REPORT DATE: 18 December 2025

Solar Irrigation Pumps' Quantified Benefits to Smallholder Farmers

Based on Interviews of 136 Randomly Selected Pump Customers from Eleven Village Solar Shops Across Seven Districts of Malawi

ABSTRACT

During the dry season in Malawi, solar irrigation pumps allow much greater areas to be farmed than hand watering, at lower cost than diesel pump irrigation. This provides food security and boosts income. Key findings were:

1. Shared pumps with multiple users produced 3.2 times more net income than singly owned pumps.
2. Users who shared pumps each had dry season net earnings that were 86% of users of singly owned pumps.
3. 24% of pumps broke in 2024, but only half of broken pumps resulted in zero net gain or income loss.
4. In 2024 the pump systems were sold at a subsidized price of about 75% of total costs.
5. Every donor dollar generates an average of $28 of village income (90% confidence range: $14 - $49)
6. ROI for single pump users was over 400% and for shared pump users was over 1,500%.

Authors: John R. Wolfe MEng, Robert Van Buskirk PhD, Nathan Hunt PhD, Thomson Ngupete BSc, Chitani Chatama, Emily Chu and Chifuniro Mthunzi BSc.

Interviewers: Thomson Ngupete & Chitani Chatama

Cover Photo: Agnes Makwale, chair of a five women group that shares the pump she is holding along with a 50m hose and two 100W solar panels.

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Overview: The Solar4Africa Solar Irrigation Pump System

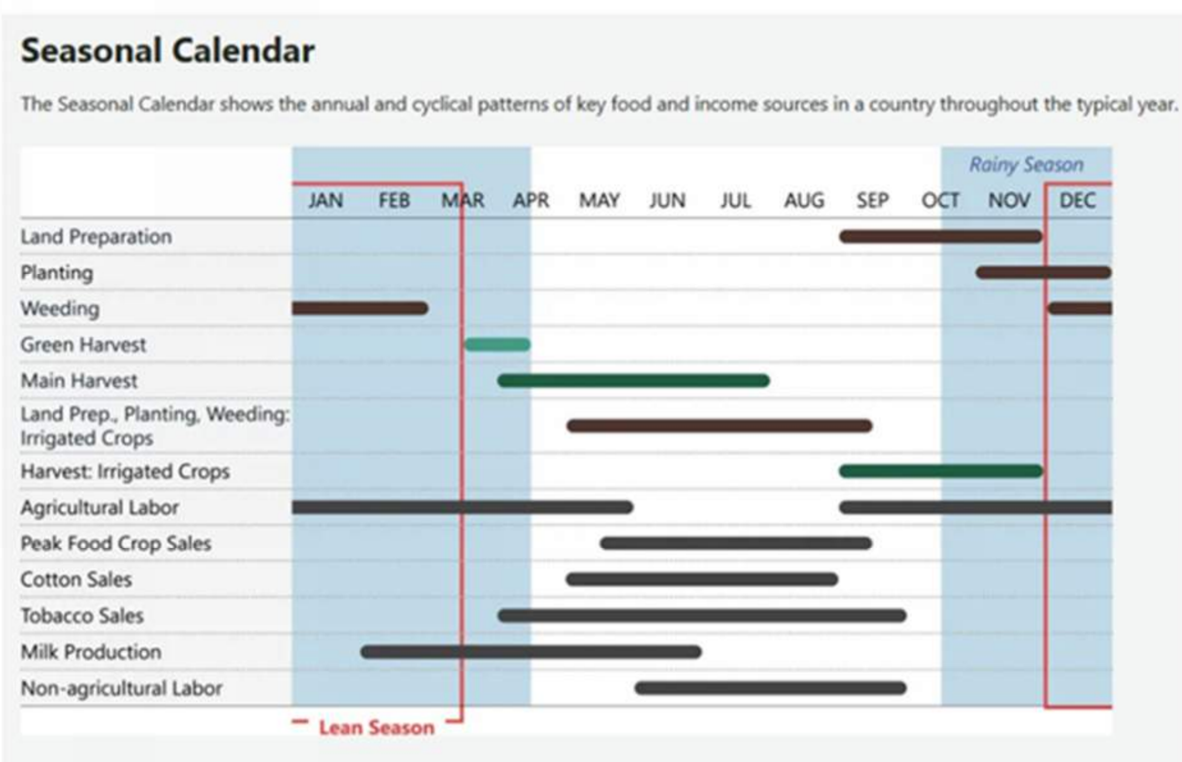
Solar irrigation pumps hold great promise to increase villager income and food security in areas of rural Africa with verdant wet seasons and sere dry seasons. The Solar4Africa irrigation system consists of a pump, hose and panels (see Figure 1). Solar pumps allow greater areas to be cultivated than hand watering, and at lower cost than diesel pump irrigation. Farming in the dry season allows villagers to harvest crops in the "lean/hungry" time when wholesale prices are more than double those at the end of the wet season.[1] Figure 2 shows the annual wet and dry farming periods in Malawi.

Figure 1: Solar Irrigation Pump System. The solar panels and water-filled lay-flat hose are visible. The pump is submerged in the stream beyond.

From July 2022 to the end of 2025, over two thousand solar irrigation pump systems have been sold at subsidized prices to rural smallholder farmers across southern and central through a network of over a dozen village solar workshops run by women's groups. Most of the village solar shops were organized by Rachel & Christina Solar Devices with import, warehousing and assembly support from Kachione LLC (both Malawi small businesses), research and pump repair technician training by Affordable

[1] Malawi has a warm wet season from November to April during which 95% of the annual precipitation takes place (ref: metmalawi.com). Most farming in Malawi focuses on the reliably wet weather time window from mid-December to mid-March. For the seasonal variations in the wholesale price of maize, see Figure 2.

Solar for Villagers (local Malawi NGO), and donations and technical support from Solar4Africa.org (a US volunteer organization). The joint effort of these sister organizations is branded as Solar Ku Midzi (meaning "solar to the villages" in the Chichewa language).



https://fews.net/southern-africa/malawi?utm_source=chatgpt.com

Figure 2: Seasonal Agricultural Calendar
This figure shows typical wet season planting/weeding/harvest periods and dry season irrigated planting/weeding/harvest periods. Source: FEWS NET, Famine Early Warning System Network. URL link at bottom left corner of figure above.

Figure 3: The Women-Led Village Solar Shops located across Malawi.

The irrigation system consists of a pump, hose and solar panel(s). The system has evolved from:

1. Original Generation 1 System ("small pump" system):
    a. Pump: 48 volt DC brushed motor, 185W,
    b. Hose: 32 mm (1.25") diameter x 50m long,
    c. Solar Panels: two 100W, 24 Voc (wired in series to create 48 Voc)
2. Generation 2 System ("big pump" system):
    a. Pump: 48 volt DC brushless motor, 300W - 370W,
    b. Hose: 32 mm (1.50") or 50mm (2.00") x 100m long,
    c. Solar Panel: one 360W or 370W, 48 Voc

Figure 4: The Original "Small Pump" System. A brushed pump & lay-flat hose are shown. The two 100W solar panels are not shown.

Most of the customers interviewed in this randomized study, as well as in our previous case study, had purchased and were using the original "small pump" system.

Previous 2023 Study: Case Study based on Interviews with 24 Village Farmers

Our previous report was titled *Case Study Estimates of Solar Irrigation Pump Impact on Smallholder Farmer Income: Interviews with Twenty-Four Village Farmers, Mwambo Traditional Area, Zomba District, Malawi*. The interviewed farmers all belonged to one of eight pump-sharing women's collectives. The farmers lived in or near Mpokwa village, near the town of Jali. The women were first interviewed in August through October, 2023, during the dry season. Follow up interviews occurred in January 2024 to get reports about their dry season crop harvests and the wholesale prices they were receiving.

The 2023 Case Study report found that the solar pump systems enabled the users to double their farm income on average. The added dry season income generated by the solar pumps, divided by donor subsidies, estimates that $16 of harvest income was generated for every dollar donated. This study's results are approximate, based on a non-random sample of customers selected by Rachel & Christina Solar Devices through word-of-mouth recommendations from customers in the Jali town area of Zomba district.

This 2024 Study's Methodology: Random Selection from a Customer Database

UPYA Pump Customer Database

This 2024 study randomly sampled a subset of an initial database of 677 solar pump system customers who had purchased pumps between July 2022 and December 2024. Customers were either sole users, or more typically, the chairwoman for a group of women who purchased the pump together. The customers were found and entered into an UPYA[2] database by a two-woman data collection team, Stella Chikafa and Bridget Mathesa. 100 pumps were imported in July 2022, and 1,000 more arrived in May 2023, so by early 2024 1,100 pump systems had been sold to village customers (see Figure 5). The UPYA database of 677 customers is a subset of the 1,100 pumps that had been sold by early 2024.

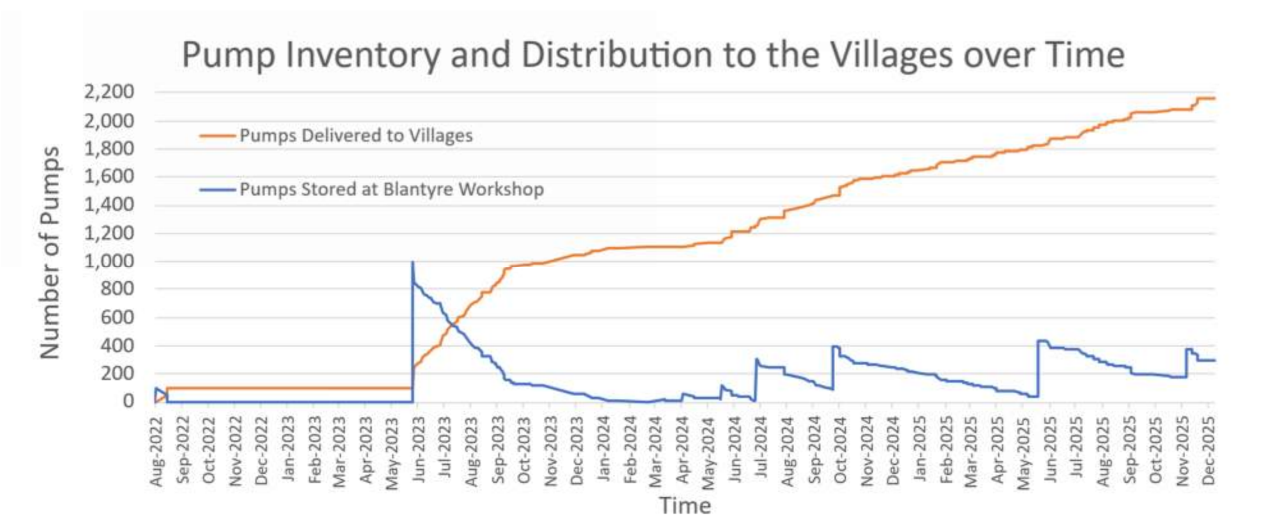


Figure 5: Pump Inventory & Distribution to the Villages over Time.
The blue line represents pump inventory in shipping containers at the Kachione workshop. The orange line represents pump systems distributed to the village solar shops and then sold to village customers.

Randomly Ordered Customer Contact Lists for each Village Shop

In a subsequent data sorting effort by student interns Emily Chu (Stanford University) and Chifuniro Mthunzi (University of Malawi at Zomba), the customers were divided into groups according to the solar shop

[2] UPYA refers to a database platform offered by Upya Technologies. The name Upya is a Kiswahili word for "newness" or renewal, reflecting the company's goal of bringing digital innovation to businesses in rural Africa.

they were nearest, where they likely purchased their pump system. For each of the eleven most active village shop, a randomly ordered list of customers was then generated.

Figure 6: The Solar Pump Interview Planning Team.
(from left to right) Solar Pump Interviewers Thomson Ngupete and Chitani Chatama discuss field work phone apps with student interns Chifuniro Mthunzi (University of Malawi Zomba) and Emily Chu (Stanford University). Chifu and Emily created the randomly-ordered lists of solar pump customers.

The pump interview team Thomson Ngupete and Chitani Chatama then went to each village shop area. Starting with the first customer on the list, they sought that person through word-of-mouth and also through the GPS latitude/longitude coordinates provided for each customer.[3] When they could not find a customer after exerting significant effort, they went on to the next customer on the randomly ordered list. Figure 8 on the next page shows that the interview team found 57% of the customers on their lists. When they did find a customer, they asked if the person owned and used the pump system by themselves, or shared the ownership and use of

[3] The GPS lat/long coordinates appeared in the database as decimal degrees, but we later learned that most of these numbers were degree-minutes-seconds-hundredths of seconds that were simply entered as xx.yyzzzz numbers to represent xx° yy’zz.zz”. While the interns provided the field interview team with Google Maps with all customer locations, the field team found most of the coordinates to be inaccurate. Instead, they relied on village shop and villager word-of-mouth to find most customers. This method tended to locate customers in villages nearest to the village shops, with less luck finding customers further away.

the pump with a group. If they were part of a group, the interview team then sought out and interviewed as many other members as possible who used that pump system, before proceeding to the next customer on the randomized customer list.

The pump interview team made initial contact with the pump users in July and August 2024, while the dry season was underway. One of the questions was to estimate their 2024 dry season crop harvest and resulting income. The pump interview team then re-contacted as many users as possible in January and February 2025 to determine the actual dry season harvest and the income they had received.

The UPYA customer database focused on equipment purchased, with one person identified as the customer. If a collective group of women purchased the pump system, the UPYA database only lists one person, usually the group's chairwoman.

This study not only interviewed the single pump system owners and the chairwomen of the pump groups, we also interviewed as many shared pump system users as possible. As a result, this study reports data on both a per-pump basis and a per-user basis. The study encompasses 72 pumps and 136 users. This allows us to report interesting differences between single user pumps and shared user pumps. For instance, the average income for single user **pumps**, for shared **pumps**, and for **users** sharing pumps are separate and distinct numbers for each harvest season.

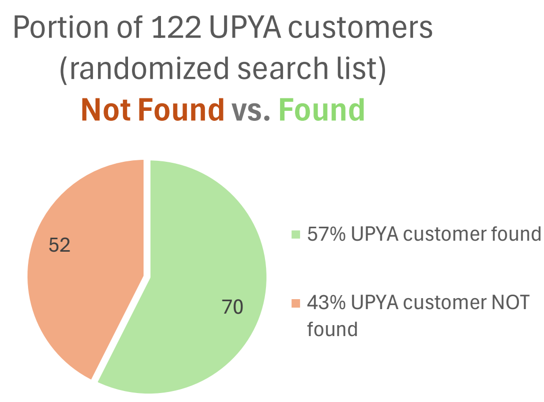


Figure 8: Portion of UPYA Customers Found

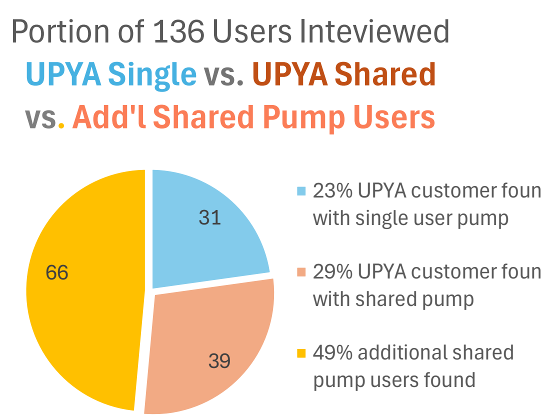


Figure 7: Portion of Pump Users Interviewed

Interviewed Pump Users: UPYA Customers Found, Other Shared Pump Users Subsequently Found

Based on the UPYA customer database, the solar pump interview team went down the randomly sequenced pump customer list for each village shop area and sought to interview each customer in the specified order. For all villages combined, they looked for 122 UPYA customers. They found the sought customer 57% of the time (70 UPYA customers, see Figure 8). If they did not find the sought customer, they would continue down the list.

56% of the customers found (39 customers) were part of a shared pump group, while 44% (31 customers) were single pump users. When a shared pump group was found, the interview team would seek out as many other users in the pump group as possible. In this way 66 additional pump users were found and interviewed.

Out of a total of 136 interviewed users, 23% (31 users) were single pump user UPYA customers, 29% (39 users) were shared pump UPYA customers, and 49% (66 users) were additional shared pump users (see Figure 7). As a result, only 23% (31 users) were single pump users while 77% (105 users) shared pumps.

Evaluation for Possible Bias

Table 1 shows the distribution of pump customers (purchasers/owners) across villages as documented in the UPYA database. Because the UPYA database often lists pump, hose and panel ownership as separate entries, the 1213 Total "Customers (incl. redundancy)" in Table 1 includes much duplication. The number of unique pump system customers in this database is 677, which is about 62% of the total 1,100 systems sold at the time the UPYA database was sampled. We do not know how closely the UPYA database matches the geographic distribution of all pump customers. Nevertheless, an attempt was made to distribute the pump interview team's efforts to roughly match the UPYA database's distribution of pump purchasers across the eleven most active village shops. The column labeled "Goal: % of Total" was the geographic distribution of pump customers in the UPYA database. The column labeled "Result: % Pumps Found" was the geographic distribution of pump customers in the 2024

Table 1: Comparison: UPYA database's village distribution with pumps & users interviewed.

