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# Case Study: Preliminary Estimates of Solar Irrigation Pump Impact on Smallholder Farm Income

Interviews with
Eight Village Farmers
Mwambo Traditional Area
Zomba District, Malawi


## ABSTRACT

During the dry season in Malawi, solar irrigation pumps allow greater areas to be farmed than hand watering, at lower cost than diesel pump irrigation. Farming in the dry season provides food security and boosts income, allowing villagers to harvest crops in the "lean/hungry" time, when wholesale prices are more than double those at the end of the wet season. The farmers purchased the solar irrigation pump systems at a subsidized price. For the farmers interviewed, total income increased by an average of 48% and farm income almost doubled. The added dry season income for the eight farm families, divided by donor subsidies, suggests a benefit of $28 for every dollar donated. In an appendix that uses a different method and a range of assumptions, the benefit ranges from $3 to $95 with a median value of $21. This study is preliminary. It is based on a non-random sample of customers selected by local solar pump distributors. The current version of this report is based on the farmers' mid-season estimates of future wholesale prices, and 80% of their predicted dry season crop yield. This report will be updated in early 2024 when the end of dry season price and harvest data becomes available.



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

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## Introduction

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. 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 1: Typical solar irrigation pump system installed each day.*
*Solar panels and Inflated lay-flat hose in the foreground, pump concealed in the stream beyond.*

Between May and October of 2023, nine hundred solar irrigation pump systems were sold to rural smallholder farmers across southern and central Malawi through a network of sixteen village solar workshops run by women's groups. Most of the village solar shops were organized by Racheal & Christina LLC

[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 5.

with support from Kachione LLC (both Malawi small businesses) and solar4africa.org (a US volunteer organization).

The irrigation system consists of a 48 volt pump, a 32 mm diameter x 50m long hose, an on/off switch, and two 100 watt solar panels. While the total cost of the system was approximately $300 (including overseas shipping, customs duties, storage and local delivery), it was sold at a subsidized price for about half the actual cost, at $150 (MWK 150,000 in May-August, MWK 160,000 in Sept-Oct)[2].

## Farmers Interviewed for this Case Study

Eight smallholder families were interviewed for this case study. The families lived 0.5 to 4.5 kilometers northwest of the town of Jali in the Mwambo Traditional Area of Zomba District in Southern Malawi, south of Lake Malawi and immediately east of Lake Chilwa. Seven of the farms were alongside the Namiwawa Stream, while one was 1.5 km from that stream, alongside a hand-dug open well. These families were smallholders, with cultivated areas ranging from one-tenth to one half hectare. Six families had landholding rights,


*Figure 2: Location of case study area in Malawi.*

[2] MWK = Malawi Kwacha. For most of the case study period, May-August, 2023, the foreign exchange rate was approximately MWK 1,050 per USD, then rose to approximately MWK 1,150 in September and October. The in-country cash exchange rate for US dollars is significantly greater: approximately MWK 1,700 in May-August, increasing to MWK 1,800 by October.

while two families rented their cropland from landlords. The pumps[3] were purchased by the woman of the family, usually as a member of a women's group. Six families shared the pump in a group of five, one in a group of ten, and one family owned their own pump. Seven of the women had spouses, and all had children (Table 1). Family size ranged from two to nine. Adult family members readily estimated their monthly expenses. Based on their estimates, daily expenses per person ranged from approximately 300 to 700 MWK (US $ 0.30 to 0.70 /day). Average number of children per family was 3.5, close to the 3.9 national fertility rate[4]. Average family size is 5.4, somewhat higher than the national average of 4.3.[5]


*Figure 3: Locations of Interviewed Smallholder Farmers with Solar Irrigation Pumps. Seven of the farms were located along the Namiwawa Stream, the eighth (north marker) was beside an open well.*

[3] In the text, we will use the shorthand "pump" to refer to a solar irrigation pump system consisting of a pump, hose and solar panels.
[4] Malawi Fertility Rate 2021 per Statistica, https://www.statista.com/statistics/520563/fertility-rate-in-malawi/
[5] ArcGIS Hub, 2021 average people per Malawi household, https://hub.arcgis.com/maps/esri::average-household-size-in-malawi/about

Table 1: Basic Demographic Information of Interviewed Farmers

| Farmer Name | Husband | No. of Children | Adopted children | Family Size | Farm Area sq.m. | Monthly Expenses | Expense/ Person/Day USD | Pump Share |
|---|---|---|---|---|---|---|---|---|
| Memory Nkoma* | Austin Magwira | 7 | 6 | 9 | 3,200 | 100,000 | $ 0.35 | 20% |
| Mirriam Chimtengo | Blessings Gilbert | 2 | 1 | 4 | 4,300 | 80,000 | $ 0.63 | 20% |
| Alice Chabwera* | Ganizani Mlotha | 4 | | 6 | 1,100 | 50,000 | $ 0.26 | 20% |
| Eunice Dick* | Hopeson Maotche | 3 | 1 | 5 | 5,000 | 80,000 | $ 0.50 | 20% |
| Annie Phephelu | none | 1 | | 2 | 2,800 | 40,000 | $ 0.63 | 10% |
| Memory Lizeo* | Patrick Mtolire | 3 | | 5 | 3,500 | 110,000 | $ 0.69 | 20% |
| Agnes Makwale* | Robert Kulupando | 4 | 2 | 6 | 3,900 | 80,000 | $ 0.42 | 20% |
| Gladys Chatama | Kalikokha Chatama | 4 | | 6 | 4,000 | 100,000 | $ 0.52 | 100% |
| *chairwoman of 5 member solar pump purchase group | | | | | | | $ 0.50 average | 2.30 sum |

***Interview Process***

Case study interviews were conducted by the first author on 29-31 August 2023. The area selected was where over two hundred pumps had been sold over the previous three months. Most interviews were conducted in Chichewa, with Chitani Chatama translating into English. As the son of farmer Gladys Chatama, Chitani was familiar with the local agricultural practices and input costs. Chitani also assisted in measuring the field dimensions using a 50m tape. Solar pump chairwomen Memory Lizeo and Agnes Makwale accompanied the first author on most interviews. Both Christina Moris and Racheal Kanyerere of Racheal & Christina LLC (R&C LLC) were present on the evening interview on 29 August, Christina was present and installing electric meters on the pumps on 30 August, and Racheal was present and installing electric meters on 31 August. One of the two R&C LLC customer data collectors, Bridget Mathesa and Stella Chikafa, was also part of the interview team, and measured GPS lat/long coordinates at the approximate center of each farmer’s fields.

Follow-up interviews were conducted in September 2023 by Chitani Chatama, asking questions conveyed by the first author. The purpose of the additional questions was to verify field notes and more accurately estimate the fractional increase in annual income afforded by the pumps. A second round of follow-up interviews are planned for late December 2023, after the dry season crops are harvested.

This case study method of estimating income increase is preliminary and based on a non-random sample. The farmers interviewed in this report are early adapters, eager to try a technology that has the potential to double their farm income, and willing to risk a significant investment in seed and fertilizer. The true impact will not be known for at least two more years, when harvests from several dry and wet seasons can be averaged, and when a random sampling based on a large customer database can be made.

