962	24,654	45,077
MAX	120,000	80,000	120,000
MIN	3,000	2,000	5,000

OPEX for itemised monthly running costs were collected and itemised, and shown in Figure 23. The number in brackets indicates how many non-zero responses there were. It can be seen that diesel costs dominate OPEX for irrigation, with staff salary, personal salary and subcontractors all contributing relatively equally following diesel.

FIGURE 23 IRRIGATION OPEX BY TYPE



It is interesting to note that no irrigation businesses are connected to the national grid, which is intuitive as they are likely to be rurally located.

For the purposes of business planning, OPEX were calculated without energy costs (subtracting diesel costs from total OPEX costs), assuming that a solar PV irrigation system will not have to spend money on diesel. The results are shown in Table 8. The OPEX used for business planning is **28,500 MWK**

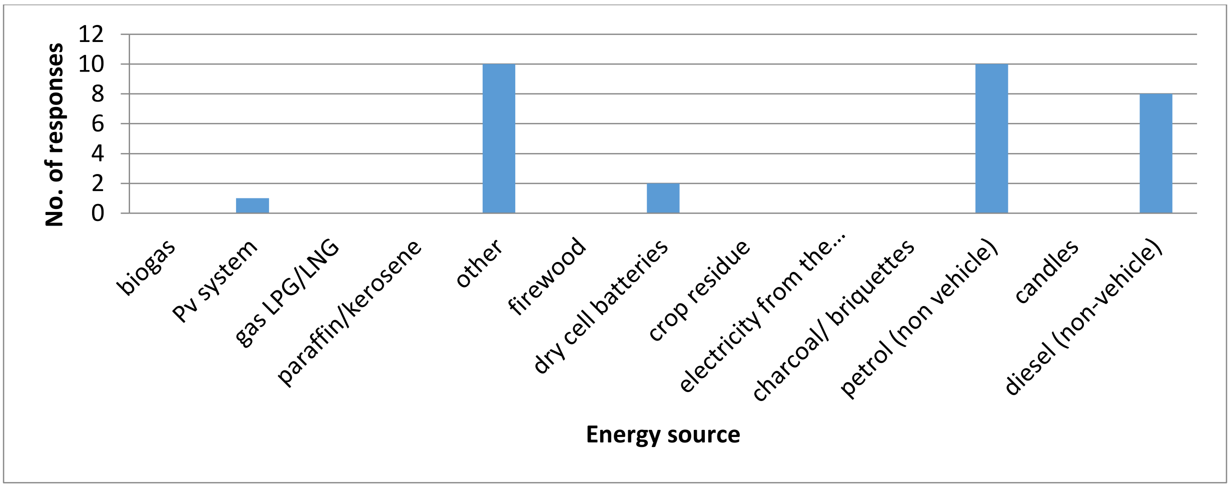
TABLE 8 IRRIGATION OPEX COSTS AND EXCLUDING DIESEL COSTS

	OPEX total (MWK)	OPEX without energy (MWK)
MEAN	52,459	28,370
MAX	340,000	320,000
MIN	5,000	0

5.2.4. Irrigation Energy loads and system requirements

This section includes a brief description of the energy use of irrigation systems based on the data collected. Figure 24 shows the number of energy sources used by irrigation farmers.

Figure 24 Energy use by type for irrigation farmers



In summary:

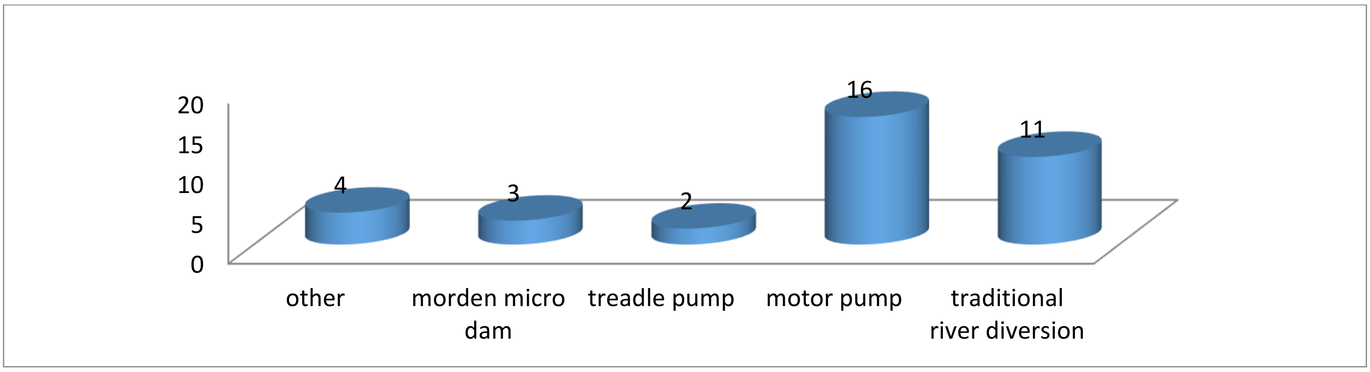
- 18 enterprises use petrol or diesel as their source of energy;
- 10 enterprises which use other sources of energy such as human power and daylight (sun);
- 8 enterprises use diesel;
- 2 enterprises use dry cell batteries;
- 1 enterprise use PV system;
- None of the enterprises uses biogas, gas LPG/LNG, paraffin, candles, electricity from the grid and charcoal.

Frequency of buying energy source and cost per month:

- Candle (@ MK10000, @MK600);
- Diesel (MK8000, MK16000);
- Petrol (mk8000, MK12000, MK20000, MK42000, MK60000, MK64000, MK80000);
- Dry cell batteries (none).

The research survey identified types of energy an irrigation use. Figure 25 identifies the energy types based on their level of use.

FIGURE 25 TYPE OF IRRIGATION



It has been noticed that most frequently used is a motor pump which uses either diesel or petrol and diesel is most used on the operation cost. Water diversion from the river is the second method used. This uses free gravitation energy flow of water into the irrigation farm land.

5.2.5. Irrigation Income

The box and whiskers plot for irrigation on an average, bad and good month is shown in Figure 26, displaying a significant range with on farmer giving high outliers. Figure 27 shows the same graph with the outliers removed.

FIGURE 26 IRRIGATION INCOME WITH OUTLIERS

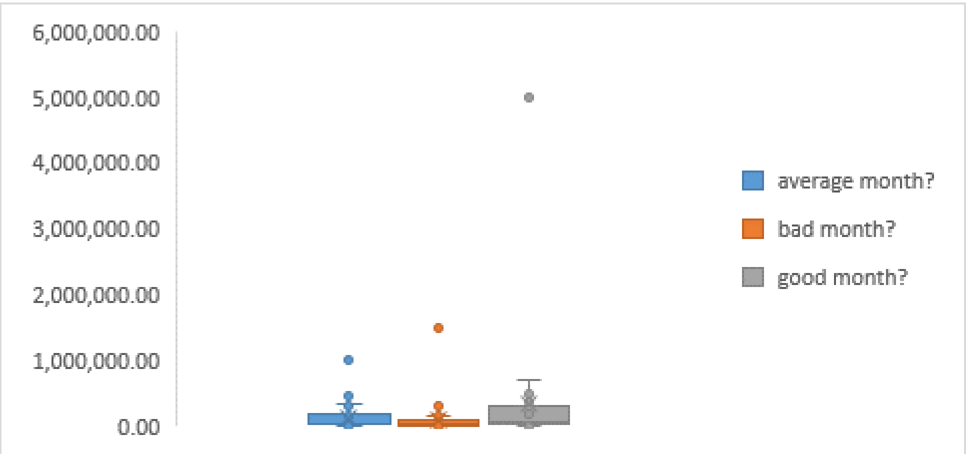


FIGURE 27 IRRIGATION INCOME WITH OUTLIERS TAKEN OUT

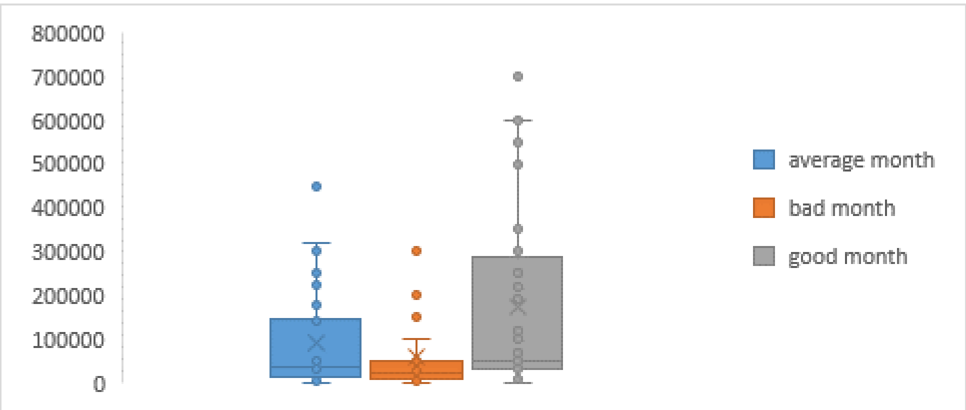


TABLE 9 IRRIGATION INCOME SUMMARY

	Average (MWK)	Bad (MWK)	Good (MWK)
AVERAGE	120,000	103,000	321,000
MAX	1,000,000	1,500,000	5,000,000
MIN	900	700	1500

5.2.6. Irrigation System Design and Costs

Costs from FISD are shown below. The company offer a variety of solar powered irrigation products. The first two options require a borehole to be dug, with a casing and submersible pump, which add to the initial cost. The final option allows a farmer to float the pump in a nearby river with a hose to transport the water to the land. The final option has the lowest set up costs (assuming a borehole doesn't already exist) and the easiest to initiate as a project, however the applications will be very site specific, as it is only suitable for farmers living in the vicinity of a river or open water source. Indicative water table depths are given below (taken from a conversation with FISD engineer):

TABLE 10 INDICATIVE WATER TABLE DEPTHS IN MALAWI

Location	Town	Depth of Borehole
North	Mzuzu	Generally more than 20m
Central	Lilongwe	15 – 20m
South	Chikwawa	5m

TABLE 11 COSTS AND DESCRIPTION OF SOLAR POWERED PUMPS AVAILABLE IN LILONGWE (FISD, 2017)

	Description	PV array	Pump rating	Pumping rate	Head	Area Irrigated	Cost (MWK)
Grundfos Pump	Submersible (in drilled borehole with casing)	500W	1.1kW	4-5 m^3/h	50m - 300m (Dynamic head 50m)	1 acre	Pump: 6,600,000 Borehole: 8,000,000 TOTAL: 14,600,000
Small Pump system	DC pump put in river, comes with a 120Ah battery, 25m cable and pipe with safety rope	250W	128W	360 l/h	50m	0.5 acres	Pump: 950,000 Borehole: 2 – 3,000,000 TOTAL: 3,450,000
Floating pump	Throw into a river or open water 25m pipe. Straight panel to pump (no battery)	250W or 128W		15,000 l/h	8m	4 ha	Pump: 1,100,000 Storage tank 5,000l = MWK 600,000 TOTAL: 1,700,000

5.2.7. Irrigation Cash Flow

For the following cash flow analysis, the assumptions were used as follows:

Solar PV OPEX has been calculated as 5% of capital costs annually, as with Maize Mills, not batteries are present in the system so maintenance costs will be lower. This has been calculated for a monthly cost and added on the OPEX to determine the total OPEX, shown below. Figures have been rounded to the nearest 500 MWK.