District		Village Shops	Shop Abbrev	Customers (incl. redundancy)	Goal: % of Total	Goal: Days of Effort	Result: # Pumps Found	Result: % Pumps Found	Result: # Users Found	Result: % Users Found
Blantyre (Lundu	1	Lundu	LUN	78	6%	2.3	12	16%	39	22%
Chiradzulu	2	Chiradzulu	CHZ	47	4%	1.4	3	4%	8	4%
Zomba	3	Mpokwa (Jali)	MPK	415	34%	12.3	5	6%	19	11%
Zomba	4	Chinamwali	CHN				12	16%	17	9%
Zomba	5	Ndonsondole	NSD				4	5%	14	8%
Machinga	6	Machinga	MAC	122	10%	3.6	11	14%	26	15%
Balaka	7	Balaka	BAL	96	8%	2.8	5	6%	11	6%
Dedza	8	Dedza	DDZ	45	4%	1.3	5	6%	7	4%
Ntcheu		no shop		49	4%	1.5	0	0%	0	0%
Lilongwe	9	M'bang'ombe	MBA	331	27%	9.8	7	9%	10	6%
Lilongwe	10	Kabudulu	KAB				5	6%	6	3%
Kasungu	11	Kasungu		30	2%	0.9	0	0%	0	0%
Mangochi	12	Mangochi	MAN				8	10%	22	12%
Total				1213	100%	36.0	77	100%	179	100%
Single-shop District										
Multi-shop District										
No-shop District										

interviews. As indicated in Table 1, the distribution of interviewed customers does not stray too far from the UPYA database. Customers in Ntcheu district (4% of UPYA) and in Kasungu district (2% of UPYA) were not interviewed in this study. The UPYA database did not include customers from Mangochi district, a village shop opened just a few months ago before the July-August 2024 interviews, so customers from this new shop were added to the interview effort and amounted to 10% of the pump customer interviews.

Table 2: Percentage of Shared Pumps

	# of pumps	% of pumps
Total UPYA pumps, 2022-2023	677	100%
Shared UPYA pumps	479	71%
Total Pumps This Study in 2023	46	100%
Shared Pumps 2023	32	70%
Total Pumps This Study in 2024	72	100%
Shared Pumps 2024	44	61%

Another potential indicator of bias is the difference between the two databases (UPYA and this study) is the percentage of pumps that were shared by groups instead of owned by single users. Table 2 indicates that the percentages are quite similar between the UPYA customer database (71%), and the 2023 dry season and 2024 dry season pumps that were reported as shared in this study (70% and 61%, respectively). This suggests a lack of bias in the selection of the subset of 77 pumps from the larger UPYA database of 677 pumps.

Note that significantly more pumps were tracked in our survey in 2024 than 2023 (72 vs 46) as more pump systems were purchased in time for the 2024 dry season. The decreasing percentage of shared pumps between 2023 and 2024 may also suggest a trend toward more pump systems being purchased by single users instead of groups. Later in this report we will show that shared pumps generate much more village income, so this one year trend toward more single users should be critically evaluated and probably discouraged. Instead it appears strategic to encourage the organization of more pump-sharing groups, especially women's groups.

Demographics of Pump Users

Average Household Size

Table 3: Average Household Size

	Total # Adults	Total # children	Total householc size
Total	205	423	628
Mean	1.74	3.58	5.32
Percent	33%	67%	100%

The demographics of the pump using families reflects the demographics of rural Malawi. Table 3 shows that mean household size in this survey was 5.3 people, significantly higher than the 4.4 persons / rural household determined from the 2019-2020 Fifth Integrated Household Survey conducted by the Malawi National Statistical Office. The fraction of children under 18 in our survey is 67%, also significantly higher than the rural average of around 52%. This suggests that the pump-using households served by Solar4Africa/SolarKuMidzi may be even more rural and poorer than average rural Malawian households.

Another interesting statistic from our survey is the number of non-biological children in these households, 55 out of 423 children, or 13%. For comparison, the percentage of adopted plus foster children in the United States is only 3%. This may reflect a relatively common informal family arrangement in Malawi where family members in towns and cities send their children to live with the children's older siblings, aunts or uncles in rural villages, often in exchange for some financial support.

Per Capita Expenses and Income

From our previous year's survey, we found that it was quite challenging to determine income per household, for several reasons:

- Very high rate of inflation: approximately 32%, with food price inflation even greater
- Inconsistent highly variable income sources
- Difficulty determining net earnings for various home businesses and differentiating between gross revenues and income net of business costs

One the other hand, almost all household adults could estimate their monthly expenses, because this is the household budget they're trying to maintain. Given the very high inflation rate, households must constantly increase their monthly budget, so looking back on recent months' expenses, there may be slight tendency to underestimate monthly expenses in the current moment and looking forward. The effect may be a 5 to 10%

underestimate if people look back over the past three or four months to estimate their monthly expenses, given the 32% annual inflation. In a high inflation environment, cash currency deflates very quickly, so surplus income is usually put into physical assets (such as stored maize, small pieces of land ownership, home improvements, bicycles or motorcycles, and yes, solar pump systems) instead of cash savings. The household expense budget may underestimate ***income*** if the family manages to put significant amounts of surplus income into physical assets.

Table 4: Avg. & Median Expenses per Mo. & Day

	Est. family expns./mo.	Expns. / person.day	Expns. / person.day
Mean	MWK 181,415	MWK 1,128	$ 0.47
Median	MWK 150,000	MWK 1,000	$ 0.42

Table 4 shows mean and median expenses for the interviewed households as expenses per month, and per capita per day. The average expenses per person was 181,400 Malawi kwacha (MWK) per month or 1,28 MWK per day. Because of the skewed distribution toward zero with a long upper expense tail, the median expenses per person were a bit lower, 150,000 MWK per month and 1,000 MWK per day. If we convert to US dollars at a cash shop exchange rate of 2,400 MWK/USD (see discussion in later sections regarding exchange rates), this translates to an average expense per capita per day of $0.47, and a median of $0423.

Malawi's average 2024 gross domestic product (GDP) per capita is about $552 per year or $1.50 per day.[4] National GDP per capita has been trending downward since 2021. This average national income is much greater than the expenses per capita found for the villagers in this study.

We believe there are three reasons why the mean expenses per day of $0.47 are so much lower than the national mean GDP per capita:

- Rural income and expenses are significantly lower than urban areas,
- Village ***expenses*** underestimate ***income*** for the following reasons:
  - inflation (since retrospective averages will be skewed low),

[4] World Bank data via Trading Economics: https://tradingeconomics.com/malawi/gdp-per-capita#:~:text=Summary,GDP%20per%20Capita

- non-cash economy: crops grown for home consumption, or barter,
- frugality, keeping expenses low to save sporadically earned income,
- investments of savings into physical assets or cash savings, or
- sharing of earnings with family members and friends outside of the household to accumulate social capital

The village households in this study had average per capita expenses that were only 25% of national GDP per capita ($0.38/$1.50). In other words, the pump users seem to reflect the poverty (or at least cash-lean) levels of rural Malawi. The families at the very lowest end of the histogram of Figure 9 are likely to be subsistence farmers with negligible cash income or expenses. Contrary to some expectations, the villagers who invest in these small hand-carried solar irrigation pump systems may not be self-selected from the wealthiest highest income subgroup of villagers.

On the other hand, the solar pumps may attract frugal wealth-building villagers who do keep expenses very low so they can invest most cash income into physical assets. We know of an instance where an enterprising woman farmer (and chair of her pump group) invested almost all of her dry season crop income into purchasing streamside land so she would no longer have to rent her land from others.

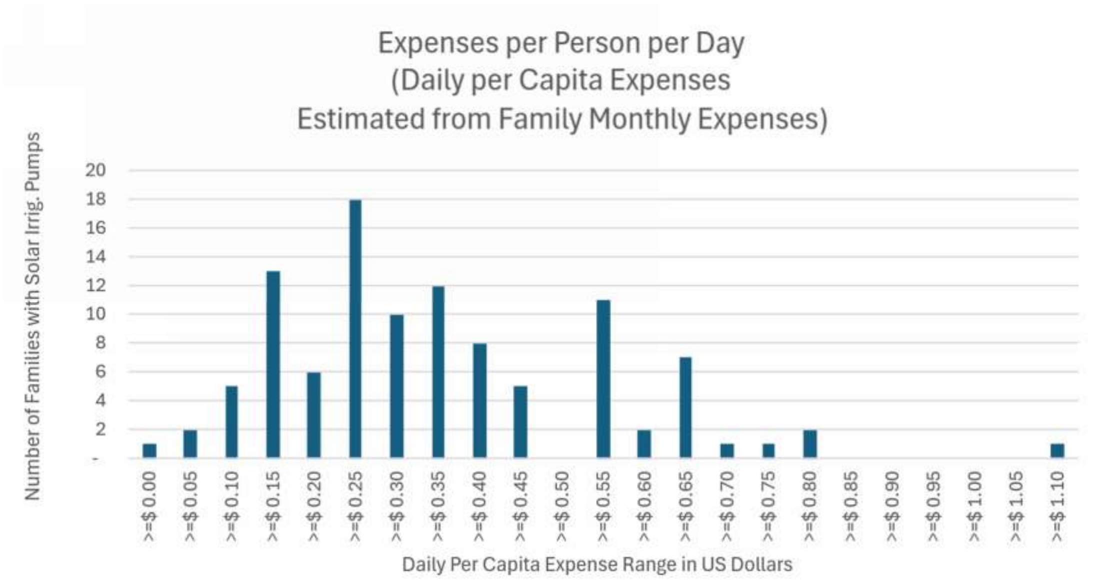


Figure 9: Histogram of Expenses per Person per Day

Appendix Table A1 Discussion

Appendix One Table A1 provides the basis for the demographic information discussed in the previous section. This table lists all the pump users (for both singly owned and shared pumps), as well as the customers on the randomized list who could not be located (see the column labeled "Customer or User found?"). Where a customer from the random sequence list, or a user within a discovered pump group, cannot be found, the "Customer or User found" row is listed "no". The row is also shaded grey.

The list of customers and users is anonymized by hiding the columns with full names and replacing these full names with ID numbers. For instance, the first customer on the village shop list would include an abbreviation for the village area such as MPK for Mpokwa Village, Zomba district. See Appendix One Table A2 for a translation between shop abbreviations and the anchor village and district names.

The abbreviation would be followed by 1.01, to indicate the first customer, and 2.01 to indicate the second customer. Regardless of whether a customer was found or could not be located, the customer would be labeled X.YZ where X was the sequence number of customers in the random ordered list. Note that once a village shop area customer list is randomly ordered, the customer list remains unchanged thereafter. While the "X" refers to a pump customer who was found or not, the decimal "YZ" refers to a specific person. The customer from the customer list is always .01 regardless of whether the customer was found or not, and regardless of whether the pump was shared or not. If the person was part of a shared pump group (often the chairwoman for her group), the additional members of the pump group would be numbered .02, .03, .04 and so forth.

Each pump customer and pump user is therefore given a unique identifying code. For instance, if the second customer on the Mpokwa village list was the chair of a group of five pump users, her ID number would be MPK 2.01, while the other members of her pump group would be MPK 2.02, MPK 2.03, MPK 2.04 and MPK 2.05. Likewise, if the third customer on the Mpokwa village list could not be found, their number would be MPK 3.01. If the fourth customer on the Mpokwa list was found, and was the only owner and user of a pump, they would be MPK 4.01.

The customer and pump user IDs are listed in rows. For all the pump customers and users who were found, a long list of data columns follows. For customers that were not found, the column "Customer or User Found" would simply say "no" and no other data is listed for this unfound customer.

Results: The Beneficial Impact of the Pump Systems

Shared Pumps and Shared Pump Users vs. Single User Pumps

The 2024 Interviews covered 72 pumps and 136 Users. One of the key characteristics of how a pump is used is whether it is shared by a group or owned by a single user. The pie charts below show the proportions of shared and single users.

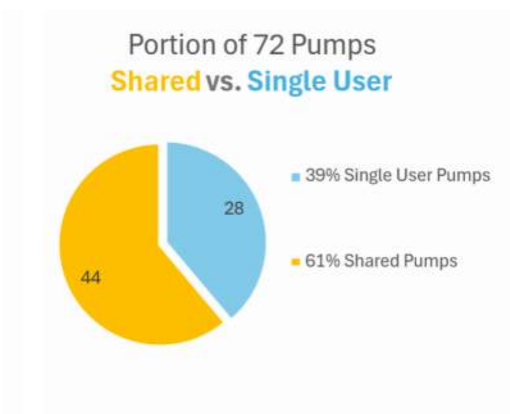


Figure 11: Portions of PUMPS: Shared vs. Single

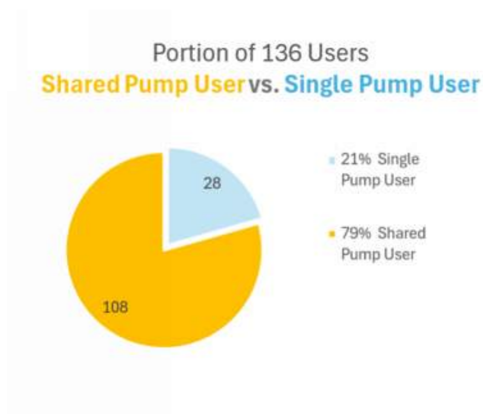


Figure 10: Portions of USERS: Shared vs. Single

Table 5: Pump Group Size Characteristics

	Pump Group Size
# Pumps in 2024	72
Mean Group Size	2.95
Median Group Size	3
Average Shared (>1) Group Size	4.13

The statistics of pump group sizes can be described by average group size including groups of one, average group size for shared pump groups only (group sizes greater than one), and the median group size including groups of one, as shown in Table 5. The mean and median group size is 2.95 and 3, respectively, while the average shared group size is 4.13 (a bit over 4).

The distribution of pump group sizes is perhaps best described by a histogram, as shown in Figure 12. The most frequent shared pump group size is 3, followed by 4, 5 and 2. Smatterings of larger pump group sizes also occurred.

The group of 10 users shared two pumps, not one, so that group can also be thought of as two groups of five, each with a pump. In that case the histogram would be called "Group Size for 72 Pumps", and the group of ten would disappear and two more groups of 5 would appear.

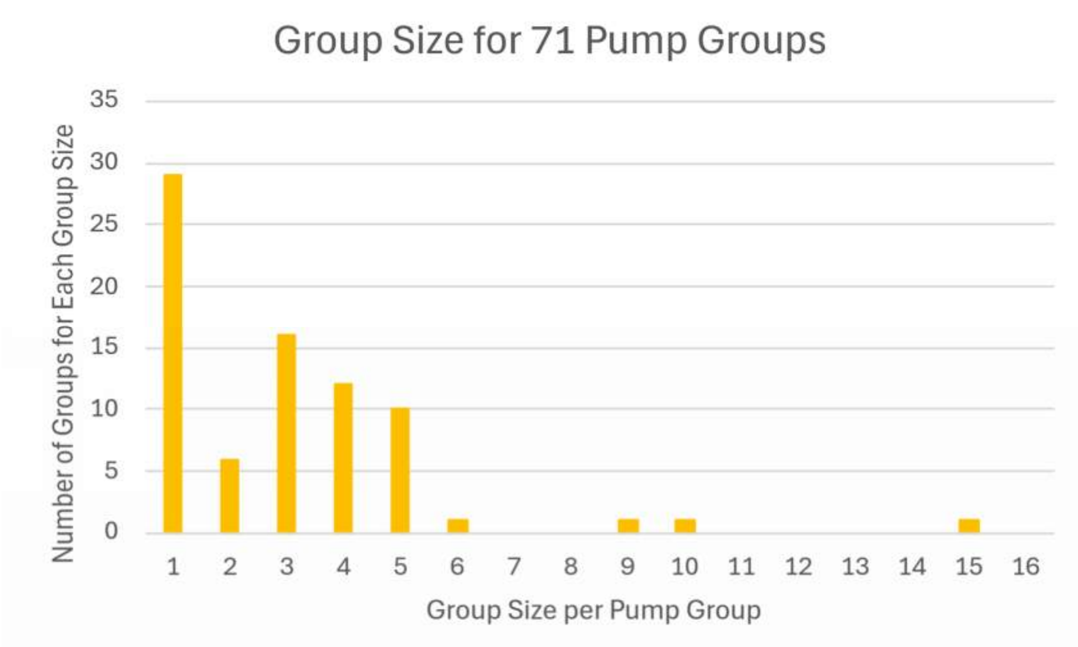


Figure 12: Histogram of Pump Group Sizes

2024 Dry Season Net Income, Single Users vs. Shared Pumps and Shared Users

Pumps owned and used by a single person can be compared to pumps shared by multiple users. Table 6 shows that average net income ***per pump*** was 3.2 times higher for shared pumps, and that net income ***per shared user*** was 86% of that for single users. The most effective way to increase income generated per pump is to

Table 6: 2024 Dry Season Crop Net Income: Single vs. Shared Pumps and Shared Pump Users

	2024 dry season net: SINGLE PUMP USERS	2024 dry season net/PUMP: SHARED PUMPS	2024 dry season net/USER: SHARED PUMP USERS
Mean:	MWK 828,238	MWK 2,651,552	MWK 714,101
Shared/Single Ratio:		**3.20**	**0.86**

encourage its use by a collective group that owns the pump together – ensuring that the pump will be used almost every day. For donors, it Is valuable to encourage the most productivity per pump system, so there are strong reasons to encourage the formation of pump-buying groups. Because the cost per user (farmer) is also dramatically reduced, this also reduces the need for up-front loans. In our experience, loans create additional administrative and programmatic challenges that are best avoided.