*Figure 4: Inaugural meeting of the 16th women's solar shop in the village of Mpoka. Christina Moris (left, with back to picture) and Racheal Kanyerere (standing) are in the work uniforms with reflective arm bands. Sitting on the floor in front of Racheal, left to right, Ester Chikungwa, Lucy Mwenyedini, and Interviewed farmers Agnes Makwale (with grey cap holding child), Gladys Chatama (blue headscarf) and Memory Lizeo. Solar pump customer data collectors Stella Chikafa and Bridget Mathesa are to the right of Racheal. Not shown: Mpoka shop member Eunice Dick.*

## Smallholder Farm Economics

### *Expenses*

Agricultural input expenses include seed, fertilizer and pesticides. For some farmers they may also include land rent, land clearing labor, irrigation labor, open well digging labor, and hose rental for cases where the 50m hose must be extended to reach fields farther from the water source. The cost of seed and fertilizer in the dry season is substantially more than that of the wet season because the government usually subsidizes seed and fertilizer costs at the beginning of the wet season. The farmers told us that the government policy varies from year to year, but at the beginning of the 2022 wet season seed costs were about 80% and fertilizer costs were about 40% of the 2023 dry season costs. The 2023 dry season input costs ranged from MWK 141,000 to 1,165,000, with an average cost of MWK 470,000, not including the solar pump. If the MWK 150,000 pump cost is shared among five women and averaged over a three year minimum expected life for the pump and hose (the solar panels' lifetime is at least ten years), then an annual pump cost is MWK 150,000 / 5 women / 3 years = MWK 10,000, which is only two percent of the average dry season typical input costs. This illustrates three things:

(1) The solar pump investment is small compared to the investment farmers make in hybrid seed, chemical fertilizer, and pesticides.

(2) The solar pumps are financially critical equipment. If a pump breaks, it jeopardizes an entire dry season crop that represents an enormous investment in seed, fertilizer, and other costs[6].

(3) Because of the dry season investment hurdle, some of the women in the five women groups held back this first year, investing in the pump but not in the seed and fertilizer required to plant large

[6] For this reason, Kachione LLC replaces broken pumps free of charge. Of the 900 pumps sold in 2023, so far 35 broke and were returned (about 5%). Preliminary investigation suggests that these failures were burned out brushes caused by running the pumps out of the water, contrary to instructions given during orientation. The next round of pumps ordered in January 2024 will be brushless pumps, thereby preventing this failure mode.

areas, waiting to see if the chairwoman and others in their group were successful in the first dry season.

Appendix 2 provides details of the 2023 dry season and typical wet season harvest income and input costs for each of the eight farmers.

### *Income*

***Dry Season Farm Income:*** While the main cash crop is maize[7], other dry season crops include mustard, pumpkins, beans of different varieties, potatoes, and tomatoes. While input costs are higher in the dry season, wholesale prices at the end of the season are also much higher than at the end of the wet season. Notably, maize prices are 2.5 times higher (see Figure 5), while tomato wholesale prices vary from MWK 500 to 10,000 per ten liter bucket, depending on seasonal supply and demand.

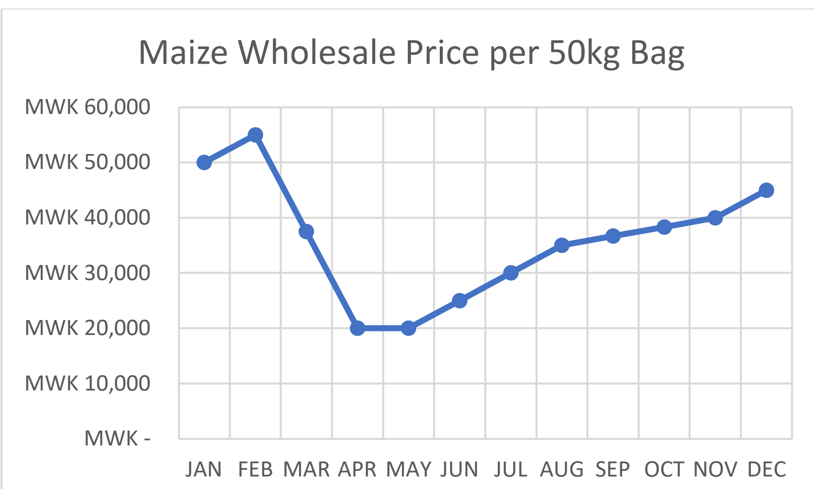


*Figure 5: Wholesale Price of Maize as a function of month of year.*
*Prices peak at the beginning of the wet season, when grain stores are depleted, and bottom out at the end of the wet season when the market is glutted with grain. Source: farmer interviews.*

The solar pumps were purchased in early or mid-June. Some farmers planted maize immediately, with crops ready to harvest in October, while others delayed planting by a month or two,

[7] Maize and corn are used interchangeably. This paper uses maize, the primary term in Malawi.

to ensure a crop harvest in November or December when the wholesale prices are greater. After harvest, farmers with sufficient grain storage capacity plan to stretch out the sale of their maize over four months, selling one quarter of their harvest each month, to take advantage of the highest prices in early and mid-wet season[8].

## Table 2: Typical Farm and Non-Farm Income

| Farmer Name | Typical Wet Season | | | Typical Dry Season | | | Typ. Annual | Annual Non- |
|---|---|---|---|---|---|---|---|---|
| | Costs | Gross | Net | Costs | Gross | Net | Farm Income | Farm Income |
| | MWK | MWK | MWK | MWK | MWK | MWK | MWK | MWK |
| Memory Nkoma | 392,400 | 800,000 | 407,600 | 218,571 | 500,000 | 281,429 | 689,029 | 510,971 |
| Mirriam Chimtengo | 196,800 | 600,000 | 403,200 | 246,250 | 750,000 | 503,750 | 906,950 | 240,000 |
| Alice Chabwera | 85,800 | 200,000 | 114,200 | - | - | - | 114,200 | 485,800 |
| Eunice Dick | - | - | - | - | - | - | - | 1,000,000 |
| Annie Phephelu | 99,000 | 300,000 | 201,000 | - | - | - | 201,000 | 279,000 |
| Memory Lizeo | 152,400 | 385,000 | 232,600 | - | - | - | 232,600 | 1,087,400 |
| Agnes Makwale | 360,000 | 1,100,000 | 740,000 | - | - | - | 740,000 | 840,000 |
| Gladys Chatama | 363,000 | 1,300,000 | 937,000 | - | - | - | 937,000 | 960,000 |

## Table 3: Income with Solar Pump Compared to Typical Income

| Farmer Name | Solar Pump Dry Season | | | Annual Non- | Pump Total | Typ. Total | Solar Pump/ |
|---|---|---|---|---|---|---|---|
| | Costs | Gross | Net | Farm Income | Ann. Income | Annual Inc. | Typ. Income |
| | MWK | MWK | MWK | MWK | MWK* | MWK | ndim |
| Memory Nkoma | 612,000 | 1,400,000 | 788,000 | 510,971 | 1,706,571 | 1,200,000 | 1.42 |
| Mirriam Chimtengo | 394,000 | 1,200,000 | 806,000 | 240,000 | 1,449,200 | 1,146,950 | 1.26 |
| Alice Chabwera | 151,000 | 184,000 | 33,000 | 485,800 | 633,000 | 600,000 | 1.06 |
| Eunice Dick | 373,000 | 1,060,000 | 687,000 | 1,000,000 | 1,687,000 | 1,000,000 | 1.69 |
| Annie Phephelu | 195,000 | 400,000 | 205,000 | 279,000 | 685,000 | 480,000 | 1.43 |
| Memory Lizeo | 350,500 | 652,000 | 301,500 | 1,087,400 | 1,621,500 | 1,320,000 | 1.23 |
| Agnes Makwale | 2,215,000 | 3,460,000 | 1,245,000 | 840,000 | 2,825,000 | 1,580,000 | 1.79 |
| Gladys Chatama | 450,000 | 1,265,000 | 815,000 | 960,000 | 2,712,000 | 1,897,000 | 1.43 |
| | | | 4,880,500 | | | | median |
| | | | sum | | | | 1.42 |
| | | | | | | | average |
| *includes Table 2 Typical Wet Season Net Farm Income | | | | | | | 1.41 |

[8] Per 31-Aug-2023 interview with Blessings Gilbert.