TABLE 12 SUMMARY OF INPUT PARAMETERS FOR IRRIGATION CASH FLOW

Scenario	Description	Income (MWK)	OPEX (MWK)	Solar OPEX (MWK)	Total OPEX (MWK)	CAPEX (MWK)	Pump CAPEX (MWK)
1	Low Income, Floating pump	103,000	28,500	7,000	35,500	199,000	1,700,000
2	Average Income, Small Pump	120,000	28,500	14,500	43,000	199,000	3,450,000
3	High Income, Grundfos Pump	321,000	28,500	61,000	89,500	199,000	14,600,000

FIGURE 28 SCENARIO 1 – LOW INCOME, FLOATING PUMP: PAYBACK IN YEAR 2, MWK 6,201,000 PROFIT AT YEAR 10

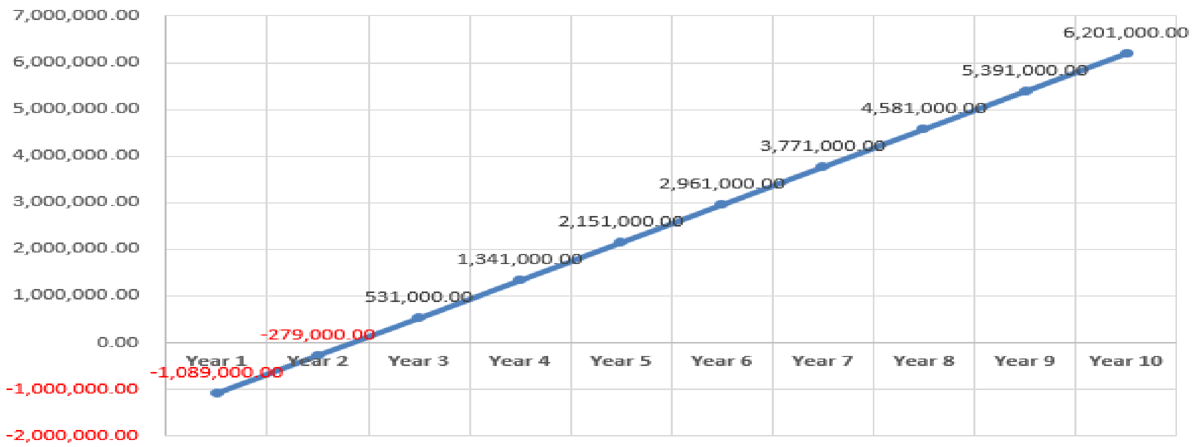
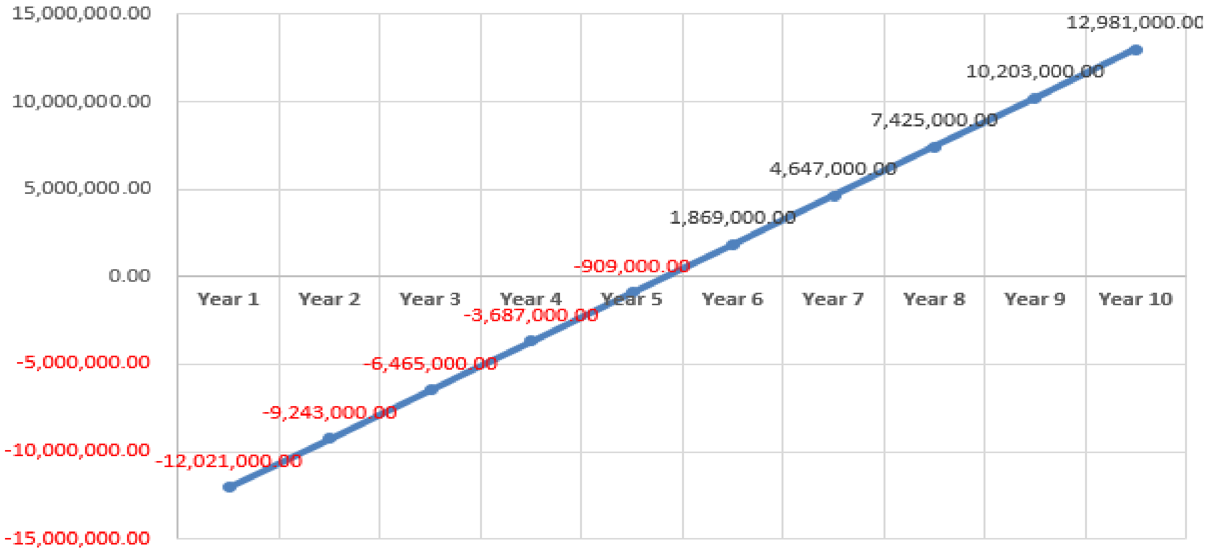


FIGURE 29 SCENARIO 2 – AVERAGE INCOME, SMALL PUMP: PAYBACK IN YEAR 3, MWK 5,591,000 PROFIT AT YEAR 10

FIGURE 30 SCENARIO 3 HIGH INCOME, GRUNDFOS PUMP, PAYBACK AFTER 5 YEARS, MWK 12,981,000 PROFIT AT YEAR 10



5.2.8. Irrigation Conclusions and Discussion

There is a high profit margin for Irrigation from the answers that were given in the surveys. Similar to maize milling, the number of farmers in Malawi is high, so finding a profitable business model for solar PV irrigation would attract a high customer base.

The fastest payback comes from a low income on the cheapest pump, which breaks even in the second year. If this was modelled with average or high incomes then the payback period would reduce further. This indicates that floating pumps are feasible for irrigation farmers in Malawi. The small pump options give a payback after 3 years, which is possible with the right funding model and could still be attractive to farmers in Malawi. The Grundfos pays back after 5 years which would be less attractive for farmers in Malawi but still not unfeasible. In general, irrigation seems profitable and viable businesses can be devised around solar irrigation.

The business models calculated are very site specific, site assessments must be made for the suitability of water courses. The highest viability scenario is for floating pumps, which are specifically suited for communities living close to rivers. The actual number of farmers living in areas close to rivers might be relatively low.

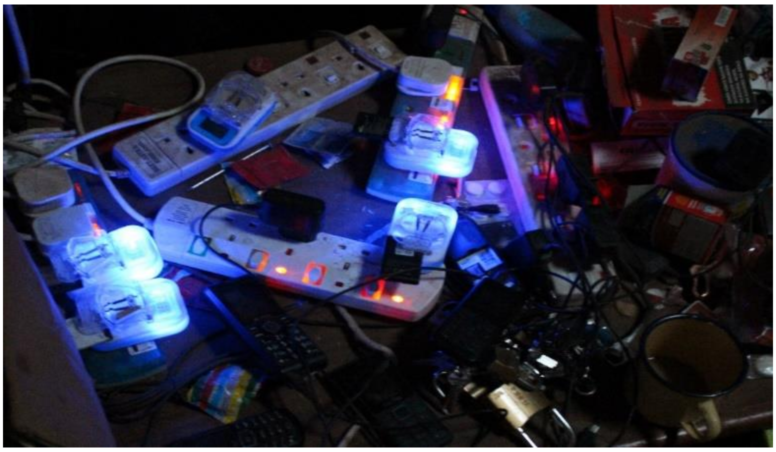
If the farmer has to purchase land then the payback periods could increase. The analysis gives a basis indication using the assumptions stated, further research is needed into the profit that can be made from high income crops – specifically what the hectares irrigated results in income for different types of crops. Also dependent will be soil type, availability of seeds and equipment.

5.3. Small Sales and service businesses

The examples of the sale and services shops include grocery, phone charging, barber shop and selling cold drinks. There are already many of these types of businesses in rural Malawi being powered by solar PV systems. The comparative low start-up costs would indicate that this scale of business, with the right business plan and appropriate funds for start-up, could be successful in Malawi. It was found that income is seasonal, as when farmers sell their produce they have spare cash to buy more products and services. 20 businesses gave information on small sales and services. 25% said they were already using a PV system, others said they weren't connected because it wasn't available.

Sales and service businesses were split into two categories (large and small) to reduce skewed results. Large businesses are classes as >100,000 per month income, small businesses <100,000 per month. Large business had very skewed results and few entries, so were not included in this study. Additionally, the large sales and service businesses fell into the category of grocery and hardware sales. The electrical needs for these shops will be mostly lighting, so the business case for including PV is not as clear, however investigating the feasibility for utilising PV should be included in a further study.

FIGURE 31 PHONE CHARGING BUSINESS



Most of the businesses surveyed were either barbershops or offering phone charging. Entertainment was also listed, with Other including "Sale electronic accessories", "Printing and photocopying", "Agro dealers of maize seeds" and "Uploading music in phones". Figure 32 shows the percentage of respondents offering a certain business, while Figure 33 shows the frequency of different combinations of businesses offered.

FIGURE 32 PERCENTAGE OF RESPONDENTS OFFERING A CERTAIN BUSINESS

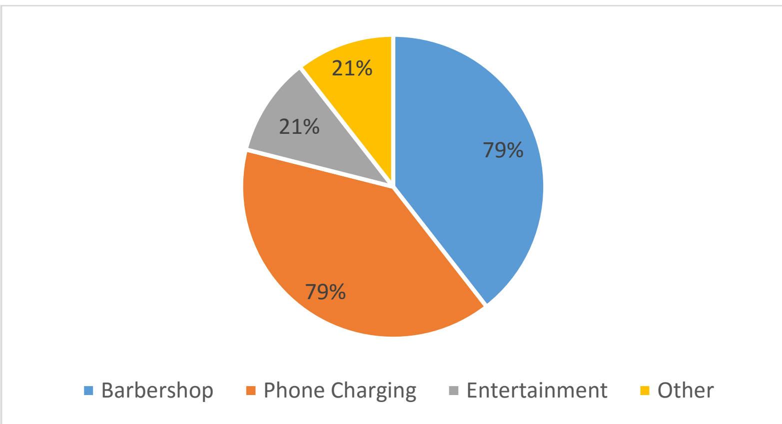
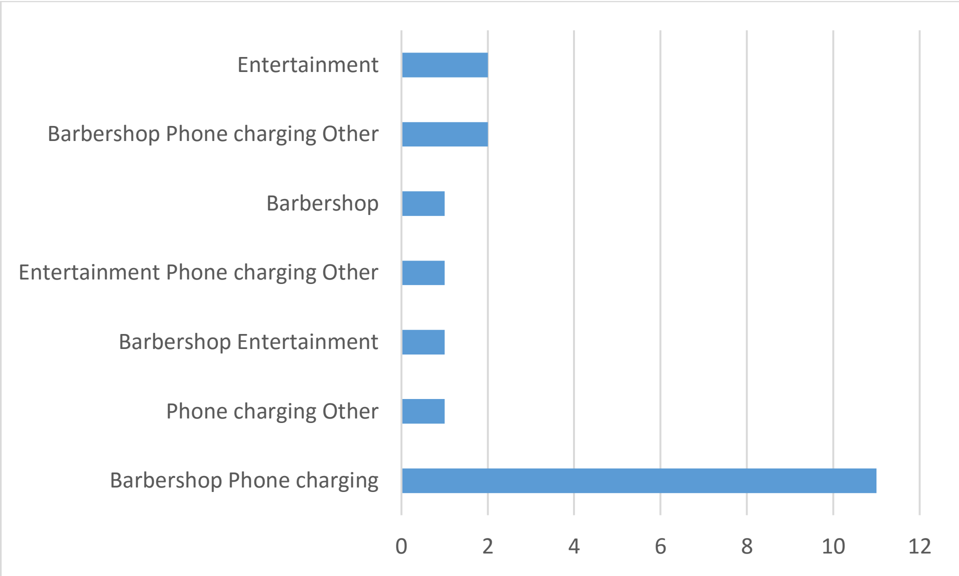


FIGURE 33 FREQUENCY OF DIFFERENT COMBINATIONS OF BUSINESSES OFFERED.



It can be seen that barbershop and phone charging is the most popular combination of services offered. This business method will be used for the system design and cash flow forecasting later in this section.

5.3.1. Sales and Services Load Profiles

Table 13 Power use and appliance cost for each device for service businessesshows the cost of the main appliances used in sales and services, with their associated cost and Power rating. All appliances were AC. Figure 34 shows the probability of a certain appliance being on or off during the day. The busiest part of the day can be seen coinciding with usual opening hours.

Figure 35 and Figure 36 show the same probability multiplied by the power rating for each device. This gives an indication of the load profile for each appliance over the day and relative to each other in terms of power use.