If single pump users and shared users earned the same dry season income per user, and the average shared group size was about 4 (refer back to Table 5), then we would expect the ratio of shared pump income to single user pumps to be 4:1 instead of the actual 3.20. The average income per shared user is in 86% of single users.

Various conjectures can explain why shared pump users earn a bit less than single users:

- shared pump users have less opportunity to water their crops more than once a week, on the sunniest days of the week, resulting in less irrigation of their crops
- shared pumps are used more heavily and therefore break down more frequently (however, this survey's data actually shows that shared pumps break down slightly less frequently than single user pumps)
- single pump users have more money to purchase a pump on their own and therefore may have higher incomes that allow them to rent or own more and better land near water sources, and to afford larger investments in seeds, fertilizers, pest control and farm labor.

The difference between 2024 dry season net income single pump users and shared pumps users per pump versus per user becomes more evident when examining the histograms of income intervals for both the per pump and per user cases, by comparing Figure 13 against Figure 14. Note that for Figure 13 there are 24 pumps with single users and 27 shared pumps. For Figure 14 there are also 24 single pump users, but 102 shared pump users, hence the dark bar single pump users are a much smaller proportion relative to the lighter orange users. In

Figure 13 the shared pumps clearly have a larger mean income ***per pump***, while in Figure 14, the single pump users have a larger mean income ***per user***.

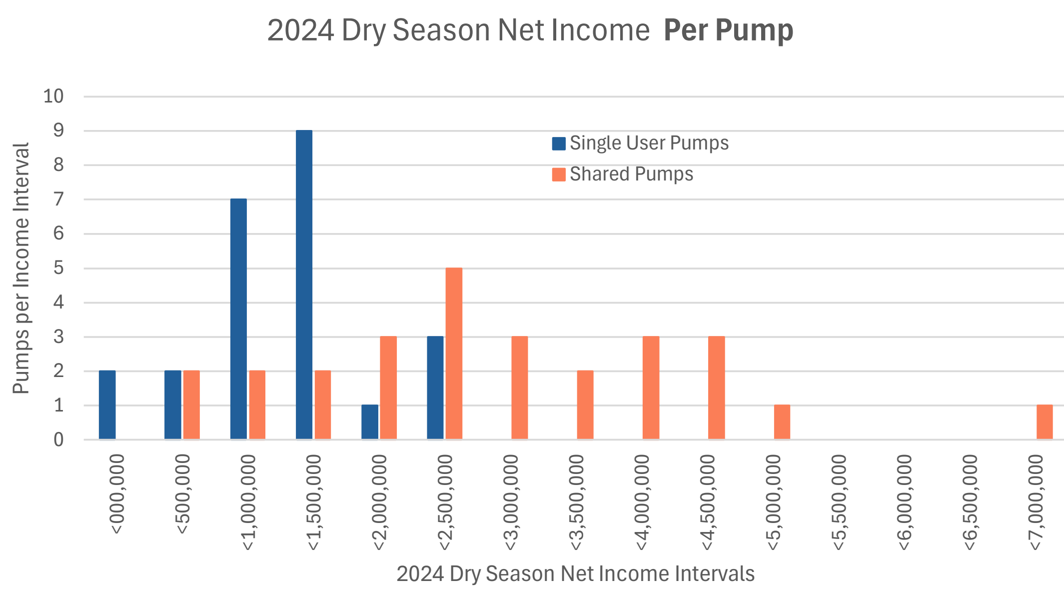


Figure 13: 2024 Dry Season Net Income PER PUMP

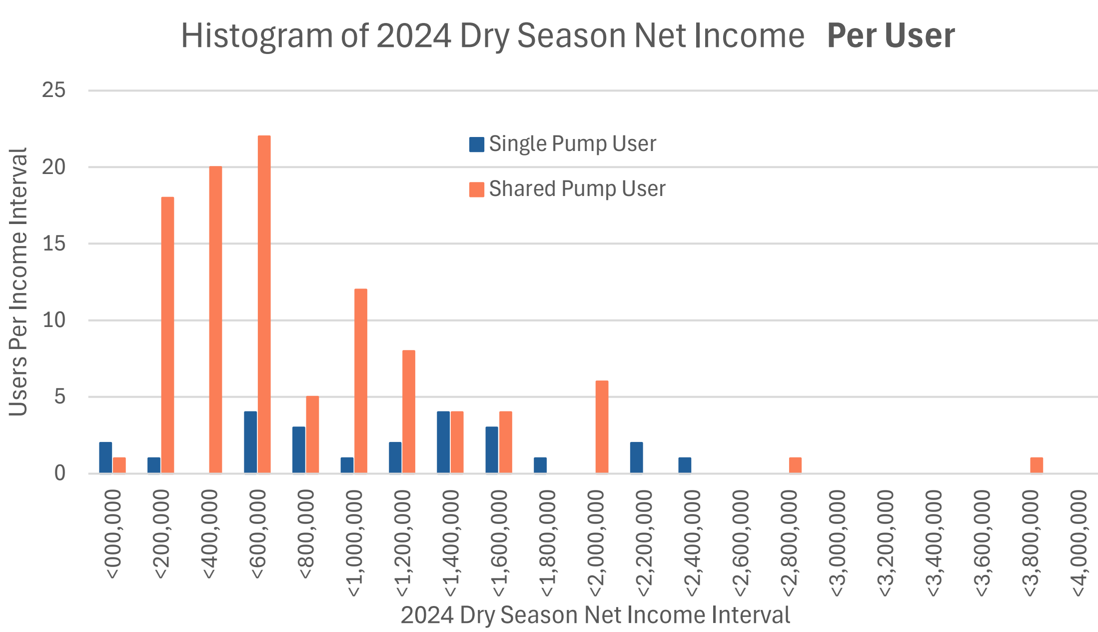


Figure 14: 2024 Dry Season Net Income PER USER

Dry Season Crop Net Income in 2023 and 2024

An interesting comparison can be made between the 2023 and 2024 dry seasons' net incomes, on a per user basis, for 66 pump users who reported net income in both the 2024 and 2024 dry seasons, and had no equipment breakdowns or other non-equipment problems such as losing their farmland. In other words, the same consistently successful users were compared for both years. Results are shown in Table 7.

Net income increased significantly, 27% after accounting for 32% annual overall inflation (weighted average of food and non-food inflation, see Table 9). Part of this can be attributed to increased gross harvest income. While maize production increased modestly when corrected for wholesale price increases, a shift to other more profitable crops was the main driver of increased gross income. While maize production per user only increased 6%, tomato production increased 12%. We also suspect that production of other lucrative crops, such as onions, also increased significantly[5].

There was a significant decrease in input costs if the costs are adjusted for inflation. This could be due to the farmers learning how to decrease input costs, or it could be the result of country-wide lower per unit prices for seed or fertilizer in 2024 compared to 2023, or it could be an artifact where 2023 input costs were reported in 2024 kwacha prices rather than accounting for lower input costs in 2023 due to kwacha inflation. Because the average dry season net/gross income ratio is about 0.75, the input costs are only about 25% of gross income, so a change in input costs has a smaller proportionate impact on net income. For example, a 50% increase in input costs would only reduce net income by 17%. In our case, if 2024 input costs are 80% of 2023 input costs (inflation adjusted), and the net/gross income ratio is 0.75, the net income would only increase around 7%.

[5] General perusal of the original handwritten forms suggests a trend toward greater crop diversity. Significant data extraction effort would be required to quantify this trend more accurately.

Table 7: 2024/2023 Dry Season Net Income Comparison for the Same 2023 & 2024 Pump Users

567,699	2023 Average Dry Season **Net** Income Per User, Same 2023 & 2024 Users
949,298	2024 Average Dry Season **Net** Income Per User, Same 2023 & 2024 Users
1.67	2024/2023 Net Income Ratio Per Same Users, Not Adjusted
1.27	2024/2023 Net Income Ratio Per Same Users, 32% Inflation Adjusted
728,144	2023 Average Dry Season **Gross** Income Per User, Same 2023 & 2024 Users
1,109,152	2024 Average Dry Season **Gross** Income Per User, Same 2023 & 2024 Users
1.52	2024/2023 Gross Income Ratio Per Same Users, Not Adjusted
1.23	2024/2023 Gross Income Ratio Per Same Users, 24% Whlsale Price Adj.
159,853	2023 Average Dry Season **Input Costs** Per User, Same 2023 & 2024 Users
160,445	2024 Average Dry Season **Input Costs** Per User, Same 2023 & 2024 Users
1.00	2024/2023 Input Costs Ratio Per Same Users, Not Adjusted
0.81	2024/2023 Input Costs Ratio Per Same Users, 32% Inflation Adjusted
8.11	2023 Average Dry Season **Maize Bags** Per User, Same 2023 & 2024 Users
8.61	2024 Average Dry Season **Maize Bags** Per User, Same 2023 & 2024 Users
1.06	2024/2023 Maize Bag Harvest Ratio Per Same Users, Not Adjusted
26.77	2023 Average Dry Season **Tomato Bckts** Per User, Same 2023 & 2024 Users
30.06	2024 Average Dry Season **Tomato Bckts** Per User, Same 2023 & 2024 Users
1.12	2024/2023 Tomato Buckets Harvest Ratio Per Same Users, Not Adjusted

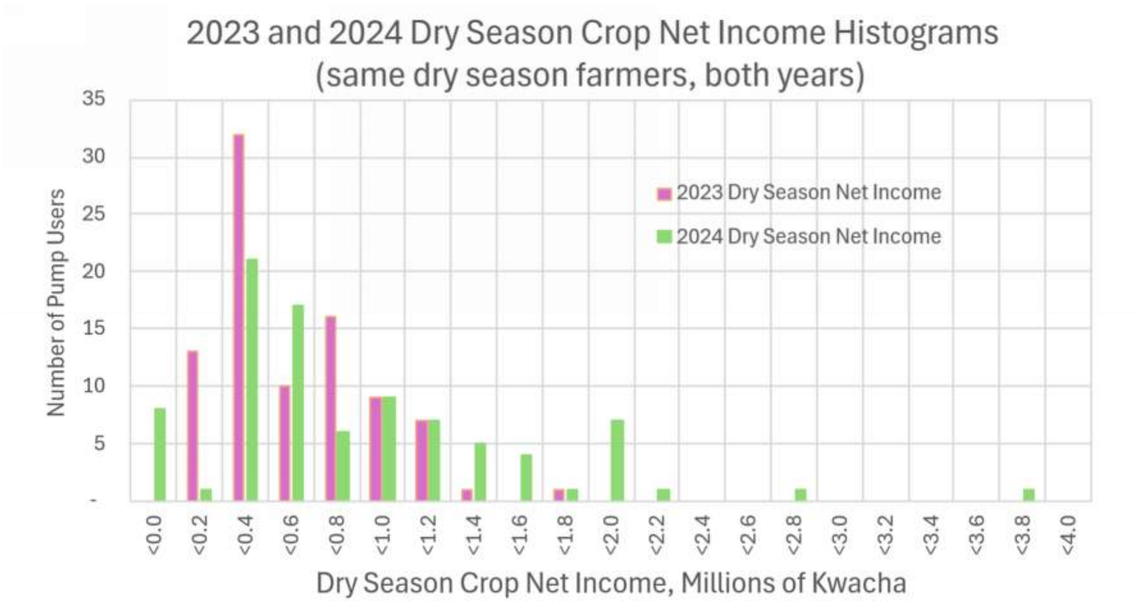


Figure 15: 2023 & 2024 Dry Season Net Income for the Same Farmers (Users)

The histogram in Figure 15 shows the distribution of net income for the same farmers in both the 2023 and 2024 dry seasons, providing more nuance to the 27% increase in mean net income.

The significantly greater income for the same pump users in their second dry season (or for a few, their third dry season), suggests several explanations:

- Most of the pump users purchased their pumps between May and September 2023. The users who purchased pumps later in that dry season had a shorter growing season in 2023.
- The pump users were cautious in their first dry season. After initial success, they planted more crops in their second dry season.
- The pump users learned from themselves and others better planting and irrigation techniques, and better more profitable crops to grow.
- The income from the first season allowed the pump users to invest more in renting or buying land, and paying for more seed, fertilizer, pest control and labor in the second season.

Some further insight into the changes in dry season pump use and productivity can be gained by looking at overall productivity increases for all pump users and dividing by the associated total pump shares. Unlike the statistics above, this does not follow just the cohort of pumps that were active in both years 2023 and 2024. This is shown in Table 8 for both maize and tomatoes.

Table 8: Comparison of 2023 & 2024 Dry Season Maize & Tomato Harvests

	2023 Dry Season	2024 Dry Season	2024/2023 Dry Season
total bags of maize	646	1,003	1.55
total maize pump shares	34.0	48.0	
avg. bags maize per pump	19.0	20.9	1.10
avg. maize price per 50 kg bag	48,964	61,496	1.26
total baskets tomatoes	1,299	2,131	1.64
total tomato pump shares	21.1	27.6	
avg. baskets tomatoes per pump	61.7	77.3	1.25
avg. tomato price per 10L basket	13,857	16,563	1.20

In Table 8, there are two key things to note:

(1) Maize production per pump only increased 10%, while the wholesale price increased 26% (39% increase in gross maize sales), and

(2) Tomato production per pump increased 25%, while the wholesale price increased 20% (50% increase in gross tomato sales).

This suggests that the farmers shifted some maize production to other crops in the second year. After maize, the second most popular crop was tomatoes. Other crops reported, especially in the second year, included onions, cabbage, beans, sweet potatoes, Irish potatoes and leafy greens. Table 8 also shows that wholesale price increases given to the farmers were far less than the increase in food prices. Farm wholesale prices increased 26% for maize and 20% for tomatoes, compared to 42% food inflation over the same period. This suggests that smallholder farmers have little control over wholesale prices. Even when there are significant food shortages, grain and produce dealers, and not farmers, profit from the shortage. See Table 9 for 2024 national inflation figures. Note that food inflation is much higher than non-food inflation.

Table 9: Malawi 2024 Inflation: Overall, Food & Non-Food Categories

Category	Estimate of 2024 annual inflation / price increase
Overall CPI / headline inflation	~ 32.2 % IMF +4
Food inflation	~ 40.2 % capitalradiomala... +2
Non-food inflation (cost of goods / non-food)	~ 21.2 % capitalradiomala... +2

Wet Season Crop Income in 2023 and 2024

Both the 2023 and 2024 wet seasons were impacted by climate difficulties: in early 2023 Cyclone Freddie destroyed crops in local areas by flooding low lying streamside areas, while devastation from the early 2024 drought was much more widespread, especially in the Southern Region. Table 10 shows this impact by comparing net income from the 2023 and 2024 wet seasons[6]. To account for inflation, the 2023 net income was increased 26%, which is an extrapolation from the difference in DRY season wholesale maize prices. Average wet season net farm income, adjusted for inflation, was only 52% in 2024 compared to 2023.

The poor harvest in the 2024 wet season may have been an additional impetus that created the big jump in solar-pump driven dry season income observed in 2024 compared to 2023's dry season.

Table 10: 2023 and 2024 Wet Season Net Income Comparison

	2023 Wet Season	2024 Wet Season	2024/2023 Wet Season
Mean Net Income	1,033,268	590,024	0.57
Median Net Income	684,180	351,000	0.51

Note: 2023 wet season income is adjusted by an assumed 26% inflation rate.

[6] While the wet season runs from late November through April, the nominal year of the wet season is the year in which that wet season ended. So "2023 wet season" refers to the wet season that ran from November 2022 to April 2023.