While mustard, beans and pumpkins make up a small part of anticipated dry season sales, tomatoes offer great promise, with two farmers focusing almost as heavily on tomatoes as maize, with anticipated income that matches or exceeds expected maize sales.

The interviews were conducted in late August before any substantial dry season harvests. Based on experience, the farmers reported their expected dry season yields, and the wholesale prices they expect. To be conservative, farmers' dry season income was based on 80% of their estimated dry season maize yields. For the current version of this report, the dry season yields and prices are provisional. They will be confirmed with follow-up interviews with the same farmers at the end of dry season/ beginning of the wet season (late December 2023).

Only two of the eight farmers raised maize for sale in past dry seasons (by hand watering). Anticipated dry season yields with solar pumps were two to four times higher than previous dry seasons simply because they can now reliably irrigate a much larger area of land. In past dry seasons, most of the remaining farmers only hand watered small areas of crops for home consumption.

***Wet Season Farm Income:*** Typical wet season yields are based on the farmers' experience over many years. This past wet season crop was devastated by Cyclone Freddie in late February and early March 2023, the largest wind and rain event in Malawi's recorded history. Crop loss for the eight interviewed farmers ranged from 40 to 100% compared to typical years. Average maize yields were only 33% of typical wet season yields. In calculating long term income increase from solar pumps, comparison was made to typical years, not the most recent wet season, which was exceptionally poor.

***Non-Farm Income:*** All the interviewed village farmers had significant non-farm income, diluting the impact the solar pumps have on total annual income. Non-farm (non-harvested crop) income included farm stands, middleman distribution of specialty crops, sewing and tailoring, and in one case, government paid work to vaccinate small farm animals (mainly chickens and goats) across the region.

Solar pump related income includes commissions on sales of pump systems by one enterprising family, and rental of a pump system by another family with 100% ownership of a system. In coming years, commissions on sales and rent of products through the newly formed Mpoka Village Women's Solar Shop may provide substantial income for the six women who will staff this nascent business (refer back to Figure 4).

## Table 4: Income Comparisons

| Farmer Name | Solar Pump/ Typ. Income ndim | Solar Farm Incm/ Typ Farm Income ndim | Typ. Farm Inc./ Total Income ndim | Cyclone Freddie/ Typ. Income ndim | Cyclone + Pump/ Typ. Income ndim |
|---|---|---|---|---|---|
| Memory Nkoma | 1.42 | 1.74 | 0.57 | 0.79 | 1.21 |
| Mirriam Chimtengo | 1.26 | 1.33 | 0.79 | 0.72 | 0.98 |
| Alice Chabwera | 1.06 | 1.29 | 0.19 | 0.86 | 0.91 |
| Eunice Dick | 1.69 | - | - | 1.00 | 1.69 |
| Annie Phephelu | 1.43 | 2.02 | 0.42 | 0.59 | 1.02 |
| Memory Lizeo | 1.23 | 2.30 | 0.18 | 0.82 | 1.05 |
| Agnes Makwale | 1.79 | 2.68 | 0.47 | 0.59 | 1.38 |
| Gladys Chatama | 1.43 | 1.87 | 0.49 | 0.54 | 0.97 |
| | median | median | median | median | median |
| | 1.42 | 1.87 | 0.47 | 0.75 | 1.04 |
| | average | average | average | average | average |
| | 1.41 | 1.89 | 0.44 | 0.74 | 1.15 |

***Relative Impact of Solar Pumps on Annual Income:*** The last column of Table 3 and the first column of Table 4 both show that irrigating with solar pump systems in the dry season is estimated to increase annual income by 6% to 79%, with a median increase of 42% and an average increase of 41%. If one looks at the increase in farm income (instead of total income that includes nonfarm income), the solar pumps almost double farm income, with an average increase of 1.89. All these percentages are based on the conservative assumption that the dry season maize yields will be 80% of what the farmers predict. If, as we hope, the farmers' predictions are correct, then these percentages will increase.

The lowest income increase of 6% for Alice Chabwera is of particular interest. Alice has the second lowest annual income and the lowest per capita annual income. She is the sole breadwinner for her family, with a disabled husband and four children. Faced with a devastating crop loss from Cyclone Freddie, harvesting only five 50kg bags of maize instead of the usual fifteen bags, she invested in digging an open well on rented land so she could grow crops during the 2023 dry season. Because of significant investments in clearing the field, digging the well, buying a 20% share in a solar pump system, as well as the input cost of seed, fertilizer and pesticides, she will barely eke out a net gain, with an expected net of only 15% of her anticipated gross sales. However, she is growing a diverse crop of beans, pumpkins, tomatoes, and maize in the dry season. Her real motivation is simply food security: with the losses from Cyclone Freddie, her family might otherwise run out of food. This basic non-sale home consumption does not show up in monetary income, and yet it plays a key role in food security and her family's health.

Table 5: Solar Pump Mitigation of Cyclone Freddy Impact based on Maize Yields

| Farmer Name | Typ. Wet Season 50kg bags | Cyclone Freddie 50kg bags | Freddie/ Typical Wet 50kg bags | Typ. Dry Season 50kg bags | Solar Pump Dry Season 50kg bags | Fred.+Pump/ Typ. Wet+Dry 50kg bags |
|---|---|---|---|---|---|---|
| Memory Nkoma | 40 | 25 | 63% | 10 | 35 | 120% |
| Mirriam Chimtengo | 30 | 13 | 43% | 15 | 30 | 96% |
| Alice Chabwera | 15 | 5 | 33% | 0 | 4 | 60% |
| Eunice Dick | 0 | 0 | | 0 | 26 | |
| Annie Phephelu | 15 | 1 | 7% | 0 | 10 | 73% |
| Memory Lizeo | 10 | 0 | 0% | 0 | 10 | 100% |
| Agnes Makwale | 50 | 15 | 30% | 0 | 40 | 110% |
| Gladys Chatama | 50 | 10 | 20% | 0 | 22 | 64% |
| | 210 | 69 | 33% | 25 | 177 | 105% |

## Impact of Solar Pumps on Recovery from Cyclone Freddie

By coincidence, solar4africa placed an order of one thousand pumps and nine hundred hoses just two months before Cyclone Freddy devastated Malawi on March 12, 2023. For the eight interviewed farmers, maize crop yields ranged from 0 to 63% of typical wet season yields, with an average yield of 33%. Despite these losses, most of the farmers with solar irrigation pumps estimate that they will be able to maintain their annual maize yields, with maize yield ranging from 64% to 120% of a typical year and averaging 105% (Table 5, last column). When looking at total income (both farm and nonfarm), if the interviewed farmers did not have solar pumps, their income this year, with Cyclone Freddy, would be around 74% of typical years (Table 4, fourth column). With the solar pumps, the farmers will be able to maintain or increase their income, increasing by 15% on average (Table 4, fifth column). This 15% average will be even greater if the farmers' dry season maize yields meet their predictions, instead of being 80% of their predictions.

