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# IMPACT ASSESSMENT FRAMEWORK

**JULY 2022**

SOLAR WATER PUMPS

**The Framework for solar water pumps is one of four frameworks that aims to facilitate the reporting and shared measurement of impact evidence for a variety of stakeholders (e.g., distributors, developers, funders, appliance users and researchers). Ultimately, this project seeks to contribute to the creation of an industry-wide consensus for the assessment, reporting, and measurement of the impact of high-performing appliances.**

This Framework was developed by Rural Senses, SVT, CLASP and Energy Saving Trust as part of the Low Energy Inclusive Appliances programme, Efficiency for Access' foundational initiative. Efficiency for Access is a catalyst for change, accelerating the growth of off-grid appliance markets to boost incomes, reduce carbon emissions, improve quality of life and support sustainable development.

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The framework was authored by Yau Ben-Or, Ramit Debnath, Richa Goyal, Stephanie Hirmer, Makena Ireri, Thalia Konaris, Sara Olsen, David Pritchard, and Josephine Tumwesige.

The Framework was developed using the best available evidence. Nevertheless, users of the Framework should be aware of the limitations and caveats below. Given these limitations as well as changes that will occur over time, it is likely that when reviewing and using the Framework users may find one or many of the following apply. Please do feel free to report anything via the feedback form:

- some indicators are no longer important to stakeholders
- the calculation of the indicator is not accurate
- data needed to calculate the indicator are impossible to obtain
- new evidence suggests improvements to the indicators or the creation of new indicators

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# TABLE OF CONTENTS

# ABBREVIATIONS

*See the section, Framework at a Glance, for abbreviations for the variables used in the indicators. Refer to the tables for input variables and standard variables, as well as the list of IDs used for indicators.

| | |
|---|---|
| **FAO** | Food and Agriculture Organization (United Nations) |
| **FTE** | Full-time equivalent |
| **IRENA** | International Renewable Energy Agency |
| **LMIC** | Low and middle income country |
| **MCDA** | Multi-Criteria Decision Analysis |
| **NGOs** | Non-governmental organisations |
| **NREL** | National Renewable Energy Laboratory (United States) |
| **OPEX** | Operational expenditure per litre over the lifetime of a technology |
| **PV** | Photovoltaic |
| **RS-SVT** | Rural Senses and SVT Group |
| **SHS** | Solar home system |
| **UNDP** | United Nations Development Programme |
| **UNEP** | United Nations Environment Programme |
| **UNICEF** | United Nations Children's Fund |
| **UPV** | User-Perceived Value |
| **WHO** | World Health Organization |

## DEFINITIONS

| | |
|---|---|
| **Degree of urbanisation** | Description of territories or countries within three different categories of urbanisation as follows: (a) cities (densely populated areas); (b) towns and suburbs (intermediate density areas) and (c) rural areas (thinly populated areas).[1] |
| **End-user** | People who use the appliances. |
| **Formula** | The specific data points necessary to calculate a given impact metric or indicator and how they should be combined to arrive at the impact indicators result. |
| **High-performing appliances** | High-quality and efficient off- and weak grid appliances that are intentionally designed for end-users living in an energy-constrained environment and advertised for use primarily with a PV module or a solar home system.[2] |
| **Indicator** | The means by which an impact can be gauged. |
| **Input variables** | Variables the user needs to provide data for based on the impact the user is assessing. |
| **Multi-criteria decision analysis** | A process used to help make a decision or choice by explicitly evaluating multiple criteria that may be in conflict with each other to choose the best option. |
| **Multi-criteria decision score** | Potential indicators were given a score of 0, 1, or 2 depending on how well they satisfied several criteria that are desired of impact indicators. See section below on Multi-Criteria Decision Analysis and Appendix 1. |
| **PAYGo** | The Pay-As-You-Go (PAYGo) business model is an innovative financial mechanism that enables off-grid customers to pay for high-quality solar products in a 'rent-to-own' system. The innovation that emerged to address the energy access challenge and to provide electricity generated from renewable energy sources at affordable prices, with payments facilitated by technologies and mobile phone credit.[3] |
| **Pipeline variables** | Variables that are of interest but where data is not yet available. While there is no set plan for these pipeline variables, we invite people to undertake research to close the existing data gap. |
| **Standard variables** | Variables provided within the Framework based on existing evidence. |
| **The Framework** | A description of metrics, indicators and formulae that are to be used in assessing the social, economic, and environmental impacts of the four types of appliances namely fans, refrigerators, solar water pumps and TVs. The Framework consists of Objective 1 from the original Efficiency for Access Request for Proposals: “Suggested metrics for industry use to report impact” (the ‘impact metrics’), and Objective 2: “Formulae for impact indicators that the industry may be unable to report on, but are nevertheless important to develop to provide a framework that could capture holistic impact” (the ‘impact indicators’). |
| **User** | People who use the Framework. |
| **User-perceived value** | This term refers to “the benefits, concerns, feelings, and underlying drivers’ that vary in importance and act as the main motivators in the lives of the people (as perceived and defined by the [end-users] themselves at a given time”.[4] |
| **Value** | The regard that something is held to deserve; the importance, worth, or usefulness of something. Specifically with respect to impact assessment, value or social value is the quantification of the relative importance that people place on the changes they experience in their lives. Some, but not all of this value is captured in market prices.[5] |
| **Variables** | A quantity which, during the calculation of a formula, is assumed to vary or be capable of varying in value.[6] |
| **Off- and weak-grid** | A place that is not connected to the main electricity grid, or a system that suffers from frequent brown / blackouts and voltage fluctuations / instabilities. |

1 Eurostat, Applying the Degree of Urbanisation. (2021) OECD. https://doi.org/10.1787/4bc1c502-en
2 Efficiency for Access, 'The State of the Off-Grid Appliance Market (2019) https://efficiencyforaccess.org/publications/2019-state-of-the-off-grid-appliance-market-report
3 UNCC. 2021. Pay-As-You-Go Solar Technology: A Key to Unlocking Energy Access - Kenya and Peru. UNFCCC. https://unfccc.int/climate-action/momentum-for-change/activity-database/pay-as-you-go-solar-technology-a-key-to-unlocking-energy-access
4 Stephanie Hermer and Guthrie, P. 2017. The benefits of energy appliances in the off-grid energy sector based on seven off-grid initiatives in rural Uganda. Renewable and Sustainable Energy Reviews, 79, 924–934. https://doi.org/10.1016/j.rser.2017.05.152
5 Impact Management Project, Who. (2021) Impact Management Project. https://impactmanagementproject.com/impact-management/impact-management-norms/who/
6 Oxford Languages. N/A. https://languages.oup.com/google-dictionary-en/

## LIST OF TABLES

## LIST OF TABLES

# Purpose and Context

**This report outlines the Impact Assessment Framework for solar water pumps used in off- and weak-grid settings. This Framework was developed by the Efficiency for Secretariat team, Rural Senses and SVT from 2020–2022 in consultation with other stakeholders such as end-users, investors, donors, and companies. You can read more about the development process here. This Framework for solar water pumps is one of four standard Impact Assessment Frameworks for off- and weak-grid high-performing appliances. The other frameworks are for fans, TVs, and refrigerators.**

### Purpose of the Framework

The Framework aims to facilitate the shared measurement and reporting of the impacts of solar water pumps for a variety of stakeholders (e.g., distributors, developers, funders, appliance users and researchers) through the development of evidence-based social, environmental and economic impact indicators. Ultimately, this work seeks to contribute to the creation of an industry-wide consensus for the assessment, reporting and measurement of the impact of solar water pumps. For more information on how this and the other three frameworks were developed, you are encouraged to consult the Off- and Weak-Grid Appliances Impact Assessment Framework: Methodology and How-to-Use Guide.

This report harmonises existing evidence from a wide range of studies into an easy to use and robust set of impact indicators for solar water pumps. Some of the suggested indicators can be used now to report impacts, while others are not yet ready, mainly due to data gaps. Indicators that are not yet ready are nevertheless important to provide a framework that captures a holistic set of impacts.

### Context

A holistic understanding of the impacts of high-performing appliances is important because their use has been growing over the years. GOGLA's report, Global Off-Grid Solar Market Report Semi-Annual Sales and Impact Data recorded sales of 470,000 off-grid solar appliances between July and December 2020. While recorded global sales were lower than anticipated due to the impacts of COVID-19, the easing of related lockdowns and restrictions in some countries during the second half of 2021 may have contributed to an increase in sales for this period. This is despite additional constraints on cash flows, underscoring the critical role of high-performing appliances in providing homes and businesses with essential services.

Solar water pumps are becoming increasingly important in off- and weak-grid communities for pumping water from water sources such as wells, boreholes, lakes and rivers for:

- the irrigation of crops, for household consumption or selling, within agricultural communities
- providing water to help rear livestock within agricultural communities
- providing water for household use such as drinking, cooking, showering, cleaning the home or doing the laundry, either directly or by filling an overhead water tank.

There are several solar water pump technologies currently on the market. While there is ongoing research on passive thermal technologies that use thermal energy from the sun to pump water, most commercial options involve the use of photovoltaic (PV) systems to convert solar energy into electrical energy, which is then used to run a DC or AC motor-based solar water pump.

As such, the metrics in this section distinguish between the use of solar water pumps at the household level for improving access to water and hygiene at the home, and their use at the commercial level by smallholder farmers to irrigate crops or care for their animals. Furthermore, the metrics focus on PV-powered solar water pumps as they are the most widely commercialised option. So far, we have not considered different pump types (e.g., submersible or surface), although examining the relevance of these technologies could help develop indicators that focus on groundwater extraction, for example. This is something we hope to examine in the future.

This report was developed and authored by Rural Senses and SVT Group on behalf of Efficiency for Access. Efficiency for Access appreciates and recognises GOGLA, Sustainable Energy for All, SELCO and Energy4Impact for participating in the peer review process.

### Use of the Framework

The primary use cases of this Framework are:

- for organisations to assess the holistic impact that they create by distributing solar water pumps
- to support funding decision-making with regard to solar water pumps
- to inform mitigation strategies for the unintended negative impacts of solar water pumps
- to guide further research

To use the Framework to estimate the impact of solar water pumps and/or their distribution, users should follow these steps:

1. Choose the indicators you wish to use based on the type of impact you wish to estimate from the tables in Section 3 (or the spreadsheet).
2. Once you have identified the metrics in the summary table, please consult the associated detailed table in Section 4;

you can identify them by their indicator ID. Please note that easy navigation is possible by using the spreadsheet version of the framework.

3. Consult the detailed table to check that the list of assumptions associated with that metric is valid in your specific use case. Only use the provided metric if the assumptions are suitable for your use case.
4. Calculate the impact by applying the input variables and standard variables:
   - **Input variables** are marked as 'input by user'. These are variables that the user of the Framework needs to provide values for based on the impact being assessed.
   - **Standard variables** [7] are 'plug and play' values based on existing evidence. It is important to check the detailed information about each standard variable as the most appropriate value may depend on the specific geography and degree of urbanisation of your product and customers. You can use the detailed information to ensure the value you choose matches the specific context of your product or service.
5. Where the value for the standard variable is given as a percentage e.g., 3%, when used in the indicator formula it will need to be input in its decimal equivalent e.g., 0.003.
6. You can describe the impact using the phrasing of the impact statement and the results of your calculation. For example, "950kg of $CO_2$ emissions was saved through the distribution of solar water pumps in 2021".
7. While using the Framework, you may find data or conduct research that either supports or improves the Framework or challenges the metrics or standard variables used in the Framework. In this case, please share these findings with the off-grid impact ecosystem as described below.

### How to challenge the Framework

We invite users, researchers, sceptics, appliance users and others to challenge the framework and identify opportunities for improvement. For example, you may find:

- the framework uses indicators that are no longer important to stakeholders
- the calculation of the indicator is not accurate
- data needed is difficult to obtain
- new evidence suggests improvements to the indicators or the creation of new ones

**Please share with us evidence that could challenge or improve the metrics, variables, assumptions and data used in the framework by completing through this form.**


7 Values for the 'standard variables' may be given in ranges because of a specific context (i.e., geography and degree of urbanisation). Refer to the specific variable sheet for more information.

# The Framework at a Glance

**IMPORTANT: For easy navigation, we recommend that you use the spreadsheet version of the Framework.**

The Framework consists of:

1. A table summarising the current indicators and formulae that were developed and make up the framework for solar water pumps.
2. A table of the agreed variables (standard variables) to be used in the metrics, as well as variables that require the Framework users' input (input variables).

The table below summarises the framework for solar water pumps. The table shows the ID for each of the indicators that are defined under the 'Indicator' column, which can be used to link to a more detailed table on each indicator. For each appliance, the ID starts with the letter of the appliance, in this case, 'SWP' for solar water pumps. Where the ID starts with an 'A', the indicator also applies to other appliances, not just solar water pumps. This is followed by the indicator category: ENV for environmental, ECO for economic and SOC for social.

The formula to measure the impact, which can be positive or negative, is then given next. The indicators and variables are described in detail in the sections that follow.

The Multi-Criteria Decision Analysis (MCDA) Score refers to the sum of the scores given to each indicator according to how well they each compare against desired characteristics: widely applicable, comparable, robust, relevant, time-bound/timely, specific and dynamic. (The maximum score is 14). Please refer to the methodology report for more details.

The status (readiness level) of the different indicators is indicated in the summary tables using a traffic light system. A green dot means that the indicator is ready to use, an orange dot means that parts of the indicator can be used and a red dot means that the indicator is not yet ready.