TABLE 13 POWER USE AND APPLIANCE COST FOR EACH DEVICE FOR SERVICE BUSINESSES

Item	Cost (MWK)	Power (W)
Radio	61,000	14
Hair clippers	14,000	25
Fridge	180,000	300
Laptop	100,000	12
Amplifier	47,500	559.5
TV screen	36,500	47.5
DVD player	15,000	25

FIGURE 34 THE PROBABILITY OF EACH SALES AND SERVICE APPLIANCE BEING 'ON' AT DIFFERENT TIMES OF DAY (BETWEEN 0 AND

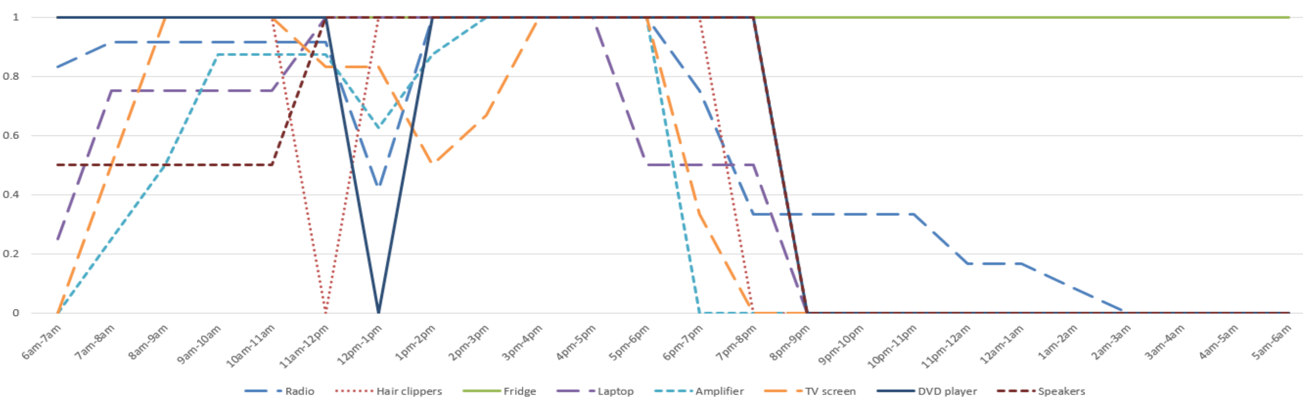


FIGURE 35 THE PROBABILITY MULTIPLIED BY THE POWER RATING OF THE APPLIANCE TO GIVE THE RESPECTIVE LOAD PROFILES FOR EACH APPLIANCE.

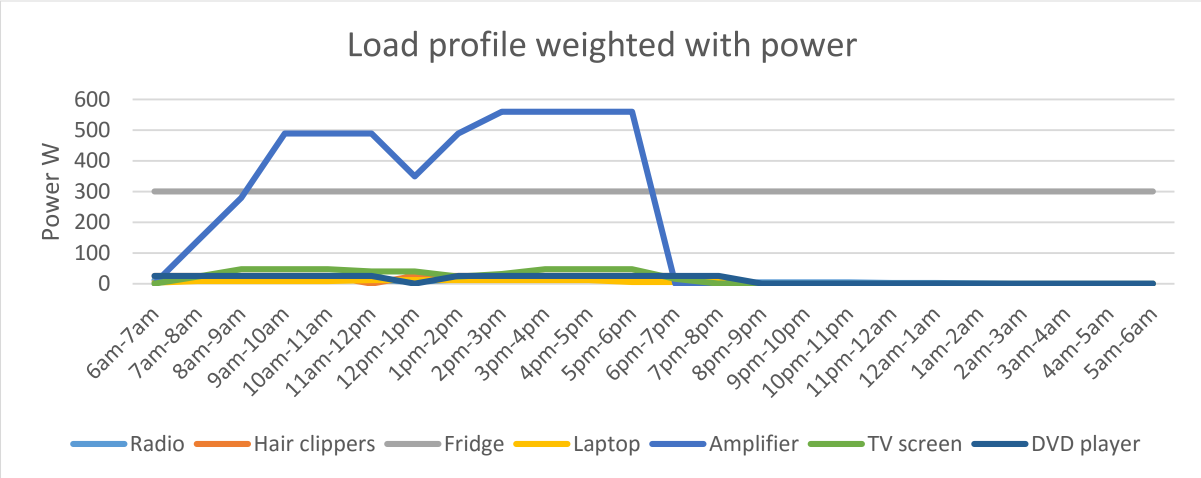
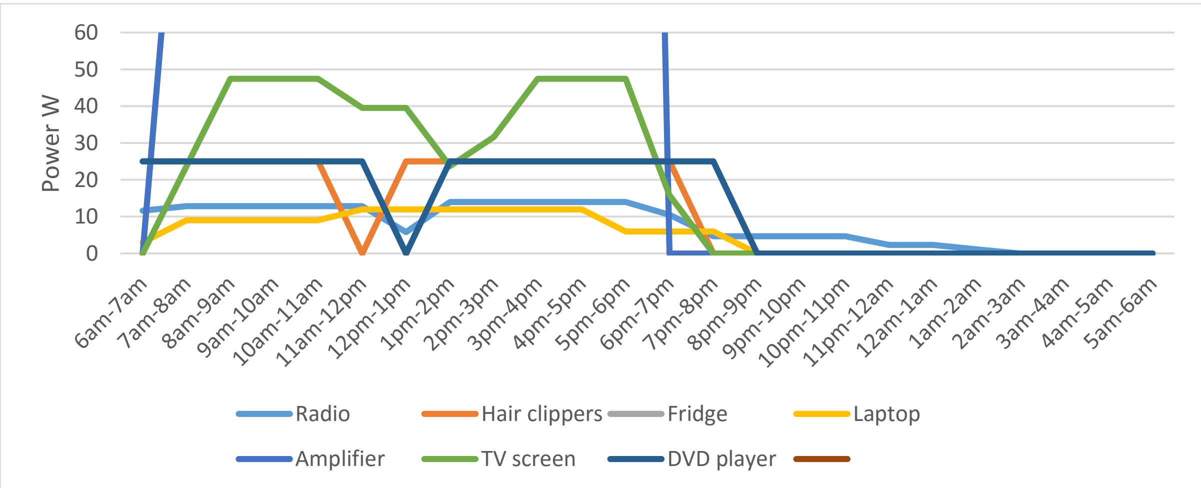


FIGURE 36: ZOOM INTO THE RELATIVE LOW LOAD APPLIANCES (THE SAME AS THE PREVIOUS GRAPH).



5.3.2. Sales and Services Design and Costs

Assumptions made for the design can be found in Appendix 6, a description of the systems is below with associated costs. All costs are in MWK. The costs include 2.5mm cables and circuit breakers.

TABLE 14 ASSUMPTIONS FOR DESIGN OF SYSTEMS

Type of system	Size of PV(W)	Rating of Battery(Ah)	Charge Controller(A)	Inverter (Watts)	Appliances
Phone Charging station	60	100	6	300	Phones, Bulb
Video show	1000	576	30	300	TV,DVD/Decoder, Bulb
Phone Charging Barbershop*	60	100	6	300	Phones. Shavers, bulb
Barbershop	60	100	6	300	shavers, bulb
Refrigeration+	500	288	30	500	Refrigerator, bulb

*This design assumes that a maximum of 30 phones will be charged per day

+The design assumes that the refrigerator will operate for 8 hours

TABLE 15 COST OF SYSTEMS

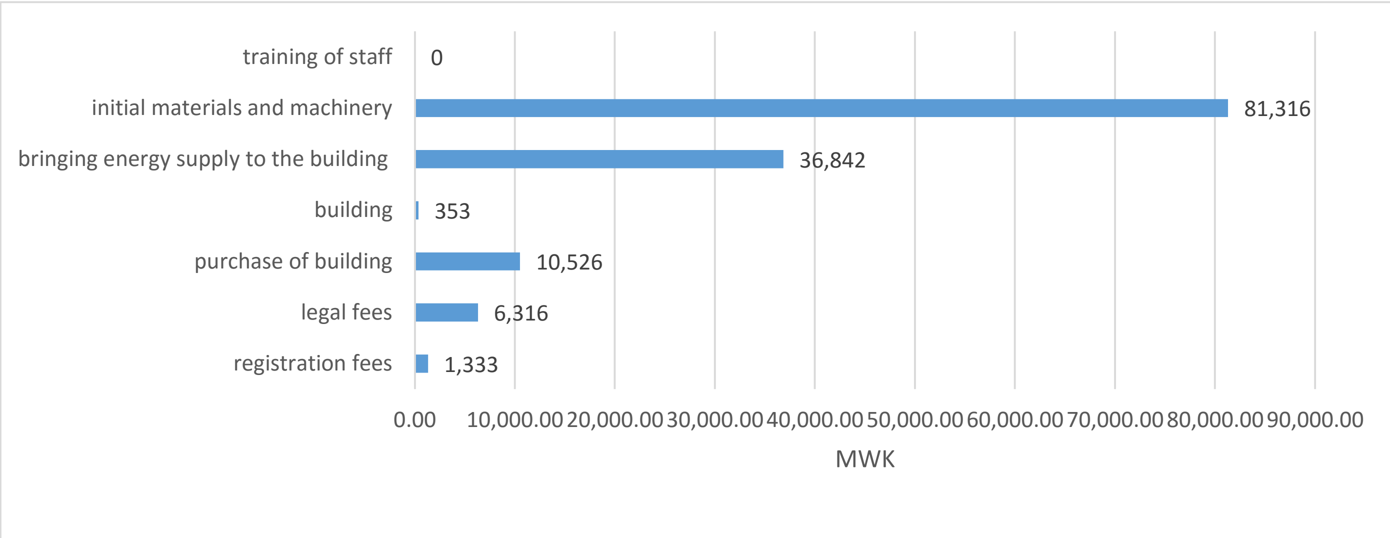
Type of system	PV (MWK)	Battery (MWK)	Charge Controller (MWK)	Inverter (MWK)	Other Accessories (MWK)	Installation Costs (MWK)	Total System Cost (MWK)
Phone Charging station	58,000	125,552	25,000	40,432	10,000	77,695	336,679
Video Show	880,000	632,016	70,000	40,432	20,000	492,734	2,135,182
Barbershop	58,000	125,552	25,000	40,432	10,000	77,695	336,679
Barbershop + Phone Charging	87,000	125,552	25,000	40,432	15,000	87,895	380,879
Refrigeration	440,000	697,680	70,000	140,000	25,000	411,804	1,784,484

For the business forecasting, a barbershop and phone charging system will be used, at a cost of **MWK 381,000** (rounded to the nearest MWK 500).

5.3.3. Sales and Services CAPEX

The CAPEX summary for sales and services is shown below, along with a max, min and mean for the total CAPEX displayed in Figure 37. A large variation in CAPEX cost is shown in purchase of building, initial materials and machinery and bringing in energy supply. These CAPEX items can vary significantly depending on business and energy connection.

FIGURE 37 SALES AND SERVICE CAPEX BY TYPE



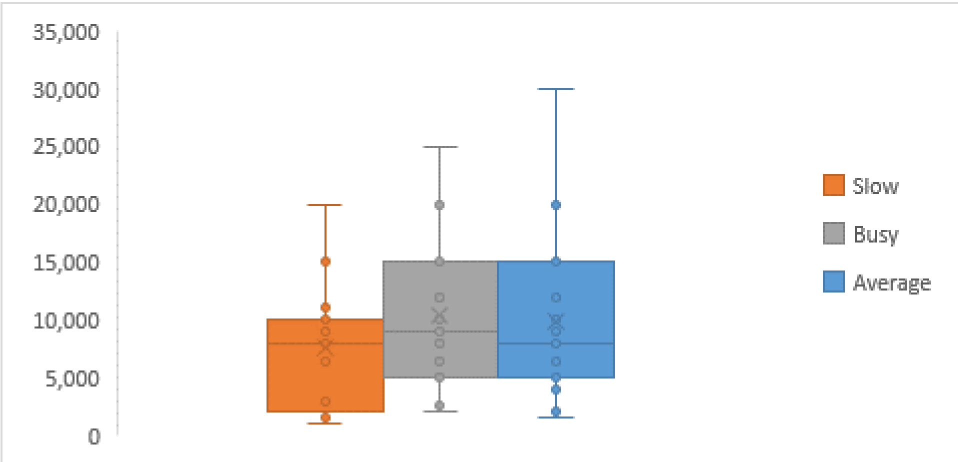
TOTAL CAPEX	
MEAN	136,616
MAX	360,000
MIN	0

The CAPEX used for business cash flow forecasting is the mean, which is **136,616 MWK**

5.3.4. Sales and Service OPEX

The OPEX costs for a slow, busy and average month are shown in Figure 38, with a summary of the mean, max and min values for each scenario listed underneath. Mean values range from 9,800 MWK to 10,363 MWK, minimum range from 1,000 MWK to 2,000 MWK and mean values range from about 7,500 MWK in a slow month to 10, 300 MWK in a busy month. There is not a huge variation in figures.