This demonstrates another benefit of the solar irrigation pump systems: climate resiliency. Being able to grow crops in the dry season is one aspect of this resiliency, buffering the effect of a poor wet season harvest. The ability to irrigate crops during unexpected droughts in the wet season is another aspect of resiliency that the pumps offer.

A third aspect of climate resiliency is being able to plant wet season maize crops much earlier, in mid-October, and irrigating the young maize in the dry months of October and November. Seed Co says that this early planting approach will increase wet season yields by over 60%, will increase yield by one bag (50kg) per hectare for every day the maize is planted before late December, and will increase yield from 5.5 tons to 9 tons per hectare.[9] It also allows harvesting early enough in the wet season that maize wholesale prices will still be significantly elevated. The only disadvantage is that the Malawi

[9] Malawi Maize Growers' Guide by Seed Co. Link: https://seedcogroup.com/mw/fieldcrops/wp-content/uploads/2022/08/Malawi-Maize-Growers-Guide_1.pdf

government's Agricultural Inputs Program (AIP) may not be in effect until the wet season starts, so seed and fertilizer costs may be higher because subsidized inputs are not yet available.

## Table 6: Cost of the Solar Irrigation Pump System

| Solar Pump Irrigation System Cost To Users and Donors | | | | | |
|---|---|---|---|---|---|
| Currency Conversion | MWK 1,220 | MWK/USD | | | Average of Forex and In-Country Cash Exchange |
| | | | | | (1,020 + 1,420)/2, Exchange Rates, May 4, 2023 |
| Component | unit cost, MWK | units | quantity | compnt cost | Unit Cost Notes & Reference |
| 100W panel | MWK 62,900 | MWK/panel | 2 | MWK 125,800 | Ex.: 12-June-23 field trip by Rachel & Christina |
| 48V pump* | MWK 42,450 | MWK/pump | 1 | MWK 42,450 | 2023-03-07_packing list and invoice_hoses and pumps...xlsx* |
| Hose, 50m x 1.25" (32mm) | MWK 28,400 | MWK/hose | 1 | MWK 28,400 | 2023-03-07_packing list and invoice_hoses and pumps...xlsx |
| Electrical connections | | | 1 | MWK 4,695 | Sockets & Wire = 93,000 + 76,000 / 36 pumps = MWK 4,695 |
| Subtotal, Parts Cost | | | | MWK 201,345 | |
| Loss, Damage & Theft | | | 11% | MWK 22,148 | Assumes 5% damage rate + 5% theft rate = 1/0.9 = 1.11 |
| Inflation | | | 13% | MWK 26,175 | Assume 20% inflation per year x 8 months = 13% |
| **Subtotal, Inflated Parts Cost** | | | | **MWK 249,668** | **Parts, Adjusted for Loss and Inflation** |
| | | | | | * includes 50% increase for brushless more reliable pump |
| **DETAILED ESTIMATE, INDIRECT COSTS** | | | | | |
| Workshop Overhead | | | 1 | MWK 3,690 | Rent & Security: Montly: 553,600/150 pumps = 3,690/pump |
| Assembly Salaried Labor | | | 1 | MWK 8,000 | Monthly Salary: 1,200,480/150 pumps = 8,000/pump |
| Assembly Commission | | | 1 | MWK - | No assembly commission (minor assembly in shop) |
| **Subtotal, Assembled Cost** | | | | **MWK 11,690** | **Assembly** |
| Village Shops (rent & security) | | | 1 | MWK 390 | (1/2)x115,000 = MWK 57,500 / 150 pumps = MWK 383 |
| Transportation | | | | MWK 4,800 | Ref 03-07-2023 field trip to Zomba, Chirudzulu & Balaka |
| Food & Lodging | | | 1 | MWK 3,150 | Ref 03-07-2023 field trip to Zomba, Chirudzulu & Balaka |
| Delivery Commission | | | 1 | MWK 10,000 | Kachione delivery commission |
| **Subtotal, Distribution Cost** | | | | **MWK 18,340** | **Delivery** |
| Sales Commission | MWK 15,000 | MWK/install | 1 | MWK 15,000 | Commission to Village Shops for pump sale |
| Sales Commissions | | | | **MWK 15,000** | **Sales** |
| Subtotal, Detailed Estimate of Indirect Costs | | | | **MWK 45,030** | **Subtotal, Detailed Estimate of Indirect Costs** |
| **Total Kachione Costs, Solar Pump System** | | | | **MWK 294,698** | **Parts, Assembly, Delivery, Sales and Installation Costs** |
| | | | | MWK 5,894 | Fiscal Sponsor Fees |
| | | | | MWK 2,037 | St. Lucia freelancer.com accounting fees |
| | | | | **MWK 302,629** | **Total Costs** |
| Customer's Fee per Light System | | | **53%** | MWK 160,000 | Customer's Fee per Light System |
| | | | **47%** | **MWK 142,629** | **Updated Net Cost to Donors 25-Oct-2023** |
| | | | | **$ 116.91** | **Equivalent Dollar Value** |

## The Benefit Multiplier

The donors' subsidy to allow village farmers to purchase solar pump systems results in a tremendous increase in income. The benefit multiplier is the number of dollars that villagers earn from a donor's contribution of one dollar. For all eight farming families, the total net income for the dry season with pumps amounts to MWK 4,880,500 (the sum of the third column in Table 3). Assuming the pump systems last at least three years (a very conservative assumption), the income over three years will be MWK 14,641,500. Note that due to food inflation costs which are currently running 35 to 40% per year in Malawi, the future net income is likely to be much higher, so the MWK 14,641,500 three-year income can be thought of as inflation-adjusted back to August 2023 MWK.

Table 6 provides a detailed cost breakdown of the costs to import, assemble and deliver the pump systems. The analysis shows that the donor subsidy amounts to MWK 145,000. Adding up the ownership shares for the group of eight farmers amounts to 2.3 pumps (i.e. the sum of the last column of Table 1). However, we were also told that in this first year of use, some women in the five women groups held back, leaving the remaining women with a larger effective share of the pump this year. If we assume 50% participation on average for the first year, then the shared pump percentages double for the seven farmers who share pump ownership, increasing the number of pumps shared by the eight interviewed farmers to 3.6 pumps. The donor cost for 3.6 pump systems therefore amounts to MWK 145,000 x 3.6 = MKW 522,000. The income in kwacha (or dollars) generated per donor kwacha (or dollars) invested can be called the benefit multiplier, and is:

*(MWK 4,880,500 income/year) (3 year min. pump life) / [ (MWK 145,000 donation /pump) (3.6 pumps) ] =*

*(MWK 14,641,500 income over 3 years) / (522,000 donor investment) = 28 benefit multiplier*

A benefit multiplier of 28 may be conservative because the pumps and hoses are likely to last at least five years (instead of the assumed three years), and the solar panels are likely to last at least ten years (and up to twenty years). Since the cost of pump and hose approximately equals the cost of two

100 watt solar panels, the actual average lifetime of the system is likely to be at least (5+10)/2 = 7.5 years, resulting in a benefit multiplier of 28(7.5/3) = 70, which approaches solar4africa's target multiplier of 100.