The Figure 16 histogram also gives a sense of how much higher the wet season income was in 2023 (darker blue bars) compared to the subsequent year in 2024, due to the 2024 wet season drought. Note, for instance, that twice as many farmers in 2024 had net incomes less than zero due to drought-caused crop loss, compared to 2023.[7]

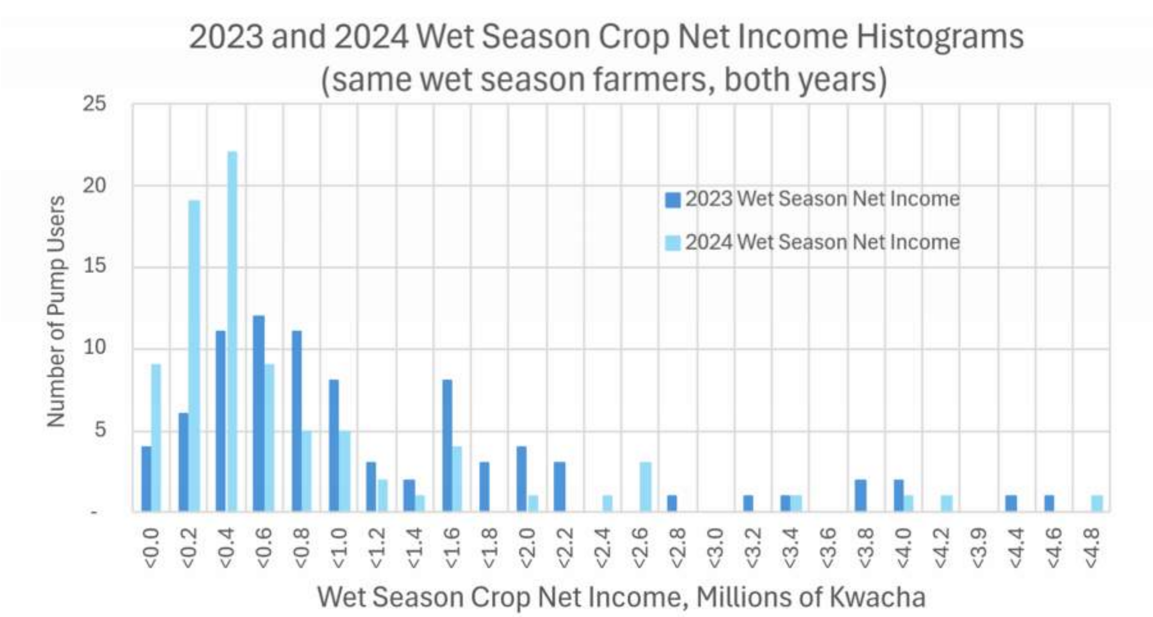


Figure 16: 2023 and 2024 Wet Season Net Income Comparison

2024 Wet and Dry Crop Income Compared to Household Annual Expense

[7] In a future version of this report, 2023 wet season maize yields and wholesale prices will be extracted from the source data for comparison with the 2024 wet season. The comparison of the 2023 & 2024 wet seasons is relevant because there is disagreement, in retrospect, about how severe the drop in the 2024 wet season harvest was compared to prior years. Initial assessments suggested a national maize harvest only 60% of the five year average, while some retrospective figures suggest the harvest was 85% of normal. Anecdotal accounts of the late 2024/early 2025 famine, combined with our survey of 2024 wet season net income, suggest that the initial assessments were accurate, especially in the Southern Region of Malawi.

Comparing farm income to annual expenses can give a sense of how important farm income is to a family's budget. For some households, farm income covered a significant portion of family expenses, while for others, farm income was less significant. This can be expressed as the percentage of net farm income / total annual expenses. Wet season farm income, dry season farm income, and total farm income, were all compared against total annual expenses. See Table 11. At least for 2024 (an admittedly unusual year due to the wet season drought), the dry crop net income created by the solar pumps actually exceeded the wet season net income (49% dry compared to 36% wet). It is informative to also check which pump users obtain less than 10% of their total expenses from farm income. For the 2024 wet season, 58% of all pump users covered less than 10% of their total annual expenses with net proceeds from their wet season harvest. The great majority, 44% of all pump users, were shared pump users. This suggests that many of the shared pump users are too poor to rent or own land to grow a significant wet season crop. Instead, during the wet season, the adults of the household may be hired as laborers for other farmers. Being part of a pump collective allows them to gain significant dry season income from a shared pump.

Table 11: Percentage of Net Farm Income/Annual Expenses

	2024 Wet Crop Inc./Ann. Exp.	2024 Dry Crop Inc./Ann. Exp.	2024 Farm Inc./Ann. Exp.
Mean	36%	49%	85%
Median	7%	34%	50%
# of Users	105	105	105
all pump users w <10%	58%	12%	7%
single pump users w <10%	14%	7%	4%
shared pump users w <10%	44%	6%	3%

Figure 17 and Figure 18 show the distribution of Farm Income as percentages of family total annual expenses. Figure 18 compares Dry Crop income to Wet + Dry Crop Income. The spread is quite wide, ranging from less than zero (net income loss) to over 500% of (five times) total annual expenses. Figure 17 adds in the 2024 wet season income, which immediately demonstrates that for a very large portion of pump users (58 %), the wet season covered less than 10% of their total annual expenses. While wet season income for a small subset of households can cover well over 100% of household expenses, far more households get very little (or even zero) relative income from wet season harvests. This is especially true for shared pump users. This suggests that a significant proportion of dry season pump users weren't able to earn significant 2024 wet season farm income, either because they didn't have farmland to rent or own, or did have access to land but lost or made very little income because of the 2024 wet season drought.

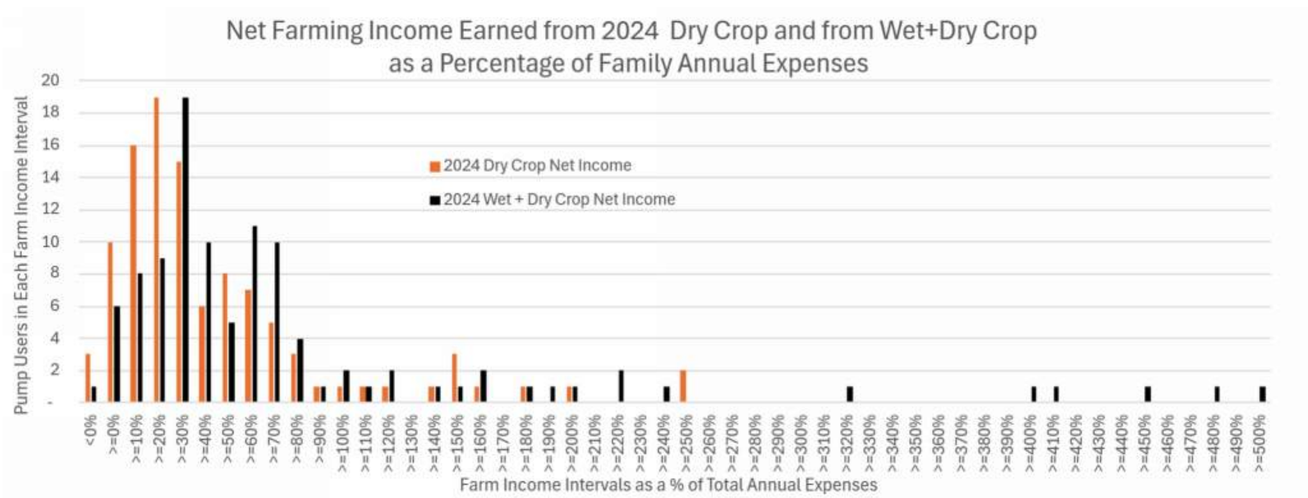


Figure 18: 2024 Dry Crop, and Wet + Dry Crop Income as a Percentage of Total Annual Expenses

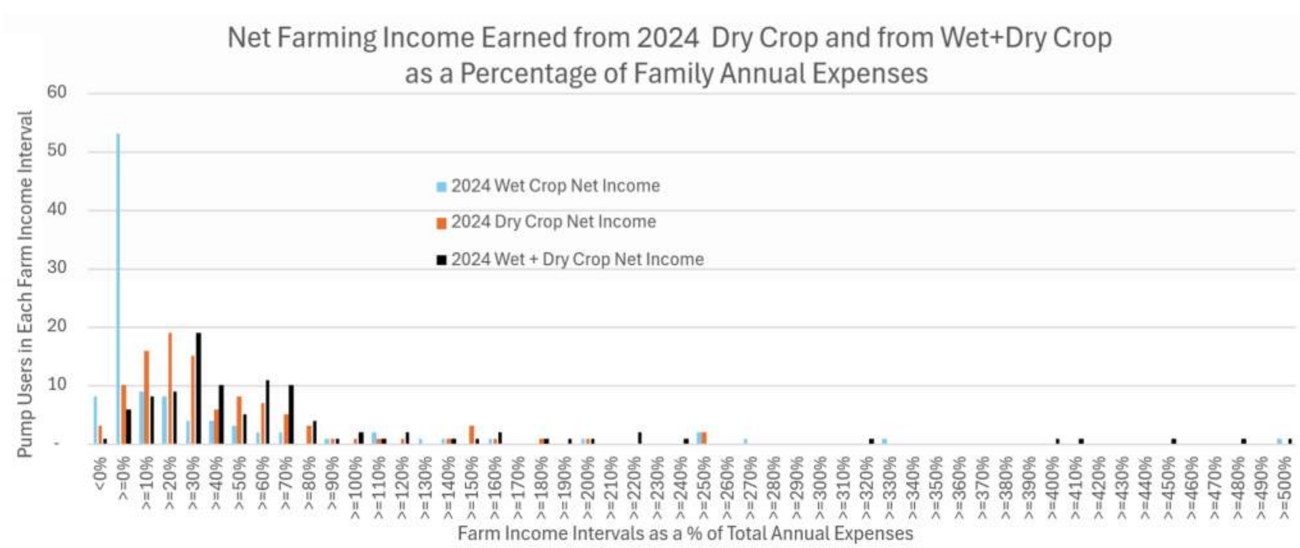


Figure 17: 2024 Wet Crop, Dry Crop & Wet + Dry Crop Income as a Percent of Total Annual Expenses

Broken Pumps' Impact on Dry Season Crop Income

Table 12: Proportions of Single User & Shared Pumps, and Unbroken & Broken Pumps

677	100%	**Total Pumps, UPYA Database Jul 2022 - Dec 2023**			
198	29%	Single User Pumps, UPYA			
479	71%	Shared Pumps, UPYA			
72	100%	**Total Pumps, Detailed Interviews Jul 2024 - Feb 2025**			
28	39%	Single User Pumps	36%	Percent Broken,Unused	
44	61%	Shared Pumps	27%	Percent Broken,Unused	
50	69%	Unbroken Pump System			
22	31%	Broken or Unused Pump System			
10	14%	Broken or Unused Single User Pump System	60%	Percent w/ Loss	
12	17%	Broken or Unused Shared User Pump System	50%	Percent w/ Loss	
18	25%	Unbroken Single User Pump System			
32	44%	Unbroken Shared User Pump System			
72	100%	Total Pumps		Single	Shared
50	69%	Unbroken Pumps		18	32
2	3%	Unused Pumps without Equipment Problems		1	1
3	4%	Broken Panel(s)		3	0
9	13%	Broken Pumps with Zero or Negative Income		4	5
8	11%	Broken Pumps Repaired, with Significant Income		2	6
Note 1: Pump System = Pump + Panel(s) + Hose					
Note 2: "Broken" includes 2 unused pumps without equipment problems					

This study encompassed 72 pumps (see Table 12). Over half the pumps (61%) were shared, while the remainder were used by a single owner. Since each shared pump has multiple users, the proportion of the 136 pump users who shared pumps was a larger percentage (77%). Over the two years of this study, 22 of the systems (31%) broke or were unused in the 2024 dry season. This included broken pumps, broken panels and two cases where the system was not used for a reason unrelated to the the equipment's durabiilyt (for instance, rented farmland was sold away and a new lease could not be negotiated). Contrary to expectation that the more heavily used shared pumps would break more frequently, the shared pumps broke slightly less frequently (27%) than the single user pumps (36%), although the difference may not be large enough to be statistically significant. See Table 12 and Figure 19.

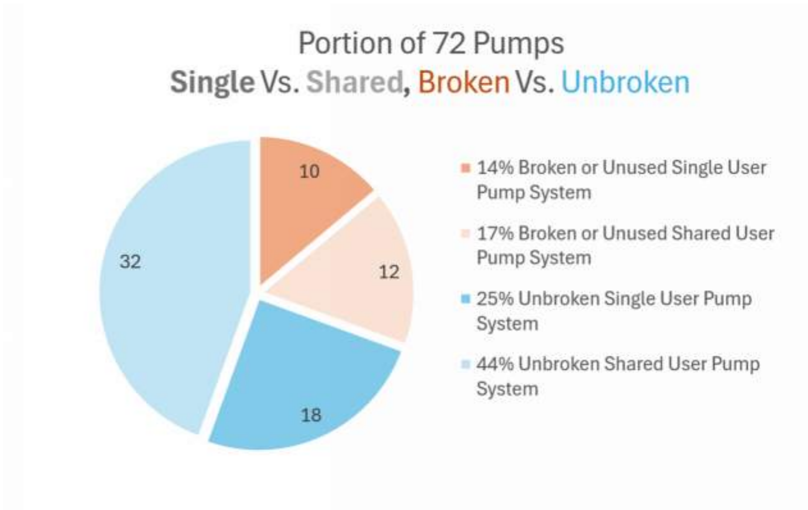


Figure 19: Portion of Pumps: Shared vs. Single, Unbroken vs. Broken

Of the 20 systems that broke, 17 were pump breaks and 3 were panel breakss. The panel breakage rate is 3/72. For the customers interviewed, the purchase date is difficult to extract, but in many cases is at least two dry seasons, or at least 1.5 years. If we conservatively assume the period of use for the average system was one year, the panel breakage rate is 3/72 per year, or about 4% per year. That amounts to a (.96)^10 = 66% survival rate over ten years, and 75% over seven years. Fatigue breakage of wires leading into the panel junction box may be as significant as panel cracking. Taking the panels back and forth to the fields every day puts the panels at greater risk than normal stationary rooftop installations.

Pumps are the greater cause of the irrigation system failing, with a rate of 17/72 = 24%, conservatively taken over one year. The breakage rate is likely to be nonlinear, with a greater proportion of brushes and bearings wearing out in the second or third year than the first. During the 2024 dry season, there was an attempt to have five back-up pumps in a box in each shop. That system was not effectively implemented in 2024, and it took some customers three or more weeks to get a new or replacement pump. Also during this time, the Blantyre workshop was not well-stocked with the correct replacement parts.

In 2025 these issues have been addressed more effectively. The five pumps-in-a-box is implemented in more shops. More importantly, thirteen technicians from ten shops came to the Blantyre workshop for a four-day training session in June 2025 (see Appendix 2). They were also supplied with kits of repair parts and tools. Most active village shops now have technicians nearby trained and equipped to repair pumps on short notice. The technicians also have a lively WhatsApp chat where they share tips on pump repair.

Given the replacement and repair shortcomings of the 2023 and 2024 dry seasons, it is remarkable that of the 17 pump failures, only half resulted in near-zero or negative income (see Figure 20). Some of this had to do with luck and some had to do with pluck: some pumps broke earlier in the dry season (June, July, even August) instead of the very hot very dry months of September and October; some pumps were replaced in two or three weeks (instead of longer), some farmers had a neighbor with a working solar pump that they could borrow, or the farmers managed to hand water their large areas of crops in the meantime (often hiring laborers to help).