Indicators can have a positive, negative, or positive / negative impact. This is indicated using the following signs respectively +, –, + / –. Indicators are also elaborated individually; refer to the corresponding spreadsheets.

**Table 1: Solar water pump framework**

| ID | INDICATOR | FORMULA | MCDA SCORE | STATUS | IMPACT |
|---|---|---|---|---|---|
| ENVIRONMENTAL | | | | | |
| **Emissions** | | | | | |
| A-ENV1 | **Tonnes of CO2 emissions avoided** | (S × (1 – DL) × DR-GHG × PL × G) / 1000 | 13 | Green | + |
| **E-waste** | | | | | |
| A-ENV2a | **Annual tonnes of electric waste added** | S × WS / 1000 | 14 | Green | – |
| A-ENV2b | **Annual tonnes of electric waste avoided** | S × WS × WRP / 1000 | 12 | Green | + |
| ECONOMIC | | | | | |
| **Business income** | | | | | |
| SWP-ECO1 | **Number of people experiencing an annual increase in business income of at least x% (30% or 50% increase)** | SL × (1 – DL) × (1 – DR-Access) × PI-30<br>SL × (1 – DL) × (1 – DR-Access) × PI-50 | 13 | Green | + |
| SWP-ECO2 | **Number of households experiencing an annual increase in agricultural yields of at least 30%** | S × (1 – DL) × (1 – DR-Access) × PY_30 | 13 | Green | + |
| **Expenditure** | | | | | |
| A-ECO1 | **USD savings in fuel costs (solar-powered appliance replacing a non-solar-powered appliance)** | S × (1 – DL) × DR-GHG × PL × OPEXD | 12 | Green | + |
| **Job opportunity** | | | | | |
| A-ECO2 | **Number of new jobs created** | S × EF × EFa | 13 | Green | + |
| SOCIAL | | | | | |
| **Health and wellbeing** | | | | | |
| SWP-SOC1 | **Number of people benefiting from improved access to water and enhanced sanitation & hygiene** | SL × (1 – DL) × (1 – DR-Access) × DWASH × H | 13 | Orange | + |
| SWP-SOC2a+b | **The number of people / women who perceive that a solar water pump provides them with more free time** | SL × (1 – DL) × (1 – DR-Access) × PT<br>SL × (1 – DL) × (1 – DR-Access) × WomenT | 13 | Orange | + |
| SWP-SOC3 | **Number of people who perceived improved health** | SL × (1 – DL) × (1 – DR-Access) × H × PQL | 13 | Green | + |
| **Food security** | | | | | |
| SWP-SOC4 | **Number of people who perceive that using the appliance improves food security** | SL × (1 – DL) × (1 – DR-Access) × H × PFS | 13 | Green | + |

| ID | INDICATOR | FORMULA | MCDA SCORE | STATUS | IMPACT |
|---|---|---|---|---|---|
| Access and inclusion | | | | | |
| A-SOC1 | **Number of people who gained access to an off-grid appliance for the first time** | S × (1 – DL) × (1 – DR-Access) × H | 12 | ● | ⊕ |
| A-SOC2 | **Number of customers currently accessing off-grid appliances through flexible financing** | SL-PAYGo × (1 – DL) × (1 – DR-Access) | 12 | ● | ± |
| A-SOC3 | **Number of people below the poverty line with access to an appliance** | S × (1 – DL) × (1 – DR-Access) × H × RPL | 11 | ● | ⊕ |
| Ownership | | | | | |
| A-SOC4 | **Affordability of monthly repayments** | (PAYGoMC / IMAC) × 100 | 14 | ● | ± |

## Variables

Below is a summary of the variables that are used in the formulae used to calculate the indicator. These are separated into input variables, which need to be entered by the user of the Framework, and standard variables, which are provided with the Framework. The latter is based on existing evidence and end-user research conducted as part of this work.

### Input Variables

List of the variables where the user of the Framework needs to provide the value.

| VARIABLES | DEFINITION |
|---|---|
| **DWASH** | Percentage of people who use a solar water pump for improved water and hygiene |
| **IMAC** | Average monthly income of the customer base (USD or equivalent) |
| **PAYGoMC** | Average monthly PAYGo commitment (USD or equivalent) |
| **SL-PAYGO** | Number of units sold through flexible financing currently in use (number of units) |
| **PL** | Estimated product lifespan (minimum of 1.5 × financing period, or 1.5 × warranty period in cash payments) (years) |
| **RPL** | Percentage of people who are under World Bank's International Poverty Line when gaining access to the appliance. The poverty line is determined as half of the median household income. Regional values for the average (or median) household income by country can be found in the World Population Review.[8] |
| **S** | Number of units sold (cumulative, i.e. ever) (number of units) |
| **SL** | Number of units sold which are estimated to currently be in use (based on the products estimated lifespan being 1.5 × financing period, or 1.5 × warranty period in cash payments) (number of units) |
| **WRP** | Proportional weight of each appliance that will be recycled (%) |
| **WS** | Weight of solar-powered appliance (kg) |

### Standard Variables

Standard variables are those for which a reasonably reliable estimate was found in the literature review and 'end-user' research conducted as part of this project. These values are included within the framework. The values for some standard variables are given as ranges. Users should consult each specific variable sheet for information on local context (such as geography and the degree of urbanisation[9]), to decide which value is most appropriate for their products, as well as the confidence rating[10] of each value.

For more information, please refer to the standard variables section.

Variables marked as 'pipeline variables' are of interest, but data are not yet available. While there is no set plan for these pipeline variables, we invite people to undertake research to close the existing data gap. Refer here for the corresponding sheet in the excel version of the Impact Assessment Framework for off- and weak-grid high-performing appliances.

8 World Population Review. N/A. https://worldpopulationreview.com/country-rankings/median-income-by-country

9 Degree of urbanisation describes territories or countries within three different categories of urbanisation as follows: (a) cities (densely populated areas); (b) towns and suburbs (intermediate density areas); (c) rural areas (thinly populated areas) (Eurostat, 2021).

10 The confidence level was assessed for each value for 'standard variables'. Three stars (***) indicate that a study is 'up to date' (i.e., was conducted within five years of the assessment) and has, at the same time, a 'large sample size' (meaning that the data came from one study with 500+ samples or several studies with a total of 500+ samples). Two stars (**) indicate that studies are either 'up to date' or have a 'large sample size', and one star (*) indicates that the studies are not up to date and have small sample size.

List of variables that are based on existing evidence and that have a predefined value. Each variable is described in more detail in the corresponding sheets, marked with a 'V_' and the corresponding variable ID. Refer to each sheet for more information on values, particularly where a range is given. Values may vary depending on geography or degree of urbanisation. Pipeline indicators are indicators for which data are not yet available, but are of interest.

| VARIABLES | DEFINITION | VALUE |
|---|---|---|
| **DL** | Discount for loss: products not working or not in use, excluding loss in supply chain (%) | **8.50%** |
| **DR-Access** | Discount for repeat sales for estimating new access to solar powered appliance (including different companies) (%) | **1%** |
| **DR-GHG** | Ratio capturing sales replacing a diesel genset-powered appliance (%) | **35%** |
| **EF** | Employment factor (jobs / item sold) | **0.0197** |
| **EFa** | The proportion of employment factor relevant to each appliance | **100%** |
| **G** | Average amount of greenhouse gases avoided per appliance, due to diesel displacement (kg / $CO_2$ / year) | **2,297** |
| **H** | Household size (number of people) | **5.5** |
| **OPEXD** | Annual operational fuel cost of a diesel-powered appliance (USD / year) | **2160–2,748** |
| **PI-30** | Percentage of people who experienced at least a 30% annual income increase (%) | **65%** |
| **PI-50** | Percentage of people who experienced at least a 50% annual income increase (%) | **45%** |
| **PQL** | Percentage of people associating the appliance with improved quality of life (%) | **64–90%** |
| **PFS** | Percentage of people associating the appliance with improved food security (%) | **90–12%** |
| **PT** | Percentage of people with access to a [appliance name] who perceive that the appliance contributes to 'time benefit', 'time management' or 'unburdening' (% of people) | **29–36%** |
| **PY-30** | Percentage of people who experienced at least a 30% annual yield increase (%) | **39%** |
| **WomenT** | Percentage of women with access to a [appliance name] who perceive the appliances contributes to 'time benefit', 'time management' or 'unburdening' to the [appliance name] in a representative sample ( percentage of women) | **Pipeline Variable** |

# Impact Indicators

**Here we give a detailed description of the evidence for the indicators and values proposed for solar water pumps.**

The following tables provide an overview of the indicators and for each indicator:

- the formula and agreed values of the different variables
- a paragraph describing the different data sources used to reach the values, including insights from literature, end-user research and stakeholder input
- a discussion of data gaps and limitations, with special attention to limitations in terms of context (rural/urban, East Asia / East Africa)
- notes on indicators that were considered but not included in the final version

More detailed information about the values can be found in the respective tables for the variables.

**Table 2: Environment**

A-ENV1: Tonnes of $CO_2$ emissions avoided

| METRIC | TONNES OF $CO_2$ EMISSIONS AVOIDED | | |
|---|---|---|---|
| | | | STATUS |
| **ID** | A-ENV1 | | ● |
| | | | IMPACT |
| **Appliance name** | All | | ⊕ |
| **Unit of measurement** | Tonnes $CO_2e$ / year | | |
| **Definition** | $CO_2$ emissions saved during operation, for households or businesses replacing a diesel-powered appliance with a solar-powered appliance. | | |
| **Usefulness of metric** | Quantifying the benefit of replacing diesel-powered appliances with solar-powered appliances in terms of $CO_2$ emissions. | | |
| **Impact statement** | X tonnes of $CO_2$ emissions were saved through the distribution of [appliance name] since [start date of distribution]. | | |
| **Calculation** | (S × (1 – DL) × DR-GHG × PL × G) / 1000 | | |
| | **VARIABLES** | **DEFINITION** | **VALUE** |
| | S | Number of units sold (cumulative, i.e. ever) (number of units) | This variable is to be inserted by the user |
| | DL | Discount for loss: products not working or not in use, excluding loss in supply chain (%) | 9% |
| **Variables** | DR-GHG | Ratio capturing sales replacing a diesel gen set-powered appliance (%) | 35% |
| | PL | Estimated product lifespan (minimum of 1.5 × financing period, or 1.5 × warranty period in cash payments) (years) | This variable is to be inserted by the user |
| | G | Average amount of greenhouse gases avoided per appliance, due to diesel displacement (kg $CO_2$/year) | 2,297 |
| **Assumptions** | • The operational CO2 emissions of a solar appliance are assumed to be zero.<br>• Nonetheless, the US National Renewable Energy Laboratory (NREL) conducted a harmonisation study on all published lifecycle analyses of residential and utility-scale solar PV systems, harmonising the lifecycle emissions of PVs at 40gCO2e/kWh,[11] with operational emissions estimated at 8.4 – 10.4gCO2e/kWh.<br>• This indicator does not apply for cases in which a solar water pump supplements a diesel-powered pump. It only applies to cases where a solar water pump is replaces a diesel-powered pump completely. | | |
| **Supporting literature** | • The International Renewable Energy Agency (IRENA) estimates that accelerated deployment of solar PV alone can lead to significant emission reductions of 4.9 gigatonnes of carbon dioxide (Gt $CO_2$) in 2050.[12]<br>• Solar water pump introduction to replace the use of diesel / petrol-powered water pumps can bring about significant environmental benefits in terms of reduced $CO_2$ emissions during the operation of the pump. | | |

11 LC Stages, Life Cycle Greenhouse Gas Emissions from Solar Photovoltaics. J. Ind. Ecol. (2012)

12 IRENA, Future of Solar Photovoltaic: Deployment, investment, technology, grid integration and socio-economic aspects (A Global Energy Transformation: paper), International Renewable Energy Agency, Abu Dhabi, 2019

| METRIC | TONNES OF $CO_2$ EMISSIONS AVOIDED |
|---|---|
| **Supporting literature** | • The potential reduction in GHG emissions per unit of energy used for water pumping ($CO_2$-eq/kWh) is 95–97% compared to pumps operating with grid electricity (global average energy mix), and 97–98% compared to diesel pumps.[13] For example, a study in India found that five high power (3.73 kW) capacity irrigation pumps (average capacity in India) powered by solar, diesel and grid-electricity, and running for 1,250 hours per year, would emit zero, 4 and 5.2 tonnes of $CO_2$ annually.[14] As a result, replacing just half of the 10 million diesel pumps in India with a solar irrigation system could help abate 26 million tonnes of $CO_2$ emissions annually. This would be equivalent to 1.2% of 1.39 metric tonnes, India's total carbon dioxide emissions in 2010.[15] Alternatively, a nationwide level assessment found that replacing 1 million diesel irrigation pumps with solar pumps would result in diesel use mitigation of 9.4 billion litres over the lifecycle of solar pumps which translates into diesel subsidy saving of USD 1.2 billion and the emission abatement of 25.3-meganewton tonnes of $CO_2$.[16] |
| **Data gaps** | • Addressing more accurate usage pathways of appliances and especially solar water pumps. In what percentage of the cases a solar-powered appliance is used in addition to the diesel-powered appliance.<br>• Identifying lifecycle emissions reduction, also considering production, transportation, maintenance and replacement of solar-powered appliances. |
| **Usage notes** | • Impact insights from other Global South regions, especially Sub-Saharan Africa.<br>• Impact insights broken down by different appliance access use cases: gender access, actual access level (period) or extent of functionality.<br>• Impact insights broken down into differences of geography, seasonality or differences in time-use. |