In Appendix 1 we present an alternative engineering-based calculation of this benefit multiplier, showing that depending upon the details of how the pump is applied, the income generated per dollar of donor subsidy can range from 3 to 95 dollars (90% confidence range).

## Conclusion

These findings are preliminary because they rely on the farmers' mid-season estimates. This report will be updated in January 2024 when the farmers' dry season crop yields and the wholesale prices for their crops will be known. Funds for the 2024 dry season solar pumps must be raised by the end of December 2023 so that the pumps and hoses can be ordered from China in January, in time for arrival in Malawi in April or May 2024, at the beginning of the dry season.

These preliminary results, with an estimated benefit/cost multiplier of about 28, can encourage donors to immediately support the distribution of a thousand or more solar irrigation pump systems in Malawi in 2024. Assuming support for this program remains steady or increases, in two or three years a randomized study by independent reviewers will allow a more precise determination of the benefit/cost multiplier.

## Background & Acknowledgements: Solar for Africa Solar Pump Project

The solar irrigation pump project is the outgrowth of eight years of organizing and research effort in Malawi by the second author, Robert Van Buskirk PhD. Seven years ago Laurence Kachione founded Kachione LLC specifically to collaborate with Robert on importing, assembling and distributing low cost solar products to Malawi villagers. Five years ago Robert's friend Lesia Whitehurst, a San Francisco bay area high school science teacher, organized and led a women's empowerment workshop in a rural Malawi area, teaching village women how to assemble solar light systems invented by Robert. The best students in that workshop were Racheal Kanyerere and Christina Moris, who were then invited to join the Kachione team in Blantyre. A year ago, while still working for Kachione, Racheal and Christina formed their own business, Racheal & Christina LLC, specifically to organize village womens' groups into collectively run village solar shops and supply solar products to those shops. Over this past year they organized 14 village shops, adding to the two village solar shops organized by Kachione. Meanwhile over the past three years Lesia and her friend Evelyn Anabila (formerly of the Institute of Industrial Research of Ghana) have made annual trips to Malawi, conducting solar irrigation pump demonstrations in collaboration with Racheal and Christina, generating interest and excitement. Distributing 900 pumps in five months to smallholder farmers would not have been possible without Robert's, Laurence's, Racheal's, Christina's, Lesia's and Evelyn's special efforts.

They have been supported by

- The staff of Kachione LLC: Laurence Kachione, Gilbert Robert, James Majoni, Racheal Kanyerere, Christina Moris, Victoria Baloyi, Gift Kawanga, Eggrey Gonera, Henry Kawabu and Judith Julius.
- The staff of Racheal & Christina LLC, specifically customer data collectors Stella Chikafa and Bridget Mathesa.
- Solar4africa.org American volunteers Tim Bell and Skyler Selvin.

- Solar4africa and Kachione LLC donors, most notably the UK AID MECS program, Eric Selvin, and Craig Harmer.

In addition to the key contributors noted above, the authors are grateful to all the village farmers using solar irrigation pumps, especially the eight farm families in the Mwambo Traditional Area outside of the town of Jali in Zomba District who patiently answered questions by first author John Wolfe through Chichewa/English interpreter Chitani Chatama. On the same days in late August 2023, Robert Van Buskirk gained further insight by briefly interviewing another set of farmers in the same area while installing electric power meters on the solar pumps. The meters will be used to record kilowatt-hours of solar energy used, providing the basis for poverty and CO2 reduction credits to be granted to current users to allow them to upgrade their systems at deeply discounted prices.

# APPENDIX 1: ALTERNATIVE METHOD OF CALCULATING THE BENEFIT MULTIPLIER

## *Appendix 1.1: Estimation methodology*

An alternative method for estimating the net benefits of the solar pump is to first estimate the peak daily pump output and compare the pump output to the crop irrigation requirements to estimate the area of crop that is being irrigated by the pump. Then once the crop area is estimated, one uses estimates of the crop yield per unit area and the net income per unit crop yield to estimate net income from the irrigated crops. In this case, the equation for crop area ($A_{crop}$) is:

$$A_{crop} = Q_{pump} \times Hrs / (ET_{crop} / Eff_{irr})$$

Where $Q_{pump}$ is the pump flow rate, ***Hrs*** is the hours per day that the pump is used on a high irrigation day, $ET_{crop}$ is the water requirements of the crop at 100% irrigation efficiency, and $Eff_{irr}$ is the actual efficiency of the irrigation application.

Then the net income from the crop is the net income per unit yield, times the yield per unit area, times the new irrigated area that is enabled by the pump, times the total number of crop rotations that the pump facilitates over its lifetime.

## *Appendix 1.2: Accounting for uncertainty and variability*

Because the inputs that influence impact cost-effectiveness of an intervention can be both uncertain and variable, the results of a cost-effectiveness (CE) calculation is most appropriately provided as a probability distribution.

The standard approach to performing a benefit-cost calculation with variable or uncertain inputs is to perform a Monte Carlo simulation (The Wikipedia page on this topic is quite good: https://en.wikipedia.org/wiki/Monte_Carlo_method). In our CE estimation with uncertain inputs, we implement a highly simplified Monte Carlo method that we call a simplified Monte Carlo or "poor man's" Monte Carlo calculation.

In our simplified Monte Carlo calculation, we initially estimate ranges for all or most of the input parameters, and represent these ranges by low, median, and high values. Given a probability distribution of what values a parameter may take, the low value represents the average value of the lowest 1/3 of possibilities, the median value represents the average of the middle 1/3 of probable values and the high value represents the average of the largest 1/3 of probably values. This approximates a probability distribution of possible input parameter values by three discrete values of equal probability.

Once all of the input parameters are represented by three values of equal probability, then the CE result is calculated for all combinations of input parameters. If each of the input parameters are independent and uncorrelated, then the set of CE values that result from all combinations of inputs all have equal probability. A histogram of the full set of CE results is then constructed to illustrate the full range of possible CE values and their respective approximate probabilities.

### *Appendix 1.3: Monte Carlo estimation results*

Table 1 provides the range of values used in a Monte Carlo calculation of donation cost-effectiveness which is measured as the net benefit provided to the pump users per dollar of subsidy that is provided for the solar pump system purchase.

**Table A-1: Cost-effectiveness input parameter ranges for Monte Carlo estimation**

| Variable | Low | Med | High |
|---|---|---|---|
| Evapotranspiration (mm/day) | 3.5 | 3.5 | 3.5 |
| Irrigation Efficiency | 40% | 50% | 70% |
| Irrigation Requirement (m^3/ha) | 87.5 | 70.0 | 50.0 |
| Pump use (hours/day) | 3 | 4.5 | 6 |
| Pump flow (l/min) | 30 | 45 | 60 |
| Water pumped (m^3) per day | 5.4 | 12.15 | 21.6 |
| Hectares irrigated | 0.062 | 0.174 | 0.432 |
| Yield (tons/ha) | 2 | 5 | 8 |
| Price (MWK/50kg) | 35,000 | 40,000 | 50,000 |
| Fertilizer and other costs | 5,000 | 7,500 | 10,000 |
| Net Price (MWK/50kg) | 30,000 | 32,500 | 40,000 |
| Fractional new area | 40% | 50% | 75% |
| Rotations per pump (/lifetime) | 5 | 10 | 15 |

The results of the simplified Monte Carlo calculation is illustrated in Figure A-1. The distribution of possible results has a 90% confidence interval that ranges from $3 to $95 of net benefit per $1 donated, with a median value of $21 net benefit per $1 donated.

