MALAWI SOLAR HOME SYSTEM STUDY
BASELINE REPORT

EPPSA TEAM

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KEY FINDINGS

- **Current owners of VITALITE Solar Home Systems (SHS) have higher incomes, expenditures, and more assets than the general population**
- **SHS owners spend approximately $2.16 USD per month on solar and $7.85 USD per month on household energy compared to non-SHS owners who spend approximately $0.09 USD per month on solar and $1.81 USD per month on household energy**
- **SHS owners have more hours of lighting than households without SHS and spend less time traveling to charge phones**
- **SHS ownership increases nightly lighting to 10.9 hours compared to 7.2 hours among households without SHS, and of that, 8.7 hours of the nightly lighting is from high quality sources (SHS and other modern sources) compared to only 1.0 hours among non-SHS owning households**
- **SHS ownership is not associated with time spent on productive (vs. leisure) activity during evening hours; we observe no differences between household heads, spouses, and children**
- **Access to financial services (such as mobile money usage and holding a bank account) is associated with SHS ownership**

BACKGROUND

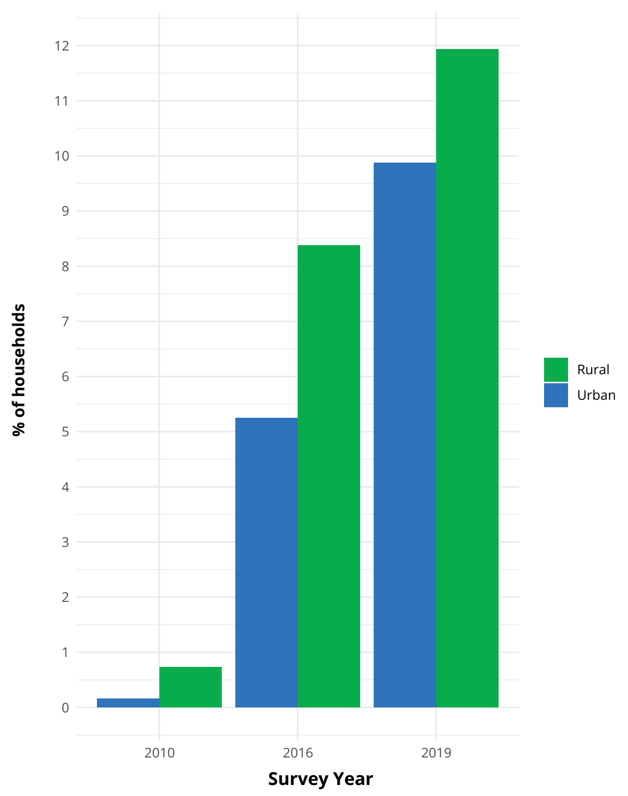
Solar devices are promoted by donors, non-governmental organizations, governments, and the private sector as a key electricity solution for low income households. Solar includes both SHS and standalone panels; non-solar modern sources include grid, generator, and car battery; and low-quality lighting sources include candles, torches (including mobile phone torches), and kerosene lamps. In Malawi, the prevalence of solar device ownership among households has increased significantly over the past decade. For example, among households in Lilongwe District, Malawi, solar device ownership has increased from less than 1% in 2010 to 12% in 2020, with slightly higher uptake of solar panels among rural households compared to urban (**Figure 1**).

In 2022, the Energy Poverty PIRE in Southern Africa (EPPSA) research team and the social enterprise VITALITE Malawi implemented a study focused on the adoption and impact of solar home systems among rural households in the central region of Malawi. Like in other parts of the country, rural households in Lilongwe District, Malawi have very limited access to electricity grid infrastructure and rely on flashlights, candles, and other low-quality lighting sources. Over the years, there has been a proliferation of **solar home systems (SHS)**. SHS are electrical appliance bundles which include a solar-rechargeable battery/inverter along with a set of light bulbs and solar powered radio. These systems are accessible financially through a pay-as-you-go (PAYGO) scheme, where users lease the system and pay for tokens to unlock time use on the device on a monthly, weekly, or daily basis.

Whether the increased ownership of SHS has resulted in increased use of solar devices is not clear. Therefore, this study is designed to generate empirical evidence to improve understanding of household adoption, use, and impacts of solar electricity-providing devices and electricity-dependent appliances among rural

Figure 1: Household solar panel ownership in Lilongwe District

Solar panel ownership among households in Lilongwe District 2010–2019
Based on population weighted estimates from the Malawi Integrated Household Survey Waves III–V



Source: Malawi National Statistical Office. Integrated Household Survey Data (2010, 2016, 2019), Malawi

1 According to population weighted estimates from The World Bank's Malawi Integrated Household Survey. DOI: doi.org/10.48529/yqn3-zv74.

households in central Malawi. One of the primary direct impacts of solar technologies is greater availability of lighting. One of the outcomes of this research was to provide empirical evidence about the impact of increased lighting on a household's time use and quality of life. Increased lighting benefits households by increasing the number of hours that can be used for productive activities (household tasks, childcare, cooking, community meetings, and other work/services) and leisure activities (watching television, listening to the radio, worship/prayer, rest, exercise, socializing, or personal hygiene).

Additionally, SHS technologies with a chargeable battery benefit households by supplying a direct source of electrical power for small appliances such as hair clippers, radios, TVs, and mobile phones. We collect data and focus our analysis on the following outcomes for households in our study:

- Hours of lighting
- Energy expenditures
- Lighting expenditures
- Productive activity time (with details about gender and age for individuals)
- Electric appliance ownership and use
- Time and distance traveling to charge mobile phones

Further, the uptake and sustained use of solar technologies in low- and middle-income countries is not fully understood. This study collects detailed information about households who currently use solar home systems and other solar devices in rural Malawi, as well as the characteristics of people who may adopt solar technologies. The baseline data reports differences between current users of VITALITE solar home systems, potential users of VITALITE solar home systems, and a control group where we expect limited uptake of VITALITE SHS until after our study is concluded in 2024.