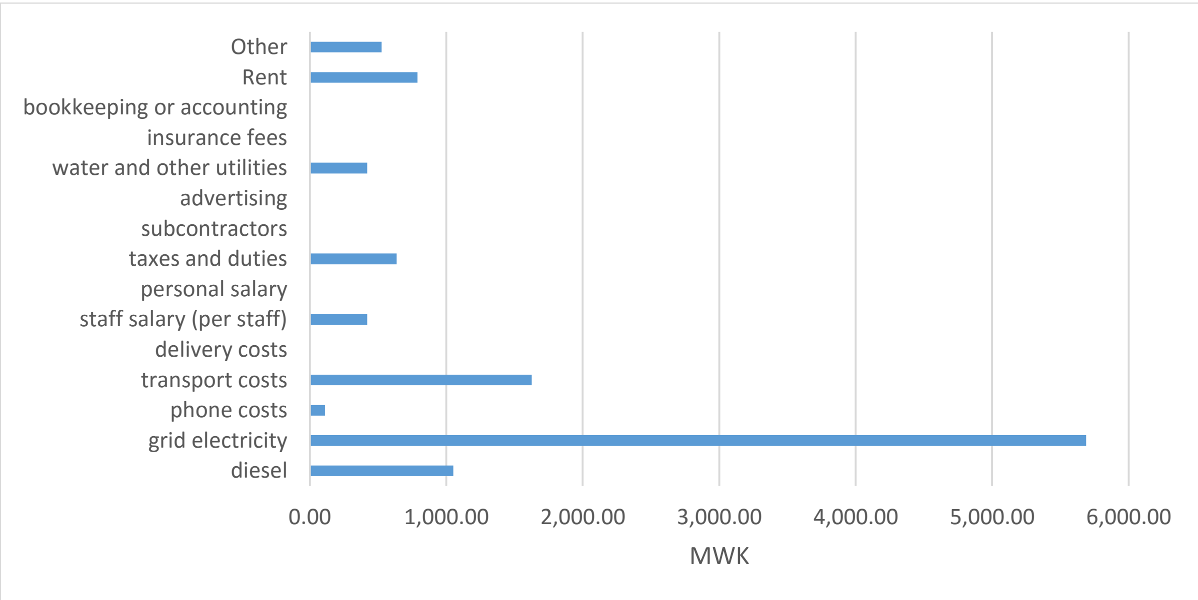
FIGURE 38 SALES AND SERVICE OPEX



	Average	Slow	Busy
MEAN	9,811	7,547	10,363
MAX	30,000	20,000	25,000
MIN	1,500	1,000	2,000

These costs are then broken down into OPEX by type, which is shown in Figure 39 below. It is clear that grid electricity costs dominate the OPEX, and that electricity is a driving cost of the business. It is interesting to note that personal salaries are not reported, assuming that as it is a small business then the profits are taken directly. Transport, rent and taxes are other noticeable OPEX costs, but in general the OPEX costs are few, and low in cost.

FIGURE 39 SALES AND SERVICES OPEX BY TYPE



Given the large energy OPEX costs, analysis was completed to remove the grid electricity and diesel from the calculation, to model a business running from solar PV that does not have these costs. The Max, Min and Mean values following this analysis is shown below, and will be used for the business modelling.

Table 16 Summary of Sales and Service OPEX used for business planning

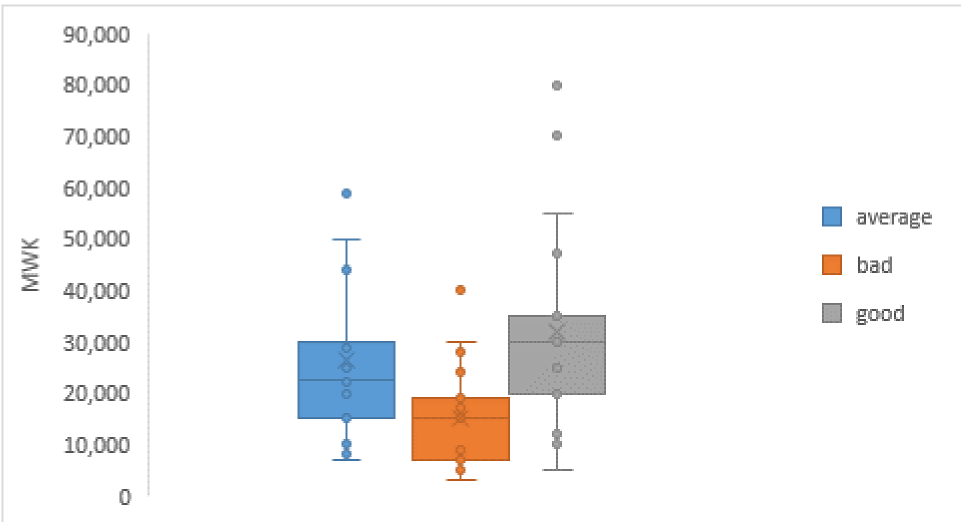
	OPEX (MWK)	OPEX without energy (MWK)
MEAN	11,268	4,526
MAX	47,100	23,100
MIN	1,400	0

It is interesting to note that many businesses only stated grid electricity as their only OPEX costs, which meant their overheads were zero without energy costs included. Although it is unlikely they will have no OPEX costs, the business owners obviously regard them as negligible in comparison to the energy costs they've stated. Similarly, as mentioned previously, business training is needed to assist business owners in keeping track of these costs, as they are obviously not being recorded. For the business forecasting a value of **MWK 4,500** will be used for OPEX without energy

5.3.5. Sales and Service Income

Shop keepers were asked to estimate their income for a good, bad and average month. This is shown in the graph below, with a summary of the mean, max and min values for each monthly scenario. The incomes are approximately double the OPEX cost previously calculated.

Figure 40 Sales and Services monthly Income as estimated by the shop keepers.



	Average (MWK)	Bad (MWK)	Good (MWK)
MEAN	26,500	15,000	32,000
MAX	60,000	40,000	80,000
MIN	7,000	3,000	5,000

The respondent included their cost of service charges and for barbershop and phone charging are displayed below:

Figure 41 Prices for Barbershop and Phone Charging Businesses

Business	**Range (MWK)**	**Most common answer (MWK)**
Barbershop	100 – 200	mostly 150
Phone Charging	30 – 100	mostly 50

5.3.6. Sales and Services Cash Flow

As with previous business cases, different scenarios have been run on a profit and loss basis to determine the viability of businesses. Income is taken from the mean of average, good and bad estimates respectively (rounded to the nearest 500 MWK), OPEX is set as the mean without energy. Solar OPEX is taken as 20% of Solar PV Capital costs, annually, divided by 12 to get a monthly figure. All numbers have been rounded to the nearest 500. Scenarios are run for a barbershop and phone charging business.

TABLE 17 SUMMARY OF SALES AND SERVICE INPUT PARAMETERS FOR BUSINESS CASH FLOW

Scenario	Description	Income	OPEX	Solar OPEX	Total OPEX	CAPEX	Solar CAPEX
1	Good	32,000	4,500	6,500	11,000	136,500	381,000
2	Average	26,500	4,500	6,500	11,000	136,500	381,000
3	bad	15,000	4,500	6,500	11,000	136,500	381,000

FIGURE 42 SCENARIO 1 PAYBACK IN YEAR 2, MWK 2,002,500 PROFIT IN YEAR 10

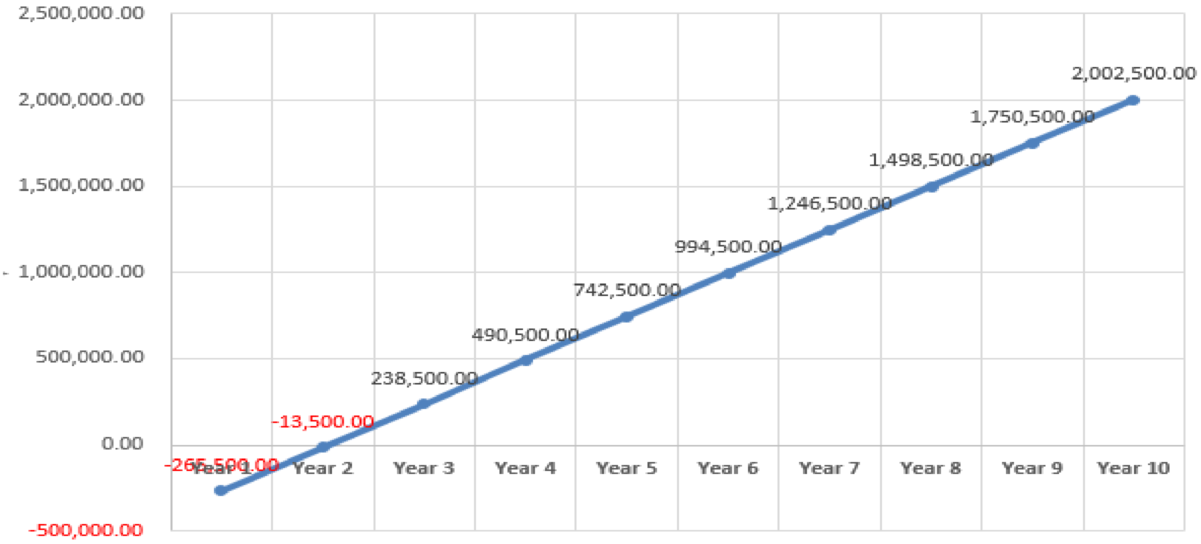


FIGURE 43 SCENARIO 2 PAYBACK IN YEAR 2, MWK 1,342,500 PROFIT IN YEAR 10

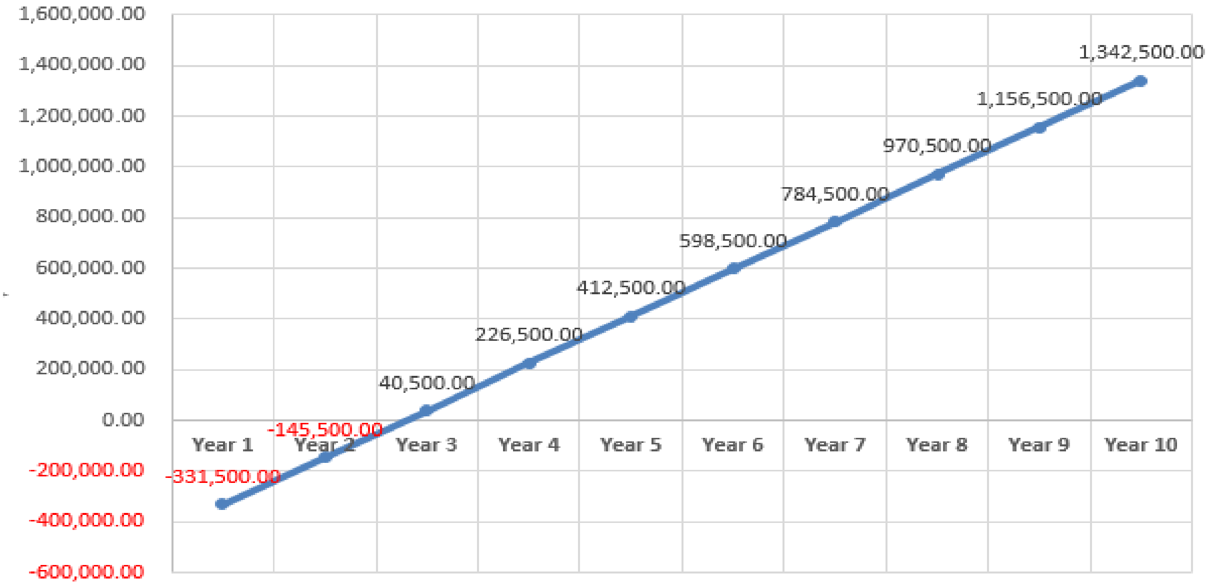
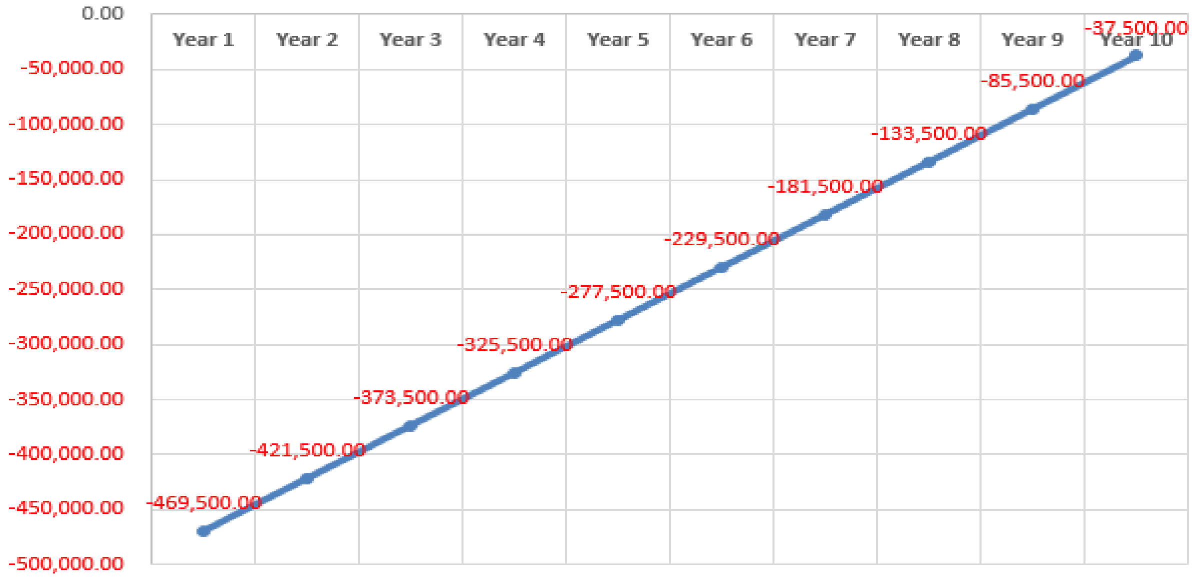