**Table 3: Environment**

A-ENV2a: Annual tonnes of electric waste added

| METRIC | ANNUAL TONNES OF ELECTRIC WASTE ADDED | | |
|---|---|---|---|
| | | | **STATUS** |
| **ID** | A-ENV2a | | ● |
| | | | **IMPACT** |
| **Appliance name** | All | | ⊖ |
| **Unit of measurement** | Tonnes | | |
| **Definition** | Tonnes of electronic waste added annually due to the ownership and disposal of an off-grid appliance by households or businesses. | | |
| **Usefulness of metric** | Quantifying the electronic waste added to the environment when off-grid appliances are disposed of in the absence of a disposal plan. | | |
| **Impact statement** | Since [start date of distribution], X tonnes of electronic waste was added to the environment due to the distribution of off-grid appliances, in the absence of a recycling or reuse plan. | | |
| **Calculation** | S × WS / 1000 | | |
| **Variables** | **VARIABLES** | **DEFINITION** | **VALUE** |
| | S | Number of units sold (cumulative, i.e. ever) (number of units) | This variable is to be inserted by the user |
| | WS | Weight of solar-powered appliance (kg) | This variable is to be inserted by the user |
| **Assumptions** | • It is assumed that the entire appliance, whether non-solar-powered or non-solar-powered, will be disposed of in full, without recycling or reuse.<br>• The indicator does not address the difference in environmental impact of different mass elements (all kgs are equal). | | |
| **Supporting literature** | • E-waste is defined as "all types of electrical and electronic equipment that have been discarded".[17] For our purposes, we include all parts in the appliance including all electrical components, as well as metal and plastic fractions, and excluding packaging and external power source.<br>• Appliances that include a majority of mechanical components, such as solar water pumps, are also considered e-waste.[18]<br>• "The expected quantity of e-waste going to landfill as a result of using solar appliances is 78 million tonnes by 2050".[19] No appliance-specific data currently exist. | | |

13 Julian Schnetzer & Lucie Pluschke, Solar-Powered Irrigation Systems (p. 9). Food and Agricultural Organisation (FAO) (2017). http://www.fao.org/3/bt437e/bt437e.pdf

14 S. Agrawal & A. Jain, Sustainable deployment of solar irrigation pumps: Key determinants and strategies. 2019, WIREs Energy and Environment, 8(2), e325. https://doi.org/10.1002/wene.325

15 S. Agrawal & A. Jain, Sustainable deployment of solar irrigation pumps: Key determinants and strategies. 2019, WIREs Energy and Environment, 8(2), e325. https://doi.org/10.1002/wene.325

16 K.P.M Goerdeler, Feasibility analysis for solar agricultural water pumps in India. 2014, KPMG Advisory Services Private Limited

17 Step, Solving the E-Waste Problem (Step) White Paper: One Global Definition of E-waste. https://www.step-initiative.org/files/_documents/whitepapers/StEP_WP_One%20Global%20Definition%20of%20E-waste_20140603_amended.pdf, 2014

18 Constantinos S. Psomopoulos Dimitrios Barkas, and George Ch. Ioannidis, 'The Recycling Potential of Submersible Sewage Pumps in the EU', Recycling, 2018, MDPI AG, 3(2), p. 14. doi: 10.3390/recycling3020014

19 S. Weckend, A.Wade, and G.A. Heath, End of life management: solar photovoltaic panels (No. NREL/TP-6A20-73852). National Renewable Energy Lab.(NREL) (2016) , Golden, CO (United States)

| METRIC | ANNUAL TONNES OF ELECTRIC WASTE ADDED |
|---|---|
| **Supporting literature** | • A two-fold increase in the global sales of small-scale solar devices, including PV-based solar lanterns, solar water pumps, solar refrigerators and solar home systems was predicted between 2010 and 2022. Sales reached 130 million units between 2010 and 2017, and were expected to increase up to 250 million units in 2017 and 2022.[20] These sales were concentrated in developing countries located in Sub-Saharan Africa, especially in East Africa, and to a lesser extent in South Asia and Latin America.<br>• Recent research highlighted an 'emerging disposal problem' associated with the exponential rise in sales of small-scale and off-grid solar devices.[21] The World Bank estimated that of the 130 million off-grid solar devices sold in 2017, around 26 million off-grid solar devices went out of use.[22] Estimates show that solar e-waste represented less than 0.5% of the overall e-waste stream in 14 Sub-Saharan African countries in 2014. In 2014, an estimated 2,500 tonnes of off-grid solar products were put on the market of which 800t went into the waste stream. Solar e-waste disposal was expected to increase up to 10,000 tonnes by 2020. Kenya leads the share with 3,800 tonnes, followed by Nigeria (530 tonnes) and Rwanda (350 tonnes).[23]<br>• The International Renewable Energy Agency estimated that by 2050, the global cumulative solar e-waste volumes could reach 78 million metric tonnes.[24] |
| **Data gaps** | Addressing different components according to their environmental impact (e.g., battery vs cables). |
| **Usage notes** | • WS includes only the appliance and inbuilt battery. Exclusive of packaging and external power source but including any other part of the appliance.<br>• WC determined depending on models being replaced OR weight of most commonly available diesel-powered solar water pump.<br>• Only use WC in case of a replacement of an existing appliance, otherwise the value should be zero. |

**Table 4: Environment**

A-ENV2b: Annual tonnes of electric waste avoided

| METRIC | ANNUAL TONNES OF ELECTRIC WASTE AVOIDED | | |
|---|---|---|---|
| | | | STATUS |
| **ID** | A-ENV2b | | ● |
| | | | IMPACT |
| **Appliance name** | All | | ⊕ |
| **Unit of measurement** | Tonnes | | |
| **Definition** | Tonnes of electronic waste avoided annually due to the existence of a recycling plan. | | |
| **Usefulness of metric** | This metric rewards organisations that promote recycling and raise awareness of e-waste recycling. | | |
| **Impact statement** | Since [start date of distribution], X tonnes of electronic waste was avoided thanks to recycling plans. | | |
| **Calculation** | S × WS × WRP / 1000 | | |
| **Variables** | VARIABLES | DEFINITION | VALUE |
| | S | Number of units sold (cumulative, i.e. ever) (number of units) | This variable is to be inserted by the user |
| | WS | Weight of solar-powered appliance (kg) | This variable is to be inserted by the user |
| | WRP | Proportional weight of each appliance that will be recycled (%) | This variable is to be inserted by the user |
| **Assumptions** | • It is assumed that the entire appliance, whether solar-powered or non-solar-powered, will be disposed of in full, in the absence of recycling or reuse plans.<br>• The indicator does not address the difference in the environmental impact of different mass elements (all kgs are equal). | | |
| **Supporting literature** | See A-ENV2a. | | |
| **Input from stakeholders** | Input from people / investors / donors. | | |
| **Data gaps** | • Solar appliance recycling potential in East Africa and Asia.<br>• Including the e-waste saved through using reused materials in the manufacturing process. | | |
| **Usage notes** | • WS only includes the appliance and inbuilt battery.<br>• Excludes packaging and external power source but includes any other part of the appliance.<br>• WRP is determined during the project/intervention depending on the recycling / reuse plan available.<br>• The above indicator could be improved or added to incorporate reduction in e-waste. | | |

20 Lighting Global, Off-grid solar market trend report 2018 (No. 4; p. 24). International Finance Corporation, 2018. https://www.lightingglobal.org/wp-content/uploads/2018/02/2018_Off_Grid_Solar_Market_Trends_Report_Summary.pdf

21 Bensch, G., Peters, J., & Sievert, M. (2017). The lighting transition in rural Africa—From kerosene to battery-powered LED and the emerging disposal problem. Energy for Sustainable Development, 39, 13-20

22 Lighting Global. (2018). Off-grid solar market trend report 2018 (No. 4; p. 24). International Finance Corporation. https://www.lightingglobal.org/wp-content/uploads/2018/02/2018_Off_Grid_Solar_Market_Trends_Report_Summary.pdf

23 F. Magalini, D. Sinha-Khetriwal, D. Rochat, J. Huismann, S. Munyambu, J. Oliech, I.C. Nnorom, & O. Mbera, Electronic Waste (E-waste) Impacts and Mitigation Options in the Off-grid Renewable Energy Sector (p. 62). UK Department for International Development (DFID), 2016, https://www.gov.uk/research-for-development-outputs/electronic-waste-e-waste-impacts-and-mitigation-options-in-the-off-grid-renewable-energy-sector

24 IRENA, End-of-life management: Solar Photovoltaic Panels. International Renewable Energy Agency (2016). https://irena.org/publications/2016/Jun/End-of-life-management-Solar-Photovoltaic-Panels

**Table 5: Economic**

A-ECO1: USD savings in fuel costs

| METRIC | USD SAVINGS IN FUEL COSTS (SOLAR-POWERED APPLIANCE REPLACING A NON-SOLAR-POWERED APPLIANCE) | | | |
|---|---|---|---|---|
| | | | | STATUS |
| **ID** | A-ECO1 | | | ● |
| | | | | IMPACT |
| **Appliance name** | All | | | ⊕ |
| **Unit of measurement** | USD | | | |
| **Definition** | Total USD saved in fuel-related operational costs for households or businesses replacing a diesel-powered appliance with a solar-powered appliance, throughout the solar-powered appliance's lifetime. | | | |
| **Usefulness of metric** | The indicator provides an economic business case for solar appliances by highlighting the amount of operational costs that a household or business saves throughout its lifetime. | | | |
| **Impact statement** | Since [start date of distribution], people saved x USD in operational costs due to moving from diesel-powered [appliance name] to a solar-powered appliance. | | | |
| **Calculation** | S × (1 – DL) × DR-GHG × PL × OPEXD | | | |
| **Variables** | **VARIABLES** | **DEFINITION** | **VALUE** | |
| | S | Number of units sold (cumulative, i.e. ever) (number of units) | This variable is to be inserted by the user | |
| | DL | Discount for loss: products not working or not in use, excluding loss in supply chain (%) | 8.5% | |
| | DR-GHG | Ratio capturing sales replacing a diesel genset-powered appliance (%) | 35% | |
| | PL | Estimated product lifespan (minimum of 1.5 × financing period, or 1.5 × warranty period in cash payments) (years) | This variable is to be inserted by the user | |
| | OPEXD | Annual operational fuel cost of a diesel-powered appliance (USD / year) | 2160–2,748 | |
| **Assumptions** | • The annual operational expenditure of a solar appliance is assumed to be zero.<br>• Only fuel cost reduction is accounted for i.e. costs such as seeds, fertiliser and labour are not considered. | | | |
| **Supporting literature** | • A solar water pump can bring about significant financial savings for farmers and households using conventional (diesel/petrol-powered) water pumps including reducing fuel consumption. GOGLA estimates that the lifecycle costs of a solar water pump are 22–56% of the lifecycle costs of diesel pumps, enabling a payback period of two years.[25]<br>• Several studies have been conducted to quantify these savings further. For example, a study in Western India by IRENA found that with the help of solar water pumps, farmers reduced production costs and increased reliability and efficiency of harvest, with annual savings of farmers rising by 161% compared to using diesel-powered pumps, with a return on investment after three years.[26]<br>• Another study in the same state found that households reduced average electricity consumption of over baseline in Jaipur and Sikar by 1–17% and in Sri Ganganagar by 17–134%, reducing average diesel consumption in Bikaner, Jaisalmer, Sri Ganganagar and Chittorgarh by 50–106%; increasing income security with higher annual profits in Jaipur and Sikar by 3.1–41.5% and in the diesel-using districts by 14–76%.[27]<br>• Another study in South India on electrified households found that with solar water pumps, households saved 40 KWh/day on grid electricity, leading to savings on the electricity bill of USD 12/year (Padmavathi et al., 2011).Overall, nationwide, it is estimated that USD 300 million per year of foreign expenditure could be saved on diesel imports, if 1m diesel pumps, translating into USD 4.5 billion forex savings over the lifetime of the pump.[28]<br>• Furthermore, a study in Kenya, Uganda and Tanzania involving 400 farmers who had owned solar water pumps for four–five months found a 91% reduction in farming expenditure. | | | |
| **Data gaps** | • Include other expenses that are not fuel.<br>• Magnitude of replacement market for solar appliances.<br>• The operational costs of solar appliances. | | | |
| **Usage notes** | Values for OPEXD vary depending on the geography. To find the most suitable value please refer to the elaborated variable sheet (click on the variable name). | | | |

25 GOGLA, Off-Grid Solar. A Growth Engine for Jobs. 1–40. GOGLA (2019), https://www.gogla.org/resources/off-grid-solar-a-growth-engine-for-jobs

26 IRENA, End-of-life management: Solar Photovoltaic Panels. International Renewable Energy Agency, (2016), https://www.irena.org/publications/2016/Jun/End-of-life-management-Solar-Photovoltaic-Panels

27 E. Gupta, The impact of solar water pumps on energy-water-food nexus: Evidence from Rajasthan, India. Energy Policy (2019), 129, 598-609

28 KPMG, Feasibility analysis for solar agricultural water pumps in India, KPMG India (2014), https://shaktifoundation.in/wp-content/uploads/2014/02/feasibility-analysis-for-solar-High-Res-1.pdf