STUDY DESIGN AND SAMPLING

The study is a quasi-experimental quantitative impact evaluation with a one-year follow-up. It takes place in rural communities across the southeastern region of Lilongwe District in Malawi (**Figure 2**). There are three arms in this study at baseline: current users of VITALITE Solar Home Systems (Treatment 1 or T1), prospective users of VITALITE Solar Home Systems (Treatment 2 or T2), and control households (Control or C). **In total, 1,279 households were interviewed.**

The current user group households were selected in collaboration with VITALITE Malawi from their 2022 customer database. Current customers located in the southeastern, rural Lilongwe District areas were contacted for interviews. If households agreed to participate, study team members administered the same household survey administered to the prospective users and control group members. A total of **126 current user households** were successfully interviewed at baseline across three Traditional Authorities (TAs) TA: TA Chadza (62 households), TA Chiseka (44 households), and TA Kalumba (20 households). Geographic and population characteristics of the current user study arm (T1) are reported in Table A1 with descriptive data generated based on a five-kilometer buffer area around the geographic center of all households in this arm.

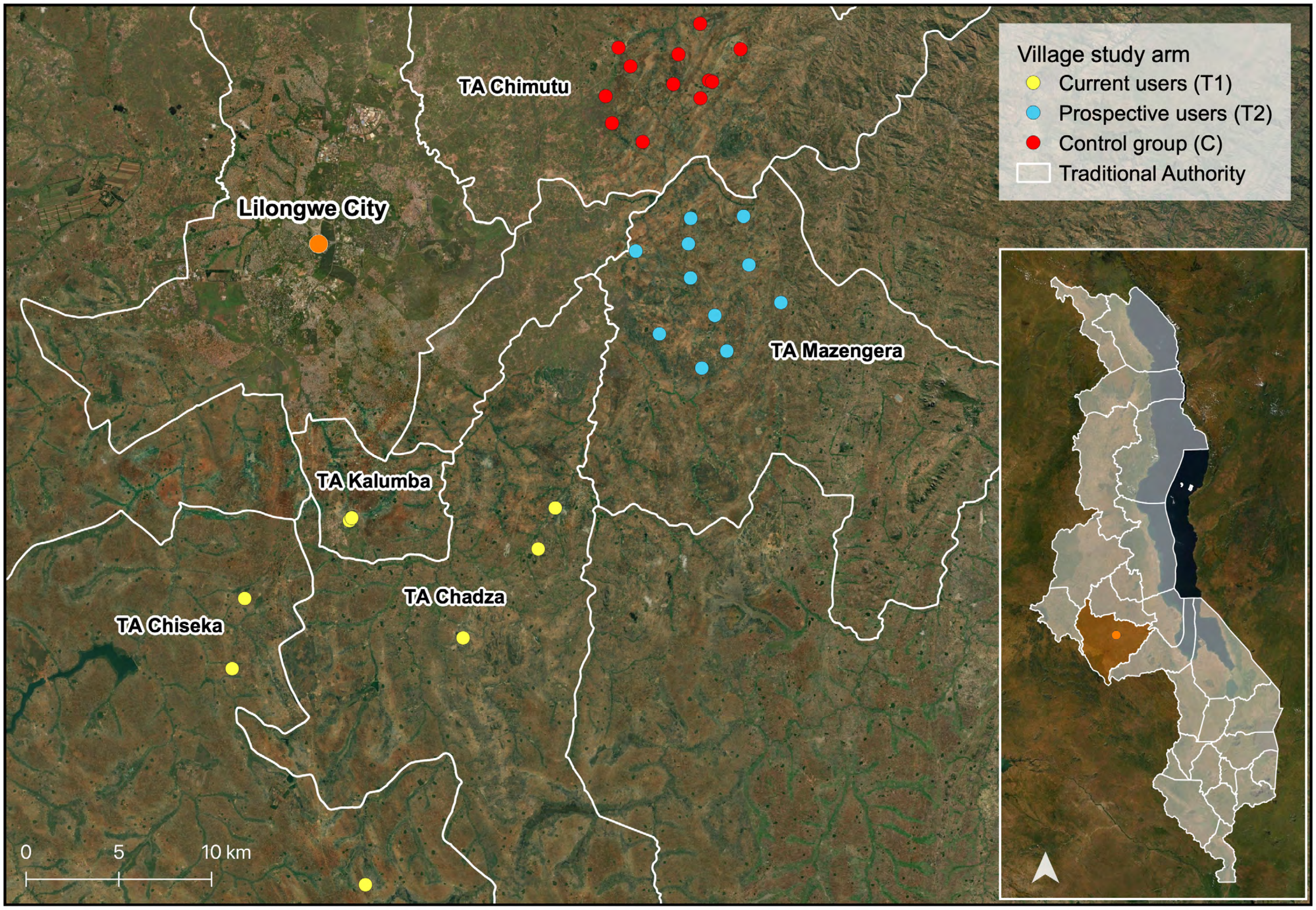
The prospective user and control group households were selected in a two-stage clustered sampling design, where several communities for each study arm were selected based on comparable population and geographic characteristics, and then households were randomly sampled from these communities. To sample comparable communities, the study team carried out the following procedures. First, using a geographic information system, circles with a five-kilometer radius were overlaid on a map of Lilongwe District in several rural candidate areas where VITALITE had not implemented marketing efforts as of July 2022.

Source: Solar Home Systems in Malawi (Credit: VITALITE Malawi)

Within the candidate areas, the following characteristics were compared: population density (based on gridded population data from WorldPop), Euclidean distance from Lilongwe City center, road distance and travel time based on Google Maps calculations from Lilongwe City center, whether or not high- and medium-voltage electric grid infrastructure ran through the center of the area, and estimated share of the population in the area that lived within one kilometer of electricity grid. Two areas were chosen in TA Mazengera and TA Chimutu based on similar characteristics (see **Table A1** in Appendix for a summary of these characteristics). Then, villages were selected to represent full geographic coverage of the selected study areas and to represent the target number of households for the study. We randomly sampled households from ten communities for the control group arm and from eleven communities for the Treatment 2 arm by walking outward from the center of each village in all directions for complete geographic coverage. Every fifth household was selected for participation; if the household was not available or refused, the nearest household was selected for replacement. At baseline, 728 prospective user households were interviewed from TA Mazengera and 425 control group households from TA Chimutu were interviewed, for a **total of 1,153 households across T2 and C groups.**

The baseline survey for this study was conducted over a period of 6 weeks in July and August 2022. A team of ten enumerators and two field team supervisors were recruited and trained at the Centre for Agricultural Research and Development (CARD) at the Lilongwe University of Agriculture and Natural Resources (LUANAR). A detailed household survey taking approximately 45–60 minutes to respond to was administered to the head of each household to answer questions about the household's demographics, economics, use of energy-consuming assets, detailed use of solar technologies, time-use, and hours of lighting (see Table A2 for a summary of all survey modules). Between September 2022 and June 2023, the VITALITE team targeted marketing efforts for the sale of solar home systems towards the prospective user group (T2) and avoided marketing directly in the control (C) group villages. Endline data collection will be carried out in July and August 2023 in all three study arms, twelve months after the baseline data were collected.