FIGURE 44 SCENARIO 3 – NO PAYBACK IN YEAR 10



5.3.7. Sales and Services Conclusions

For the average and good scenarios, the business cash flows show the shortest paybacks of all the business modelled so far (2 years). The key reason for this is low CAPEX and relatively low OPEX. The relatively low start-up fee will make these options attractive to entrepreneurs, but a cost of MWK 381,000 still may be prohibitive for many, without financing arrangements. The jump to >10 year payback for the worst scenario is due to significantly lower income estimates for this scenario from the business owners. This should be taken into consideration as any business can suffer a slow month which can affect cash flow. However, of all the businesses modelled, a barber shop and phone charging business gives some of the lowest paybacks of all modelled businesses so should be pursued as viable options for solar powered businesses in rural Malawi.

Scenarios have not been run for refrigeration or grocery businesses, as system costs to run a fridge are substantially higher. Similarly the link between income and electricity is less easy to quantify for grocery businesses, however cold drinks and shop lighting was indicated as a need in the community so the business case for these businesses should be investigated in further studies.

The systems have been designed to be of higher quality and associated higher cost, lower cost systems may be possible which would reduce the initial start-up costs, however guarantee cannot be given on quality. The 20% solar maintenance cost has caused the low income option to be unfeasible, due to the tight margins on income and expenditure, if there was a way to reduce these costs by training local technicians to conduct maintenance could reduce these costs and make the systems feasible.

5.4. Repair and Manufacture Businesses

Businesses offering repair and manufacture were considered together, 23 businesses offering these services were surveyed. This includes phone repair (2), tailoring (4), grinding and welding (8), carpentry (6) and electrical repair (3). These businesses are grouped together as their energy requirements are expected to be significantly more than businesses offering 'services and sales'. Utilising information found in previous markets assessments outline din the literature review, a focus has been put on tailoring and metal workshop businesses, as these have scored highly on priority within communities in Malawi.

FIGURE 45 WELDING BUSINESS

5.4.1. Repair and Manufacture Load Profiles

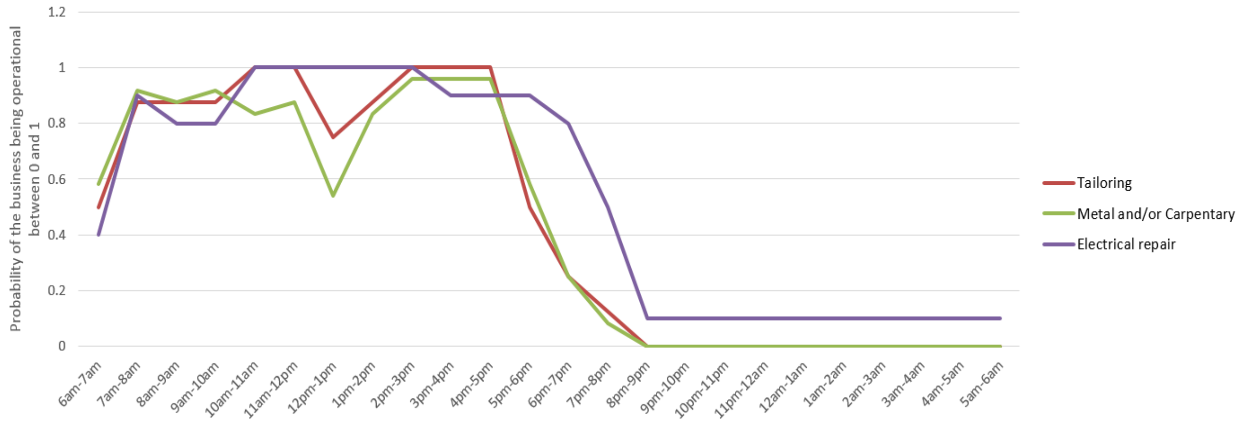
For all repair and manufacture businesses surveyed, the machinery is run using grid electricity (as seen in OPEX spend) rather than diesel. From survey responses, Table 18 summarises the electrical appliances and machinery being used by repair and manufacture businesses with cost rating and usage.

The information in Table 18 can be used to consider repair and manufacture energy use through the working day and therefore business load requirements. Figure 46 shows the load profiles expected over the day for tailoring, metal work and/or carpentry (many businesses did both) and electrical repair.

TABLE 18 ITEMS NECESSARY FOR REPAIR AND MANUFACTURE BUSINESSES AND THEIR POWER RATING FROM THE SURVEY RESULTS.

Item	cost MWK	Power W	AC/DC	Number of hrs ran
Welding equipment	150,000	2000	AC	unknown
Drilling machine	30,000	65	AC	4
Soldering station	450,000	2	AC	2
Laptop	75,000	800	AC	12

Figure 46 Load profile over one day (probability between 0 and 1) based on survey responses for the different medium businesses of tailoring, metal or carpentry workshop and electrical repair



5.4.2. Repair and Manufacture CAPEX

The CAPEX for these businesses shows initial materials and machinery as a significant spend at the start of a repair and manufacture business. 23 repair and manufacture business owners gave information on CAPEX for starting a repair and manufacture business within the categories of:

Table 19 Repair and Manufacture CAPEX

Capex type	Number of businesses	Average cost
Initial materials and machinery	19	120,000 MWK
Registration fees	11	6,600 MWK
Other	6	4,000 MWK
Bringing energy supply to the building	3	75,000 MWK
Purchase of building	3	83,000 MWK
Renovation of building	1	10,000 MWK

Figure 47 shows a typical CAPEX spend profile for repair and manufacture businesses. The most significant expenses are bringing energy supply and building purchase, closely followed by initial materials and machinery. The average CAPEX value is 134,000 MWK for repair and manufacture businesses (as shown in **Error! Reference source not found.**).

Figure 47 Typical CAPEX for repair and manufacture businesses, from a survey of 23 repair and manufacture businesses.

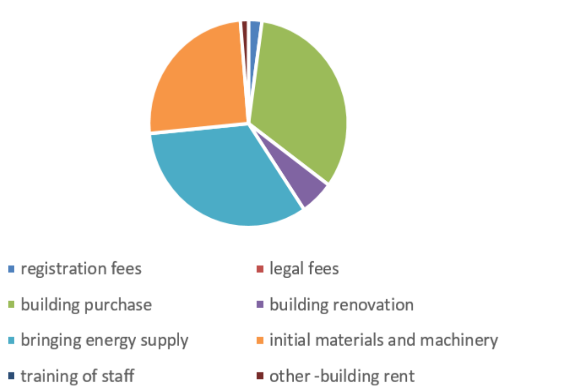


Figure 48 CAPEX values for repair and manufacture businesses.

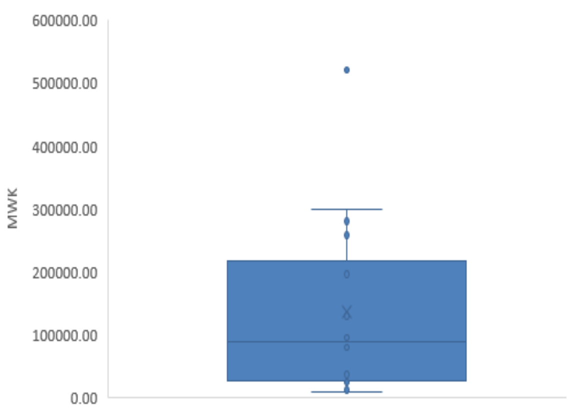
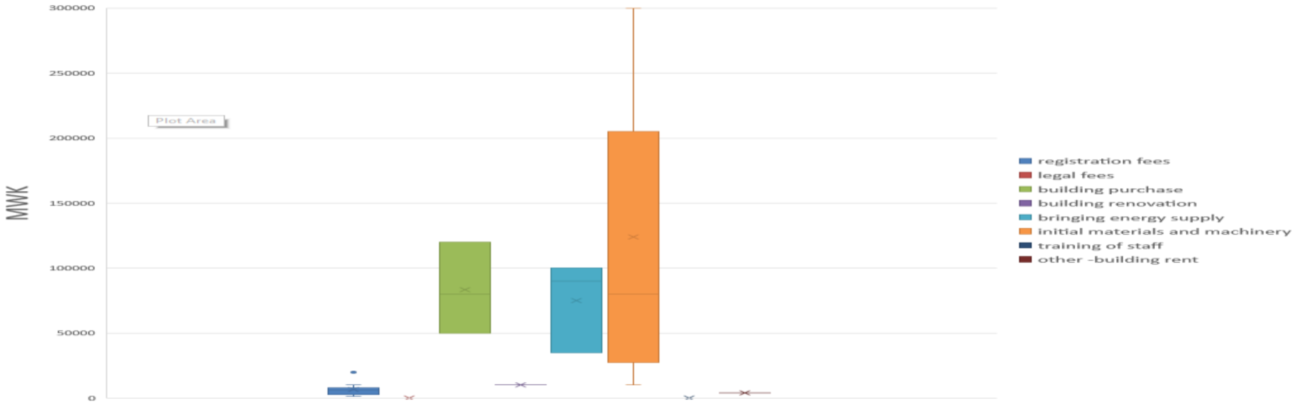


Figure 49 shows the data for CAPEX spend for repair and manufacture businesses. The three most significant CAPEX spends of energy supply, building purchase and initial materials and machinery dominate with large spreads.

FIGURE 49 SPEND ON CAPEX FOR SALES AND SERVICE BUSINESSES. THE THREE MOST SIGNIFICANT CAPEX SPENDS OF ENERGY SUPPLY, BUILDING PURCHASE AND INITIAL MATERIALS AND MACHINERY DOMINATE WITH LARGE SPREADS.



Further Analysis was conducted to get accurate CAPEX costs for Tailoring and Metal Workshop for business planning, shown below.

TABLE 20 TAILORING AND METAL WORKSHOP CAPEX

	Tailoring (MWK)	Metal workshop (MWK)
AVERAGE	71,250	155,557
MAX	200,000	520,000
MIN	15,000	10,000

5.4.3. Repair and Manufacture OPEX

The OPEX spend for repair and manufacture businesses can be similarly analysed. 23 repair and manufacture business owners gave information on OPEX for running a repair and manufacture business within the categories outlined below.

TABLE 21 REPAIR AND MANUFACTURE OPEX BY CATEGORY

OPEX Category	Number of Businesses	Average Cost (MWK)
Transport costs	11	14,000
Grid electricity costs	9	8,000
Staff salary	9	16,000
Personal salary	7	29,000
Phone costs	4	3,000
Delivery costs	3	10,000
Taxes and duties	2	2,000
Water and other utilities	2	3,000
Charcoal and cells for torch	2	500
Advertising	1	7,000
Subcontractors, Legal costs, Diesel costs, Book keeping or accounting, Insurance fees	0	

Figure 50 and 51 shows a typical OPEX spend profile for repair and manufacture businesses. The most significant expenses are personal salary, followed by staff salary and transport costs. Most noticeable, is the lack of spend on diesel, which is a significant spend for other businesses. The average OPEX value is 31,000 MWK for repair and manufacture businesses.