**Table 6: Economic**

A-ECO2: Number of new jobs created

| METRIC | NUMBER OF NEW JOBS CREATED | | |
|---|---|---|---|
| | | | STATUS |
| ID | A-ECO2 | | ● |
| | | | IMPACT |
| Appliance name | All | | ⊕ |
| Unit of measurement | Number of jobs | | |
| Definition | Increase in job opportunities within the business (manufacturing, assembly, distribution). | | |
| Usefulness of metric | Enables demonstration of the contribution of the high-performing appliance supply chain to the local job market. | | |
| Impact statement | A total of x jobs have been created in local markets through the high-performing appliance supply chain. | | |
| Calculation | S × EF × EFA | | |
| Variables | VARIABLES | DEFINITION | VALUE |
| | S | Number of units sold (cumulative, i.e. ever) (number of units) | This variable is to be inserted by the user |
| | EF | Employment factor (jobs / item sold) | 0.0082 |
| | EFA | Proportion of employment factor relevant to each appliance | 25% |
| Assumptions | The jobs are created within the geographical area being served. | | |
| Supporting literature | The values for EF and EFA are taken from the Power for All report, "Powering Jobs Census 2019".[29] Evidence from the same publication and others suggests that the off-grid solar value chain could generate up to 1.3 million full-time equivalent (FTE) jobs by 2022, excluding manufacturing.[30,31] For further details, we recommend consulting the original report. | | |
| Data gaps | Explore indirect jobs from upstream sectors and potential job displacement from traditional energy sectors. | | |
| Usage notes | • The above indicators would be applied to a specific geographical region that is the area of interest.<br>• The jobs being counted are those generated within that geographical region.<br>• The formula should not be used for appliances sold as a bundle with solar home system (SHS). | | |

**Table 7: Economic**

SWP-ECO1: Number of people experiencing an annual increase in business income of at least x% (30% or 50% increase)

| METRIC | NUMBER OF PEOPLE EXPERIENCING AN ANNUAL INCREASE IN BUSINESS INCOME OF AT LEAST X% (30% OR 50% INCREASE) | |
|---|---|---|
| | | STATUS |
| ID | SWP-ECO1 | ● |
| | | IMPACT |
| Appliance name | Solar water pump | ⊕ |
| Unit of measurement | Number of people | |
| Definition | Number of businesses without previous access to a powered water pump, benefiting from an increase in income due to ownership of a solar water pump. | |
| Usefulness of metric | This indicator aims to capture the number of businesses with a 30% or a 50% increase in income due to the use of a solar water pump. | |
| Impact statement | X businesses without previous use of a diesel-powered water pump, are achieving a 30% (or 50%) increase in income due to ownership of a solar water pump. | |
| Calculation | SL × (1 – DL) × (1 – DR-Access) × PI-30<br>SL × (1 – DL) × (1 – DR-Access) × PI-50 | |

29 Power for All, Powering Jobs Census 2019: The Energy Access Workforce, Power for All (2019), https://www.powerforall.org/resources/reports/powering-jobs-census-2019-energy-access-workforce

30 Lighting Global, Off-grid solar market trend report 2018 (No. 4; p. 24). International Finance Corporation (2018) https://www.lightingglobal.org/wp-content/uploads/2018/02/2018_Off_Grid_Solar_Market_Trends_Report_Summary.pdf

31 Power for All, Powering Jobs Census 2019: The Energy Access Workforce, Power for All (2019), https://www.powerforall.org/resources/reports/powering-jobs-census-2019-energy-access-workforce

| METRIC | NUMBER OF PEOPLE EXPERIENCING AN ANNUAL INCREASE IN BUSINESS INCOME OF AT LEAST X% (30% OR 50% INCREASE) | | |
|---|---|---|---|
| | **VARIABLES** | **DEFINITION** | **VALUE** |
| **Variables** | SL | Number of units sold which are estimated to currently be in use (based on the products estimated lifespan being 1.5 × financing period, or 1.5 × warranty period in cash payments) (number of units) | This variable is to be inserted by the user. |
| | DL | Discount for loss: products not working or not in use, excluding loss in supply chain (%) | 8.5% |
| | DR-Access | Discount for repeat sales for estimating new access to solar powered appliances (including different companies) (%) | 1% |
| | PI-30 | Percentage of people who experienced at least a 30% annual income increase (%) | 65% |
| | PI-50 | Percentage of people who experienced at least a 50% annual income increase (%) | 45% |
| **Assumptions** | • Businesses purchasing solar water pumps use these appliances to generate income.<br>• While income increases are dependent on increased yields, which depend on the crop and context, different crop types and contexts are not considered. | | |
| **Supporting literature** | • Studies have shown that moving from rainfed irrigation to solar water pump-based irrigation increased household incomes and improved community resilience to variable climate conditions. This increase occurs through enabling production of a wider range of crop types or through allowing farmers to diversify their income sources, for example by selling excess water to their neighbours or surplus energy to the grid.[32]<br>• A study in Zimbabwe reported an increase in income of 47% for middle income groups, 173% for the poor, and 286% for the very poor due to the use of solar water pumps.[33]<br>• A study in Central India found that 45% and 25% of farmers increased their annual income by 50% and 70% respectively due to the use of a solar water pump. A 190% increase in income was observed by farmers in Southern India (Srinivasarao et al., 2020). Furthermore, a nationwide assessment of the potential solarisation of agricultural pumps found that solar water pumps contributed to better crop yields that could improve agricultural output by Rs 2,000 Crore (~ USD 300 million) per annum (10% yield improvement for an installed base of 1 million solar pumps) or Rs 30,000 Crore (~ USD4.5 billion) over the lifetime of the pump.[34] | | |
| **Data gaps** | • The different impacts for different types of businesses and for farm sizes.<br>• Different types of yield for different types of crops and context as a variable for increase in income. | | |

**Table 8: Economic**

SWP-ECO2: Number of households experiencing an annual increase in agricultural yields of at least 30%

| METRIC | NUMBER OF HOUSEHOLDS EXPERIENCING AN ANNUAL INCREASE IN AGRICULTURAL YIELDS OF AT LEAST 30% | |
|---|---|---|
| | | **STATUS** |
| **ID** | SWP-ECO2 | ● |
| | | **IMPACT** |
| **Appliance name** | Solar water pump | ⊕ |
| **Unit of measurement** | Number of households | |
| **Definition** | Captures the number of farmers experiencing an increase of at least 30% in yields due to the use of solar water pumps for irrigation. | |
| **Usefulness of metric** | Increase in annual income as a result of increased yield and selling water are significant catalysts for poverty alleviation. | |
| **Impact statement** | Solar water pump distribution led to an increase of at least 30% in the yields of approximately x smallholder farmers. | |
| **Calculation** | S × (1 – DL) × (1 – DR-Access) × PY-30 | |

32 Halimatou Alaofè, Jennifer Burney, Rosamond Naylor, & Douglas Taren, Solar-Powered Drip Irrigation Impacts on Crops Production Diversity and Dietary Diversity in Northern Benin, Food and Nutrition Bulletin, (2016) 37(2), 164–175. https://doi.org/10.1177/0379572116639710

33 John Magrath, Transforming lives in Zimbabwe: Rural sustainable energy development project, Oxfam (2015), https://policy-practice.oxfam.org/resources/transforming-lives-in-zimbabwe-rural-sustainable-energy-development-project-567000/

34 KPMG, Feasibility analysis for solar agricultural water pumps in India, KPMG India, (2014), https://shaktifoundation.in/wp-content/uploads/2014/02/feasibility-analysis-for-solar-High-Res-1.pdf

| METRIC | NUMBER OF HOUSEHOLDS EXPERIENCING AN ANNUAL INCREASE IN AGRICULTURAL YIELDS OF AT LEAST 30% | | |
|---|---|---|---|
| | **VARIABLES** | **DEFINITION** | **VALUE** |
| **Variables** | S | Number of units sold (cumulative, i.e., ever) (number of units) | This variable is to be inserted by the user |
| | DL | Discount for loss: products not working or not in use, excluding loss in supply chain (%) | 9% |
| | DR-Access | Discount for repeat sales for estimating new access to solar powered appliances (including different companies) (%) | 1% |
| | PY-30 | Percentage of people who experienced at least a 30% annual yield increase (%) | 39% |
| **Assumptions** | • That increase in yield has been brought about due to improved irrigation rather than other conditions such as improved seeds or improved agricultural practices.<br>• While income increases are dependent on increased yields, which is dependent on the crop and context, different crop types and contexts are not considered. | | |
| **Supporting literature** | • Evidence suggests that using a solar water pump for irrigation could increase both the yield and the crop cycles for a farmer. A study in Central India of 200 farmers found that they experienced 36% increased crop yields and a 66% increase in crop cycles as a result of the efficient irrigation potential.[35] A study in Central and South India found that using solar water pumps helped shift cropping patterns, leading to increases in crop cycles of up to three cycles per year (Suman, 2018). While a nationwide assessment in India found that overall, one million solar water pumps could deliver a 10% yield improvement and increase in agricultural production by Rs 2,000 Crore (~ USD300 million) per annum.[36]<br>• Furthermore, a UNEP report supports that for every 10% increase in farm yields, there has been an estimated 7% reduction in poverty in Africa and more than 5% in Asia.<br>• A study found that solar-powered drip irrigation in northern Benin helped two village women's agricultural groups (400 women) increase their vegetable and fruit production by 26% and 55% respectively. It further showed that the groups were three times more likely to improve their productivity using solar drip irrigation systems. Additionally, 57% of the women spent their additional income on food, 54% on healthcare, and 25% on education.[37] | | |
| **Input from stakeholders** | Input from people / investors / donors. | | |
| **Data gaps** | • The different impact for different types of businesses and for farm size.<br>• Different types of yield for different types of crops and context as a variable for increase in income. | | |
| **Usage notes** | For simplicity and wide applicability, we use percentage increases and not absolute values, which depend on type of crop, size of land etc. It is up to the user to decide on the most common context and setting that this is applicable for. | | |

**Table 9: Social / Health Impact**

A-SOC1: Number of people who gained access to an off-grid appliance for the first time

| METRIC | NUMBER OF PEOPLE WHO GAINED ACCESS TO AN OFF-GRID APPLIANCE FOR THE FIRST TIME | |
|---|---|---|
| | | **STATUS** |
| **ID** | A-SOC1 | ● |
| | | **IMPACT** |
| **Appliance name** | All | ⊕ |
| **Unit of measurement** | Number of people | |
| **Definition** | Number of people engaging and benefiting from the off-grid market due to access to a high-performing [appliance name]. | |
| **Usefulness of metric** | Enables demonstration of the number of people who have benefited from clean energy using appliances. | |
| **Impact statement** | High-performing appliances are enabling an estimated x people to access and use clean energy. This will allow them to build up assets, which could help them to access more products and services in the future. | |
| **Calculation** | S × (1 – DL) × (1 – DR-Access) × H | |

35 Shikha Suman, Evaluation and Impact Assessment of the Solar Irrigation Pumps Program in Andhra Pradesh and Chhattisgarh Report (2018), https://www.ssael.co.in/images/Library/files/Solar-Pumps-Impact--SSAEL-Report.pdf

36 KPMG, Feasibility analysis for solar agricultural water pumps in India. KPMG India (2014), https://shaktifoundation.in/wp-content/uploads/2014/02/feasibility-analysis-for-solar-High-Res-1.pdf

37 Halimatou Alaofè, Jennifer Burney, Rosamond Naylor, & Douglas Taren, Solar-Powered Drip Irrigation Impacts on Crops Production Diversity and Dietary Diversity in Northern Benin, Food and Nutrition Bulletin, (2016) 37(2), 164–175. https://doi.org/10.1177/0379572116639710

| METRIC | NUMBER OF PEOPLE WHO GAINED ACCESS TO AN OFF-GRID APPLIANCE FOR THE FIRST TIME | | |
|---|---|---|---|
| **Variables** | **VARIABLES** | **DEFINITION** | **VALUE** |
| | S | Number of units sold (cumulative, i.e., ever) (number of units) | This variable is to be inserted by the user |
| | DL | Discount for loss: products not working or not in use, excluding loss in supply chain (%) | 8.5% |
| | H | Household size (number of people) | 5.5 |
| | DR-Access | Discount for repeat sales for estimating new access to solar powered appliances (including different companies) (%) | 1% |
| **Assumptions** | That the majority of the customers are first-time owners, and the appliance is not only allowing them to benefit from its functionality, but also enabling them to become more financially included. | | |
| **Supporting literature** | • The Powering Opportunity in South Asia report found that 39% of respondents, the SHS owners, had their first experience of access to clean, modern power.[38]<br>• "M-KOPA's 'Pay-As-You-Go' solar model has helped to open up exciting new consumer markets. As off-grid energy connections increase, we are seeing millions of new consumers with greater financial stability and, for the first time, access to power".[39]<br>• Efficiency for Access & 60 Decibels' report[40] on the Uses & Impacts of Solar Water Pumps in Kenya, Rwanda, Senegal, Tanzania, Uganda & Zambia found that 91% of the participants were accessing a solar water pump for the first time. | | |
| **Data gaps** | • Explore the impacts of access on financial inclusion and further engagement in the appliance market (e.g., customer upgrades, use of PAYGo to purchase other products and services).<br>• Disaggregate this indicator for gender and income levels. | | |