Figure 2: Study area in Lilongwe District, Malawi



SUMMARY OF FINDINGS

Household Demographics

Table 1 summarizes household characteristics in the already user (T1), prospective user (T2), and control (C) groups. Across the groups, the majority of the households in the sample are male headed, with household size of around 4 people, and own rather than rent their homes. Characteristics between T2 and C are generally well-balanced, meaning the two groups of households are quite similar, though households are marginally larger and more educated in C than in T2. Additionally, C households have a significantly lower average annual incomes than those in T2, though socioeconomic index scores are similar between the groups. C households have slightly more valuable assets than those in T2, though the difference is not statistically significant.

When we compare current users are compared to non-users of solar home systems, households in T1 display some notable different characteristics than those in T2 and C. T1 households are more educated, younger, and wealthier than T2 and C households. Annual income, asset value, and socioeconomic index scores are significantly higher in T1 households than in those of T2 and C, suggesting greater affluence among T1 households even prior to adopting solar home systems. Overall household expenditures are also markedly higher in T1 households than T2 and C, reflecting the greater affluence among T1 households.

Table 1: Household characteristics, mean (standard deviation in parentheses)[1]

VARIABLE	STUDY GROUP					
	ALREADY USER (T1)	PROSPECTIVE USER (T2)	CONTROL GROUP (C)	TOTAL	MIN	MAX
Household size (number)	4.94 (1.81)	**4.09 (1.62)**	**4.32 (1.89)***	4.25 (1.75)	1	16
Household head age (years)	41.53 (12.00)	45.59 (17.72)	45.45 (17.22)	45.14 (17.10)	18	99
Male-headed household (%)	73.81 (44.14)	66.76 (47.14)	63.06 (48.32)	66.22 (47.31)	0	100
Household head education (years)	8.81 (3.76)	**5.74 (3.84)**	**6.21 (3.86)***	6.20 (3.94)	0	16
Dependency ratio (dependents: independents)[2]	0.89 (0.77)	1.08 (0.96)	0.95 (0.96)	1.02 (0.94)	0	6
Own home (%)	80.16 (40.04)	95.60 (20.51)	93.65 (24.42)	93.43 (24.78)	0	100
Household annual income (USD)	1764.96 (3108.14)	**783.18 (1764.52)**	**540.67 (978.69)***	799.32 (1774.30)	0	27610
Household asset value (USD)	560.29 (2028.63)	69.75 (198.39)	83.18 (212.84)	122.54 (678.92)	0	22595
Non-energy related assets (number)	11.19 (7.24)	**5.40 (4.25)**	**5.97 (4.30)***	6.16 (4.94)	0	42
Value of non-energy related assets (USD)	402.82 (1920.73)	51.04 (152.71)	59.16 (165.56)	88.40 (627.71)	0	21486
Annual household expenditures per capita (USD)	265.68 (384.59)	115.42 (137.50)	118.64 (139.43)	131.29 (183.43)	0	2271
Socioeconomic status index[3]	1.74 (2.38)	-0.24 (1.18)	-0.12 (1.27)	0 (1.49)	-2.92	18.58
N	126	728	425	1279		

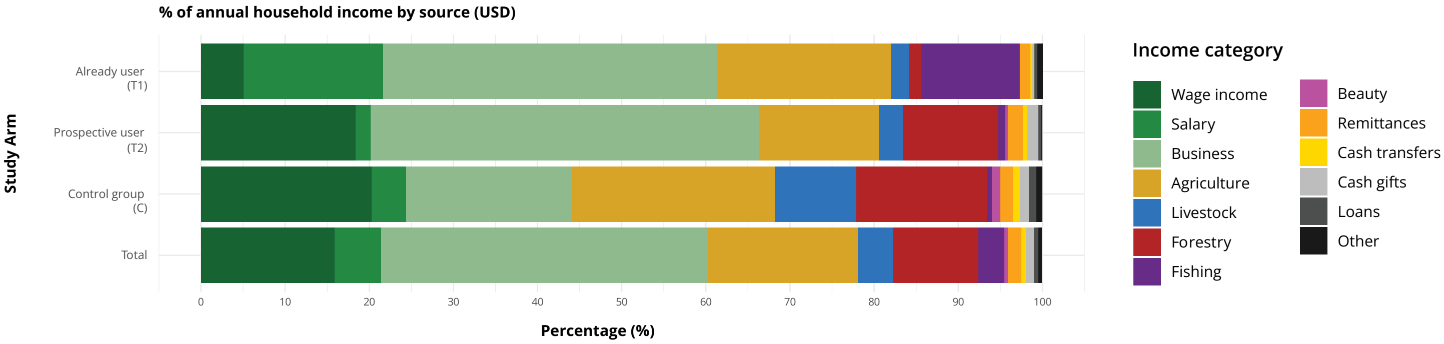
1. '*' and bolded indicate the significance level of the difference in mean between T2 and C (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$).
2. Dependency ratio is coded as 1 for households with only adult elders (>65 years).
3. The Socioeconomic Status Index was calculated with polychoric principal component analysis method using socioeconomic indicators from the baseline survey data. For this index, we included: dependency ratio, years of education, someone in your household chronically ill or disabled, frequently cook only one or no meals per day OR go to bed hungry, number of rooms in the primary dwelling, the roofing material of the primary dwelling, the floor of the primary dwelling, main water source, toilet facilities owned, primary source of cooking energy, total land owned in acres, total value of animals owned, total value of household assets, total hours of lighting, total annual household income, total annual household expenditures. A higher number indicates greater socioeconomic status.