FIGURE 50TYPICAL OPEX SPEND FOR REPAIR AND MANUFACTURE BUSINESSES.

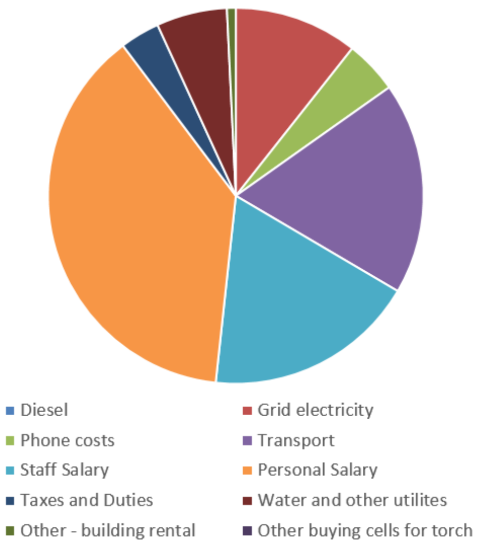
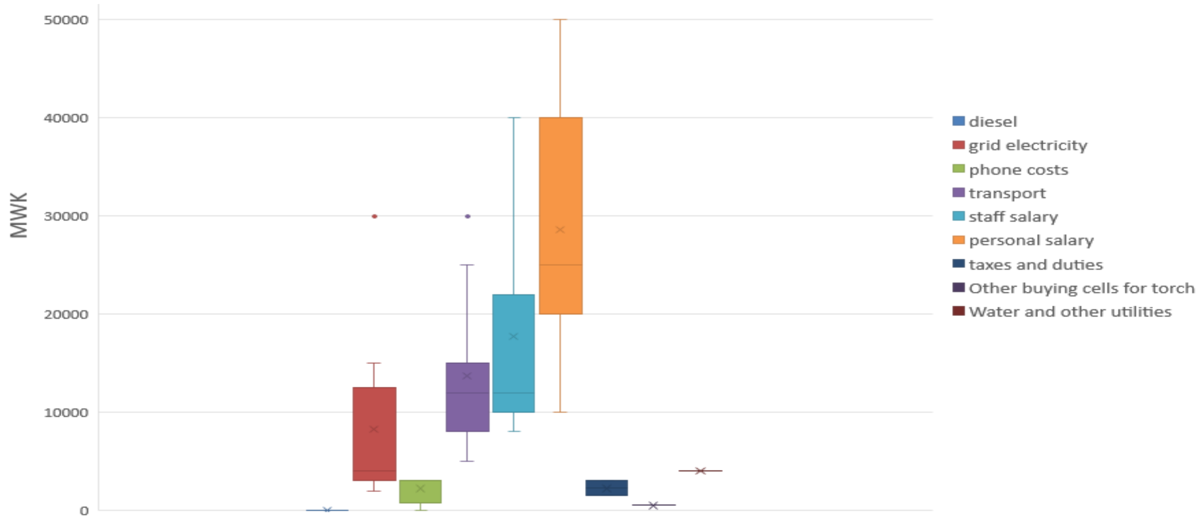


FIGURE 51 OPEX SURVEY DATA FOR 23 REPAIR AND MANUFACTURE BUSINESSES PER MONTH.



Additional analysis was conducted to separate out OPEX for Tailoring and a metal workshop, results rounded to the nearest 500 MWK are show below. These figure will be used for the business cash flow forecasting.

TABLE 22 TAILORING AND WOOD/METAL WORKSHOP OPEX

	Tailoring (MWK)	Metal Workshop (MWK)
average	7,000	71,500
slow	6,000	59,500
busy	9,500	93,000

5.4.4. Profit/Income

The business owner was asked to estimate the business income per month, as shown in Figure 52 for tailoring, Figure 53 for metal work and carpentry and Figure 54 for electrical repair. The estimated income from the owner per month for the three clasifications used for business cash flow is outlined in Table 23.

TABLE 23 INCOME FOR REPAIR AND MANUFACTURE BUSINESSES

	Average	Slow	Good
Tailoring	13,000 MWK	23,000 MWK	30,000 MWK
Metal workshop	246,000 MWK	192,000 MWK	314,000 MWK
Electrical repair income	150,000 MWK	75,000 MWK	170,000 MWK

FIGURE 52 INCOME AS ESTIMATED BY THE BUSINESS OWNER FOR TAILORING BUSINESSES.

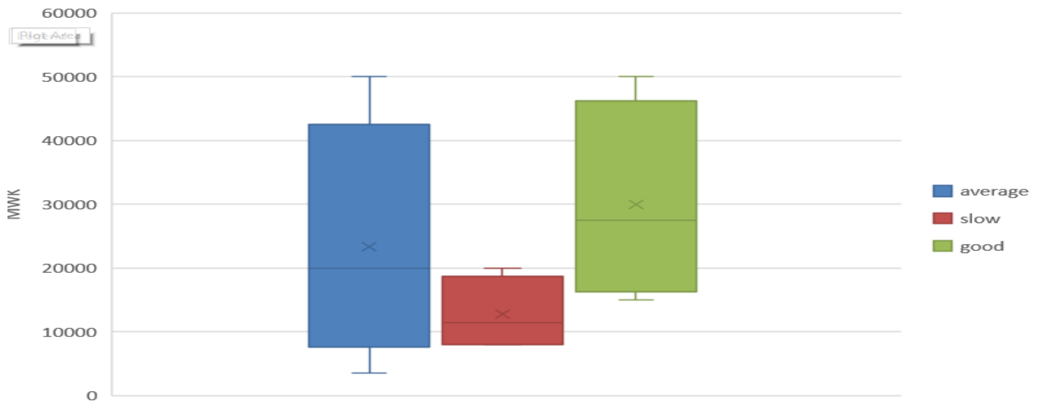


FIGURE 53 INCOME AS ESTIMATED BY THE BUSINESS OWNER FOR METAL WORK AND CARPENTRY

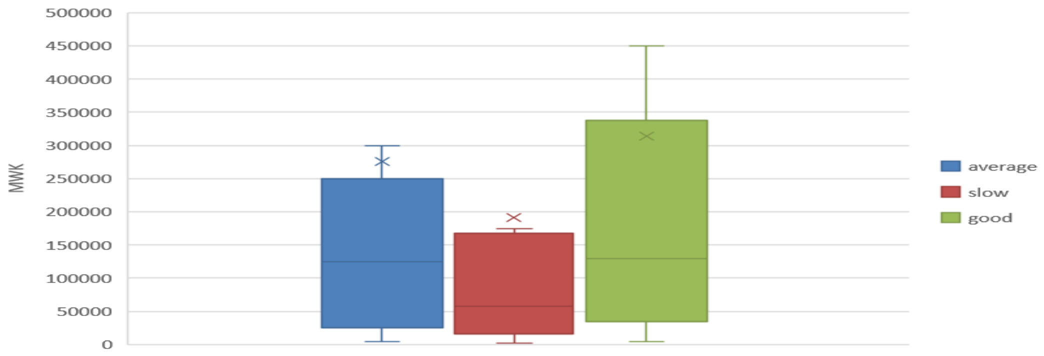
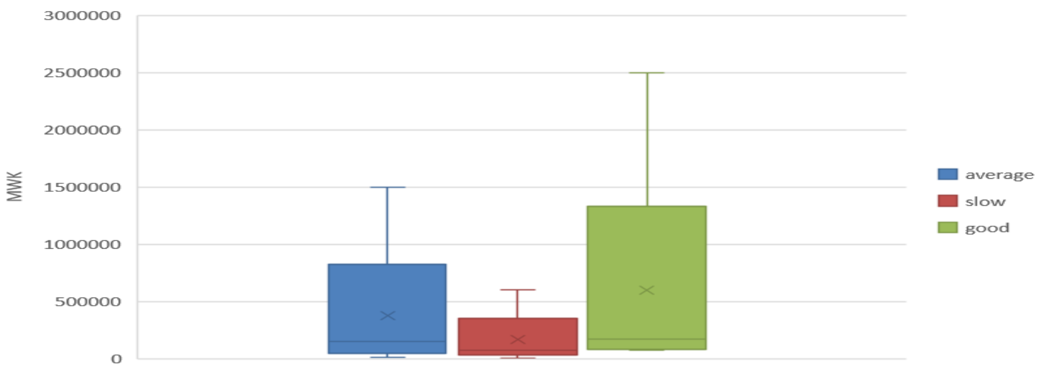


FIGURE 54 INCOME AS ESTIMATED BY THE BUSINESS OWNER FOR ELECTRICAL REPAIR.



5.4.5. Repair and Manufacture Design and Costs

Systems were designed by Community Energy Malawi, using the following assumptions:

- The Angle grinder has been designed to operate for 4 hours while as the welding machine has been designed to operate for 1 hour.
- The sewing machine is rated at 100W and assumed to be used at full power for 4 hours, with the rest of the working day spent cutting, positioning and designing the fabric work.

An overview of the system parameters and associated component costs is outlined in Table 24 and Table 25 below.

TABLE 24 REPAIR AND MANUFACTURE SYSTEM PARAMETERS

Type of system	Size of PV (W)	Rating of Battery (Ah)	Charge Controller (A)	Inverter (W)
Sewing Machine	250	200	30	300
Metal Workshop	10,500	9,400	30	5,000

TABLE 25 REPAIR AND MANUFACTURE SYSTEM COSTS

Type of system	PV (MWK)	Battery (MWK)	Charge Controller (MWK)	Inverter (MWK)	Other Accessories (MWK)	Installation Costs (MWK)	Total System Cost (MWK)
Sewing Machine	220,000	105,336	70,000	40,432	15,000	135,230	585,998
Metal Workshop	3,960,000	4,700,000	70,000	490,000	20,000	2,772,000	12,012,000

5.4.6 Tailoring Cash Flow

3 Scenarios for tailoring businesses have been modelled, based on good, average and bad income with associated OPEX. As before, 20% maintenance costs have been calculated monthly and included in the total OPEX costs. 10 year cash flows for the three scenarios are show in Figures 56 – 58 below.

TABLE 26 SUMMARY OF INPUT PARAMETERS FOR TAILORING CASH FLOW

Scenario	Description	Income	OPEX	Solar OPEX	Total OPEX	CAPEX	Solar CAPEX
1	Good	30,000	9,500	10,000	19,500	71,250	586,000
2	Average	23,500	7,000	10,000	17,000	71,250	586,000
3	bad	13,000	6,000	10,000	16,000	71,250	586,000