**Table 10: Social / Health Impact**

A-SOC2: Number of people currently accessing off-grid appliances through flexible financing

| METRIC | NUMBER OF CUSTOMERS CURRENTLY ACCESSING OFF-GRID APPLIANCES THROUGH FLEXIBLE FINANCING | | |
|---|---|---|---|
| | | | **STATUS** |
| **ID** | A-SOC2 | | ● |
| | | | **IMPACT** |
| **Appliance name** | All | | ± |
| **Unit of measurement** | Number of people | | |
| **Definition** | Number of people with current access to high-performing clean energy appliances through financing. | | |
| **Usefulness of metric** | Enables demonstration of the number of people who have benefited from high-performing clean energy appliance financing through flexible financing. | | |
| **Impact statement** | PAYGo appliance financing is enabling an estimated x people access to high-performing clean energy appliance financing. This will allow them to build up a credit history, which could help them access more products and services in the future. | | |
| **Calculation** | SL-PAYGO × (1 – DL) × (1 – DR-Access) | | |
| **Variables** | **VARIABLES** | **DEFINITION** | **VALUE** |
| | SL-PAYGO | Number of units sold through flexible financing currently in use (number of units) | This variable is to be inserted by the user |
| | DL | Discount for loss: products not working or not in use, excluding loss in supply chain (%) | 8.5% |
| | DR-Access | Discount for repeat sales for estimating new access to solar powered appliances (including different companies) (%) | 1% |
| **Assumptions** | • Currently, most of the information about flexible financing comes from the PAYGo systems and excludes other micro financing options.<br>• That the majority of PAYGo customers are unlikely to have a strong credit history and, as such, PAYGo financing is not only providing more affordable high-performing appliances, but also enabling them to become more financially self-sufficient.<br>• Most sales are PAYGo and therefore, the discount for loss is approximately equal to the discount for loss for all sold appliances. | | |

38 ALTAI & GOGLA, Powering Opportunity in South Asia: From Work to Well-being, the Important Role of Small Scale Solar, GOGLA (2020), https://www.gogla.org/resources/powering-opportunity-in-south-asia-from-work-to-well-being-the-important-role-of-small

39 MKOPA, Tuned In: Television and Civic Engagement in Off-Grid Society, MKOPA (2017), https://sun-connect-news.org/fileadmin/DATEIEN/Dateien/New/TUNED_IN.pdf

40 Efficiency for Access & 60 Decibels, Uses & Impacts of Solar Water Pumps, Efficiency for Access Coalition (2021), https://storage.googleapis.com/e4a-website-assets/Uses-Impacts-of-SWPs-July-2021.pdf

| METRIC | AFFORDABILITY OF MONTHLY REPAYMENTS |
|---|---|
| **Supporting literature** | The Powering Opportunity in South Asia found that 39% of respondents, the SHS owners, had their first experience of access to clean, modern power.[41] |
| **Data gaps** | • Explore the impacts of access on financial inclusion and further engagement in the appliance market (e.g., customer upgrades, use of PAYGo to purchase other products and services).<br>• Disaggregate this indicator for gender and income levels.<br>• Gather data about number of customers with access to flexible financing beyond PAYGo. |
| **Usage notes** | • This metric is equal to the number of people currently financing their appliance through PAYGo.<br>• The number excludes those who may have purchased a product previously through PAYGo financing and have already benefited from this level of financial inclusion. |

**Table 11: Social / Health Impact**

A-SOC3: Number of people below the poverty line with access to an appliance

| METRIC | NUMBER OF PEOPLE BELOW THE POVERTY LINE WITH ACCESS TO AN APPLIANCE | | |
|---|---|---|---|
| | | | **STATUS** |
| **ID** | A-SOC3 | | ● (green) |
| | | | **IMPACT** |
| **Appliance name** | All | | ⊕ |
| **Unit of measurement** | Number of people | | |
| **Definition** | The number of people who live under the World Bank's International Poverty Line for the specific region and have access to a high-performing appliance. | | |
| **Usefulness of metric** | Increasing the inclusivity of high-performing appliances among marginalised groups is essential for realising their positive impact. This metric rewards organisations that reach low- income consumers and allows them to monitor the progress of the sector as a whole. | | |
| **Impact statement** | X people under the poverty line gained access to high-performing [appliance name]. | | |
| **Calculation** | S × (1 – DL) × (1 – DR-Access) × H × RPL | | |
| **Variables** | **VARIABLES** | **DEFINITION** | **VALUE** |
| | S | Number of units sold (cumulative, i.e. ever) (number of units) | This variable is to be inserted by the user |
| | DL | Discount for loss: products not working or not in use, excluding loss in supply chain (%) | 8.5% |
| | DR-Access | Discount for repeat sales for estimating new access to solar powered appliances (including different companies) (%) | 1% |
| | H | Household size (number of people) | 5.5 |
| | RPL | Percentage of people who are under World Bank's International Poverty Line when gaining access to the appliance. The poverty line is determined as half of the median household income (OECD, 2015). Regional values for the average (or median). Household income by country can be found at World Population Review | This variable is to be inserted by the user |
| **Assumptions** | This formula does not include increases in income post-purchase | | |
| **Supporting literature** | • In 2018, over 40% of the Sub-Saharan African population was under the World Bank's International Poverty Line. In East Asia, the same rates reached over 15% in 2014. The WHO dimension in the Impact Management Project recommends identifying how underserved the stakeholders of the intended impact are when measuring impact.[42]<br>• Efficiency for Access and 60 Decibels' research[43] from Kenya, Rwanda, Uganda and Tanzania found that 30% of customers surveyed were living in poverty. | | |
| **Data gaps** | • Improving the mapping of income level at the day of purchase.<br>• Disaggregate this indicator for gender. | | |

41 ALTAI & GOGLA, Powering Opportunity in South Asia: From Work to Well-being, the Important Role of Small Scale Solar, GOGLA (2020), https://www.gogla.org/resources/powering-opportunity-in-south-asia-from-work-to-well-being-the-important-role-of-small

42 Impact Management Project, 'Who', Impact Management, Impact Management Project (2021), https://impactmanagementproject.com/impact-management/impact-management-norms/who/

43 Efficiency for Access & 60 Decibels, Use & Impact of Solar TVs: Lean Data Insights from Kenya, Rwanda, Tanzania, Uganda, Efficiency for Access Coalition (2020), https://storage.googleapis.com/e4a-website-assets/Solar-TV-Report__-FINAL.pdf

**Table 12: Social / Health Impact**
A-SOC4: Affordability of monthly repayments

| METRIC | AFFORDABILITY OF MONTHLY REPAYMENTS | | |
|---|---|---|---|
| | | | STATUS |
| ID | A-SOC4 | | ● |
| | | | IMPACT |
| Appliance name | All | | ± |
| Unit of measurement | Percentage | | |
| Definition | The affordability of the monthly instalments | | |
| Usefulness of metric | Enables understanding of the affordability of high-performing appliances for the end-user. | | |
| Impact statement | At [point in time] the average monthly payment for [appliance name] is x% of the average monthly income of our target customers. | | |
| Calculation | (PAYGoMC / IMAC) × 100 | | |
| | VARIABLES | DEFINITION | VALUE |
| Variables | S | Number of units sold (cumulative, i.e. ever) (number of units) | This variable is to be inserted by the user |
| | DL | Discount for loss: products not working or not in use, excluding loss in supply chain (%) | 8.5% |
| Assumptions | That the majority of PAYGo customers struggle to meet the monthly PAYGo repayments. This implies that the access to high-performing appliances presents an 'unreasonable burden' to the individual or household. | | |
| Supporting literature | • ALTAI & GOGLA's report [44] "Powering Opportunity in East Africa: Proving Off-Grid Solar is a Power Tool for Change" found that 4% reported negative effects, with the most common being feeling more stressed, likely related to repayments.<br>• For example, regarding solar-powered TVs, Efficiency for Access and 60 Decibels' report on the use and impact of the appliances found that 61% of the respondents reported that they have to make unacceptable sacrifices to make repayments. 2% have to cut back on consumption to make repayments.[45] | | |
| Data gaps | • More work on how to include changes in income post purchase in the case of productive use of energy (e.g., irrigation).<br>• Including the income increase post-purchase.<br>• Measure the default rates of appliances as a more accurate proxy for affordability.<br>• Disaggregate this indicator for gender. | | |
| Usage notes | • This metric defines and measures the affordability to a household, using the payment method which is based on the ratio of the payment for a particular commodity to a household's total resources.<br>• In case IMAC is not available, users can use national household surveys, or the FAO estimates available here.<br>• PAYGoMC includes everything that is included in the monthly payment, including anything in the bundle<br>• IMAC is calculated as yearly income divided by 12 recognising that there is a seasonal effect in monthly incomes.<br>• In case and for PAYG payments that are not monthly, or not equal every month, PAYGoMC is calculated as the monthly equivalent. | | |

44 ALTAI & GOGLA, Powering Opportunity in East Africa: Proving Off-Grid Solar is a Power Tool for Change, GOGLA (2019), https://www.gogla.org/resources/powering-opportunity-in-east-africa-proving-off-grid-solar-is-a-power-tool-for-change#:~:text=Confirming%20the%20positive%20socioeconomic%20impact,to%20their%20quality%20of%20life

45 Efficiency for Access and 60 Decibels, Use & Impact of Solar TVs: Lean Data Insights from Kenya, Rwanda, Tanzania, Uganda, Efficiency for Access Coalition, (2020), https://storage.googleapis.com/e4a-website-assets/Solar-TV-Report__-FINAL.pdf

**Table 13: Social / Health Impact**

SWP-SCO1: Number of people benefiting from improved access to water, sanitation & hygiene

| METRIC | NUMBER OF PEOPLE BENEFITING FROM IMPROVED ACCESS TO WATER, SANITATION & HYGIENE | | |
|---|---|---|---|
| | | | STATUS |
| **ID** | SWP-SOC1 | | ● |
| | | | IMPACT |
| **Appliance name** | Solar water pump | | ⊕ |
| **Unit of measurement** | Number of households | | |
| **Definition** | The number of people benefiting from improved access to water and hygiene due to having access to a solar water pump. | | |
| **Usefulness of metric** | This indicator captures the benefit to health and wellbeing of a household due to having readily available and affordable water. | | |
| **Impact statement** | X households are benefiting from improved water and hygiene due to access to a solar water pump. | | |
| **Calculation** | SL × (1 – DL) × (1 – DR-Access) × DWASH × H | | |
| **Variables** | **VARIABLES** | **DEFINITION** | **VALUE** |
| | SL | Number of units sold which are estimated to currently be in use (based on the products estimated lifespan being 1.5 × financing period, or 1.5 × warranty period in cash payments) (number of units) | This variable is to be inserted by the user. |
| | DL | Discount for loss: products not working or not in use, excluding loss in supply chain (%) | 8.5% |
| | DR-Access | Discount for repeat sales for estimating new access to solar powered appliances (including different companies) (%) | 1% |
| | DWASH | Percentage of people who use a solar water pump for improved water and hygiene | This variable is to be inserted by the user. |
| | H | Household size (number of people) | 5.5 |
| **Assumptions** | • That individuals within a household have equal access to the solar water pump for accessing water or for irrigation. For example, in countries where menstruation taboos still exist in rural communities, such as in India and Nepal, women are not permitted to use their home or kitchen for the duration of their menstruation each month.[46]<br>• That a single household uses a single solar water pump. Not considering the indirect impact of improved agricultural performance on the livelihoods and the food security of households of those being employed on the land, rather than the farmers (solar water pump-owners) themselves. | | |
| **Supporting literature** | • In weak or off-grid communities without access to water at home, fetching water is one of the main tasks of the household, especially burdening women and children. An example of the gender-specific problems associated with the absence of a supply of water nearby comes from Bangladesh, where 'difficulty during pregnancy and deformity in posture' is reported simply due to the 'carrying of traditional water pitchers on the hip'.[47]<br>• Using a solar water pump to pump water directly from a well, a borehole, a river or a lake, or to fill an overhead water tank, can increase the safety, health and hygiene of households benefiting from it. The presence of a communal and nearby water supply through the use of a solar water pump can also reduce the threat of 'physical abuse and sexual harassment from well owners. Further gender benefits can be found in the improved health and safety of women during childbirth because of an adequate water supply — this same water supply also allowing improvements to women's 'personal hygiene, especially during their menstrual period, as they are able to bathe regularly'.[48]<br>• Rural Senses' survey of people in Uganda and India shows that 67.9% and 80.5% of respondents respectively associated the use of a solar water pump with water security, accessibility to services and hygiene & sanitation.[49] | | |
| **Data gaps** | Missing data about percentages of cases where a household is using more than one solar water pump, or that few households share a pump. | | |

46 UNICEF, Nepal Girl Summit: Girls are the Future of Nepal. vol. 49, UNICEF (2016), https://www.unicef.org/nepal/media/14366/file/Nepal%20Girl%20Summit%202016.pdf

47 F Sultana, & B Crow, Water concerns in rural Bangladesh: A gendered perspective. In Pickford, J (Ed.), Water, sanitation and hygiene—Challenges of the Millennium: Proceedings of the 26th WEDC International Conference, Dhaka, Bangladesh (2000), (pp. 415–419)

48 UNICEF, How solar-powered water pumps are changing lives in Akwa Ibom state. Accessed on July 2021, UNICEF (2017), https://www.unicef.org/nigeria/stories/how-solar-powered-water-pumps-are-changing-lives-akwa-ibom-state

49 Rural Senses, Impact Assessment Framework End-User Research in Uganda & India' (End-User research unpublished), (2021)