Figure 3 shows the share of income households receive from different sources across the three study arms. Across the sample, households primarily earn income from wage labor, non-agricultural business, agriculture, and forestry. On average, households in T1 earn a smaller share of their income from wages and forestry (e.g., includes fuelwood and charcoal production) and a larger share from salary compared to households in T2 and C. T1 households earn the largest share of their income from non-agriculture related businesses they operate. Households in T2 and C earn a similar proportion of income from wages. However, C households receive a much smaller share of income from business activities than those in T2. Notably, C households earn a larger share of income from agriculture, livestock, and forestry compared to T2 and T1 households.

ENERGY AND LIGHTING

Table 2 shows the descriptive statistics for household access to energy and lighting. Grid connectivity is minimal across all groups, with slightly higher connectivity in T1 than in T2 or C (4% in T1; 0% in T2; 2% in C). Additionally, energy expenditures and the share of total household expenditures spent on energy is substantially higher among T1 households than those of T2 or C. This difference may be attributed to solar home system rental and monthly usage payments among T1 households, households in this group exhibit higher expenditures in for other energy related expenditures in T1. As expected, the value of all energy-related assets value is much higher among T1 households than T2 and C households, suggesting that there is an association between energy related asset ownership and SHS ownership.

Figure 3: Annual household income by source



Note: the large proportion of income from fishing in T1 is heavily skewed by one household.

Table 2: Energy and lighting, mean (standard deviation in parentheses)[1]

VARIABLE	STUDY GROUP					
	ALREADY USER (T1)	PROSPECTIVE USER (T2)	CONTROL GROUP (C)	TOTAL	MIN	MAX
Connected to grid (%)	3.97 (19.60)	**0.27 (5.24)**	**1.88 (13.61)***	1.17 (10.77)	0	100
Annual energy-related household expenditure per capita (USD)	36.10 (108.94)	6.65 (20.63)	6.14 (14.79)	9.38 (39.42)	0	1116
Share of total expenditure spent on energy (%)	10.29 (13.12)	4.79 (7.16)	5.19 (8.15)	5.47 (8.41)	0	100
Total # energy-related assets	4.94 (2.92)	**2.19 (1.77)**	**2.48 (1.91)****	2.56 (2.11)	0	23
Total value of energy-related assets (USD)	157.47 (221.65)	18.71 (61.66)	24.03 (76.81)	34.14 (102.93)	0	1406
Time spent traveling to charge phone (minutes per week)	4.00 (10.83)	13.85 (20.53)	17.60 (23.71)	13.25 (20.79)	1	105
Average hours of lighting between 6pm to 6am from all sources	10.35 (3.15)	7.14 (4.56)	7.14 (4.48)	7.45 (4.52)	0	12
N	126	728	425	1279		

1. '*' and bolded indicate the significance level of the difference in mean between T2 and C (* p < 0.05, ** p < 0.01, *** p < 0.001).

Hours of lighting in the household and time spent traveling to charge mobile phones are impacts of solar technologies that we are interested in exploring with our study. T1 households report over three extra hours of lighting each night on average compared to T2 and C. T1 households report traveling for significantly less time to charge phones (4.00 minutes in T1; 13.85 in T2; 17.60 in C). Among T1 households who own a mobile phone, 84% charge it with a solar home system.

Figure 4 shows the average monthly household expenditures on energy for various common household energy needs (see **Table A3** for data in Table format and **Table A4** for annualized per capita expenditures on household energy sources). **Figure 5** shows the relative contribution of each energy expenditure by source for each study group arm. Values are based on a four week recall of household expenditures and are not normalized on a per capita basis.

Households who own a SHS in T1 spend much more on energy sources overall ($7.85 per month). Nearly 30% of their monthly energy expenditures are on solar with average monthly solar expenditure estimated at $2.16. These households also spend more on charcoal and fuelwood, the most popular cooking fuels in Malawi, than households in our other two study arms. Conversely, T1 households spend less on batteries and candles than the general population, both in absolute value terms ($0.35 compared to $0.57 and $0.68 in T2 and C respectively) and in overall share of their monthly energy expenditures (4% compared to 33% and 36% respectively). Across all groups, approximately 30–40% of household energy expenditures go towards household lighting sources (solar, candles, batteries). However, T1 households spend slightly smaller shares of their energy expenditures on lighting sources.