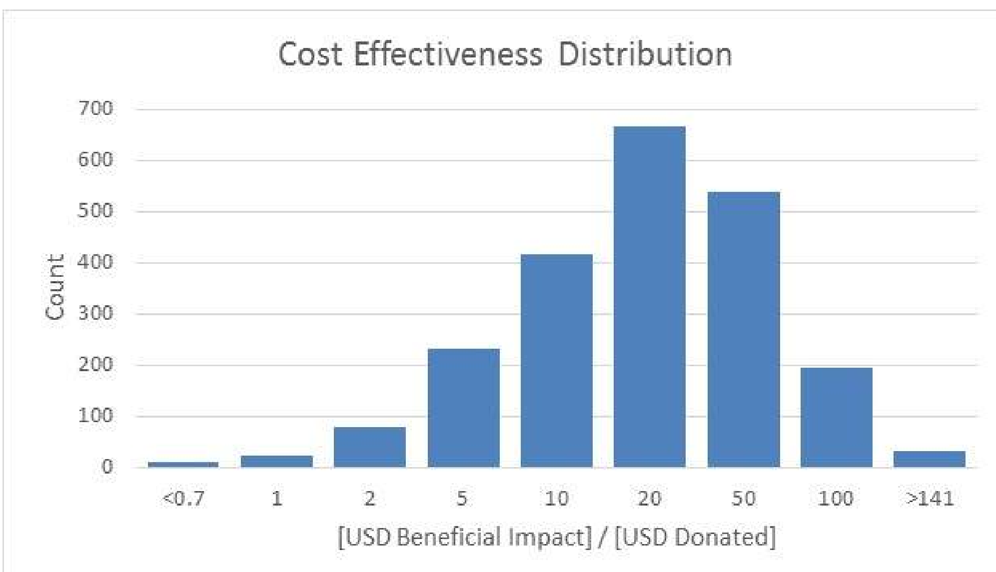


Figure A-1: Distribution of estimated benefit multipliers.

One of the co-authors has posted on the Effective Altruism forum a somewhat more conservative cost-effectiveness methodology at:

https://forum.effectivealtruism.org/posts/icxnuEHTXrPapHBQg/a-simplified-cost-effectiveness-estimation-methodology-for

This more conservative methodology would estimate a somewhat lower benefit multiplier because the more conservative methodology tries to account for inefficiencies of implementation and the partial causal attribution of philanthropic donation financing.

## APPENDIX 2: DETAILED COSTS & PROJECTED INCOME FOR EACH FARM FAMILY

### *Appendix 2.1: Memory Nkoma and Austin Magwira*

Memory Nkhoma and Austin Magwira have seven children, six adopted. Memory chairs a group of five women who have collectively shared the purchase price of a solar irrigation pump system. They cultivate two fields, one rented and one owned, on opposites sides of the Namiwawa Stream. They focus on growing maize for sale, both in the wet and dry seasons, with other crops only grown for home consumption. In past dry seasons they hand watered maize over a smaller area, typically growing one quarter of what could be grown in the wet season.

Table 7: Memory Nkoma & Austin Magwira Farm Economic Data

| Farmer | Memory Nkhoma & Austin Gilbert | | |
|---|---|---|---|
| | | | |
| DRY SEASON w/ PUMP | | | |
| Harvest Income, Maize | MWK | 1,400,000 | 0.8x35 bags @ MWK 50,000 |
| Harvest Income, Other Crops | | | |
| Seed Cost | -MWK | 48,000 | seed (24kg x 2,000) |
| Fertilizer Cost | -MWK | 400,000 | fertilizer (5kg x 75,000) |
| Pesticide Cost | -MWK | 64,000 | pesticide |
| Labor Cost | | | |
| Pump Cost/3 yrs | -MWK | 10,000 | 150,000/(5 women x 3 yrs) |
| Other Costs | -MWK | 90,000 | land rent (15,000/mo), other |
| Other Costs | | | |
| Net Income | MWK | 788,000 | |
| Net/Gross Income Ratio | | 56% | |
| Dry Season Non-Pump Costs | -MWK | 602,000 | |
| | | | |
| WET SEASON | | | |
| Harvest Income, Maize | MWK | 800,000 | 40 bags @ MWK 20,000 |
| Harvet Other Crops | MWK | - | |
| Seed Cost | -MWK | 38,400 | seed (24kg x 1,600) |
| Fertilizer Cost | -MWK | 200,000 | |
| Pesticide Cost | -MWK | 64,000 | |
| Other Costs | -MWK | 90,000 | |
| Net Income | MWK | 407,600 | 36 bags @ MWK 50,000 |
| Net/Gross Income Ratio | | 51% | |
| Wet Season Costs | -MWK | 392,400 | |

### *Appendix 2.2: Mirriam Chimtengo and Blessings Gilbert*

Merrium Chimtengo and Blessings Gilbert have two children, one adopted. Mirriam is part of a women's group of five that shares a solar irrigation pump system. They cultivate a field that abuts Memory Nkoma and Austin Magwira's, less than a half kilometer outside of the town of Jali. They cultivate two fields on opposite sides of the Namiwawa stream, both owned by the couple. They focus on growing maize for sale, both in the wet and dry seasons, with other crops only grown for home consumption. In past dry seasons they hand watered maize over a smaller area, typically growing half of what could be grown in the wet season. Blessings also has a small business in Jali selling vegetables.

## Table 8: Mirriam Chimtengo & Blessings Gilbert

| Farmer | Miriam Chitengo & Blessing Chimombo | | |
|---|---|---|---|
| | | | |
| DRY SEASON w/ PUMP | | | |
| Harvest Income, Maize | MWK | 1,200,000 | 0.8x30 bags @ MWK 50,000 |
| Harvest Income, Other Crops | | | |
| Seed Cost | -MWK | 36,000 | seed (18kg x 2,000) |
| Fertilizer Cost | -MWK | 300,000 | fertilizer (4kg x 75,000) |
| Pesticide Cost | -MWK | 48,000 | pesticide |
| Labor Cost | | | |
| Pump Cost/3 yrs | -MWK | 10,000 | 150,000/(5 women x 3 yrs) |
| Other Costs | MWK | - | blessing owns both fields |
| Other Costs | | | |
| Net Income | MWK | 806,000 | |
| Net/Gross Income Ratio | | 67% | |
| Dry Season Non-Pump Costs | -MWK | 384,000 | |
| | | | |
| WET SEASON | | | |
| Harvest Income, Maize | MWK | 600,000 | 30 bags @ MWK 20,000 |
| Harvet Other Crops | MWK | - | |
| Seed Cost | -MWK | 28,800 | seed (18kg x 1,600) |
| Fertilizer Cost | -MWK | 120,000 | fertilizer (4kg x 30,00) |
| Pesticide Cost | -MWK | 48,000 | pesticide |
| Other Costs | | | blessing owns both fields |
| Net Income | MWK | 403,200 | |
| Net/Gross Income Ratio | | 67% | |
| Wet Season Costs | -MWK | 196,800 | |