**Table 14: Social / Health Impact**

SWP-SCO2a+b: Number of new people (and women specifically) who perceive that using a solar water pump will help them save time

| METRIC | NUMBER OF NEW PEOPLE (AND WOMEN SPECIFICALLY) WHO PERCEIVE THAT USING A SOLAR WATER PUMP WILL HELP THEM SAVE TIME | | | |
|---|---|---|---|---|
| | | | | **STATUS** |
| **ID** | SWP-SOC2a, SWP-SOC2b (women only) | | | ● |
| | | | | **IMPACT** |
| **Appliance name** | Solar water pump | | | ⊕ |
| **Unit of measurement** | Number of people / women | | | |
| **Definition** | The number of people / women who perceive that using a solar water pump provides them with more free time. | | | |
| **Usefulness of metric** | The indicator gives an estimate of the number of people, especially women, who benefit from more free time in their daily lives to engage in other income-generating activities as a result of owning a solar water pump. | | | |
| **Impact statement** | X people / women experienced an increase in free time and a reduction in drudgery as a result of using a solar water pump. | | | |
| **Calculation** | S × (1 – DL) × (1 – DR-Access) × PT [SWP-SOC2a]<br>S × (1 – DL) × (1 – DR-Access) × WomenT [SWP-SOC2b] | | | |
| **Variables** | **VARIABLES** | **DEFINITION** | **VALUE** | |
| | S | Number of units sold (cumulative, i.e. ever) (number of units) | This variable is to be inserted by the user | |
| | DL | Discount for loss: products not working or not in use, excluding loss in supply chain (%) | 8.5% | |
| | DR-Access | Discount for repeat sales for estimating new access to solar powered appliances (including different companies) (%) | 1% | |
| | PT | Percentage of people with access to a [appliance name] who perceive that the appliance contributes to 'time benefit', 'time management', or 'unburdening' (% of people) | 29–36% | |
| | WomenT | Percentage of women with access to a [Appliance name] who perceive that the appliance contributes to 'time benefit', 'time management', or 'unburdening' to the [Appliance name] in a representative sample (% of women) | Pipeline Variable | |
| **Assumptions** | That reduction in the time taken to fetch water due to the use of a solar water pump disproportionately benefits women in terms of unburdening them of daily tasks. | | | |
| **Supporting literature** | • Studies have shown that owning modern appliances improves household welfare among those living in poverty by reducing female drudgery and saving time on daily activities like washing, cooking and cleaning.[50] Other factors like built environment quality, income levels, socio-cultural aspects, and aspirational factors associated with appliance ownership are found to collectively influence wellbeing and stress collectively (e.g.,[51,52,53]).<br>• Solar water pumps specifically save countless hours that used to be spent fetching water for daily household needs.[54] The exact amount will depend on the distance to water sources. For those tasked with water collection, usually women or children, solar water pumps have brought about improvements in health and hygiene, education and increased revenues from other livelihoods due to time being freed up. For example, in Sudan, 15 solar powered pumping stations have been installed in four states. One immediate benefit of this is a reduction in time and effort expended by women and children — many of whom previously had to travel for over five kilometres daily to collect water.[55] | | | |

50 Ramit Debnath, Ronita Bardhan, & Minna Sunikka-Blank, How does slum rehabilitation influence appliance ownership? A structural model of non-income drivers, Energy Policy, (2019) 132, 418–428. https://doi.org/10.1016/j.enpol.2019.06.005

51 Iwona Bisaga, and Priti Parikh, To climb or not to climb? Investigating energy use behaviour among Solar Home System adopters through energy ladder and social practice lens. Energy Research & Social Science, (2018) 44, 293–303. https://doi.org/10.1016/j.erss.2018.05.019

52 Ramit Debnath, Ronita Bardhan, Sarah Darby, Kamiar Mohaddes, Minna Sunikka-Blank, Ana Cristina Villaca Coelho, & Abdulrasheed Isa, Words against injustices: A deep narrative analysis of energy cultures in poverty of Abuja, Mumbai and Rio de Janeiro, Energy Research & Social Science, (2021), 72, 101892. https://doi.org/10.1016/j.erss.2020.101892

53 Ramit Debnath, Ronita Bardhan, & Minna Sunikka-Blank, How does slum rehabilitation influence appliance ownership? A structural model of non-income drivers, Energy Policy, (2019) 132, 418–428. https://doi.org/10.1016/j.enpol.2019.06.005

54 UNDP, Solar empowerment: Solar-powered solutions promoting climate-resilient livelihoods across five countries, Reliefweb (2016), https://reliefweb.int/report/mali/solar-empowerment-solar-powered-solutions-promoting-climate-resilient-livelihoods-across

55 UNDP, Solar empowerment: Solar-powered solutions promoting climate-resilient livelihoods across five countries, Reliefweb (2016), https://reliefweb.int/report/mali/solar-empowerment-solar-powered-solutions-promoting-climate-resilient-livelihoods-across

| METRIC | NUMBER OF NEW PEOPLE (AND WOMEN SPECIFICALLY) WHO PERCEIVE THAT USING A SOLAR WATER PUMP WILL HELP THEM SAVE TIME |
|---|---|
| **Supporting literature** | • Solar irrigation systems made the water supply more cost-effective and efficient for distributive justice to women farmers in Nepal.[56] These systems further helped them to irrigate cash crops like eggplant, potato, chilli, garlic coriander, onion seed, green leafy vegetables and pointed gourd during the dry season, resulting in 50% more income. In Senegal, solar pumps made it possible for women to work in better conditions — not having to carry water for irrigation, they could develop their market garden activities and improve the nutritional balance of food served in their homes.[57] In Gambia, solar water pumps empowered women to be more flexible with irrigation times. The women were very happy with the solar irrigation systems; their men and children appreciated the rich and varied food they enjoyed. They also claimed that diseases decreased significantly.[58]<br>• In 2021, Rural Senses conducted a survey in Uganda and India where 35.7 % and 28.6 % of participants respectively indicated the benefit of time and labour saving.[59] |
| **Data gaps** | More data on the gender-specific impact of solar water pumps. |
| **Usage notes** | • PS and WomenS are derived specifically from the intervention.<br>• PT and WomenT are determined from a UPV game and/or Questionnaire. |

**Table 15: Social / Health Impact**

SWP-SOC3: The number of people who perceive an enhanced quality of life through using a solar water pump

| METRIC | THE NUMBER OF PEOPLE WHO PERCEIVE AN ENHANCED QUALITY OF LIFE THROUGH USING A SOLAR WATER PUMP | | |
|---|---|---|---|
| | | | **STATUS** |
| **ID** | SWP-SOC3 | | ● |
| | | | **IMPACT** |
| **Appliance name** | Solar water pump | | ⊕ |
| **Unit of measurement** | Number of people | | |
| **Definition** | The number of people benefiting from an increased sense of quality of life due to using a solar water pump. | | |
| **Usefulness of metric** | The indicator gives an indication of solar water pump users who perceive that using it helps enhance their quality of life. | | |
| **Impact statement** | X people are benefiting from an enhanced quality of life due to using a solar water pump. | | |
| **Calculation** | SL × (1 – DL) × (1 – DR-Access) × H × PQL | | |
| **Variables** | **VARIABLES** | **DEFINITION** | **VALUE** |
| | S | Number of units sold (cumulative, i.e. ever) (number of units) | This variable is to be inserted by the user |
| | DL | Discount for loss: products not working or not in use, excluding loss in supply chain (%) | 8.5% |
| | DR-Access | Discount for repeat sales for estimating new access to solar powered appliances (including different companies) (%) | 1% |
| | H | Household size (number of people) | 5.5 |
| | PQL | The percentage of people associating the appliance with enhanced quality of life (%) | 64–90% |
| **Assumptions** | That it is possible to identify a representative sample that will represent the perceptions of a large majority in the target region. | | |
| **Supporting literature** | • A survey of 400 farmers owning a solar water pump in Kenya, Uganda and Tanzania showed that 55% of users moved up the energy ladder, and studies linking energy service demand in poverty and wellbeing show significant relationships between improved energy services and improving household welfare. 81% of solar water pump customers in East Africa reported that their pump | | |

56 Ram Bastakoti, Manita Raut, and Bhesh Raj Thapa, Groundwater Governance and Adoption of Solar-Powered Irrigation Pumps: Experiences from the Eastern Gangetic Plains, World Bank Group (2019), https://openknowledge.worldbank.org/bitstream/handle/10986/33245/Groundwater-Governance-and-Adoption-of-Solar-Powered-Irrigation-Pumps-Experiences-from-the-Eastern-Gangetic-Plains.pdf?sequence=1amp;isAllowed=y

57 Hans Hartung and Lucie Pluschke, The benefits and risks of solar-powered irrigation—A global review (p. 87), Food and Agricultural Organisation (FAO) (2018), http://www.fao.org/documents/card/en/c/I9047EN

58 Hans Hartung and Lucie Pluschke, The benefits and risks of solar-powered irrigation—A global review (p. 87), Food and Agricultural Organisation (FAO) (2018), http://www.fao.org/documents/card/en/c/I9047EN

59 Rural Senses, Impact Assessment Framework End-User Research in Uganda & India' (End-User research unpublished), (2021)

| METRIC | THE NUMBER OF PEOPLE WHO PERCEIVE AN ENHANCED QUALITY OF LIFE THROUGH USING A SOLAR WATER PUMP |
|---|---|
| **Supporting literature** | improved their quality of life.[60] Farmers reported more confidence in their farming outcomes, improved productivity and income generation, and an increase in the amount of land farmed. Furthermore, evidence provided in this report shows the link between solar water pump ownership and improved food security, income, increased free time, and reduction of expenditure for businesses and households. As such, these indicate an indirect link between solar water pump ownership and an increase in the levels of comfort, well-being and quality of life.[61]<br>• 90% of respondents surveyed by Rural Senses in India and 85.7% in Uganda associated ownership and use of solar water pumps with improved quality of life with proxies of water security, accessibility to services, Hygiene & Sanitation and food security.[62]<br>• 58% of the participants in the Efficiency for Access & 60 Decibels study of the Use and Impact of Solar Water Pumps said that their quality of life had very much improved as a result of having the pump. The top outcomes were increased access to clean water and increased farming productivity.[63] |
| **Data gaps** | Evidence of the impact of solar-powered appliances on individual stress and wellbeing levels. |
| **Usage notes** | PQL is determined through a UPV game and/or questionnaire. |

**Table 16: Social / Health Impact**

SWP-SOC4: The number of people who perceive that using the solar water pump improves food security

| METRIC | NUMBER OF PEOPLE WHO PERCEIVE THE USE OF THE APPLIANCE IMPROVES FOOD SECURITY | | |
|---|---|---|---|
| | | | **STATUS** |
| **ID** | SWP-SOC4 | | ● (green) |
| | | | **IMPACT** |
| **Appliance name** | Solar water pump | | ⊕ |
| **Unit of measurement** | Number of people | | |
| **Definition** | The number of people benefiting from improved food security as a result of accessing a solar water pump. | | |
| **Usefulness of metric** | To capture the benefit of improved food security and hence the advantages that arise through having access to a solar water pump. | | |
| **Impact statement** | X people are experiencing improved food security as a result of solar water pump ownership. | | |
| **Calculation** | SL × (1 – DL) × (1 – DR-Access) × H × PFS | | |
| **Variables** | **VARIABLES** | **DEFINITION** | **VALUE** |
| | S | Number of units sold (cumulative, i.e. ever) (number of units) | This variable is to be inserted by the user |
| | DL | Discount for loss: products not working or not in use, excluding loss in supply chain (%) | 8.5% |
| | DR-Access | Discount for repeat sales for estimating new access to solar powered appliances (including different companies) (%) | 1% |
| | H | Household size (number of people) | 5.5 |
| | PFS | The percentage of people associating the appliance with improved food security (%) | 90–12% |
| **Assumptions** | That individuals within a household have equal access to a solar water pump for accessing water or for irrigation. For example, in countries where menstruation taboos still exist in rural communities, such as in India and Nepal, women are not permitted to use their home or kitchen during their periods each month. | | |
| **Supporting literature** | • Using a solar water pump can significantly contribute to increased food security for the families of smallholder farmers, as it can enable an increase in crop cycles and yield of farming activities, thus increasing household income and diversity of home consumption (e.g.,[64]). | | |

60 CID & AFE, Uganda Solar Water Pumping Report Uganda, ACE (2019), https://www.ace-taf.org/wp-content/uploads/2019/10/ACE-TAF-UGANDA-SOLAR-WATER-PUMPING-REPORT-SCREEN-1.pdf
61 Efficiency for Access & 60 Decibels, Uses & Impacts of Solar Water Pumps, Efficiency for Access (2021), https://storage.googleapis.com/e4a-website-assets/Uses-Impacts-of-SWPs-July-2021.pdf
62 Rural Senses, Impact Assessment Framework End-User Research in Uganda & India' (End-User research unpublished), (2021)
63 Efficiency for Access & 60 Decibels, Uses & Impacts of Solar Water Pumps, Efficiency for Access, (2021), https://storage.googleapis.com/e4a-website-assets/Uses-Impacts-of-SWPs-July-2021.pdf
64 Shikha Suman, Evaluation and Impact Assessment of the Solar Irrigation Pumps Program in Andhra Pradesh and Chhattisgarh Report, Shri Shakti Alternative Energy Limited (2018), https://www.ssael.co.in/images/Library/files/Solar-Pumps-Impact--SSAEL-Report.pdf

| METRIC | NUMBER OF PEOPLE WHO PERCEIVE THE USE OF THE APPLIANCE IMPROVES FOOD SECURITY |
|---|---|
| **Supporting literature** | • For example, a study in Benin found an improvement in food security and drought resilience following Solar Electric Light Fund (SELF)'s Solar Market Garden project, which combined solar water pumps with drip irrigation systems for irrigating crops.[65] While a study in Western India found an increase in food security of solar water pump adopters due to an increase in average cropping intensity in Jaipur and Sikar by 2–10% and in Bikaner by 2–9%, and expansion in gross cropped area under fruits and vegetables in Jaipur by 12–53% and Bikaner by 10–116%.[66]<br>• In the Sudano–Sahel region, a study analysed the food security situation of beneficiaries of solar-powered drip irrigation systems installed in communal gardens. The consumption of vegetables during the dry season increased among programme beneficiaries, and irrigators were 17% less likely to feel chronically food insecure one year after the implementation of the project.[67] |
| **Data gaps** | Better definition and evidence regarding food security, including parameters of variety, continuity and resilience of food supply. |

65 UNFCCC. (n.d.). Self's Solar Market Gardens | Benin | UNFCCC. Retrieved October 31, 2021, from https://unfccc.int/climate-action/momentum-for-change/women-for-results/selfs-solar-market-gardens

66 E Gupta, The impact of solar water pumps on energy-water-food nexus: Evidence from Rajasthan, India. Energy Policy, (2019), 129, 598-609.