Figure 4: Average total monthly household expenditures on energy sources

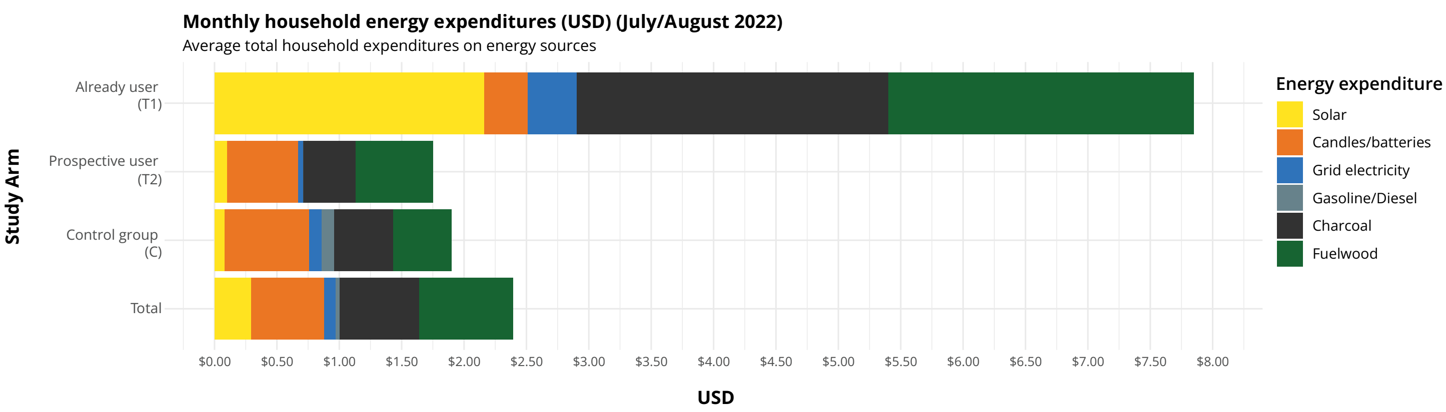


Figure 5: Percentage of monthly household energy expenditures by source

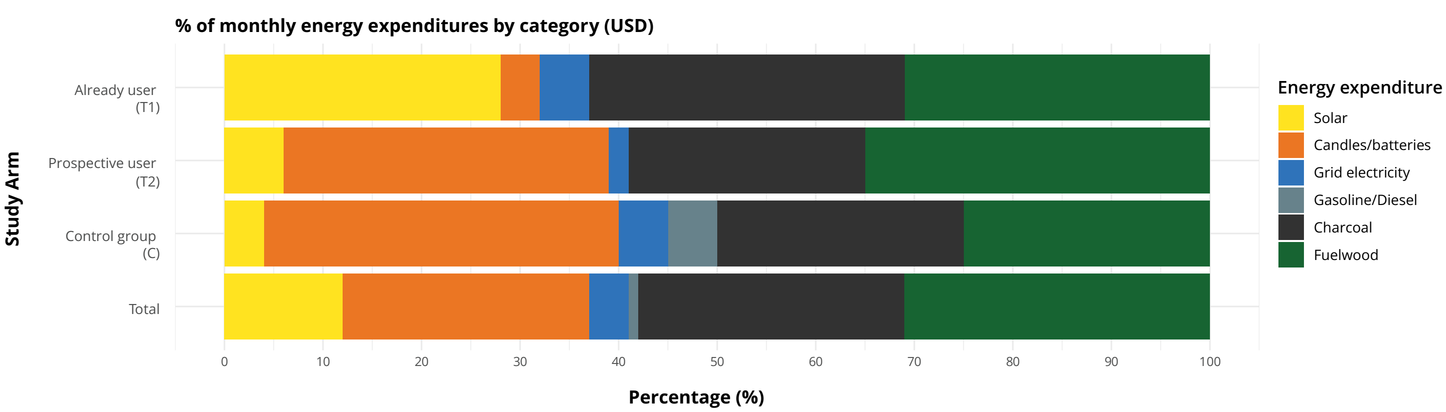


Figure 6: Energy-related assets

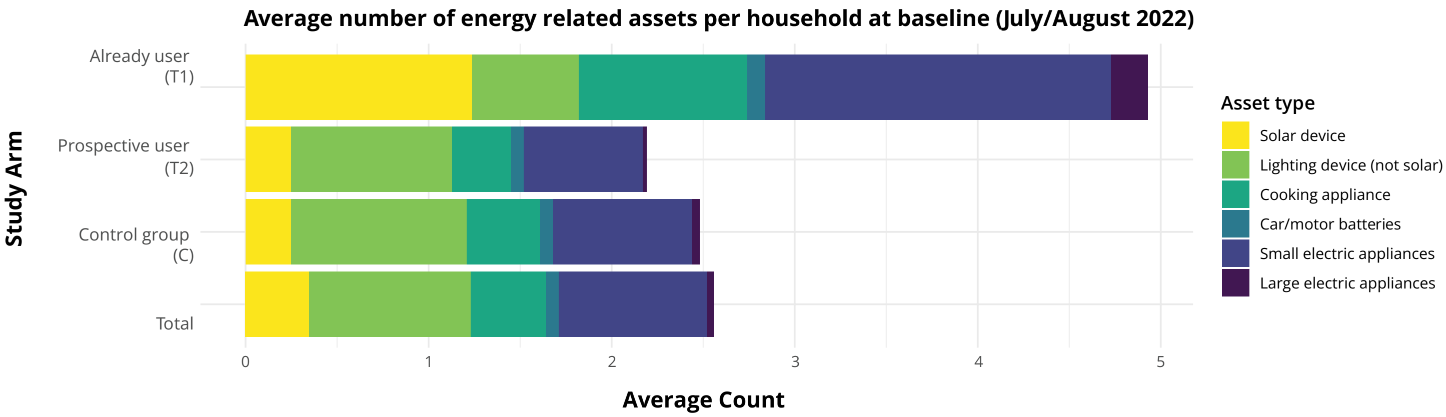


Figure 6 illustrates household ownership of the number and types of energy-related assets by category. These categories are (a) solar devices (including solar home systems and solar panels); (b) lighting devices (including lamps, torches, etc.); cooking appliances (including cookstoves and kettles); (c) car/motorcycle batteries; (d) small electricity dependent appliances (e.g., radios, mobile phones, etc.); and (e) large electricity dependent appliances (e.g, refrigerators, televisions, etc.).

On average, households in T1 own a larger number of energy-related assets compared to T2 and C households. As expected, T1 households own a greater number of solar devices on average. T1 households also own more cooking appliances, small electric appliances, and large electric appliances than households in T2 and C. T1 households own slightly fewer non solar lighting devices than T2 and C households, on average, though the difference is small. This may suggest possible stacking behavior of lighting sources among T1 households. Ownership of energy-related assets is similar across T2 and C households, though those in C tend to own slightly more assets.

SOLAR DEVICES

Table 3 presents results of ownership and usage of solar devices (solar home systems and standalone solar panels) across T1, T2, and C groups. Ninety-nine percent of households in T1 own a solar home system, compared to just 3% and 4% of households in T2 and C, respectively. Standalone solar panels are more common than solar home systems in T2 and C, with 19% of households in both groups owning at least one panel. Twelve percent of households in T1 own a standalone solar panel.

Households in T1 report the most hours of nighttime lighting powered by solar, as well as a significantly greater proportion of lighting hours powered with solar compared to T2 and C. On average, T1 powers 76% of lighting hours with solar. T2 powers a statistically significantly greater share of lighting with solar compared to C (12% in T2, 8% in C).

Thirteen percent (N=165) of households in the sample have a solar home system. Among these households, the primary appliances powered with solar are mobile phones (84%) and radios (30%). Eighteen percent (N=234) of households in the sample own a standalone solar panel. Among them, 72% charge mobile phones and 43% charge radios with their solar panels. No households power a fan or refrigerator with solar panels or solar home systems; ownership of these assets is less than 1% in our sample.