Figure 55 Scenario 1: Payback in year 5, 602,750 profit at year 10

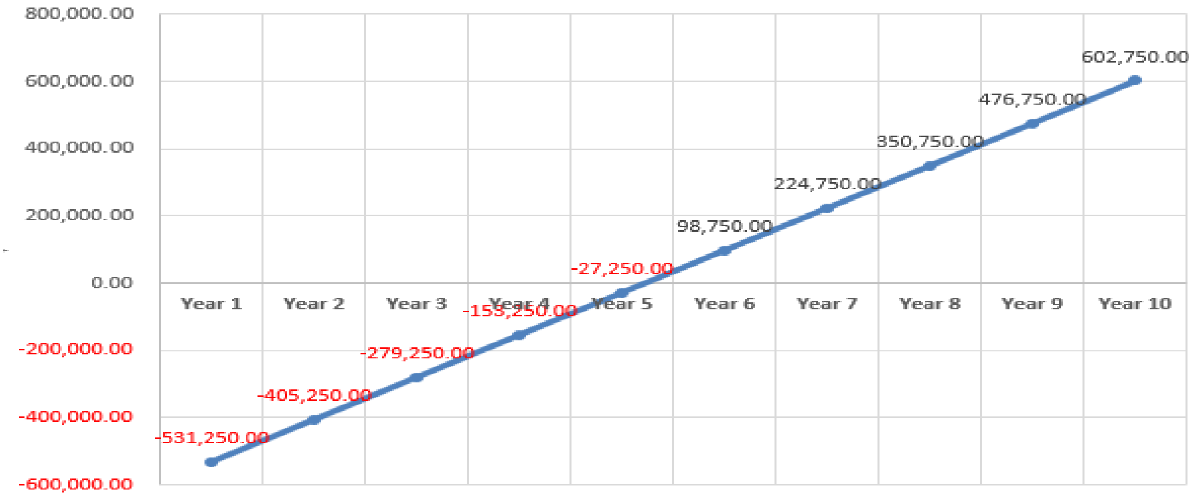


Figure 56 Scenario 2 – payback in year 8, 122,750 profit at year 10

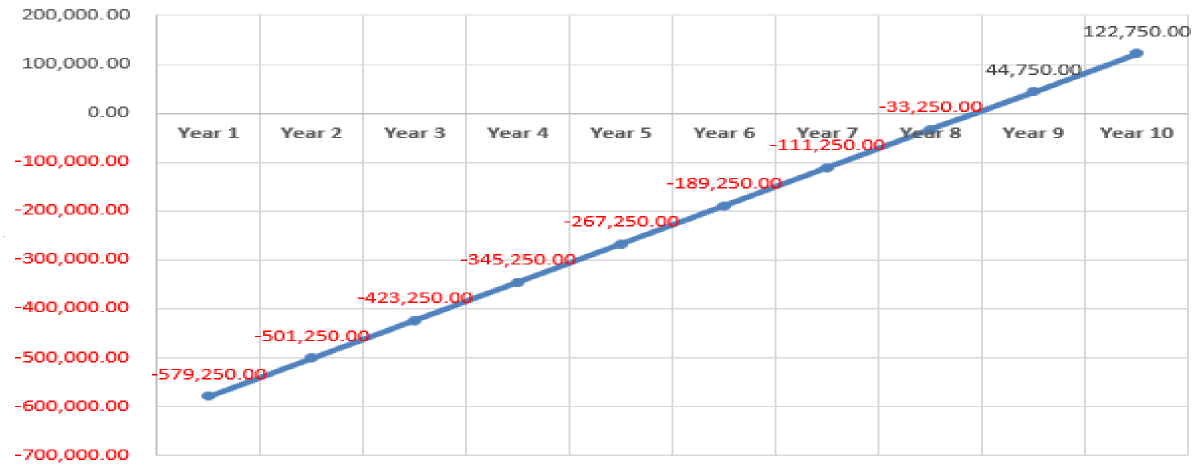
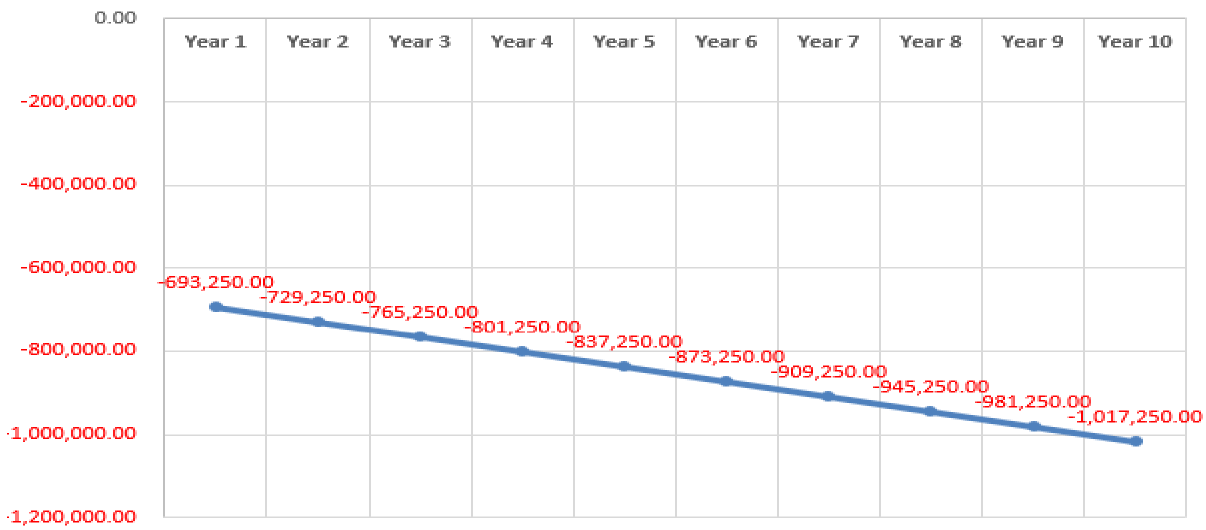


Figure 57 Scenario 3 – negative growth, no payback after year 10



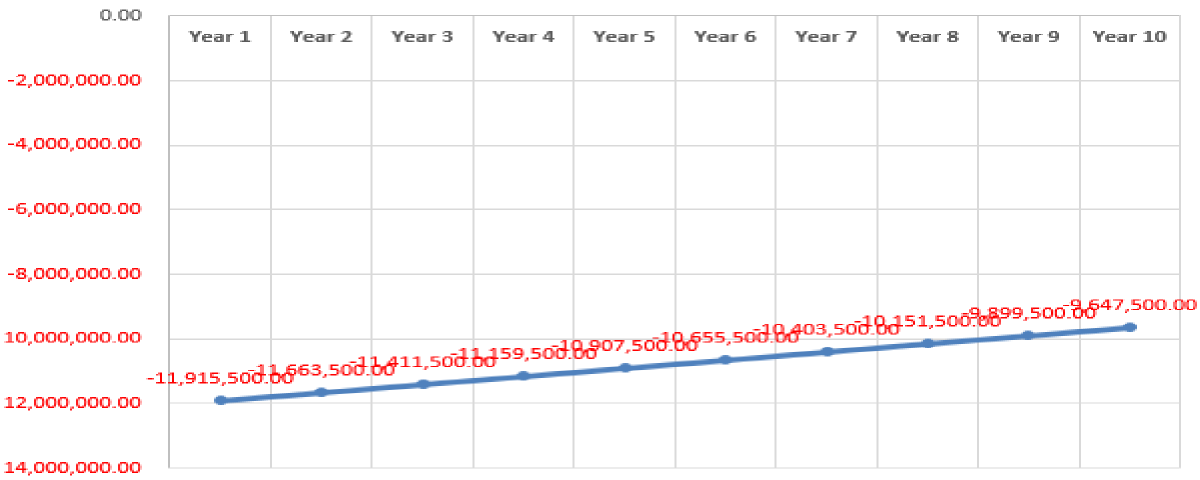
5.4.6 Metal Workshop Cash Flow

Only 3 businesses reported CAPEX of bringing electricity to the building (90,000 100,000 and 35,000), so these have not been removed from for the business cash flow forecasting. The same method has been applied as in previous businesses, whereby three scenarios have been modelled, with solar OPEX as 20% of capital costs monthly. Results for Scenario 1 are shown in Table 28. For Scenario 2 and 3, the total OPEX is higher than the income so profit will not be made, indicating no payback after 10 years, so these graphs have not been included.

TABLE 27 SUMMARY OF INPUT PARAMETERS FOR TAILORING CASH FLOW

Scenario	Description	Income	OPEX	Solar OPEX	Total OPEX	CAPEX	Solar CAPEX
1	Good	314,000	93,000	200,000	293,000	155,500	12,012,000
2	Average	246,000	71,500	200,000	271,500	155,500	12,012,000
3	bad	192,000	59,500	200,000	259,500	155,500	12,012,000

TABLE 28 SCENARIO 1 – NO PAYBACK IN 10 YEARS



5.4.7 Repair and Manufacture Conclusions

For the tailoring business, the good and average scenarios give paybacks of 5 and 8 years respectively, which indicate that businesses are profitable with a solar PV powered sewing matching, although the paybacks will likely be too high for most tailors. The low income scenario loses money each month and doesn't break even over the 10 years.

The profit margin (between income and OPEX) is relatively small, and in general the income is small. It is interesting to note that the OPEX is dominated by the solar component, and inding ways to reduce this would make the businesses more profitable.

The high cost of the solar PV system for metal workshop makes all systems unfeasible. This is despite relatively high income. The 20% solar maintenance estimate means that no profit is made on a monthly basis for the average and poor scenarios, and even on the optimistic scenario, the profit is not high enough to break even after 10 years.

6. Conclusions

6.1. Summary of Results

For the different businesses investigated, 3 scenarios have been run to output a simple profit and loss forecast over 10 years. A summary of the payback and profit at year 10 for each of the businesses modelled is shown below. An assessment of viability has been given, ranging from high to low, shown in Table 29.

TABLE 29 SUMMARY OF REPORT FINDINGS FOR DIFFERENT BUSINESS TYPES.

	Scenario 1		Scenario 2		Scenario 3		Viability
Businesses	Payback (years)	10 year profit (MWK)	Payback (years)	10 year profit (MWK)	Payback (years)	10 year profit (MWK)	
Irrigation	2	6,201,000	3	5,591,000	5	12,981,000	HIGH
Barbershop and Phone Charging	2	2,002,500	2	1,342,500	>10	0	HIGH
Maize mill	5	5,000,000	8	1,548,000	>10	0	MEDIUM
Tailoring	5	602,750	8	122,750	>10	0	MEDIUM
Metal workshops	>10	0	>10	0	>10	0	LOW

The high priority, or most viable businesses to be powered by solar PV have been shown to be Irrigation and barber shop and phone charging. Best case scenarios for these give a payback in under two years, and average scenario paybacks for 2 and 3 years respectively. Irrigation gives the highest 10 year profit of almost 13,000,000 MWK. Both are deemed to be in high demand in the communities and should be pursued.

Maize Milling and Tailoring businesses given paybacks of 5 and 8 years for best case and average case scenarios respectively, but neither pay back in 10 years in the worst case scenario. If long term financing can be arranged for these business they should be pursued. Both are also in high demand in the communities, with maize mill the most popular choice of the communities surveyed.

None of the scenarios modelled for the metal workshop business give a payback within 10 years, indicating that the system costs modelled are too high for the levels of income. Unless system costs can be reduced solar powered welding is unfeasible as a productive use in Malawi at this time.

Other businesses (cold drinks refrigeration, electronic repair, grocery shop lighting) have not been examined in detail as either they are not high priority in communities, or initial analysis has indicated expensive solar PV systems so unlikely to be profitable. Further investigation into these businesses should be completed to determine accurate 10 year cash flow forecasts.

6.2. Discussion

The analysis provides a snapshot of business costs in Malawi and it should be noted that costs are continually changing. The cost of solar PV has been reducing in recent years and may continue to do so. Similarly, as Malawi develops economically the income levels should increase with associated increase in ability and willingness to pay, making some businesses currently unfeasible more viable over time. Additionally, as economic development occurs in Malawi new types of businesses (such as ICT, internet, and communications) may become more viable as the market for such services increases.

Businesses are inherently difficult to model as they are influenced by a huge variety of parameters. The challenges for businesses in Malawi highlighted in the literature review should be considered in depth and mitigated to reduce risk to start-up businesses. More in depth financial modelling should to include interest rates on loans, and yearly increase in costs should be conducted to reveal greater insight and help to reduce risk.

For smaller system, the solar PV maintenance is quite a high proportion to the overall OPEX costs. It is essential that businesses save money to maintain and repair the systems if they fall into disrepair, however the 20% figure is making the cash flow non profitable for many businesses. The 20% is an estimate taken from experienced installers, and accurate figures should be obtained where possible. Ways of reducing the costs should also be investigated such as local technicians conducting the maintenance to reduce on transport costs. Solar PV maintenance costs increase for remote installations, as the maintenance team have further to travel so the transport costs and total costs increase. These can be reduced by training local community members in how to maintain the systems. This is a method that CEM have been promoting and should continue to do so.

For household businesses, for example a phone charging business run from somebodies house, the business owner will also be using the system for household use (e.g. lights and phone changing). These savings from household energy spend (such as a reduction in battery or kerosene uses) can be included in the modelling as effectively another source of income, which would further increase the viability of the businesses.

The system designs have assumed that all appliances used are standard AC appliances. The availability of AC appliances is high in most areas of Malawi, however the use of AC appliances necessitates the need for an inverter, which increases the costs. The use of DC appliances, which can run directly off batteries negates the requirement of an inverter which can significantly reduce costs. Examples of DC appliances include sewing machines, soldering irons, and phone chargers. These appliances are not yet common in Malawi, meaning that they will be imported and if they break, expensive and difficult to replace. However further investigation should be conducted into the cost benefit ratios of introducing DC appliances.

6.3. Limitations to the study

There were noted problems and limitations with the survey data, specifically:

- Wide ranges in inputs, indicating a big difference in the scale of the businesses
- Figures are often estimates, with business owners having low recall,
- Some businesses owners weren't able to read or write, further lowering
- Some business owners might not give correct answers for fear of tax reasons,

- Some may not keep accurate records.