67 Jennifer Burney, Lennart Woltering, Marshall Burke, Rosamond, Naylor, & Dov Pasternak, Solar-powered drip irrigation enhances food security in the Sudano–Sahel. Proceedings of the National Academy of Sciences, (2010), 107(5), 1848–1853. https://doi.org/10.1073/pnas.0909678107

# Standard Variables – Elaborated

**This section provides a detailed description of the evidence for the values proposed for the standard variables.**

The tables provide the values, geography and the degree of urbanisation for which the values are applicable; a summary of the evidence for the values; a score for the level of confidence users can have in the value based on the quality of the evidence; and limitations and potential biases with the evidence and hence values.

In the section of the table related to applicability, for each variable the 'degree of urbanisation' factor indicates which of three different categories of urbanisation the variable is appropriate for: (a) cities (densely populated areas), (b) towns and suburbs (intermediate density areas) and (c) rural areas (thinly populated areas).[68]

The confidence level was assessed for each value for 'standard variables'. Three stars (***) indicate that a study is 'up to date' (ie. conducted within five years of the assessment) and has, at the same time, a 'large sample size' (meaning that the data came from one study with over 500 samples or several studies with a total of over 500 samples). Two stars (**) indicate that studies are either 'up to date' or have a 'large sample size' and one star (*) indicates that the studies are not up to date and have small sample size.

**Table 17: DL: Discount for loss: products not working or not in use, excluding loss in supply chain (%)**

| **DL** | **DISCOUNT FOR LOSS: PRODUCTS NOT WORKING OR NOT IN USE, EXCLUDING LOSS IN SUPPLY CHAIN (%)** | | | |
|---|---|---|---|---|
| **Unit** | % | | | |
| **Appliance** | Solar water pump | | | |
| **Applicability** | **GEOGRAPHY** | **DEGREE OF URBANISATION** | **CONFIDENCE** | **VALUE** |
| | East Africa | Rural | ** | 8.5 |
| **Supporting literature** | • 'Efficiency for Access and 60 Decibels' study[69] on the Use and Impacts of Solar Water Pumps found that, in 2020–21, 34% of solar water pump owners faced challenges with their pumps, of which 43% were not resolved (i.e., 14.6% of owners experienced issues which could not be resolved). Of the issues faced, owners experiencing issues talked about unreliability due to breakages (33%), faulty valves and controllers (25%) and poor battery performance (14%).<br>• Assuming that the first two issues would make the pump unusable if not repaired, then 58% of the 14.6% experiencing issues that were not resolved would not be able to use their solar water pump. i.e., 8.5% of pumps are expected to not be in use.[70] | | | |
| **Limitations / biases** | • It is not clear from the country what proportion of solar water pumps facing issues that have not been resolved are still used or left out of service.<br>• The appliances covered in this survey were first-generation solar water pumps and are therefore more likely to be faulty, therefore the fault rate is disproportionately higher.<br>• This has been accounted for in the final value through the type of fault encountered. | | | |

**Table 18: DR-Access: Discount for repeat sales for estimating new access to solar-powered appliances**

| **DR-ACCESS** | **DISCOUNT FOR REPEAT SALES FOR ESTIMATING NEW ACCESS TO SOLAR-POWERED APPLIANCES (INCLUDING DIFFERENT COMPANIES) (%)** | | | |
|---|---|---|---|---|
| **Unit** | % | | | |
| **Appliance** | Solar water pump | | | |
| **Applicability** | **GEOGRAPHY** | **DEGREE OF URBANISATION** | **CONFIDENCE** | **VALUE** |
| | Asia | N\|A | ** | 5% |
| **Supporting literature** | 'Efficiency for Access and 60 Decibels' (2021) study [71] on The Use and Impacts of Solar Water Pumps found that 1% of the participants had used a solar water pump for irrigation prior to purchase. Of the rest, 35% had used a fuel pump prior to the solar water pumps purchase. | | | |
| **Limitations / biases** | The report does not mention solar water pump customers who may have previously owned a water pump for household use rather than for irrigation. According to the study, 12% of solar water pump owners use it primarily for household use rather than for irrigation. It is possible that some of the sales were repeat sales, but this is expected to be a small number. | | | |

68 Eurostat. 2021. Applying the Degree of Urbanisation. OECD. https://doi.org/10.1787/4bc1c502-en
69 Efficiency for Access & 60 Decibels, Uses & Impacts of Solar Water Pumps, Efficiency for Access (2021), https://storage.googleapis.com/e4a-website-assets/Uses-Impacts-of-SWPs-July-2021.pdf
70 Efficiency for Access & 60 Decibels, Unpublished Research on Refrigerators, 2022
71 Efficiency for Access & 60 Decibels. Uses & Impacts of Solar Water Pumps, Efficiency for Access (2021), https://storage.googleapis.com/e4a-website-assets/Uses-Impacts-of-SWPs-July-2021.pdf

**Table 19: DR-GHG: Ratio capturing sales replacing a diesel genset-powered appliance (%)**

| DR-GHG | RATIO CAPTURING SALES REPLACING A DIESEL GENSET-POWERED APPLIANCE (%) | | | |
|---|---|---|---|---|
| **Unit** | % | | | |
| **Appliance** | Solar water pump | | | |
| **Applicability** | GEOGRAPHY | DEGREE OF URBANISATION | CONFIDENCE | VALUE |
| | East Africa | Rural | *** | 35% |
| **Supporting literature** | Efficiency for Access and 60 Decibels' study on The Use and Impacts of Solar Water Pumps found that 1% of the participants had used a solar water pump for irrigation prior to purchase. Of the rest, 35% had used a fuel pump prior to their solar water pump purchase.[72] | | | |
| **Limitations / biases** | The report does not mention solar water pump customers who may have previously owned a water pump for household use rather than for irrigation. According to the study, 12% of solar water pump owners use it primarily for household use rather than for irrigation. It is possible that some of the sales were repeat sales, but this is expected to be a small number. | | | |

**Table 20: EF: Employment factor**

| EF | EMPLOYMENT FACTOR (JOBS / ITEM SOLD) | | | |
|---|---|---|---|---|
| **Unit** | % | | | |
| **Appliance** | Jobs / item sold | | | |
| **Applicability** | GEOGRAPHY | DEGREE OF URBANISATION | CONFIDENCE | VALUE |
| | Kenya | Nationwide | *** | 0.0095 |
| | India | Nationwide | *** | 0.0299 |
| **Supporting literature** | According to Power for All's 2019 "Powering Jobs Census 2019", the employment factor for solar water pumps in India and Kenya for 2017–2018 was 29.9 jobs and 9.5 jobs per 1,000 pumps sold respectively. The information is based on a survey carried out across 150 companies in India, Kenya and Nigeria. These companies were surveyed across the decentralised renewable energy (DRE) technology spectrum, and the survey covers the supply chain, from manufacturing and wholesale imports to sales, installation and operations. This included DRE companies working in off-grid, weak-grid or on-grid contexts.[73] | | | |
| **Limitations / biases** | The above figures relate to formal jobs created along the supply chain of the appliance and do not consider the large number of informal jobs created, of which a large proportion is occupied by women. | | | |

**Table 21: EFA: Proportion of employment factor relevant to each appliance**

| EFA | PROPORTION OF EMPLOYMENT FACTOR RELEVANT TO EACH APPLIANCE | | | |
|---|---|---|---|---|
| **Unit** | % | | | |
| **Appliance** | Solar water pump | | | |
| **Applicability** | GEOGRAPHY | DEGREE OF URBANISATION | CONFIDENCE | VALUE |
| | Global | Nationwide | *** | 100% |
| **Supporting literature** | According to the "Powering Jobs census 2019",[74] discount ratios are assigned based on the average appliance-to-total-SHS-cost ratios from the VeraSol database. These values equate to 100% of solar water pumps. | | | |
| **Limitations / biases** | The above figures relate to pico solar appliances, including systems for powering solar irrigation. They do not refer to jobs created specifically in the solar irrigation market. | | | |

72 Efficiency for Access & 60 Decibels. Uses & Impacts of Solar Water Pumps, Efficiency for Access (2021), https://storage.googleapis.com/e4a-website-assets/Uses-Impacts-of-SWPs-July-2021.pdf
73 Power for All, Powering Jobs Census 2019: The Energy Access Workforce, Power for All (2019), https://www.powerforall.org/resources/reports/powering-jobs-census-2019-energy-access-workforce
74 Power for All, Powering Jobs Census 2019: The Energy Access Workforce, Power for All (2019), https://www.powerforall.org/resources/reports/powering-jobs-census-2019-energy-access-workforce

**Table 22: G: Average amount of greenhouse gases avoided per appliance, due to diesel displacement (kg CO2 / year)**

| **G** | **AVERAGE AMOUNT OF GREENHOUSE GASES AVOIDED PER APPLIANCE, DUE TO DIESEL DISPLACEMENT (KG CO2 / YEAR)** | | | |
|---|---|---|---|---|
| **Unit** | kg CO2e / year | | | |
| **Appliance** | Solar water pump | | | |
| **Applicability** | **GEOGRAPHY** | **DEGREE OF URBANISATION** | **CONFIDENCE** | **VALUE** |
| | Internationally | N/A | *** | 2,297 |
| **Supporting literature** | Assuming that the solar equivalent appliance will have zero end-use emissions, the emissions of a single appliance equal:[75]<br>• (Required energy / 10^12) × Emissions Factor of a Diesel Generator; where the Required energy equals:<br>• (Delivered Energy × 3600 × 1 / Generator efficiency)<br>Assuming a generator efficiency of 25% and the following:<br>• pump capacity: 4.5 kW<br>• run-time of eight hours / day<br>• daily energy consumption of 36 kWh / day<br>• annual operating days of 240.<br>Then the required annual Delivered Energy is 8,640 kWh / year, which is equal to 0.031 TJ / year.<br>As such, CO2e emissions saved from using a solar water pump come to 2,297.1 kgCO2e/year. Diesel Emission Factor: 74100 kgCO2 / TJ.[76] | | | |
| **Limitations / biases** | The above figures assume that a solar water pump runs for eight hours daily for 240 days per year. However, this will vary depending on rain patterns in each region which affect the number of days of the year farmers rely on rainfed irrigation. The number of hours per week of irrigation will also depend on the type of crops and the availability of water. | | | |
| **Data gaps** | Number of days per year and number of hours per week of manual irrigation for different geographies of interest. | | | |

**Table 23: H: Household size (number of people)**

| **H** | **HOUSEHOLD SIZE (NUMBER OF PEOPLE)** | | | |
|---|---|---|---|---|
| **Unit** | Number of people | | | |
| **Appliance** | All | | | |
| **Applicability** | **GEOGRAPHY** | **DEGREE OF URBANISATION** | **CONFIDENCE** | **VALUE** |
| | South Asia | General | *** | 5.5 |
| | West Africa | Urban | *** | 6 |
| | West Africa | Rural | *** | 8 |
| | East Africa | Urban | *** | 5.3 |
| | East Africa | Rural | *** | 5.5 |
| **Supporting literature** | • 60 Decibels interviewed 25,497 individuals in its study on 'Why Off-Grid Energy Matters'" in East Africa (61%), West Africa (16%) and South Asia (14%), and recorded an average household size of 5.9.[77] Efficiency for Access[78] in their report on "Socio-Economic Impacts of Super-Efficient Off-Grid fans in Bangladesh" reported an average household size of 5.3 people. with two-thirds having between 2-6 people per household. Similarly, ALTAI & GOGLA[79] in their report 'Powering Opportunity in East Africa: Proving Off-Grid Solar is a Power Tool for Change' recorded an average household size of 5.7.<br>• ALTAI & GOGLA[80] in 'Powering Opportunity in West Africa: Improving Lives, Powering Livelihoods with Off-Grid Solar" report highlighted that 'while the average household size was seven across the research, urban households tend to be closer to six members while rural households are closer | | | |

75 Efficiency for Access & GOGLA, Standardised Impact Metrics for High-Performing Appliances : Fans and TVs, (2020), https://www.gogla.org/sites/default/files/resource_docs/gogla_impact-metrics-appliances_paper2020_def_0.pdf

76 Efficiency for Access & GOGLA, Standardised Impact Metrics for High-Performing Appliances : Fans and TVs, (2020), https://www.gogla.org/sites/default/files/resource_docs/gogla_impact-metrics-appliances_paper2020_def_0.pdf

77 Kat Harrison, Shahnaz Khan, Tom Adams, Sascha Dichter, Why off-grid energy matters. An Impact Performance Report, 60 Decibels (2020), https://60decibels.com/user/pages/energy-report/60%20Decibels%20-%20Why%20Off-Grid%20Energy%20Matters.pdf

78 Efficiency for Access, The Socio-Economic Impact of Super-Efficient Off-Grid Fans in Bangladesh. Efficiency for Access Coalition (2020), https://www.clasp.ngo/research/all/the-socio-economic-impact-of-super-efficient-fans-in-bangladesh/