See next page for table 3.

Table 3: Solar device ownership, mean (standard deviation in parentheses)[1]

VARIABLE	STUDY GROUP					
	ALREADY USER (T1)	PROSPECTIVE USER (T2)	CONTROL GROUP (C)	TOTAL	MIN	MAX
FULL SAMPLE (N=1279)						
Own solar home system (%)	99.21 (8.91)	3.30 (17.87)	3.76 (19.06)	12.90 (33.53)	0	100
Own standalone solar panel (%)	11.90 (32.51)	18.81 (39.11)	19.29 (39.51)	18.30 (38.68)	0	100
Lighting between 6pm to 6am powered with solar (hours)	8.47 (5.08)	**1.17 (3.34)**	**0.62 (2.27)****	1.71 (3.96)	0	12
Share of lighting hours between 6pm to 6am powered with solar (%)	75.54 (40.70)	**11.74 (31.44)**	**7.70 (24.88)***	16.72 (36.26)	0	100
HOUSEHOLDS WITH SOLAR HOME SYSTEMS (N=165)						
Light bulbs powered with solar home system (number)	2.22 (0.68)	3.28 (1.46)	3.57 (0.65)	2.48 (0.96)	0	6
Appliances powered with solar home system (% of households)						
Refrigerator	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0	0
Fan	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0	0
Radio	21.74 (41.40)	52.00 (50.99)	71.43 (46.88)	29.94 (45.93)	0	100
TV	0.00 (0.00)	8.00 (27.69)	14.29 (36.31)	2.26 (014.90)	0	100
Mobile phone	84.06 (36.74)	80.00 (40.82)	92.86 (26.73)	84.18 (36.60)	0	100
Battery	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0	0
Other	0.72 (8.51)	4.00 (20.00)	0.00 (0.00)	1.13 (10.60)	0	100
Acquisition of solar home system (%)						
Own	40.58 (49.28)	52.00 (50.99)	42.86 (51.36)	42.37 (49.56)	0	100
Rent-to-own	54.35 (49.99)	44.00 (50.66)	57.14 (51.36)	53.11 (50.04)	0	100
HOUSEHOLDS WITH STANDALONE SOLAR PANELS (N=234)						
Light bulbs powered with standalone solar panel (number)	1.28 (1.71)	0.76 (1.28)	0.87 (1.43)	0.84 (1.36)	0	8
Appliances powered with standalone solar panel (%)						
Refrigerator	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0	0
Fan	0.00 (0.00)	0.64 (7.98)	0.00 (0.00)	0.37 (6.09)	0	100
Radio	50.00 (51.45)	40.76 (49.30)	44.21 (49.93)	42.59 (49.54)	0	100
TV	22.22 (42.78)	3.18 (17.62)	5.26 (22.45)	5.19 (22.21)	0	100
Mobile phone	50.00 (51.45)	73.25 (44.41)	74.74 (43.68)	72.22 (44.87)	0	100
Battery	0.00 (0.00)	**7.64 (26.65)**	**1.05 (10.26)***	4.81 (21.45)	0	100
Other	0.00 (0.00)	12.10 (32.72)	6.32 (24.45)	9.26 (29.04)	0	100
Acquisition of standalone solar panel (%)						
Own	88.89 (32.34)	94.27 (23.32)	95.79 (20.19)	94.44 (22.95)	0	100
Rent-to-own	11.11 (32.34)	0.00 (0.00)	1.05 (10.26)	1.11 (10.50)	0	100

1. '*' and bolded indicate the significance level of the difference in mean between T2 and C (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$).

Figure 7 shows the share of source of lighting from each source across study groups. Across the sample, the majority of households use battery torch, mobile phone torch, and solar devices for lighting. Use of solar for lighting is minimal among T2 and C households, while T1 households power the majority of their lighting with solar.

The majority of households in T2 and C use battery torches for lighting, followed by mobile phone torches. Notably, a much smaller proportion of lighting in T1 households comes from battery torches, suggesting that households may replace battery torches with SHS. Use of candles, solar lanterns/torches, car batteries, and grid electricity for lighting is minimal across the sample.

Figures 8 & 9 shows average nighttime lighting hours and share of lighting from from each energy source respectively. Solar includes both SHS and standalone panels; non-solar modern sources include grid, generator, and car battery; and low-quality lighting sources include candles, torches (including mobile phone torches), and kerosene lamps. Overall, T1 households have more lighting hours per night compared to T2 and C households. As reflected in Figure 7, most nighttime lighting in T1 households comes from solar energy sources. T2 and C households have the same number of hours of lighting each night, on average, with the vast majority of the lighting hours coming from low quality sources and a small number coming from solar. In generals, households use solar to power a greater number and share of their nightly lighting hours and replace low quality lighting sources. Across the sample, non-solar, modern lighting sources are used minimally. Most households generally switch from low quality lighting sources directly to solar, instead of to other modern sources such as grid or generators. Grid connectivity and ownership of generators and car batteries is very low in our sample.