In the surveys it is apparent phone costs, subcontractors, insurance, advertisement, book keeping and accounting are rarely part of OPEX or CAPEX. This seems unrealistic and may be due to a lack of training and noting the costs rather than lack of the cost itself. Assuming this is true, CAPEX and OPEX costs may be slightly higher than actual results from this study to account for spend in these areas. However it can be shown that lack of training on how to carry out business operations is a challenge. This suggests that the running cost could be slightly higher than the actual found on this study.

No in depth analysis has been included on willingness to pay of the communities for the services offered. One way of making the businesses more profitable would be to increase the cost of the sales or services offered. Although most people are poor in Malawi, they are currently travelling a long distance to the nearest electricity connection to get their services. This distance travelled should relate into a willingness to pay higher costs. Quantifying these figures to feed into detailed businesses plans would add strength to the analysis presented here.

This study has focussed on standalone PV applications, although there is a high potential for this level of system, further research should investigate energy supplies from minigrids, as they have been identified as a high growth area for Malawi.

Finally, research bias should be stated as CEM and UoS have a stake in promoting PUE in Malawi.

7. Recommendations and Next Steps

Recommendations for taking forward productive uses of energy in Malawi, specifically for CEM, are given below. The main focus suggested is to pilot priority businesses, and effectively monitor the technical performance of the solar PV systems (logging loads profiles and actual use of energy) as well as monitoring financial data such as income and expenditure to determine exactly how viable these businesses are. The results of the pilot projects will inform scale up of business implementation across Malawi, at which stage appropriate financing mechanisms and training programs for entrepreneurs should be investigated fully.

Recommendation	**Description**	**Timescale**
Further analysis	The kobo surveys contained more questions looking into influencing parameters of businesses, these can be analysed to give further qualitative information to inform the study	Short
Pilot Project	Pilot projects of Solar PV PUE should be implemented, specifically for phone charging and barber shops, and irrigation. Where these projects are implemented effective data collection and monitoring should be undertaken, including measuring the load profiles and detailed accounting	Short
Offer Training to Entrepreneurs	Training should be provided to potential entrepreneurs on basic book keeping, accounting, and business planning. The CEM/UoS Renewable energy toolkit can be used for this purpose	Short
Research Willingness to Pay	More research is required specifically on willingness to pay for the services. The research should determine the willingness to pay for services in rural areas, where people are currently travelling long distances to obtain the good and service.	Medium
Energy Hub	There are examples within the Energy for Development sector in Africa of installation of 'Energy Hubs'. As an alternative to	Medium

	developing a PV stand-alone system, buildings and facilities are also developed around a PV system (for example: 10 business spaces providing opportunity for various businesses). The system and the buildings are owned by an individual or group which is able to rent out the business spaces to local businesses. In this way, the energy provision becomes a shared concern of the business owners housed within the Energy Hub. A full feasibility study for such an energy hub should be completed	
Maize Mill Pilot	CEM should engage with FISD to undertake a grant funded Maize mill project, accurate monitoring and evaluation should be undertaken on maintenance costs, and cheaper maize mill products should be researched including importation costs.	Long

8. References

Access to modern energy services is approximately 8% and comprised of mostly urban households (SEI, 2013),

Derlangen, C., 2012. *Analysis of Incentives and Disincentives for Groundnuts in Malawi*, Available at: http://www.fao.org/3/a-at563e.pdf.

Foundation for Irrigation and Sustainable Development (2017) http://www.fisdltd.com/

GIZ, 2016. Productive Use of Energy Mini Business Plan Calculator, available online https://energypedia.info/wiki/File:PUE_Mini_Business_Plan_Calculator.xlsx)

Jaicaf, 2008. *The Maize in Zambia and Malawi*,

Kooijman-van Dijk, A. (2008): The Power to Produce - The Role of Energy in Poverty Reduction Through Small Scale Enterprises in the Indian Himalayas. University of Twente. Enschede, Netherlands.

Kooijman-van Dijk, A. (2012): The Role of Energy in Creating Opportunities for Income Generation in the Indian Himalayas. Energy Policy, Vol. 41, pp. 529-53

Malawi Energy Regulatory Authority, Malawi feed-in tariff: Renewable energy resource generated electricity in Malawi. Malawi Energy Regulatory Authority (2012)

Malawi Government, Energy Regulation Act 2007

Ministry of Energy and Mining. Draft Reviewed National Energy Policy for Malawi. Lilongwe: Malawi Government; 2016.

National Statistics Office (2008) 2008 Population and housing census. National Statistics Office, Malawi.

National Statistics Office (NSO), 2008, Malawi Census 2008 http://www.nsomalawi.mw/images/stories/data_on_line/demography/census_2008/Main%20Report/Census%20Main%20Report.pdf

National Statistical Office (2012) Integrated Household Survey, 2010-2011. Government of Malawi. Available at http://microdata.worldbank.org/index.php/catalog/1003 .

Solarmilling (2017) www.solarmilling.com

Selco (2007): Solar Photovoltaics Enabling Small Businesses to Develop.

Van Campence, B., D Guide& G.Best (2000): Solar Photovoltaics for Sustainable Agriculture and Rural Development. Rome.

Veit, S. (2006): GTZ Experience with Productive Use of Rural Energy. Eschborn.

Zalengera C, Blanchard RE, Eames PC, Juma AM, Chitawo ML, Gondwe KT (2014) Overview of the Malawi energy situation and a PESTLE analysis for sustainable development of renewable energy, Renewable and Sustainable Energy Reviews.

9. Appendices

Appendix 1: Link to Survey Outlines

https://drive.google.com/drive/folders/0B6N8aX9y_yUpazlocFZyRFZmOVU?usp=sharing

Appendix 2: Link to survey data

https://drive.google.com/drive/folders/0B6N8aX9y_yUpdklhZkY2Z2hJbjQ?usp=sharing

Appendix 3: Maps

Dedza and Njonja

Map of Njonja:

Map of Chiluzi:

Appendix 4: Component Contact Details

The prices listed below were obtained from the following suppliers on 3 January, 2016:

Sonlite Solar Area 3, next to OIBM P.O Box 30182 Lilongwe Email: sonlite@gmail.com Tel: +265999375103	Solair Corporation Adjacent Area 2 Mosque P.O Box 106 Lilongwe Tel: +2651727342

Appendix 5: System Design Methodology and Assumptions

Step 1: Calculating Total Dairy System Energy Requirement (TDSER).

The first stage of the design was to add the Watt-hours needed for all appliances together to get the total Watt-hours per day which must be delivered to the appliances.

Item Number	Description	Quantity	Voltage	rating(w)	Time (h)	Dairy energy Demand (Wh)
1	**bulb**	**1**	**12VDC**	**8**	**4**	32
2	Refrigerator	1	12VDC	100	8	800
Total						832

Multiply the Dairy energy Demand (Wh) with 1.5 (the energy lost in the system) to get the total Watt-hours per day which must be provided by the panels. 50% is assumed to be lost in the system.

Step 2: Determining Number of Panels

- Select the system voltage based on the appliances and then calculate the total daily ampere hours (Daily system charge requirement) at this voltage by dividing the Total Daily Energy Requirement by the system voltage. This is the energy in ampere hours the system will require every day for reliable operation
- From meteorological data (weather data), find the design month (the worst condition - the month with lowest average number of sunshine hours at the site). Data sourced from Mzuzu University's Energy department showed that 5.1 hours is used in Malawi.
- Divide the daily System Charging Current by the operating current output of the modules available on the market to get the number of modules required. This number is usually in decimals so it is rounded to the highest round figure.

Step 3: Determining Number of batteries

- Firstly, we determined the rated capacity of batteries available on the market. A depth of discharge of 60%-80% was considered in the designs. This helped us to get the available energy in the batteries.
- Using the daily system charge requirement which was determined in the PV array sizing, we are able to get the required battery bank capacity by multiplying the system charge requirement by the days of autonomy (assumed to be 3 for Malawi)
- We then divide the required battery bank capacity by the available energy from the battery bank to get the number of batteries required. This number is usually in decimals so it is rounded to the highest round figure.

Step 4: Determining size of inverter

- The inverter size should be 25-30% bigger than total Watts of appliances so these calculations were based on this principle.

Appendix 6: System Design Assumptions

Irrigation- this system uses direct current and the batteries will only be used other accessories like phone charging and security lighting
Phone Charging - This design assumes that a maximum of 30 phones will be charged per day and that each phone will take a maximum of one hour to fully charge.
Refrigeration- The design assumes that the refrigerator will operate for 8 hours and that the system frequently goes on and off.
Metal Workshop-The Angle grinder has been designed to operate for 4 hours while as the welding machine has been designed to operate for 1 hour
Video show-The system was assumed to operate for 8 hours
Maize mill-This system is assumed to come as a complete set from the manufacturers and therefore no design calculations were carried out

Appendix 7: Supplier Average Component Prices

Item	Price (MK)	Item	Price (MK)	Item	Price (MK)
Solar panels		**Charge Controllers**		**Inverters**	
5W	8,000.00	**Steca**		**UPS**	
10W	11,000.00	Steca 6A	25,000.00	Pure Sine Wave 500W/12v UPS	150,000.00

15W	15,000.00	Steca 20A	65,000.00	Pure Sine Wave 1KVA/12v UPS	203,000.00
20W	22,000.00	**MPPT**		Pure Sine Wave 2KVA/24V UPS	343,000.00
30W	30,000.00	MPPT 10A	70,000.00	**Tingen inverters**	
50W	50,000.00	MPPT 12/24v 100v 20A	125,000.00	Pure Sine Wave 300W-12v	65,000.00
85W	85,000.00	MPPT 12v/24v /48v 100v 30A	213,000.00	Pure Sine Wave 500W-12v	110,000.00
100W	95,000.00	MPPT 12v/24v /48v 100v 40A	289,000.00	Pure Sine Wave 1000W-12v	185,000.00
140W	135,000.00	**Landstar**		Pure Sine Wave 2000W-24v	320,000.00
150W	140,000.00	5A Landstar	9,500.00	Modified Sine Wave 150W-12v	15,000.00
250W	220,000	**PWM-AUTO VOLTAGE 12/24V**		Modified Sine Wave 300W-12v	38,000.00
Batteries		10A CIEMANS controller		**Coket**	
Deltec 6V 1.4 Ah	4,500.00	10 A controller with timer (TE1024N-1)	16,500.00	Pure Sine Wave 1500 W 24V	445,000.00
Deltec 6V 4.5 Ah	7,100.00	10 A controller with usb (1024EU)	17,000.00		
Deltec 12V 4.5 Ah	15,000.00	15A PWM CM1524	18,500.00		
Deltec 12V 7.2 Ah	18,000.00	20 A controller with timer (TE3024N-1)	28,500.00		
Deltec 12V 12 Ah	26,000.00	20 A controller with usb (3024A)	29,000.00		
Raylight LeisurePak 50Ah Batteries	59,000.00	30 A controller with timer (TE3024N-1)	35,000.00		
Raylight LeisurePak 96Ah Batteries	99,000.00	30 A controller with lcd (3024A)	42,000.00		
12v 60ah Omnipower Batteries (AGM/Gel)	129,000.00	40 A controller with timer (TE4024N-1)	65,000.00		
12v 120ah Omnipower Batteries (AGM/Gel)	219,000.00	50 A controller with timer (TE5024N-1)	75,000.00		

Bulbs			
Item	**Price (MK)**	**Item**	**Price (MK)**
Hong Xing 0.5W	900.00	DC-pin 3W	2,200.00
Hong Xing 9W orange lamp	2,500.00	DC-pin 2W	1,500.00
STK bulb 5W	1,500.00	DC-screw 1W	1,500.00
KML bulbs	1,800.00	DC-screw 2W	2,200.00

Hong Xing SolarBulbs		LED tube 3W	3,600.00
Bramax 7W	3,000.00	LED tube 5W	6,400.00
Bramax 3W	1,800.00	LED tube 7W	7,400.00
AC screw 3W	1,500.00	Outdoor lamp 10W	14,000.00
AC screw 5W	3,800.00	Outdoor lamp 30W	28,000.00
Direct bulb 3W	1,500.00	AC-pin - 3W	2,000.00
Tough stuff bulb	600.00	AC-pin - 5W	3,500.00
LED 5watts High Power Bulbs			
DC-pin 7W	5,000.00		
DC-pin 5W	3,300.00		

Appendix 8: Solar Resource in Malawi

Figure: Global horizontal Irradiation in Malawi (Wind Empowerment, 2016)