Comments from pump users where pump breakage was devastating include:

- *Brushes broke and was taken to the shop for repairing in July and later was repaired In late August but the crops were already in bad shape*
- *The pump was never repaired on time hence low harvest. she couldn't afford to buy another one*
- *Broken bearings and was left at shop in June 2024. it came back end July 2024 and this affected her crop as she was using water can*
- *Brushes broke after she had planted 3 weeks earlier and was letf at the shop for repairing. She engaged in using a watering can and got the pump back after 3 wks. she lost much of her crops to drought as it was hard with the watering can*
- *Brushes broke down and was taken to the shop where it was fixed 4 wks later and the crops were damaged*

On the other hand, comments from the farmers whose pumps broke but who still managed to save most of their crops include:

- *Bearings broke early July and was repaired late July. This time they used to borrow pump from another individual farmer just not to lose their crops*
- *The pump was broken mid June and was fixed in early July. During this period she was using watering cans to save the crop. [Other members in her group had a similar experience, ultimately prevailing].*

- *Brushes broke early July and was fixed late July. She used to borrow the pump as she waited for hers to be repaired*
- *Bearing broke down. Took it to the shop, and have not been back. BUT! borrowed a neighbor's pump and had a good harvest.*
- *Faulty brushes. Broke in early July and fixed end July 2024. [The members of this group also reported reasonably good harvest income]*
- *Bearings broke at end July and were fixed late August. They used watering cans to save the crops.*

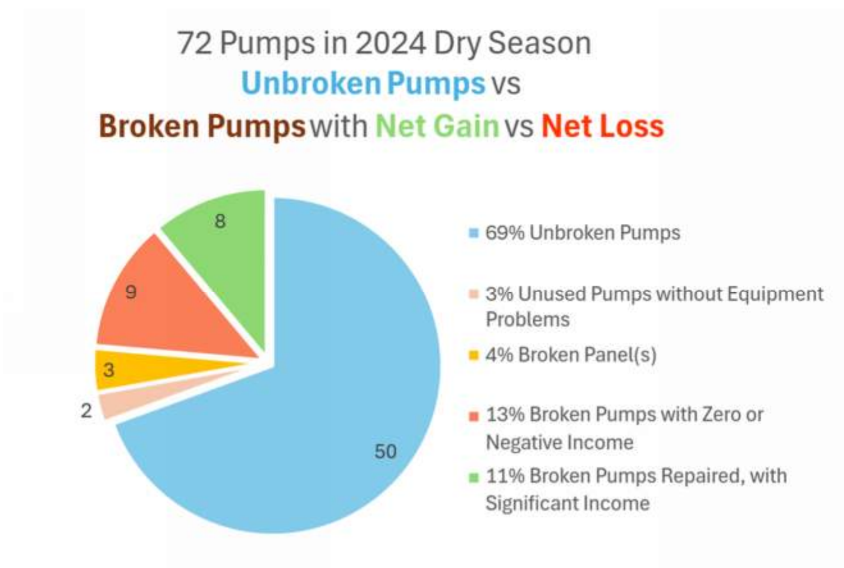


Figure 20: Unbroken vs Broken with Gain vs. Loss

The Donor's Perspective: The Donation's Benefit Multiplier

Many donors want to provide maximum benefit for dollars contributed. "Benefit" can be measured in many ways, such as (a) quantity of beneficial items distributed, (b) increase in beneficiaries' income, or (c) increase in the number of healthy years of life. Solar4Africa focuses on the first two, (a) and (b), knowing that many previous studies show that (a) and especially (b) result in (c) increased years of healthy life.

Table 13: Number of Products Delivered as a Function of Price Subsidy

subsidy	sales price as % of total cost	number of products delievered
100%	0%	1.00
95%	5%	1.05
90%	10%	1.11
85%	15%	1.18
80%	20%	1.25
75%	25%	1.33
70%	30%	1.43
65%	35%	1.54
60%	40%	1.67
55%	45%	1.82
50%	50%	2.00
45%	55%	2.22
40%	60%	2.50
35%	65%	2.86
30%	70%	3.33
25%	75%	4.00
20%	80%	5.00
15%	85%	6.67
10%	90%	10.00
5%	95%	20.00
0%	100%	infinite

(a) Maximizing number of products distributed.

One way to increase the quantity of products delivered, while ensuring that the products are needed and used efficiently, is to sell the products at a subsidized price. Table 13 shows the power of this approach. Instead of just giving products away, selling them at half of cost will double the number of products that can be delivered. Selling them at 75% of total cost will quadruple the number of products that can be delivered. In 2023 the pump systems (pump, hose, panels) were sold at about 50% of total cost. Because the solar pump systems are in such high demand, the price in 2024 (and also in 2025) could be increased to about 75% of total cost. Since the outset of the dry season in 2024, the number of pump systems delivered to rural villages across Malawi is at least four times greater than if the pump systems were given away for free.

(b) Maximizing village income. A second way of quantifying benefit is to see how much net income results. The pump user survey focused on this question, asking specific questions to quantify all farming input costs, including:

- Seed
- Fertilizer
- Pest control
- Hired labor
- Land rent
- Pump system cost
- Other costs, such as labor for digging an open pit well to access water

The interviews also quantified all gross farm income, listing all crops harvested and their wholesale prices. Crops that were raised for home consumption were also valued at wholesale prices. Farm input costs and gross income were divided up between wet and dry seasons. Net farm income for both wet and dry seasons was then calculated. The mean farm income ***per pump*** in the 2024 dry season was MWK 1,732,000 (or about $1,000 at the official government exchange rate, and about $720 at a cash shop exchange rate of 2,400 MWK/USD).

A benefit multiplier can then be calculated, showing the village dry season income generated per donor dollar invested in importing and delivering pump systems (including all direct and indirect costs). The formula is simply:

$$\text{Donor beneficial income multiplier} = \frac{\text{(net income/pump system-year x effective pump system life)}}{\text{(total cost per pump system – retail price per pump system)}}$$

Recognizing there is a spread of estimates about key factors such as (1) indirect workshop costs, (2) pump type used and its associated costs, and (3) the average lifetime of the system components (weighted by cost of each component), a range of low, medium and high estimates were made for each of the three factors. The scenario is based on the costs to import a forty-foot shipping container filled with 550 pumps, and the same number of 100m hoses and 370 W solar panels. 550 pieces is the volumetric limit of that size container, noting that weight is not the controlling factor for an equal mix of 550 pieces each for these three items. Appendix Three provides a detailed breakdown of direct and indirect pump system costs. Prices and costs are all adjusted for inflation to reflect October 2024.

45 combinations were then calculated from the combination of 3 x 3 x 5 low-medium-high estimates.

(1) Pump type and cost:[8]

a. $22 small brushed pump

b. $28 medium brushless pump

c. $40 big brushless pump

(2) Fraction of annual Blantyre workshop costs (also called total Kachione LLC expenses) covered by a single 40 ft container of pumps, hoses and panels:[9]

a. 50% of annual workshop costs

b. 75% of annual workshop costs

c. 100% of annual workshop costs

(3) the average lifetime of the system components (weighted by cost of each component)

a. 1.5 years

b. 2.0 years

c. 2.5 years

d. 3.0 years

e. 3.5 years

---

[8] A very conservative assumption made is that crop harvest and net dry season farm income matches the 2024 average for the small pump systems, and is not adjusted upward for the medium and big brushless pumps, despite the fact that the medium pump water flow rate under the same solar conditions is about 40% greater than the brushed pump and the big brushless pump is about 50% greater.

[9] Kachione LLC's expenses (workshop and staff costs) are also supported by the MECS Modern Energy Cooking Systems grant, direct Solar4Africa cash contributions, and the sale of cookers and "Forever Batteries / Bateri Lokhalitsa"

An even wider spread could be calculated by adding another factor, such as the average dry season net income as fractions of the 2024 dry season (e.g. 70%, 100% and 130%).

Table 14: Pump System Lifetime Estimate Extremes

Pump System Lifetime Estimate Extremes				
	EXTREME LOW ESTIMATE			
	Pump	Hose	Panel	System
Factory Door Cost, $	40	30	35	105
Lifetime, years	0.5	1.5	2.5	
Cost x Life	20	45	87.5	153
Weighted System Life				1.5
	EXTREME HIGH ESTIMATE			
	Pump	Hose	Panel	System
Factory Door Cost, $	28	30	35	93
Lifetime, years	2.0	3.0	5.0	
Cost x Life	56	90	175	321
Weighted System Life				3.5

The low lifetime estimate of 1.5 years is very pessimistic and does not reflect the observed lifetimes of the pump system components in the field. Pumps that only last a half year, hoses that only last a year and a half, and glass-glazed PV panels that only last 2.5 years: these are very short lifetimes that do not reflect our experience to date. Furthermore, the cost of the system already assumes a breakage rate of 10 to 15%, depending on the component. See Table 14.

The high lifetime estimate, on the other hand, is quite modest and quite possibly still an underestimate. A pump life of only 2 years is modest, especially considering that a repair technician workforce is now in place that can repair the pumps at a small fraction of their cost to keep them running even after brushes, bearings, shaft seals and gaskets wear out. The repair cost is just MWK 22,000 for a small brushed pump that initially costs MWK 150,000. Likewise, a 3-year lifetime for the hose is modest because the hose type ordered is a durable thick-walled variety, significantly tougher than the typical thin-walled irrigation hose sold in Malawi. Finally, a lifetime of only 5 years for the glass-glazed solar panels is quite modest, given that the estimated stationary panel lifetime is twenty years. The observed breakage rate of hand carried panels (3 out of 72 panels) for solar irrigation is currently only about 4.2 % per year. This implies an average lifetime of 24 years based on breakage rate (not deterioration rate), far longer than the 5-year estimate made here. Again, see Table 14.

The resulting mean of 27.9 for the benefit multiplier for this 2024 study is simply the outcome of the medium estimates for all three factors: (1) pump type & cost, (2) fraction of Blantyre workshop & staff costs covered, and (3) cost-weighted average equipment lifetime. See Table 15 for the specific values for all 3x3x5 = 45 combinations. Since 4.5 estimates are 10% of 45, and sorting the 45 estimates in numerical order, we can gauge

Table 15: Low Med High Estimate Combinations, 3x3x5=45 Combinations

	Low	Mean	High	Low	Mean	High	Low	Mean	High
% of Kachione Annual Costs	50%	75%	100%	50%	75%	100%	50%	75%	100%
Pump Cost	$22	$22	$22	$28	$28	$28	$40	$40	$40
Benefit Multiplier, 1.5 Year Lifetime	17.0	14.0	11.9	21.3	16.8	13.7	23.4	17.9	14.6
Benefit Multiplier, 2.0 Year Lifetime	22.6	18.6	15.8	28.4	22.4	18.3	31.2	23.9	19.5
Benefit Multiplier, 2.5 Year Lifetime	28.3	23.3	19.8	35.5	27.9	22.9	39.0	29.9	24.3
Benefit Multiplier, 3.0 Year Lifetime	34.0	27.9	23.7	42.6	33.5	27.5	46.8	35.8	29.2
Benefit Multiplier, 3.5 Year Lifetime	39.6	32.6	27.7	49.7	39.1	32.1	54.6	41.8	34.1

the 90% confidence interval by excluding 2.25 estimates on each end, using interpolation between the 2nd and 3rd benefit multiplier estimates at the low and high end tails. We therefore construct the 90% confidence interval as between 13.8 and 49.0.

For comparison, the mean benefit multiplier for the 2023 study was 16. The pump systems' price in 2023 was 50% of total costs, while the pump systems' price in 2024 was 75% of total costs. Given the reduced subsidy in 2024 (25% subsidy, reduced from 50%), one would expect the benefit multiplier to approximately double. The benefit multiplier between these two studies is 28/16 = 1.75, almost a doubling. It is encouraging to find such consistency between the 2023 study of 9 pumps and 24 users, and the 2024 study of 72 pumps and 136 users, especially when the former study is based on a small non-random case study of pump sharing groups while the latter is based on a much larger randomized sample.

Given the low-medium-high estimates for two factors, and a range of 5 estimates for the third factor, histograms can be constructed of varying widths of benefit multiplier intervals. See Figure 21 and Figure 22.

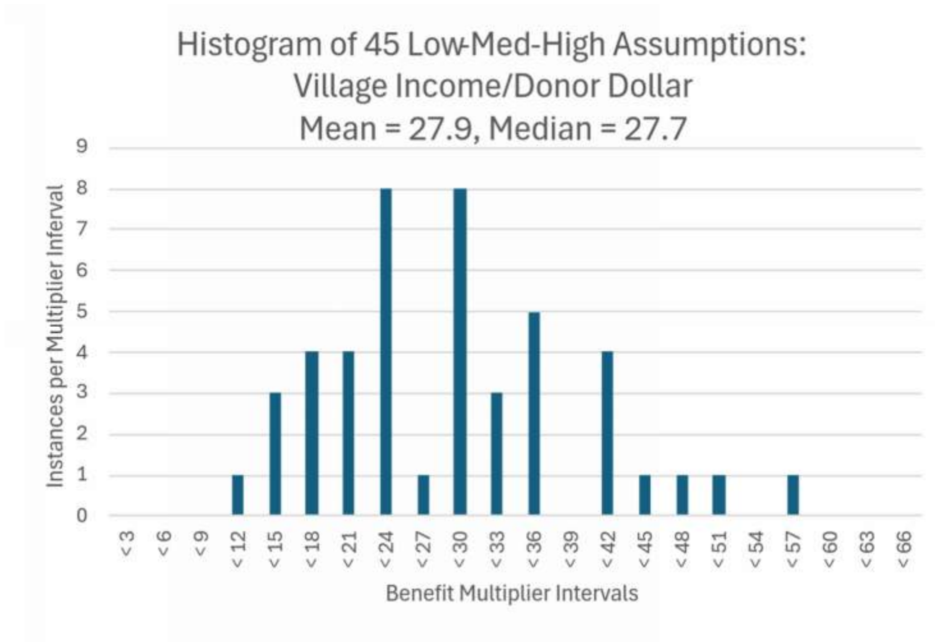


Figure 22:Histogram of Village Income / Donor Dollar ($3 intervals)

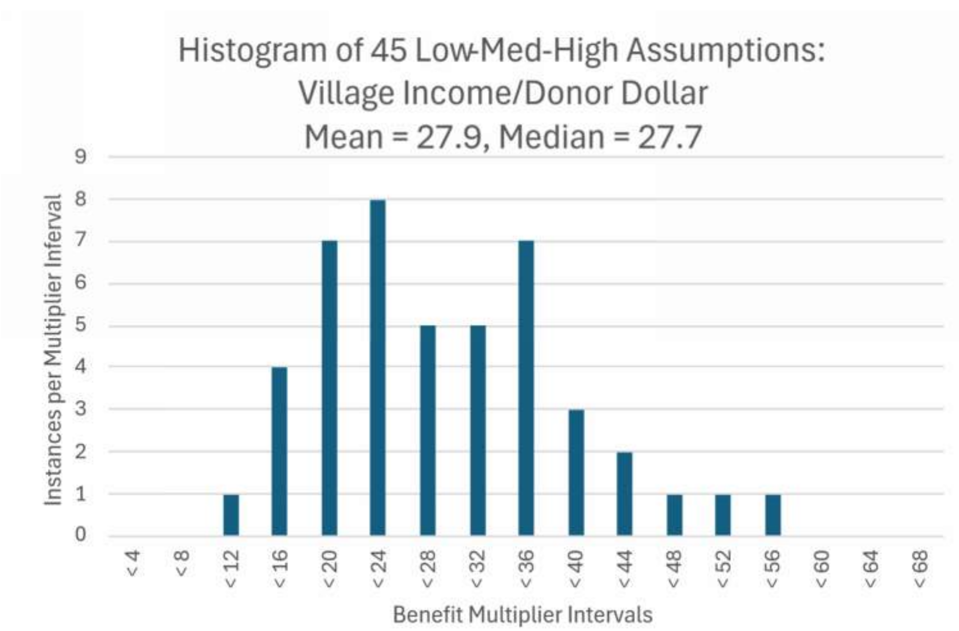


Figure 21: Histogram of Village Income / Donor Dollar ($5 intervals)

The Pump User's Perspective: Return on Investment

From a villager's perspective, investing in a solar irrigation pump system needs to compare favorably to what they could otherwise invest in additional land, seed, fertilizer and other inputs to grow more crops during the wet season. Because the pump users were asked detailed questions about their 2023 and 2024 wet season farming input costs and harvest income, we can calculate the net/gross farm income ratio, and from that, the Return on Investment, which equals (Gross Harvest Income – Farming Input Costs)/(Gross Harvest Income). The interview results are shown in Table 16.

Table 16: Wet Season Farming Return on Investment

	2023	2024
Wet Season Net/Gross Income Ratio:	0.666	0.556
Return On Investment[1]:	200%	125%

[1] If r = Net/Gross Income Ratio, then ROI = (Gross-Net)/Gross = r/(1-r)

It's important to note that 2023 was a more typical wet season (although a small subset of farmers were negatively impacted by Cyclone Freddie), while the 2024 wet season was impacted, in some cases severely, by a punishing drought that persisted for several weeks, dramatically reducing many farmer's wet season crop yields. Therefore the 2023 wet season average ROI = 200% was more typical, while 2024 wet season average ROI = 125% was unusually low. Robert Van Buskirk has noted that in conversations with many Malawian business people, the conventional go/no go decision to invest is also usually a 200% ROI, which matches typical villagers' expectations for a 200% ROI from wet season farming. Severely cash-limited Malawians in their high-risk environment need a 200% ROI, even after correcting for a 32% annual inflation rate.

For the 2023 and 2024 dry seasons, similar detailed questions were asked of solar pump users to determine input costs and dry season harvest income. The input costs included the cost of the pump system amortized over three years. If we assume a different pump system lifetime, algebraic analysis will show that we simply subtract from the net income (3-L)/3L times system cost where L = system lifetime, which is a component cost-weighted average lifetime. Intuitively the return on investment will be quite high because if a villager purchases a pump at the outset of the dry season, they can readily earn several times more than their pump investment in a three or four month growing season.

Because single users of a pump have a greater investment in a pump system and earn greater net income, it is useful to compare Single Users to Shared Pump Users. The results are summarized in Table 17.