Figure 7: Usage of different lighting sources by study group

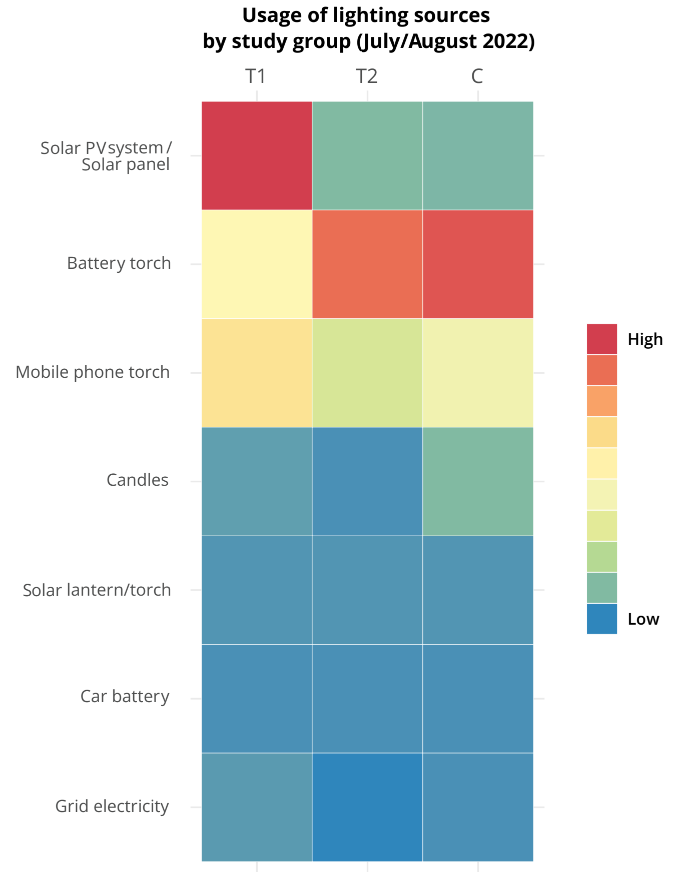


Figure 8: Hours of nightly lighting by source

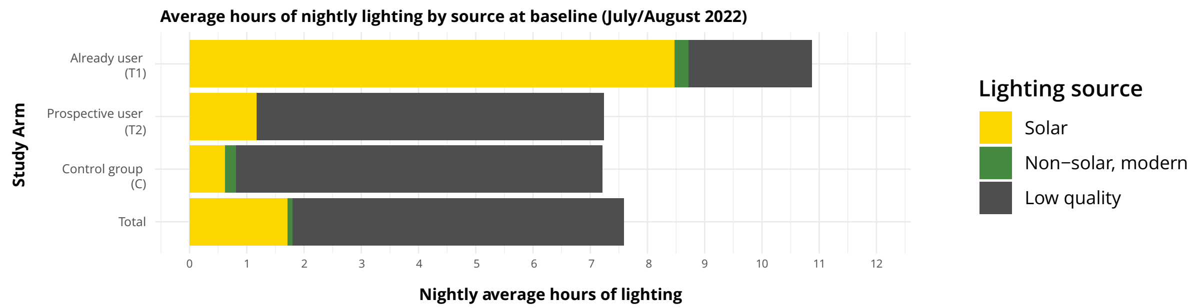


Figure 9: Percent of nightly lighting by source

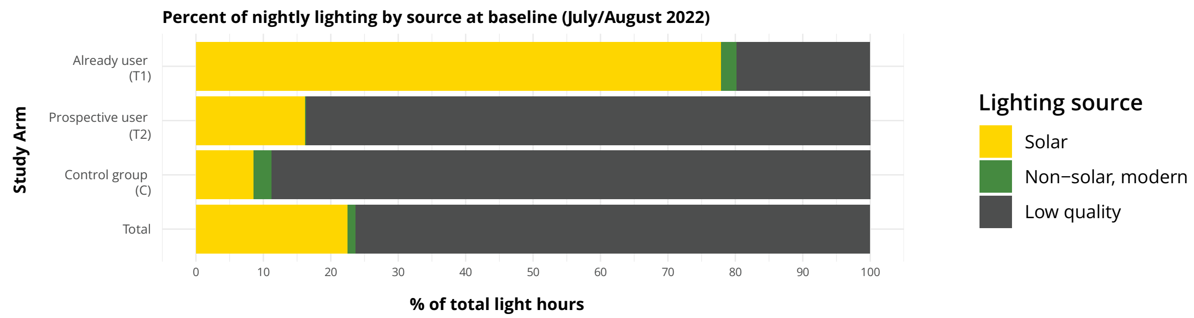


Figure 10 shows the amount of productive activity during nightly lighting hours for the household head, spouse of the household head, and school aged children in the sample. Results show that heads of household in T1 spend slightly more hours per night on productive activities compared to those in T2 and C, though the difference is very small. There is no significant difference in the number of hours devoted to productive activity during evening hours for spouses or school aged children across the three groups. School aged children in T1 and C appear to spend slightly more time in the evening studying compared to children in T2. These data are surprising and suggest that the benefit of having lighting in the household may be more related to improving general quality of life, well-being, and security rather than providing opportunities for people to engage in productive activities that might further economic or educational goals. Financial Inclusion and Social Capital.

FINANCIAL INCLUSION AND SOCIAL CAPITAL

Table 4 presents indicators of financial inclusion, household membership in community organizations, and social cohesion. Households in T1 are the most likely to have a bank account at a formal institution and to use mobile money (24% have bank account; 83% use mobile money) compared to T2 (3%; 33%) and C (6%; 39%). However, membership in a credit, microfinance, or village savings and loans group is common across T1 (37%), T2 (23%), and C (44%). Feelings of trust and community inclusion are high among all groups in the sample.

Figure 10: Hours of productive activity during nighttime lighting hours

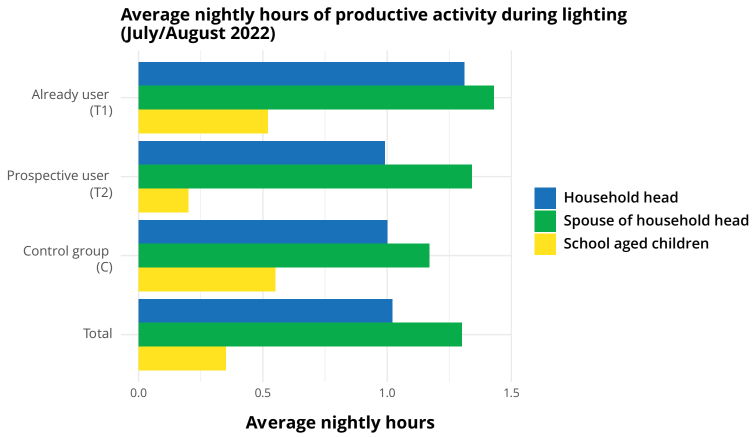


Table 4: Financial inclusion and social capital, mean (standard deviation in parentheses)[1]