### *Appendix 2.3: Alice Chabwera and Ganizani Mlotha*

Alice Chabwela and Ganizani Mlotha have four children. Ganizani is disabled, so Alice is the sole provider for the family. Alice chairs a women's group of five that shares a solar irrigation pump system. Alice rents a field near their house. At the beginning of the dry season, with a loan from her brother, Alice hired local laborers to dig a 3.5m deep open well, with groundwater to 3m depth. A couple months later, as the groundwater dropped, she dug the well deeper, to a depth of 5m. During the dry season, in addition to a small field of maize, she grows beans, pumpkins, Irish potatoes, and tomatoes. In the wet season she grows a larger field of maize, as well as vegetables. Alice also has small business selling tomatoes.

| Farmer | Alice Chabwela & Ganizani Mlotha | | |
|---|---|---|---|
| | | | |
| DRY SEASON w/ PUMP | | | |
| Harvest Income, Maize | MWK | 160,000 | 0.8x4 bags @ MWK 50,000 from smaller ar |
| Harvest Income, Other Crops | MWK | 24,000 | beans, pumpkins, potatos & tomatoes |
| Seed Cost | MWK | 2,000 | seed |
| Fertilizer Cost | -MWK | 35,000 | fertilizer |
| Pesticide Cost | -MWK | 15,000 | pesticide |
| Labor Cost | -MWK | 15,000 | clearing field |
| Pump Cost/3 yrs | -MWK | 10,000 | 150,000/(5 women x 3 yrs) |
| Other Costs | -MWK | 60,000 | land rent 1/2yr |
| Other Costs | -MWK | 18,000 | labor to dig open well/5yr * |
| Net Income | MWK | 33,000 | |
| Net/Gross Income Ratio | | 18% | |
| Dry Season Non-Pump Costs | -MWK | 141,000 | |
| | | | |
| WET SEASON | | | |
| Harvest Income, Maize | MWK | 200,000 | 15 bags @ MWK 20,000 from larger area |
| Harvet Other Crops | MWK | - | |
| Seed Cost | MWK | 3,200 | seed |
| Fertilizer Cost | -MWK | 14,000 | fertilizer |
| Pesticide Cost | -MWK | 15,000 | pesticide |
| Other Costs | -MWK | 60,000 | land rent 1/2yr |
| Net Income | MWK | 114,200 | |
| Net/Gross Income Ratio | | 57% | |
| Wet Season Costs | -MWK | 85,800 | |

### *Appendix 2.4: Eunice Dick and Hopeson Maotche*

Eunice Dick and Hopeson Maotche have three children, one adopted. Eunice chairs a women's group of five that shares a solar irrigation pump system. They rented two fields adjacent the Namiwawa Stream just in the dry summer months to use the solar pump to grow crops. One field is adjacent Annie Phephelu's field. They cultivate these fields with the help of Hopeson's brother Lameck. The field that we visited had vigorous corn and mustard and a failed tomato crop, presumably due to the deep loose sandy soil. They plan to next try carrots in this area. Hopeson vaccinates farm animals across the region for a government program. Because of his extensive contacts with farmers, Eunice and Hopeson sold over two hundred pumps for Racheal and Christina LLC. Eunice has now joined the Mpoka Village Women's Solar Shop, so future sales will be through that shop with proceeds shared with other members of that collective. Eunice also has a small business selling tomatoes.

## Table 9: Eunice Dick & Hopeson Maotche

| Farmer | Eunice Dick & Hopeson Maotcha | | |
|---|---|---|---|
| | | | |
| DRY SEASON w/ PUMP | | | |
| Harvest Income, Maize | MWK | 1,040,000 | 0.8x26 bags @ 50,000 |
| Harvest Income, Other Crops | MWK | 20,000 | mustard + misc |
| Seed Cost | -MWK | 28,000 | seed |
| Fertilizer Cost | -MWK | 200,000 | fertilizer |
| Pesticide Cost | -MWK | 60,000 | pesticide |
| Labor Cost | | | |
| Pump Cost/3 yrs | -MWK | 10,000 | pump 150,000/(5 women x 3 yrs) |
| Other Costs | -MWK | 75,000 | land rent dry season only |
| Other Costs | | | |
| Net Income | MWK | 687,000 | |
| Net/Gross Income Ratio | | 65% | |
| Dry Season Non-Pump Costs | -MWK | 363,000 | |
| | | | |
| WET SEASON | | | |
| Harvest Income, Maize | MWK | - | no wet season harvest |
| Harvest Other Crops | MWK | - | (rents land only in dry season) |

### *Appendix 2.5: Annie Phephelu*

Annie Phephelu is a single mother with one boy. She is part of a women's group of ten that shares a solar irrigation pump system. The group also purchases seed and fertilizer in bulk for a lower price. Annie cultivates a field alongside the Namiwawa Stream adjacent one of the plots rented by Eunice Dick and Hopeson Maotche. She grows maize for sale in the dry and wet seasons. We saw no other crops being grown in the dry season. In the wet season, other crops would be for home consumption. Based on Annie's expenses and expected farm income, we infer that she has another source of income, presumably a small business that earns MWK 20,000 to 25,000 per month.

Table 10: Annie Phepelu

| Farmer | Annie Phephelu | | |
|---|---|---|---|
| | | | |
| DRY SEASON w/ PUMP | | | |
| Harvest Income, Maize | MWK | 400,000 | 0.8x8 bags @ MWK 50,000 |
| Harvest Income, Other Crops | MWK | - | |
| Seed Cost | -MWK | 5,000 | seed |
| Fertilizer Cost | -MWK | 150,000 | fertilizer |
| Pesticide Cost | -MWK | 35,000 | pesticide |
| Labor Cost | | | |
| Pump Cost/3 yrs | -MWK | 5,000 | 150,000/(10 women x 3 yrs) |
| Other Costs | | | |
| Other Costs | | | |
| Net Income | MWK | 205,000 | |
| Net/Gross Income Ratio | | 51% | |
| Dry Season Non-Pump Costs | -MWK | 190,000 | |
| | | | |
| WET SEASON | | | |
| Harvest Income, Maize | MWK | 300,000 | 15 bags @ MWK 20,000 |
| Harvest Other Crops | MWK | - | |
| Seed Cost | -MWK | 4,000 | seed |
| Fertilizer Cost | -MWK | 60,000 | fertilizer |
| Pesticide Cost | -MWK | 35,000 | pesticide |
| Other Costs | | | |
| Net Income | MWK | 201,000 | |
| Net/Gross Income Ratio | | 67% | |
| Wet Season Costs | -MWK | 99,000 | |

### *Appendix 2.6: Memory Lizeo and Patrick Mtolire*

Memory Lizeo and Patrick Mtloire have three children. Memory chairs a group of five women who have collectively shared the purchase price of a solar irrigation pump system. She cultivates a large 3,500 square meter field adjacent to the Namiwawa Stream, with 1,000 square meters devoted to growing maize interplanted with beans, and other areas focusing on tomatoes and pumpkins in the dry season. In the winter she grows maize, pumpkins and pigeon peas. Memory is a member of the newly formed Mpoka Village Women's Solar Shop, which will provide some income next year when the shop is fully operational.