Table 17: 2024 Dry Season Solar Pump System Return on Investment

	Single User	Shared User
Number of Users (Owners) Per Pump:	1	4
Number of Users Interviewed in 2024:	28	108
Annual Dry Season Net Income for 2024:	828,238	714,101
Assumed System Lifetime:	2.5	2.5
System Cost (purchased in 2024):	450,000	450,000
Shared System Cost (Cost/Users):	450,000	112,500
Corrected Dry Season Net Income[1]:	798,238	706,601
Annualized System Cost:	180,000	45,000
Return On Investment:	440%	1570%

[1] Corrected Net Income is Net Income-SharedSystemCost(3-L)/(3L)

The calculated Return on Investment from solar irrigation pumps is quite astonishing: 440% for single pump users and 1,570% for shared pump users. This is several times higher than a rural villager's wet season expected ROI of 200%[10]. When we shifted from a price/total cost ratio of 50% in 2023 to a ratio of 75% in 2024, we did observe price sensitivity and noticed that demand tapered off a bit. Our mission requires us to keep the price of the system accessible to most villagers, smallholder farmers, and not just the highest income villagers and largest landowners.

Nevertheless, given these extraordinary ROIs, with sufficient philanthropic financing it should be feasible to continue to push volumes up, unit costs down, and the retail price/total cost ratio upward, perhaps even to

[10] Another ROI comparison that could be made is against similar acreage during the dry season that is irrigated using hand-carried watering cans hired labor, or is watered using treadle pumps powered by hired labor. Another comparison would be to rented or purchased diesel or petrol-powered water pumps.

exceed a ratio of one, covering all costs plus a modest profit. While this may sound exciting, we must point out that we do not envision outside investors repatriating profits from Malawi, both because it is extremely difficult and complex, and because profit-taking by outsiders is not part of our philanthropic mission and goals. On the other hand, it may be feasible to incubate a Malawi pump system business that ultimately becomes self-sustaining while continuing to serve smallholder village farmers.

APPENDIX ONE: DETAILED DATA TABLES.

Table A1: Demographic Data, Pump Usage & Breakage, and Farming Relative Income

Village Shop Abbrev.[4]	ID #	Pump usage share	Customer or user found?[2]	Pump Broke	Panel(s) Broke	Other Reason or No R.	Pump Group Size	# Pumps Owned By Group	Total # Adults	Total # children	Total Household Size	Household Expenses / Month	Expnses / person.day	Expenses / person.day[1]	2024 Wet Crop Inc. / Ann. Exp.	2024 Dry Crop Inc. / Ann. Exp.	2024 Farm Net Inc. / Ann. Exp.
		ratio	yes/no	note below	note below	note below	users	pumps	persons	persons	persons	MWK/mo.	MWK/p.day	US$/p.day	ratio	ratio	ratio
BAL	1.01	0.286	yes	X			4	1	1	5	6	150,000	833	0.35	13%	-1%	13%
BAL	1.02	0.143	yes	X					1	2	3						
BAL	1.03	0.286	yes	O					2	4	6	200,000	1,111	0.46	25%	15%	40%
BAL	1.04	0.286	yes	O					2	3	5	100,000	667	0.28	75%	20%	95%
BAL	2.01		no														
BAL	3.01		no														
BAL	4.01		no														
BAL	5.01	0.286	yes	X			4	1	2	3	5	100,000	667	0.28	28%	2%	30%
BAL	5.02	0.143	yes	O					2	2	4						
BAL	5.03	0.286	no														
BAL	5.04	0.286	no														
BAL	6.01	0.333	yes				3	1	2	3	5	250,000	1,667	0.69	23%	37%	60%
BAL	6.02	0.333	yes						2	4	6	150,000	833	0.35	5%	111%	116%
BAL	6.03	0.333	yes						2	3	5	300,000	2,000	0.83	9%	33%	42%
BAL	7.01		no														
BAL	8.01		no														
BAL	9.01		no														
BAL	10.01		no														
BAL	11.01		no														
BAL	12.01	1.000	yes	O			1	1	2	2	4						
BAL	13.01		no														
BAL	14.01		no														
BAL	15.01	1.000	yes				1	1	2	4	6	105,000	583	0.24	28%	58%	86%
CHN	1.01	0.500	yes				2	1	2	3	5	300,000	2,000	0.83	8%	51%	59%
CHN	1.02	0.500	yes						2	3	5	200,000	1,333	0.56	1%	76%	77%
CHN	2.01	0.500	yes	X			2	1									
CHN	3.01	1.000	yes				1	1	2	2	4	250,000	2,083	0.87	8%	57%	65%
CHN	4.01	0.200	yes	O			5	1	2	4	6	250,000	1,389	0.58	0%	30%	30%
CHN	4.02	0.200	yes	O					1	3	4	100,000	833	0.35	0%	32%	32%
CHN	4.03	0.200	yes	O					2	3	5	200,000	1,333	0.56	0%	65%	65%
CHN	4.04	0.200	yes	X					2	5	7	300,000	1,429	0.60	0%	0%	0%
CHN	4.05	0.200	yes	O					2	3	5	200,000	1,333	0.56	0%	35%	35%
CHN	5.01		no														
CHN	6.01		no														
CHN	7.01	0.250	yes				4	1	2	4	6	150,000	833	0.35	0%	18%	18%
CHN	8.01	0.333	yes				3	1	2	2	4	120,000	1,000	0.42	0%	41%	41%
CHN	9.01	1.000	yes	O			1	1	1	3	4	100,000	833	0.35	0%	43%	43%
CHN	10.01		no														
CHN	11.01	0.200	yes				5	1	2	3	5	150,000	1,000	0.42	0%	46%	46%
CHN	12.01	0.333	yes				3	1	2	4	6	350,000	1,944	0.81	0%	16%	16%
CHN	13.01	0.333	yes				3	1	1	3	4	200,000	1,667	0.69	0%	22%	22%
CHN	14.01	1.000	yes				1	1	2	3	5	150,000	1,000	0.42	0%	73%	73%
CHN	15.01	0.250	yes				4	1	2	6	8	350,000	1,458	0.61	0%	26%	26%
CHZ	1.01		no														
CHZ	2.01		no														
CHZ	3.01		no														
CHZ	4.01		no														
CHZ	5.01		no														
CHZ	6.01		no														
CHZ	7.01	1.000	yes	X			1	1	2	4	6	200,000	1,111	0.46	0%	3%	3%
CHZ	8.01		no														
CHZ	9.01		no														
CHZ	10.01		no														
CHZ	11.01		no														
CHZ	12.01	0.333	yes				3	1	2	6	8	140,000	583	0.24	19%	56%	75%
CHZ	12.02	0.333	yes						1	3	4	100,000	833	0.35	-15%	49%	34%
CHZ	12.03	0.333	yes						2	4	6	200,000	1,111	0.46	2%	17%	19%
CHZ	13.01		no														
CHZ	14.01		no														
CHZ	15.01		no														
CHZ	16.01	0.250	yes				4	1	2	6	8	70,000	292	0.12	22%	82%	104%
CHZ	16.02	0.250	yes						2	4	6	300,000	1,667	0.69	-5%	14%	9%
CHZ	16.03	0.250	yes						2	4	6	20,000	111	0.05	-29%	251%	222%
CHZ	16.04	0.250	yes						1	3	4	100,000	833	0.35	0%	76%	76%

Village Shop Abbrev.[4]	ID #	Pump usage share	Customer or user found?[2]	Pump Broke	Panel(s) Broke	Other Reason or No R.	Pump Group Size	# Pumps Owned By Group	Total # Adults	Total # children	Total Household Size	Household Expenses / Month	Expnses / person.day	Expenses / person.day[1]	2024 Wet Crop Inc. / Ann. Exp.	2024 Dry Crop Inc. / Ann. Exp.	2024 Farm Net Inc. / Ann. Exp.
		ratio	yes/no	note below	note below	note below	users	pumps	persons	persons	persons	MWK/mo.	MWK/p.day	US$/p.day	ratio	ratio	ratio
DDZ	1.01	0.333	yes				3	1	2	3	5	50,000	333	0.14	256%	66%	322%
DDZ	1.02	0.333	yes						2	4	6	100,000	556	0.23	118%	28%	146%
DDZ	1.03	0.333	yes						2	2	4	80,000	667	0.28	110%	84%	194%
DDZ	2.01	1.000	yes				1	1	3	1	4						
DDZ	3.01	0.333	yes	O			3	1	1	4	5	100,000	667	0.28	33%	151%	183%
DDZ	4.01	0.333	yes	O			3	1	2	4	6	200,000	1,111	0.46	52%	12%	63%
DDZ	4.02		no														
DDZ	4.03		no														
DDZ	5.01	1.000	yes		X		1	1	1	3	4						
KAB	1.01		no														
KAB	2.01	0.500	yes				2	1	1	2	3	60,000	667	0.28	334%	155%	489%
KAB	2.02	0.500	yes						2	4	6	80,000	444	0.19	258%	161%	419%
KAB	3.01		no														
KAB	4.01		no														
KAB	5.01	1.000	yes	X			1	1	2	3	5	150,000	1,000	0.42	55%	-1%	53%
KAB	6.01	1.000	yes				1	1	2	4	6	100,000	556	0.23	270%	180%	451%
KAB	7.01	1.000	yes	X			1	1	2	4	6	100,000	556	0.23	0%	-1%	-1%
KAB	8.01	1.000	yes	X			1	1	1	2	3	70,000	778	0.32	0%	-6%	-6%
LUN	1.01	0.200	yes				5	1	2	2	4	100,000	833	0.35	19%	0%	19%
LUN	1.02	0.200	yes						2	1	3	50,000	556	0.23	-8%	108%	100%
LUN	1.03	0.200	yes						1	5	6	138,600	770	0.32	0%	14%	14%
LUN	1.04	0.200	yes						2	1	3	90,000	1,000	0.42	36%	40%	76%
LUN	1.05	0.200	yes						1	5	6	70,000	389	0.16	-9%	49%	40%
LUN	2.01	1.000	yes				1	1	2	4	6	600,000	3,333	1.39	2%	6%	9%
LUN	3.01		no														
LUN	4.01	0.200	yes				10	2	2	6	8	200,000	833	0.35	0%	14%	14%
LUN	4.02	0.200	yes						1	4	5	300,000	2,000	0.83	6%	0%	6%
LUN	4.03	0.200	no														
LUN	4.04	0.200	no														
LUN	4.05	0.200	no														
LUN	4.06	0.200	no														
LUN	4.07	0.200	no														
LUN	4.08	0.200	no														
LUN	4.09	0.200	no														
LUN	4.10	0.200	no														
LUN	5.01	0.200	yes	X			5	1									
LUN	5.02	0.200	no														
LUN	5.03	0.200	no														
LUN	5.04	0.200	no														
LUN	5.05	0.200	no														
LUN	6.01	1.000	no				1	1									
LUN	7.01	0.250	no				4	1									
LUN	7.02	0.250	no														
LUN	7.03	0.250	no														
LUN	7.04	0.250	no														
LUN	8.01		no														
LUN	9.01	0.333	yes	X													
LUN	9.02	0.333	yes	X													
LUN	9.03	0.333	yes	O			3	1	1	3	4	150,000	1,250	0.52	11%	29%	39%
LUN	10.01		no														
LUN	11.01	0.167	yes				6	1	2	1	3	150,000	1,667	0.69	13%	24%	37%
LUN	11.02	0.167	yes						1	2	3	100,000	1,111	0.46	43%	29%	72%
LUN	11.03	0.167	no														
LUN	11.04	0.167	no														
LUN	11.05	0.167	no														
LUN	11.06	0.167	no														
LUN	12.01		no														
LUN	13.01		no														
LUN	14.01		no														
LUN	15.01	0.200	yes				5	1	2	3	5	200,000	1,333	0.56	9%	19%	28%
LUN	15.02	0.200	yes						1	3	4	100,000	833	0.35	33%	42%	75%
LUN	15.03	0.200	yes						1	2	3	70,000	778	0.32	65%	97%	163%
LUN	15.04	0.200	yes						2	3	5						
LUN	15.05	0.200	yes						2	4	6	150,000	833	0.35	26%	18%	44%
LUN	16.01	0.200	yes	O			5	1	2	4	6	170,000	944	0.39	20%	18%	37%
LUN	16.02	0.200	yes	O					2	2	4	100,000	833	0.35	52%	24%	75%
LUN	16.03	0.200	yes	O					2	4	6	200,000	1,111	0.46	22%	13%	35%
LUN	16.04	0.200	yes	O					2	3	5	150,000	1,000	0.42	42%	20%	62%
LUN	16.05	0.200	yes	O					2	3	5	250,000	1,667	0.69	7%	33%	40%
LUN	17.01	0.500	yes				2	1	1	2	3	100,000	1,111	0.46	20%	19%	39%
LUN	17.02	0.500	yes						2	3	5	200,000	1,333	0.56	33%	9%	43%

Village Shop Abbrev.[4]	ID #	Pump usage share	Customer or user found?[2]	Pump Broke	Panel(s) Broke	Other Reason or No R.	Pump Group Size	# Pumps Owned By Group	Total # Adults	Total # children	Total Household Size	Household Expenses / Month	Expnses / person.day	Expenses / person.day[1]	2024 Wet Crop Inc. / Ann. Exp.	2024 Dry Crop Inc. / Ann. Exp.	2024 Farm Net Inc. / Ann. Exp.
		ratio	yes/no	note below	note below	note below	users	pumps	persons	persons	persons	MWK/mo.	MWK/p.day	US$/p.day	ratio	ratio	ratio
MAC	1.01	0.250	yes			X	4	1									
MAC	2.01	0.333	yes				3	1	2	4	6	100,000	556	0.23	15%	68%	83%
MAC	2.02	0.333	yes						2	4	6	450,000	2,500	1.04	9%	36%	45%
MAC	2.03	0.333	yes						2	4	6	300,000	1,667	0.69	2%	32%	34%
MAC	3.01	0.250	yes	O			4	1	1	2	3	50,000	556	0.23	0%	65%	65%
MAC	3.02	0.250	yes	O													
MAC	3.03	0.250	yes	O													
MAC	3.04	0.250	yes	X													
MAC	4.01	1.000	yes				1	1	2	5	7						
MAC	5.01	1.000	yes				1	1	2	4	6	150,000	833	0.35	0%	39%	39%
MAC	6.01		no														
MAC	7.01	0.250	no														
MAC	7.02	0.250	yes				4	1	2	5	7	100,000	476	0.20	0%	37%	37%
MAC	7.03	0.250	no														
MAC	7.04	0.250	no														
MAC	8.01	1.000	yes				1	1	2	3	5	80,000	533	0.22	0%	54%	54%
MAC	9.01		no														
MAC	10.01	0.333	no				3	1									
MAC	10.02	0.333	no														
MAC	10.03	0.333	no														
MAC	11.01	0.250	no				4	1									
MAC	11.02	0.250	no														
MAC	11.03	0.250	no														
MAC	11.04	0.250	no														
MAC	12.01	0.333	no				3	1									
MAC	12.02	0.333	no														
MAC	12.03	0.333	no														
MAC	13.01	1.000	yes				1	1									
MAN	1.01	1.000	yes				1	1	2	7	9	270,000	1,000	0.42	0%	62%	62%
MAN	2.01	1.000	yes				1	1	1	4	5	50,000	333	0.14	0%	209%	209%
MAN	3.01	1.000	yes				1	1	1	6	7	150,000	714	0.30	0%	123%	123%
MAN	4.01	1.000	yes				1	1	2	4	6	150,000	833	0.35	0%	80%	80%
MAN	5.01	0.111	yes				9	1									
MAN	6.01	1.000	yes				1	1	1	2	3	100,000	1,111	0.46	0%	75%	75%
MAN	7.01	0.067	yes				15	1									
MAN	7.02	0.067	no														
MAN	7.03	0.067	no														
MAN	7.04	0.067	no														
MAN	7.05	0.067	no														
MAN	7.06	0.067	no														
MAN	7.07	0.067	no														
MAN	7.08	0.067	no														
MAN	7.09	0.067	no														
MAN	7.10	0.067	no														
MAN	7.11	0.067	no														
MAN	7.12	0.067	no														
MAN	7.13	0.067	no														
MAN	7.14	0.067	no														
MAN	7.15	0.067	no														
MAN	8.01	0.200	yes				5	1									
MBA	1.01	0.333	yes				3	1	1	2	3	30,000	333	0.14	537%	148%	685%
MBA	1.02	0.333	yes						2	2	4	100,000	833	0.35	205%	36%	241%
MBA	1.03	0.333	yes						1	2	3	50,000	556	0.23	161%	64%	224%
MBA	2.01	1.000	yes			X	1	1	2	2	4	100,000	833	0.35	71%	-4%	67%
MBA	3.01	1.000	yes		X		1	1									
MBA	4.01		no														
MBA	5.01		no														
MBA	6.01	0.500	yes				2	1	1	2	3	150,000	1,667	0.69	48%	21%	69%
MBA	6.02	0.500	yes						1	3	4	100,000	833	0.35	93%	34%	127%
MBA	7.01		no														
MBA	8.01	1.000	yes				1	1	2	2	4	250,000	2,083	0.87	47%	21%	68%
MBA	9.01	1.000	yes		X		1	1	2	4	6	200,000	1,111	0.46	64%	-2%	62%
MBA	10.01		no														
MBA	11.01	1.000	yes				1	1	2	8	10	250,000	833	0.35	140%	18%	158%
NSD	1.01	0.333	yes				3	1	2	7	9	150,000	556	0.23	10%	71%	81%
NSD	1.02	0.333	yes						2	3	5	300,000	2,000	0.83	-3%	54%	51%
NSD	1.03	0.333	yes						2	4	6	300,000	1,667	0.69	3%	36%	39%
NSD	2.01		no														
NSD	3.01		no														
NSD	4.01	0.500	yes				2	1	2	6	8	450,000	1,875	0.78	-1%	51%	50%
NSD	4.02	0.500	yes						2	4	6	200,000	1,111	0.46	5%	157%	162%
NSD	5.01	0.200	yes	X			5	1									
NSD	5.02	0.200	yes	X													
NSD	5.03	0.200	yes	X													
NSD	5.04	0.200	yes	X													
NSD	5.05	0.200	yes	X													