VARIABLE	STUDY GROUP					
	ALREADY USER (T1)	PROSPECTIVE USER (T2)	CONTROL GROUP (C)	TOTAL	MIN	MAX
Bank account at formal institution (%)	23.81 (42.76)	**2.61 (15.95)**	**6.12 (23.99)****	5.86 (23.50)	0	100
Involved in informal savings groups (%)	34.92 (47.86)	**19.51 (39.65)**	**41.41 (49.31)*****	28.30 (45.06)	0	100
Use mobile money (%)	82.54 (38.11)	**33.24 (47.14)**	**39.29 (48.90)***	40.11 (49.03)	0	100
Membership in credit, microfinance, and/or village savings/loans group (%)	37.30 (48.55)	**23.08 (42.16)**	**43.76 (49.67)*****	31.35 (46.41)	0	100
Acquaintances or relatives work(ed) for an improved stove/fuel company (%)	8.73 (28.34)	**0.82 (9.05)**	**4.00 (19.62)*****	2.66 (16.09)	0	100
Acquaintances or relatives work(ed) for a solar company (%)	14.29 (35.13)	1.24 (11.06)	1.18 (10.80)	2.50 (15.62)	0	100
Have faith in most people (%)	69.84 (46.08)	**78.98 (40.77)**	**70.35 (45.72)*****	75.22 (43.19)	0	100
Have space to participate in community decisions (%)	89.68 (30.54)	**89.97 (30.06)**	**85.65 (35.10)***	88.51 (31.91)	0	100
Feel like part of the community (%)	98.41 (12.55)	97.39 (15.95)	97.41 (15.90)	97.50 (15.62)	0	100
Community group memberships (number)	2.36 (2.05)	**1.73 (1.59)**	**2.56 (2.21)*****	2.06 (1.90)	0	12
N	126	728	425	1279		

1. '*' and bolded indicate the significance level of the difference in mean between T2 and C (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$).

NEXT STEPS

The endline data collection for this study is scheduled for July and August of 2023. The data collection will be led by a team from CARD/LUANAR. Per our study protocol, VITALITE marketed solar home systems in the T2 study area from September 2022 to June 2023. Our study will involve visiting the same households interviewed at baseline to create a two-wave household panel. We will ask additional questions about households' preferences and aspirations related to energy usage that were not included in the baseline survey and ask more detailed questions about use of leisure time during hours of lighting in the household. The endline study will also help us better understand the types of households that adopt SHS.

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Photo Below: Solar panel on a rooftop in a village in Lilongwe District, Malawi. (Photo credit: Dave Brenner, University of Michigan School for Environment and Sustainability).

APPENDIX

Table A1. Characteristics of study area for each study arm

	CURRENT USERS (T1)	PROSPECTIVE USERS (T2)	CONTROL GROUP (C)
Traditional Authority	Chadza, Kalumba, Chiseka	Mazengera	Chimutu
Distance from Lilongwe Center (Euclidean)	17.0 km	21.1 km	21.9 km
Distance from Lilongwe Center (road distance and estimated travel time)	23.7 km; 40 min	26.5 km; 1 hour 5 min	34.6 km; 1 hour
Population density in 5 km (persons/sq. km)	212	252	301
High voltage grid* runs through centroid	No	Yes	Yes
Medium voltage grid* runs through centroid	Yes	Yes	Yes
% of population within 1 km of medium voltage grid*	62.0	15.5	22.0
N Study Villages	7	11	10

**Grid data from Facebook "Medium-Voltage Grid (Predictive)" Downloaded July 2022. energydata.info/dataset/medium-voltage-distribution-predictive*

Table A2. Baseline survey modules

	SURVEY MODULE
A	Household identification
B	Household demographics and dwelling characteristics
C	Land and livestock ownership
D	Household assets
E	Household energy sources
F	Household fuel consumption for lighting
G	Short recall of time use during hours of lighting during the past three days
H	Income from agriculture, livestock, and other sources
I	Household expenditures
J	Financial inclusion
K	Social capital and trust/community cohesion
L	Health service provision

Table A3. Average monthly total energy expenditures by source, mean (standard deviation in parentheses)

	STUDY GROUP			
EXPENDITURE (USD)	**ALREADY USER (T1)**	**PROSPECTIVE USER (T2)**	**CONTROL GROUP (C)**	**TOTAL**
Fuelwood	2.45 (8.13)	0.62 (2.84)	0.47 (1.85)	0.75 (3.53)
Charcoal	2.50 (4.84)	0.42 (2.11)	0.47 (1.79)	0.64 (2.50)
Paraffin/Kerosene	0.00 (0.00)	0.00 (0.00)	0.00 (0.08)	0.00 (0.04)
Gasoline/Diesel	0.00 (0.00)	0.00 (0.01)	0.10 (1.71)	0.03 (0.99)
Other fuels; pallets, ethanol, briquettes	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Candles/batteries	0.35 (0.62)	0.57 (0.72)	0.68 (1.55)	0.59 (1.07)
Grid electricity	0.39 (2.28)	0.04 (0.92)	0.10 (0.91)	0.09 (1.13)
Pico/PV/Solar System Payments	2.16 (5.50)	0.10 (0.87)	0.08 (0.81)	0.29 (1.99)

Table A4. Annualized per capita energy expenditures by source, mean (standard deviation in parentheses)[1]

	STUDY GROUP			
EXPENDITURE (USD)	**ALREADY USER (T1)**	**PROSPECTIVE USER (T2)**	**CONTROL GROUP (C)**	**TOTAL**
Fuelwood	6.87 (21.65)	2.54 (15.45)	1.40 (5.12)	2.59 (13.87)
Charcoal	10.19 (25.97)	1.70 (9.82)	1.68 (7.26)	2.52 (12.01)
Paraffin/Kerosene	0.00 (0.00)	0.00 (0.00)	0.01 (0.14)	0.00 (0.08)
Gasoline/Diesel	0.00 (0.00)	0.00 (0.06)	0.30 (5.40)	0.10 (3.12)
Other fuels; pallets, ethanol, briquettes	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Candles/batteries	1.22 (3.75)	2.04 (2.76)	2.24 (4.93)	2.03 (3.72)
Grid electricity	1.76 (12.35)	0.09 (1.79)	0.28 (2.55)	0.31 (4.36)
Pico/PV/Solar System Payments	7.42 (25.74)	0.28 (2.40)	0.23 (2.23)	0.96 (8.59)

1. Annualized per capita values were calculated for each energy source after an outlier household with large gasoline/diesel expenditures for a business was removed.