## Table 11: Memory Lizeo and Patrick Mtolire

| Farmer | Memory Lizeo & Patrick Mtolire | | |
|---|---|---|---|
| | | | |
| DRY SEASON w/ PUMP | | | |
| Harvest Income, Maize | MWK | 400,000 | 0.8x10 bags @ 50,000 |
| Harvest Income, Other Crops | MWK | 252,000 | tomatoes (76 bkts@2,000ea) & pumpkins (250@400ea) |
| Seed Cost | -MWK | 15,500 | seed |
| Fertilizer Cost | -MWK | 225,000 | fertilizer (3kg x 75,000/kg) |
| Pesticide Cost | -MWK | 50,000 | pesticide |
| Labor Cost | -MWK | 50,000 | clrng land (over 3 yrs) |
| Pump Cost/3 yrs | -MWK | 10,000 | pump 150,000/(5 women x 3 yrs) |
| Other Costs | | | |
| Other Costs | | | |
| Net Income | MWK | 301,500 | |
| Net/Gross Income Ratio | | 46% | |
| Dry Season Non-Pump Costs | -MWK | 340,500 | |
| | | | |
| WET SEASON | | | |
| Harvest Income, Maize | MWK | 200,000 | 10 bags @ MWK 20,000 |
| Harvest Other Crops | MWK | 185,000 | pumpkins (250@400ea) & peas (2bags@42,500 ea) |
| Seed Cost | -MWK | 12,400 | seed |
| Fertilizer Cost | -MWK | 90,000 | fertilizer (3kgx75,000) |
| Pesticide Cost | -MWK | 50,000 | pesticide |
| Other Costs | MWK | - | |
| Net Income | MWK | 232,600 | |
| Net/Gross Income Ratio | | 60% | |
| Wet Season Costs | -MWK | 152,400 | |

### *Appendix 2.7: Agnes Makwale and Robert Kulupando*

Agnes Wakwale and Robert Kulupando have three children. Agnes chairs a group of five women who collectively share a solar irrigation pump system. Agnes has made the greatest investment in her dry season farm, planting large areas of maize with staggered planting and harvest timea. Two fields are more than 50m from the Namiwawa Stream, so she rents additional hose to reach these uphill fields. In addition to maize, she has planted pumpkins and tomatoes. When we visited in late August, she was raising seedlings she plans to transplant to other areas, timed for harvest at the beginning of the wet season when tomato prices are high. Agnes is also self-employed sewing and tailoring clothes, which provides significant non-farm income. Agnes is a member of the newly formed Mpoka Village Women's Solar Shop, which will provide some income next year when the shop is fully operational.

## Table 12: Agnes Makwale and Robert Kulupando

| Farmer | Agnes Makwale and Robert Kulupando | | |
|---|---|---|---|
| | | | |
| DRY SEASON w/ PUMP | | | |
| Harvest Income, Maize | MWK | 400,000 | 0.8x40 bags @ 45,000, lower price due to half of harvest in |
| Harvest Income, Other Crops | MWK | 2,020,000 | tomatoes: 12 tom/plantx10,000seedsx0.25/60 tom/bcktx6,000/bckt |
| Seed Cost | -MWK | 50,000 | seed maize + tomatos + pumpkins |
| Fertilizer Cost | -MWK | 600,000 | fertilizer (4kg x 75,000/kg) |
| Pesticide Cost | -MWK | 80,000 | pesticide |
| Labor Cost | -MWK | 360,000 | 3 man irrigation crew 1 day/wk |
| Pump Cost/3 yrs | -MWK | 10,000 | pump 150,000/(5 women x 3 yrs) |
| Other Costs | -MWK | 75,000 | 50m hose rental (mwk 15,000/mo x 5 months) |
| Other Costs | | | |
| Net Income | MWK | 1,245,000 | |
| Net/Gross Income Ratio | | 51% | |
| Dry Season Non-Pump Costs | -MWK | 1,165,000 | |
| | | | |
| WET SEASON | | | |
| Harvest Income, Maize | MWK | 1,100,000 | 50 bags @ MWK 20,000 |
| Harvest Other Crops | MWK | - | no wet season tomatoes |
| Seed Cost | -MWK | 40,000 | seed |
| Fertilizer Cost | -MWK | 240,000 | fertilizer |
| Pesticide Cost | -MWK | 80,000 | pesticide |
| Other Costs | | | |
| Net Income | MWK | 740,000 | |
| Net/Gross Income Ratio | | 67% | |
| Wet Season Costs | -MWK | 360,000 | |

### *Appendix 2.8: Gladys Chatama and Kalikokha Chatama*

Gladys and Kalikokha Chatama have four sons, one of whom (Chitani) acted as translator for the farmer interviews. Gladys bought a solar pump system by herself. Besides using it at her farm, she rents the systems out twice a week. She grows maize, tomatoes, mustard and pumpkins in her field alongside the Namiwawa Stream. Gladys is also self-employed sewing and tailoring clothes, which provides significant non-farm income. Gladys is a member of the newly formed Mpoka Village Women's Solar Shop, which will provide some income next year when the shop is fully operational.

Table 13: Gladys Chatama and Kalikhoka Chatama

| Farmer | Gladys Chatama and Kalikhoka Chatama | | |
|---|---|---|---|
| | | | |
| DRY SEASON w/ PUMP | | | |
| Harvest Income, Maize | MWK | 880,000 | 0.8x20 bags @ 50,000 |
| Harvest Income, Other Crops | MWK | 385,000 | 300,000 tomatoes + 5,000mustard + 80,000 pumpkins |
| Seed Cost | -MWK | 35,000 | seed maize + tomatos + pumpkins |
| Fertilizer Cost | -MWK | 450,000 | fertilizer (6kg x 75,000) |
| Pesticide Cost | -MWK | 95,000 | pesticide |
| Labor Cost | MWK | 180,000 | rent out pump 4,500/day x 2/wk x 5 mo x 4 wk/mo |
| Pump Cost/3 yrs | -MWK | 50,000 | pump 150,000/3 yrs |
| Other Costs | | | |
| Other Costs | | | |
| Net Income | MWK | 815,000 | |
| Net/Gross Income Ratio | | 64% | |
| Dry Season Non-Pump Costs | -MWK | 580,000 | |
| | | | |
| WET SEASON | | | |
| Harvest Income, Maize | MWK | 1,000,000 | 50 bags @ MWK 20,000 |
| Harvest Other Crops | MWK | 300,000 | pumpkins: 200 @ 1,500 ea. |
| Seed Cost | -MWK | 28,000 | seed, maize & pumpkins |
| Fertilizer Cost | -MWK | 240,000 | fertilizer (8kg x 30,000) |
| Pesticide Cost | -MWK | 95,000 | pesticide |
| Other Costs | | | |
| Net Income | MWK | 937,000 | |
| Net/Gross Income Ratio | | 72% | |
| Wet Season Costs | -MWK | 363,000 | |


*Figure 6: 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 7: First farm interview is with Gladys Chatama.*
*From left, Racheal Kanyerere, Bridget Mathesa , Stella Chikafa , Gladys Chatama & Robert Van Buskirk.*

*Figure 8: 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 9: Irrigating basins of maize on Agnes' farm.*
*The photo on the right is uphill from the stream photo on the left.*

*Figure 10: 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 11: Alice Chabwela's field, irrigated with water from a recently dug open well.*
*The well is to the left 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.*

*Figure 12: Memory Lizeo watering her maize. Note the straw mulch and interplanted beans.*

*Figure 13: Carrying solar panels between fields. Agnes Makwale in front, Christina Moris behind, both eating tomatoes from Memory's farm.*

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*Figure 14: 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 15: 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 16: 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 17: 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!*