Village Shop Abbrev.[4]	ID #	Pump usage share	Customer or user found?[2]	Pump Broke	Panel(s) Broke	Other Reason or No R.	Pump Group Size	# Pumps Owned By Group	Total # Adults	Total # children	Total Household Size	Household Expenses / Month	Expnses / person.day	Expenses / person.day[1]	2024 Wet Crop Inc. / Ann. Exp.	2024 Dry Crop Inc. / Ann. Exp.	2024 Farm Net Inc. / Ann. Exp.
		ratio	yes/no	note below	note below	note below	users	pumps	persons	persons	persons	MWK/mo.	MWK/p.day	US$/p.day	ratio	ratio	ratio
NSD	6.01	0.250	no				4	1									
NSD	6.02	0.250	no														
NSD	6.03	0.250	no														
NSD	6.04	0.250	no														
NSD	7.01		no														
MPK	1.01	0.200	yes				5	1	2	5	7						
MPK	1.02	0.200	yes						2	6	8						
MPK	1.03	0.200	yes						1	4	5						
MPK	1.04	0.200	yes						2	4	6						
MPK	1.05	0.200	yes						1	3	4						
MPK	2.01	0.333	yes				3	1	2	4	6	400,000	2,222	0.93	7%	26%	33%
MPK	2.02	0.333	yes						2	6	8	400,000	1,667	0.69	4%	24%	29%
MPK	2.03	0.333	yes						3	2	5	300,000	2,000	0.83	4%	25%	30%
MPK	3.01	0.200	yes				5	1	2	4	6	300,000	1,667	0.69	13%	27%	40%
MPK	3.02	0.200	yes						1	6	7	300,000	1,429	0.60	0%	29%	29%
MPK	3.03	0.200	yes						1	3	4	25,000	208	0.09	145%	256%	401%
MPK	3.04	0.200	yes						2	4	6	200,000	1,111	0.46	7%	59%	67%
MPK	3.05	0.200	no						3	3	6						
MPK	4.01	1.000	yes				1	1	2	4	6	300,000	1,667	0.69	3%	35%	38%
MPK	5.01		no														
MPK	6.01	0.167	yes				4	1	1	3	4	250,000	2,083	0.87	7%	60%	68%
MPK	6.02	0.333	yes						1	5	6	200,000	1,111	0.46	3%	15%	18%
MPK	6.03	0.333	yes						2	6	8	330,000	1,375	0.57	10%	11%	21%
MPK	6.04	0.167	yes						2	4	6	250,000	1,389	0.58	6%	23%	29%
MPK	7.01	0.333	yes				3	1	2	2	4	280,000	2,333	0.97	2%	34%	35%
MPK	7.02	0.333	yes						2	5	7						
MPK	7.03	0.333	yes						2	5	7	350,000	1,667	0.69	8%	22%	30%
		# Users[2]	# Users[2]	# X user	# X	# X			Total[2]	Total[2]	Total[2]	Mean[2]	Mean[2]	Mean[2]	Mean[2]	Mean[2]	Mean[2]
		136	136	18	3	2	# Pump	# of	205	423	628	181,415	1,129	0.47	36%	49%	85%
		# Pumps[2]		#O user			Groups[2,3]	Pumps[2,3]	Mean[2]	Mean[2]	Mean[2]	Median[2]	Median[2]	Median[2]	Median[3]	Median[4]	Median[5]
		57.91		20			71	72	1.74	3.58	5.32	150,000	1,000	0.42	7%	34%	50%
				# X pumps				% X	Percent[2]	Percent[2]	Percent[2]						
				9				13%	33%	67%	100%						
				#O pumps				% O	Median[2]	Median[2]	Median[2]						
				8				11%	2	4	5						
				%XO pmp	%X pnl	%X othr		%XO									
				24%	4%	3%		24%									

X = Pump Broke and resulted in 2024 dry season net income < 200,000

O = User Overcame pump break and earned 2024 dry season net income > 200,000

[1] Based on cash shop exchange rate of 2,400 MWK/USD (Oct 2024)

[2] Numbers are based only on cases where customer or user is found & interviewed

[3] One pump group had 2 pumps, so the total number of pumps is one greater than the number of pump groups

[4] See Table A2 for explanation of Village Shop Abbreviation and District where Shop is located

Table A2: Village Shop Abbreviations

	Abbrev.	Village or Town	District
		Mudzi olo Tauni	Boma
1	BAL	Balaka	Balaka
2	CHN	Chinamwali	Zomba
3	CHZ	Chiradzulu	Blantyre
4	DDZ	Dedza (Mganja)	Dedza
5	KAB	Kabudula	Lilongwe
6	LUN	Lundu	Blantyre
7	MAC	Machinga	Machinga
8	MAN	Mangochi	Mangochi
9	MBA	M'bang'ombe	Lilongwe
10	NSD	Nsondole	Zomba
11	MPK	Mpokwa (Jali)	Zomba

APPENDIX TWO: INTERVIEW BLANK FORMS (FOUR PAGES)

PAGE 1: BASIC CUSTOMER/PUMP INFORMATION

Date: Interviewer(s):

Pump Group: Group Chair:

Customer's First & Last Name		
Customer's UPYA ID number		
Customer's Phone Number:		
Customer's District & T/A		
Customer's Village & Village Shop		
	yes/no	if no, why?
Was customer found?		
Does customer have pump?		
Pump has matching serial number?		
Is pump actively used?		

IF YES:

If so, has pump use been verified by others?		
If so, has pump use been directly observed?		
Is pump being shared with others?		
Name of Group or Club:		
Chairwoman/Group Leader:		
How many people are in the group or club?		
Number of Pumps Owned:		
Pump System One Components*		
Pump System Two Components*		
If shared, list users:	pump cost share	pump usage share
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

IF NO (not being used):	yes/no	
Idle?		if yes, why
Broken?		what part broke, why, and why not fixed?
Missing?		which part is missing? why?

* List Pump, Hose & Panel(s)

* Pump = Brushed 185W or Brushless 300W

* Hose = 50m or 100m

* Panels = (2) 100W or (1) 250W, 355W or 370W

PAGE 2: FARM FAMILY INFORMATION

Date: Interviewer(s):

Pump Group: Group Chair:

	Data	Notes
Wife's Name * if farmer		
Husband Name * if farmer		
Contact Phone Number		
Total Number of Children		
No. of Adopted/Foster/Step Children		
Biological Children		
Other Household members		
Total Household Size		

Chair of Solar Pump Group		
Number of Women Sharing Pump		
List other women in the Pump Group		
Total Cost of Pump System		
Pump System (pump, hose & panel specs)		
Ownership (Purchase) Share *		
Usage share of Pump in 2023 *		
Usage share of Pump in 2024*		

Est. Monthly Expenses (MWK/mo)		
Expenses Per Capita Per Month		
NonFarm Type of Business 1		
NonFarm 1 Gross Income (MWK/mo)		
NonFarm 1 Business Expenses (MWK/mo)		
NonFarm 1 Net Income (MWK/mo)		
NonFarm Type of Business 2		
NonFarm 2 Gross Income (MWK/mo)		
NonFarm 2 Business Expenses (MWK/mo)		
NonFarm 2 Net Income (MWK/mo)		
NonFarm Total Net Income		

Farm Location Lat. (dec.degrees) Long. (dec.degrees)

Farm Size (sq. meters) Draw Shape & Dimensionss Below

PAGE 3: WET SEASON FARMING COST AND HARVEST INFORMATION						
Date:	Customer's First & Last Name:			Interviewer(s)		
Pump Group:	Group Chair:					
	Typical Wet Season Harvest		2023 Wet Season Harvest (Cyclone Freddy)		2024 Wet Season Harvest (Drought)	
WET SEASON	Amount	Notes	Amount	Notes	Amount	Notes
FARM AND CROP HARVEST INFORMATION						
Farm Area (sq. meters)						
Maize Area (sq.meters)						
Maize Harvest (50kg bags)						
Maize Yield, Tonnes/Ha						
Maize Amount Eaten, not Sold						
Harvest, Other Crop A						
Crop A Amount Eaten, not Sold						
Harvest, Other Crop B						
Crop B Amount Eaten, not Sold						
Harvest, Other Crop C						
Crop C Amount Eaten, not Sold						
Harvest, Other Crop D						
Crop D Amount Eaten, not Sold						
FARM INCOME						
Maize Wholesale Price (per 50 kg bag)						
Other Crop A Wholesale Price						
Other Crop B Wholesale Price						
Other Crop C Wholesale Price						
Other Crop D Wholesale Price						
Maize Gross Income						
Other Crop A Gross Income						
Other Crop B Gross Income						
Other Crop C Gross Income						
Other Crop D Gross Income						
Total Farm Gross Income						
Costs and Expenses						
Seed Cost						
Fertilizer Cost						
Pesticide Cost						
Labor Cost						
Pump Cost/3 yrs						
Land Rent						
Other Cost 1 (describe)						
Other Cost 2 (describe)						
Total Farm Costs						
Net Income and Ratios						
Net Farm Income						
Net/Gross Farm Income Ratio						
Net Farm/Total Net Income Ratio						
Dry Season Net Farm/Total Annual Income						

PAGE 4: DRY SEASON FARMING COST AND HARVEST INFORMATION							
Date:	Customer's First & Last Name:				Interviewer(s):		
Pump Group:	Group Chair:						
	Typ. Dry Season Harvest (Watering Cans)*		2023 Dry Season (Solar Pump Irrigation)*		2024 Dry Season Plans (Solar Pump Irrigation)*		
DRY SEASON	Amount	Notes	Amount	Notes	Estimated	Actual	Notes
FARM AND CROP HARVEST INFORMATION							
Farm Area (sq. meters)							
Maize Area (sq.meters)							
Maize Harvest (50kg bags)							
Maize Yield, Tonnes/Ha							
Maize Amount Eaten, not Sold							
Harvest, Other Crop A							
Crop A Amount Eaten, not Sold							
Harvest, Other Crop B							
Crop B Amount Eaten, not Sold							
Harvest, Other Crop C							
Crop C Amount Eaten, not Sold							
Harvest, Other Crop D							
Crop D Amount Eaten, not Sold							
FARM INCOME							
Maize Wholesale Price (per 50 kg bag)							
Other Crop A Wholesale Price							
Other Crop B Wholesale Price							
Other Crop C Wholesale Price							
Other Crop D Wholesale Price							
Maize Gross Income							
Other Crop A Gross Income							
Other Crop B Gross Income							
Other Crop C Gross Income							
Other Crop D Gross Income							
Total Farm Gross Income							
Costs and Expenses							
Seed Cost							
Fertilizer Cost							
Pesticide Cost							
Labor Cost							
Pump Cost/3 yrs							
Land Rent							
Other Cost 1 (describe)							
Other Cost 2 (describe)							
Total Farm Costs							
Net Income and Ratios							
Net Farm Income							
Net/Gross Farm Income Ratio							
Net Farm/Total Net Income Ratio							
Dry Season Net Farm/Total Annual Income							

APPENDIX THREE: PUMP SYSTEM TOTAL DIRECT + INDIRECT COSTS

Total Direct + Indirect Costs of Solar Irrigation System (Pump + Hose + Solar Panel)

	1734	MWK/USD for **USD to MWK** conversion based on official exchange rate					
	2400	MWK/USD for **MWK to USD** conversion based on Cash Shop Exchange Rate (to repay loan in USD)[1]					
	All	Pumps	Hoses	Panels			
Contents of a 40 ft shipping container		**550**	**550**	**550**			
Factory Price per Unit		$ 40.00	$ 30.00	$ 35.00			
Factory Price	$ 57,750	$ 22,000	$ 16,500	$ 19,250			
Sea Shipping Cost, 40 high cube	$ 12,000						
Purchase Container for Storage	$ 3,000						
January Order Cost	$ 72,750						
May Seaport to Blantyre Trucking Cost	$ 3,000						
Factory + Shipping Cost	$ 75,750						
Factory + Shipping Cost	MWK 181,800,000						
Import Taxes & Fees, % of Factory Price		12.6%	54.4%	10.3%	see Import Taxes & Fees Sheet/Tab		
Import Taxes and Fees	MWK 23,782,676	MWK 4,804,767	MWK 15,551,045	MWK 3,426,864			
		34.7%	**35.6%**	**29.7%**	Fractional Cost		
Agency Fee & In Blantyre Transit	MWK 2,000,000				of Factory Price + Shipping + Import Taxes & Fees		
Purchase Container for Storage	MWK 7,200,000						
Secure Storage Yard Rent, 1 year	MWK -	Storage yard + security costs MWK 200,000 per month.					
Cost per 40 HC Container	MWK 214,782,676	Contains pumps, hoses and panels					
Costs Above are per Shipping Containter							
Costs Below are per System (pump + 100m hose + 370W panel)							
Cost per pump system	MWK 390,514	**$ 163**	Includes all shipping, import and Malawi storage costs,				
Install Panel-Pump Connector	MWK 4,800		but not theft, breakage, warranty, assembly & distribution costs.				
Assemble with Installion & User Sheets	MWK 480						
Basic Gross Cost	MWK 395,794						
Breakage, Theft & Pump Warranty[2]	MWK 60,835		can also approximate overhead costs until sales roll in				
Cost Incl, Breakage, Theft & Wrnty	**MWK 456,629**	**$ 190**	$ 104,644				
Loan Interest	MWK -	**0%**	loan interent %/yr	**0%**	percent loan instead of grant[5]		
Local Bank & Legal Fees	MWK -	**0%**	bank & legal fees, %				
Blantyre Workshop Cost/system	MWK 133,211	**100%**	precentage of workshop annual overhead costs covered by a 40 ft container				
Women's Shop Commission	MWK 65,000						
Rachel & Christina LLC Commission	MWK 65,000						
Kachione Staff Commission	MWK 8,000						
	MWK 727,841	**$ 303**	$ 166,797				
Income, Retail Price[6]	**MWK 550,000**			1.00	Cost factor		
				Per system	Per container		
Income/Expense Ratio	76%	**0.0%**	**loan**	$ -	$ -	**$ -**	**Loan**
Net Cost/Total Cost Ratio	24%	**100.0%**	**grant**	$ 245.77	$ 135,172	**$ 135,000**	**Grant**
				$ 245.77		**$ 135,000**	**Total**
				System Cost Summary			
			100%	$ 105	Factory Door Price		
			155%	$ 163	Plus Shipping & Import Taxes & Fees		
			181%	$ 190	Plus Wire Connectors, Breakage, Theft, Pump Warra		
			289%	$ 303	Plus Commissions, Loan Int. & Workshop Overhead		
Breakage, Theft & Warranty	% of total cost	% of item	Cost				
Pump Breakage & Theft	34.7%	10%	MWK 13,719				
Pump 3-year Warranty[2]	34.7%	15%	MWK 15,378	(Total Refurb + Total Replcmnt) / Number of systems			
Hose Breakage & Theft, No Warranty[3]	35.6%	10%	MWK 14,105				
Panel Breakage & Theft, No Warranty[3]	29.7%	15%	MWK 17,633				
			MWK 60,835				
Detailed Calc of 3-Year Warranty Cost							
2024 big pumps to break in 2025	% refurb/ALL	# broken big pumps	Refurb Cost each pump	Total Refurb Cost	Replemnt Cost each pump	Total Replcmnt Cost	
50	50%	133	MWK 20,000	MWK 1,330,000	MWK 107,188	MWK 7,127,974	

All Malawian kwacha (MWK) amounts are listed in October 2024 values. Per the National Statistical Office of Malawi, as of August 2024 non-food inflation is 23%/year, and national inflation (food + non-food) is 34%/year. Personal observation suggests MWK/USD exchange rate increases approximately match national inflation.

[1] We assume cash shop exchange rate instead of much lower official bank exchange rate because it is our understanding that on a practical basis, the official exchange is nc to bank customers when converting MWK to USD to pay back bank loans by transferring funds from kwacha account to FOREX account.. Instead, to repay loans in USD, fund be withdrawn in cash from Kwacha account, transferred to the cash exchange shop, exchanged for USD at market rate, and then USD cash transferred into FOREX account.

[2] Pump Warranty Policy: Customers can trade in their broken pump for a refurbished pump 10,000 or a new pump for 30,000. Assume that cost of providing a refurbished pum 30,000 incl repair parts+labor (net 20,000 cost), and cost of a new pump is basic gross cost minus 30,000. Further assume that 50% of replacement pumps are refurbished p and 50% are new pumps.Note that these are big pumps, and they can be temporarily replaced with small pumps, until a refurbished or new big pump is avaliable. Finally, assume 15% of new pumps break in 2025, + 50 pumps from 2024.

[3] While many irrigation hoses sold in Malawi are light duty, our hoses are standard duty & expected to last several years before starting to crack and leak. No warranty for pur or other mis-use. Likewise, panels are not warranteed; since likeliest failure is cracking of panel from dropping it or strking it with a hard object, or similar mis-use.

[4] Full year interest accumulation is conservative: we would plan to pay off loan immediately after sales, on a monthly basis, to lower interest charges and reduce currency de

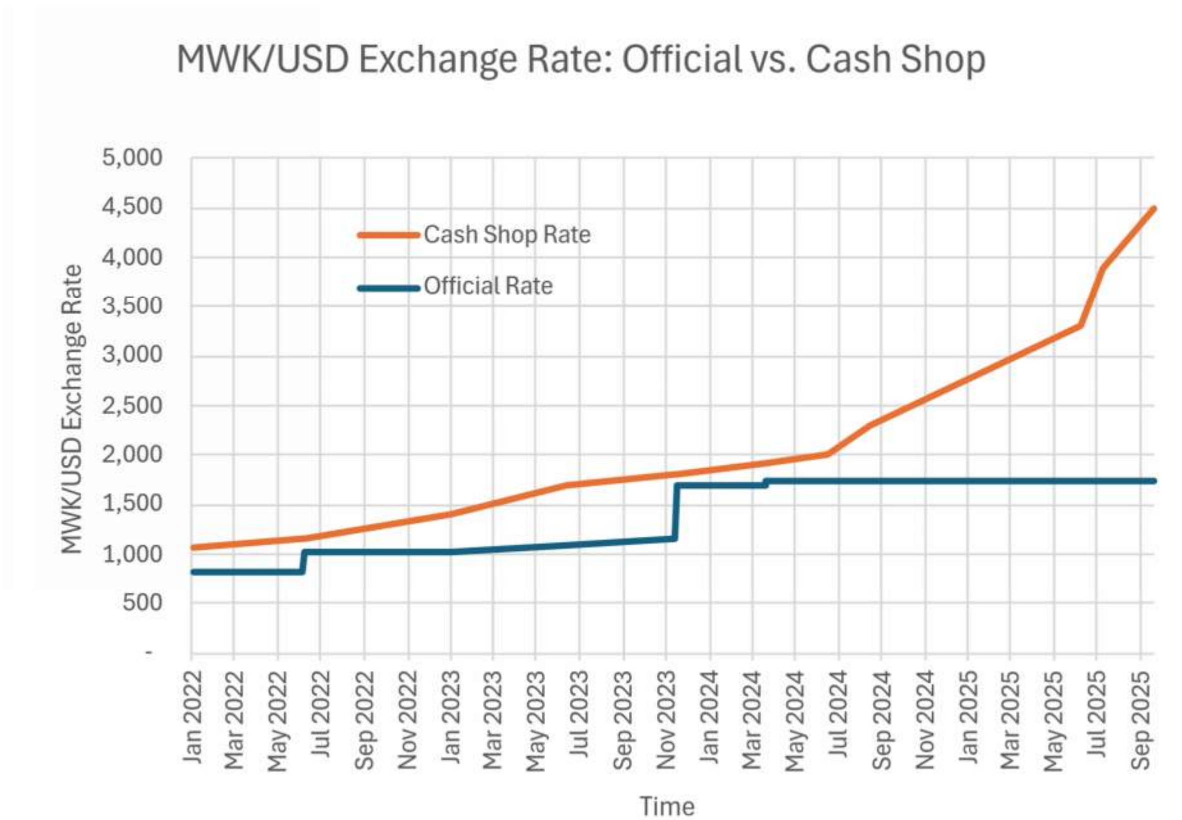
[5] Assuming a loan percentage of subsidy that is higher than that actually requested is conservative regarding costs

[6] Portion of Retail Price Allocated to Commissions:

MWK	90,000	Women's Shop Commission
MWK	65,000	Racheal & Christina LLC Delivery Commission (covers truck and field per diem costs, but not base salaries)
MWK	8,000	Kachione Staff Commission (covers pump assembly of connecctors, and moving materials at storage site)
MWK	387,000	Kachione Net Income
MWK	550,000	Total Retail Price

APPENDIX FOUR: MWK/USD CURRENCY EXCHANGE RATES

Because Malawi sets its official exchange rate well below the true market value of the Malawian kwacha, Malawi experiences a persistent foreign cash shortage and persistent inflation. It seemed that up until recently, when the discrepancy between the official and true market exchange rate[11] reached about 40%, the government would impose a currency devaluation that would bring the official and cash exchange shop rates back into closer alignment. However, for almost two years prior to the September 2025 elections, the government avoided devaluating the kwacha because sudden devaluations are unpopular. As a result, the discrepancy between the official and grey market cash exchange rates grew to an extreme difference, as shown in the figure below.

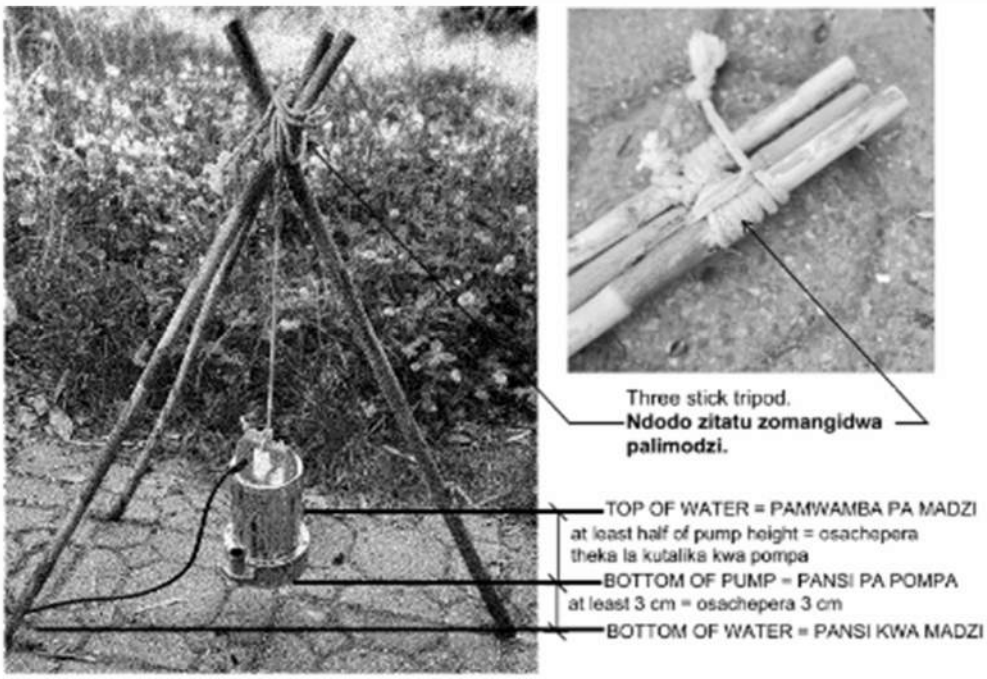


[11] In this appendix we define the "true market" exchange rate as the "grey market" or "cash shop" exchange rate where a receipt is written for a MWK/USD rate that is modestly higher than the official rate, but the actual amount of kwacha given to buy US dollars is much higher. Just prior to the September 2025 election, this "true market" rate was 2.5 times greater than the official exchange rate.

APPENDIX FIVE: PUMP USERS' GUIDE

SOLAR KU MIDZI
Affordable Solar for Villagers

SOLAR PAMPU:TSAMBA LOGWILITSA NTCHITO



MALANGIZO:

1. Nthawi zonse sungani pampu mowongoka popachika pa ndodo zitatu. Imitsani pampu kuti pansi pa pompa pasachepere 3 cm m'mwamba mwa mtsinje, komanso kuti osachepera theka la pampu limizidwe m'madzi.

2. Yatsani pampu pokhapokha litamizidwa m'madzi. Musathamangitse papu mlengalenga popanda madzi.

3.Pachikani pampu pa chogwirira chake. Musanyamule kapena kupachika pampu ndi nthambo ya magetsi.

Zina:

4. Ngati pampu yathyoka, itengereni ku shopu ya solar komwe idagulidwa kuti mukonzetse kapena kusinthitsa.

5. Ngati pampu yanu ili ndi mita ya yamagetsi, ilumikizeni nthawi zonse mukamagwiritsa ntchito kuti mugule katundu wa solar pa mitengo yotsika.

CHENJEZO: SAMALILANI BWINO PAMPU YANU KUTI IKHALE NTHAWI YAYITALI

APPENDIX SIX: PUMP REPAIR WORKSHOP June 2025

Pump Repair Workshop

Jun 17 – 22





The morning of the first day: reviewing how to wire and care for the pumps properly. Thomson Ngupete (with red hat), who normally conducts interviews of solar pump customers, teaches the technicians how to tie a tripod of sticks (Ndodo Zitatu) to hang the pump vertically in the water to increase its' operating life. Other important tips: never hang the pump by its wire (only by its handle) and never run the pump when in the air (only when in the water). The technicians promise to teach the customers these key tricks to ensure longevity.


Afternoon of the first day: Gilbert demonstrates the repair of the 2024 series small pump. Repairing the small pumps is intricate work, involving many steps.



Testing Gilbert's repaired pump in the test pond, using two 18V Forever Batteries in series to simulate full sun on this cloudy day.


Learning how to fix the other year (2022, 2023, 2025) small pumps on the second day of the workshop.




Each technician, fixing a pump on their own, with coaching, but no hands-on help.

The first challenge: fixing a pump on your own.

Testing their own repaired pumps in the test pond. Middle Photo Above: Agness' repaired pump worked so well, she got soaked!

On the third day, fixing the brushless "big" pumps with electronic innards. Compared to the small brushed pumps, they were easier to repair. Update: immediately after this workshop, we completed our tests on twelve models of brushless pumps, and picked the top two performers, the ones that run well on just one solar panel, even in cloudy conditions. The first 200 of these new pumps arrive in just a few days by shipping container (end of October, 2025), along with one thousand 370W solar panels.













SOLAR
KU MIDZI


rotatrim


Hope Chisale / Operations Manager, and Rachael Kanyere / Solar Shops Distribution Manager (bottom right photo).

At the end of the third day the technicians were awarded Solar Pump Repair Technician Certificates (see separate album). The day was topped off with an evening visit to Jacaranda Cultural Center to hear the Sounds of Malawi musician Agorosso. Dancing and much joy ensued.

We originally planned only a three day workshop, but Agness Makwale spoke on behalf of many of the technicians, asking for a longer workshop to solidify their skills. 10 of the 13 technicians stayed for the spontaneously added fourth day.

Fourth day was a review, disassembling and re-assembling a new 2025 pump, as well as repairing all the remaining broken small and big pumps to take back to the village shops.
In the afternoon we had a good discussion with the four shop chairpersons (Agness Makwale/Jali, Rhoda Chizenga/Chikwawa, Annie Jimu/Nsanje, Shawa Kapata/Machinga) about the possibility that a representative from each shop could form the Membership of the Affordable Solar for Villagers (AS4V) NGO. Legally, the Membership needs to meet once a year to advise the Board of the NGO. All the chairpersons, as well as the other technicians, liked this idea. The AS4V Board of Directors met the next day and endorsed this plan; the Board Administrative Committee will work out the details. Another idea from the afternoon discussion: Mavuto and Shawa proposed a travelling demonstration kit of SolarKuMidzi products, to increase the market "watershed" area around each village shop.

The technicians were sent home with repair parts and tool kits:
Below Left: the pump repair parts kit: Lower gasket, upper pipe outlet gasket, two brushes, the spring-loaded shaft seal, the bearings, two short bolts and nuts (for the pipe outlet gasket) and six long bolts and nuts (for the main gasket). For the start, each technician gets three repair parts kits, one for 2024 pumps and two for other years. The village shops will stock replacement parts kits. Next week we will receive and air shipment of 1,000 upper main gaskets, 100 - 2024 impellers and 200 other-year impellers. These supplemental parts will also get bagged up and sent out to the shops.
Below Right: the pump repair technician's tool kit: sandpaper, 8mm T-wrench, screw driver, electrical tape, small hammer, permanent marker (for putting customer's name on the pump to be repaired), RTV silicone sealant, pliers, 8mm wrench, voltage display and resisters (for continuity and voltage testing) and 3 repair parts kits (two for typical years, one for 2024). Not shown: rebar rod with ground round end, devised by Gilbert to create a punch to hammer recalcitrant bearings out of their pump frame sockets.

Afterword: Thomson Ngupete organized a WhatsApp group chat for those technicians with cell phones (all but three). It's a lively chat, with techs sharing repair tips with each other almost every day. Annie is especially active on it, proudly sending short videos of working pumps that she has repaired. Trevor, Mavuto, Hellenes, Mr. Shawa, Rhoda and McFord are also quite "noisy" on the chat (Malawians use "noisy" as a compliment for being actively engaged).

APPENDIX SEVEN: ADDITIONAL PHOTOS

Figure 23: Racheal and Christina preparing to leave the Blantyre Workshop.
Bookkeeper Victoria Baloyi (left) is recording the inventory movement. This is a small delivery. Two layflat hoses are in front of Racheal, and Christina has her hand on a box of two 48V DC solar pumps. The box alongside has switches and electric meters. The meters will be installed in other pump systems already in the field. The red solar vehicle, with 30km range, is for local travel, not solar pump deliveries.

Figure 24: First farm interview is with Gladys Chatama.
From left, Racheal Kanyerere, Bridget Mathesa , Stella Chikafa , Gladys Chatama & Robert Van Buskirk.

Figure 25: Putting the solar pump in the Namiwawa Stream.
Agnes Makwale is holding the pump so Bridget Mathesa can record the pump's serial number. She will also note the GPS lat/long coordinates at the center of Agnes's fields.

Figure 26: Irrigating basins of maize on Agnes' farm.
The photo on the right is uphill from the stream photo on the left.

Figure 27: Maize in the upper field of Agnes Makwale's farm.
Stella – (back to camera) and Memory Lizeo are in the left foreground. The maize in the field to the right is one month from harvest (early October). The left field has just been planted in maize, for harvest at the end of the dry season/early wet season (late December/early January).

Figure 28: Alice Chabwela's field, irrigated with water from a recently dug open pit well.
The well is to the left, with the log over it, in front of Memory Lizeo and Agnes Makwale, holding the solar panels. The maize shown will be ready for harvest at the end of the dry season.
Afterword: despite digging this well deeper as the water table fell, this well dried out at the hottest driest time, just weeks before harvest, and most of the crop was lost, causing a net loss for this women's group. Certainly, a cautionary tale for others.

Figure 29: Memory Lizeo watering her maize.

Figure 31: Carrying solar panels between fields. Agnes Makwale in front, Christina Moris behind, both eating tomatoes from Memory's farm.

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Figure 32: Setting up the panels, hose and pump.
Left to right: Christina Moris of Kachione LLC and Racheal & Christina LLC, Memory Lizeo and Agnes Makwale, both chairs of five women groups who have purchased and share solar pump systems. Christina's T-shirt says "ASK ME ABOUT Solar Water Pumps, Cookers and Lights."

Figure 33: Mirriam Chimtengo and Blessings Gilbert's maize field.
Memory Khoma and Austin Magwira's field is just beyond, and abuts Mirriam and Blessings's field.

Figure 34: Word travels fast, a conversation across the Namiwawa Stream.
A woman farmer (with husband uphill) asks Chitani Chatama how to buy a share in a solar pump system. This is at the lower edge of Eunice Dick & Hopeson Maotche's field. Note the mustard crop.

Figure 35: Annie Phephelu's son watering his mother's maize field.
This is a lot easier and much more fun than carrying water buckets and watering by hand!

Figure 36: Solar Pump Customer Interviewer Team: Chitani Chatama (in front) and Thomson Ngupete
Their extensive interview work forms the basis for this report.