79 ALTAI & GOGLA, Powering Opportunity in East Africa: Proving Off-Grid Solar is a Power Tool for Change, GOGLA (2019), https://www.gogla.org/sites/default/files/resource_docs/powering_opportunity_in_east_africa.pdf

80 ALTAI & GOGLA, Powering Opportunity in West Africa. Improving Lives, Powering Livelihoods with Off-Grid Solar, GOGLA (2019), https://www.gogla.org/resources/powering-opportunity-in-west-africa-improving-lives-powering-livelihoods-with-off-grid

| H | HOUSEHOLD SIZE (NUMBER OF PEOPLE) |
|---|---|
| **Supporting literature** | to eight members.' In South Asia, ALTAI & GOGLA[81] in their report titled 'Powering Opportunity in South Asia: From Work to Well-being, the Important Role of Small-Scale Solar', the average household size among pre-purchase interviewees was 6.9.<br>• The United Nations study[82] 'Household Size and Composition Around the World 2017' reported an average household size of 4.8 in India and 6.8 in Pakistan.[83] |
| **Limitations / biases** | Off-grid household data shows larger household sizes than the national averages; this needs to be further investigated. |

**Table 24: OPEXD: Annual operating fuel cost of a diesel-powered appliance (USD / year)**

| OPEXD | ANNUAL OPERATIONAL FUEL COST OF A DIESEL-POWERED APPLIANCE (USD / YEAR) | | | |
|---|---|---|---|---|
| **Unit** | USD / year | | | |
| **Appliance** | Solar water pump | | | |
| **Applicability** | **GEOGRAPHY** | **DEGREE OF URBANISATION** | **CONFIDENCE** | **VALUE** |
| | Egypt | Rural | ** | 4,563 |
| **Supporting literature** | An economic study of the operational costs of three different types of water pumps (solar PV powered, hybrid, and diesel-powered) under the simulated conditions of Cairo, Egypt, found the operational costs of the systems to be USD 1,236/year, USD 1,604/year and USD 4,563 / year respectively, including the consideration of operation and maintenance costs as well as fuel consumption.[84] | | | |
| **Limitations / biases** | The figures of the study above are based on theoretical modelling using HOMER software and theoretical equations governing photovoltaic operations. | | | |

**Table 25: PI-30: Percentage of people who experienced an annual income increase of at least 30% (%)**

| PI-30 | PERCENTAGE OF PEOPLE WHO EXPERIENCED AN ANNUAL INCOME INCREASE OF AT LEAST 30% | | | |
|---|---|---|---|---|
| **Unit** | % | | | |
| **Appliance** | Solar water pump | | | |
| **Applicability** | **GEOGRAPHY** | **DEGREE OF URBANISATION** | **CONFIDENCE** | **VALUE** |
| | India | Rural | ** | 65 |
| **Supporting literature** | According to a 2018 SSAEL study in Central India on 200 farmers, 45% of farmers saw an increase of 50% or more in their annual incomes thanks to the use of solar water pumps compared to using rain-fed irrigation, while 70% of respondents saw a 25% increase. Assuming a linear relationship, it can be estimated that 65% of farmers saw at least a 35% increase in income.[85] | | | |
| **Limitations / biases** | • The study was conducted on a small sample size. The percentage of farmers with an income increase of 30% and above was calculated assuming an inversely proportional relationship between the percentage of farmers experiencing an income increase, and the percentage of income increase. While this is not accurate given the complexity of factors which affect income increase, 30% is quite close to the 25% income increase value for which data are known; hence an inversely proportional relationship can be considered accurate enough.<br>• It can be expected that income increase, which depends on yield and crop cycle increase, will vary between farmers depending on the kind of crops that are being grown and the value they fetch on the market. | | | |
| **Data gaps** | Additional studies on the percentage of solar water pump users who experienced at least a 30% annual income increase as a result of using the solar water pump. | | | |

81 ALTAI & GOGLA, Powering Opportunity in South Asia: From Work to Well-being, the Important Role of Small Scale Solar, GOGLA (2019), https://www.gogla.org/resources/powering-opportunity-in-south-asia-from-work-to-well-being-the-important-role-of-small

82 UN, Household size and composition around the world. Data Booklet, UN (2017), https://www.un.org/en/development/desa/population/publications/pdf/ageing/household_size_and_composition_around_the_world_2017_data_booklet.pdf

83 UN, Household size and composition around the world. Data Booklet, UN (2017), https://www.un.org/en/development/desa/population/publications/pdf/ageing/household_size_and_composition_around_the_world_2017_data_booklet.pdf

84 Mburu, 2020

85 Shikha Suman, Evaluation and Impact Assessment of the Solar Irrigation Pumps Program in Andhra Pradesh and Chhattisgarh Report, Shri Shakti Alternative Energy Limited (2018), https://www.ssael.co.in/images/Library/files/Solar-Pumps-Impact--SSAEL-Report.pdf

**Table 26: PI-50: Percentage of people who experienced an annual income increase of at least 50% (%)**

| PI-50 | PERCENTAGE OF PEOPLE WHO EXPERIENCED AN ANNUAL INCOME INCREASE OF AT LEAST 50% | | | |
|---|---|---|---|---|
| **Unit** | % | | | |
| **Appliance** | Solar water pump | | | |
| **Applicability** | **GEOGRAPHY** | **DEGREE OF URBANISATION** | **CONFIDENCE** | **VALUE** |
| | Central India | Rural | ** | 45 |
| **Supporting literature** | According to a 2018 SSAEL study in Central India on 200 farmers, 45% of farmers saw an increase of 50% or more in their annual incomes thanks to the use of solar water pumps compared to using rain-fed irrigation, while 70% saw a 25% increase.[86] | | | |
| **Limitations / biases** | The study was conducted on a small sample size. It can be expected that income increase, which depends on yield and crop cycle increase, will vary between farmers depending on the kind of crops that are being grown and the value they fetch on the market. | | | |
| **Data gaps** | Additional studies on the percentage of solar water pump users who experienced an annual income increase of at least 50% as a result of the solar water pump. | | | |

**Table 27: PQL: Percentage of people who associate the appliance with improved quality of life (%)**

| PQL | THE PERCENTAGE OF PEOPLE WHO ASSOCIATE THE APPLIANCE WITH IMPROVED QUALITY OF LIFE (%) | | | |
|---|---|---|---|---|
| **Unit** | % | | | |
| **Appliance** | Solar water pump | | | |
| **Applicability** | **GEOGRAPHY** | **DEGREE OF URBANISATION** | **CONFIDENCE** | **VALUE** |
| | Central India | Rural | *** | 64% |
| | India | Rural | *** | 91% |
| **Supporting literature** | • A survey of 400 farmers owning a solar water pump in Kenya, Uganda and Tanzania illustrated that 55% of the sample are moving up the energy ladder, and studies linking energy service demand in poverty and well-being show significant relationships between improved energy services and improving household welfare. 81% of solar water pump customers in East Africa reported that their pump improved their quality of life. Farmers reported more confidence in their farming outcomes, improved productivity and income generation, and an increase in the amount of land farmed. Furthermore, evidence provided in this report shows the link between ownership of solar water pumps and improved food security, income, increase of free time and reduction of expenditure for businesses and households. As such, these indicate an indirect link between solar water pump ownership and an increase in the levels of comfort, well-being and quality of life.[87]<br>• 90.90% of respondents surveyed by Rural Senses in India and 85.7% in Uganda associated ownership and use of solar water pumps with improved quality of life with proxies of water security, accessibility to services, hygiene, sanitation and food security.[88]<br>• 58% of the participants in Efficiency for Access & 60 Decibels' study of the use and impact of solar water pumps said their quality of life had very much improved as a result of having the pump. The top outcomes were increased access to clean water and increased farming productivity.[89] | | | |
| **Limitations / biases** | The data is self-reported and different proxies are used for quality of life introducing several biases and reliability issues. For India, only one data point is used and although recently surveyed, the sample size is too small to generalise over the entire country or region. | | | |
| **Data gaps** | Data points with comparable proxies for quality of life. Quantitative dataset on the impact in South Asia. | | | |

86 Shikha Suman, Evaluation and Impact Assessment of the Solar Irrigation Pumps Program in Andhra Pradesh and Chhattisgarh Report, Shri Shakti Alternative Energy Limited (2018), https://www.ssael.co.in/images/Library/files/Solar-Pumps-Impact--SSAEL-Report.pdf

87 Efficiency for Access & 60 Decibels, Use & Impact of Solar TVs: Lean Data Insights from Kenya, Rwanda, Tanzania, Uganda, Efficiency for Access Coalition (2020), https://storage.googleapis.com/e4a-website-assets/Solar-TV-Report__-FINAL.pdf

88 Rural Senses, Impact Assessment Framework End-User Research in Uganda & India' (End-User research unpublished) (2021)

89 Efficiency for Access & 60 Decibels, Uses & Impacts of Solar Water Pumps, Efficiency for Access Coalition (2021), https://storage.googleapis.com/e4a-website-assets/Uses-Impacts-of-SWPs-July-2021.pdf

**Table 28: PFS: Percentage of people associating the appliance with improved food security (%)**

| PFS | PERCENTAGE OF PEOPLE ASSOCIATING THE APPLIANCE WITH IMPROVED FOOD SECURITY (%) | | | |
|---|---|---|---|---|
| **Unit** | % | | | |
| **Appliance** | Solar water pump | | | |
| **Applicability** | **GEOGRAPHY** | **DEGREE OF URBANISATION** | **CONFIDENCE** | **VALUE** |
| | Sub-Saharan Africa | General | ** | 12% |
| | India | General | ** | 90% |
| **Supporting literature** | • A study in Benin found improved food security and drought resilience following Solar Electric Light Fund (SELF)'s Solar Market Garden project, which combined solar water pumps with drip irrigation systems for irrigating crops. 400 women work in 11 gardens in 10 villages in northeast Benin, directly benefiting 3,352 family members. Consequently, 66,000 people have access to fresh fruits and vegetables grown throughout the year.[90]<br>• A study in Western India found an increase in food security of solar water pump adopters due to the rise in average cropping intensity in Jaipur and Sikar by 2–10% and in Bikaner by 2–9%, and expansion in gross cropped area under fruits and vegetables in Jaipur by 12–53% and Bikaner by 10–116%.[91]<br>• A survey of 400 farmers owning a solar water pump in Kenya, Uganda and Tanzania found that 81% of respondents reported that their pump improved their quality of life and of these, 12% attributed the improvement to more food and a balanced diet for their families.[92] | | | |
| **Limitations / biases** | The values are derived from single data points and carry the limitation of the studies and self-reporting biases. | | | |
| **Data gaps** | The proxies for food security need to be clearly defined. Independent country and regional studies with comparable indicators and quantitative scales are required. | | | |

**Table 29: PT: Percentage of people with access to a pump who perceive that the appliance contributes to 'time benefit', 'time management', or 'unburdening'**

| PT | PERCENTAGE OF PEOPLE WITH ACCESS TO A [APPLIANCE NAME] WHO PERCEIVE THAT THE APPLIANCE CONTRIBUTES TO 'TIME BENEFIT', 'TIME MANAGEMENT' OR 'UNBURDENING' (% OF PEOPLE) | | | |
|---|---|---|---|---|
| **Unit** | Number of people | | | |
| **Appliance** | Solar water pump | | | |
| **Applicability** | **GEOGRAPHY** | **DEGREE OF URBANISATION** | **CONFIDENCE** | **VALUE** |
| | Uganda | Rural | * | 36% |
| | India | Rural | * | 29% |
| **Supporting literature** | • Solar irrigation systems made the water supply more cost-effective and efficient for distributive justice to women farmers in Nepal. It further helped them to irrigate cash crops like eggplant, potato, chilli, garlic coriander, onion seed, green leafy vegetables and pointed gourd during the dry season and get 50% more income. In Senegal, solar water pumps made it possible for women to work in better conditions. Not having to carry water for irrigation, they could develop their market garden activities and improve the nutritional balance of food served in their homes. In the Gambia, solar pumps empowered women to be more flexible with irrigation times. The women were very happy with the solar irrigation systems; their men and children appreciated the rich and varied food they enjoyed. They also claimed that diseases decreased significantly.[93]<br>• In 2021, Rural Senses conducted a survey with 28 and 77 solar water pump users in Uganda and India where 35.7% and 28.6% of participants indicated the benefit of time and labour saving respectively.[94] However, these benefits did not account for the top five benefits that users associated with a solar water pump.<br>• The Government of Canada partnered with UNDP, through the Climate Change Adaptation Facility to strengthen the resilience of vulnerable communities, including introducing solar-powered water supply in Cabo Verde, Cambodia, Mali, Niger, and Sudan. In Cabo Verde, solar pumping systems helped more than 500 farmers irrigate approximately 15 hectares/37 acres of arable land. It is also reported that the pumps saved countless hours spent fetching water for daily household needs.[95] | | | |

90 UNFCCC. (n.d.). Self's Solar Market Gardens | Benin | UNFCCC. Retrieved October 31, 2021, from https://unfccc.int/climate-action/momentum-for-change/women-for-results/selfs-solar-market-gardens

91 E Gupta, The impact of solar water pumps on energy-water-food nexus: Evidence from Rajasthan, India. Energy Policy, (2019), 129, 598-609

92 CID & AFE, Uganda Solar Water Pumping Report Uganda, AFE (2019), https://www.ace-taf.org/wp-content/uploads/2019/10/ACE-TAF-UGANDA-SOLAR-WATER-PUMPING-REPORT-SCREEN-1.pdf

93 UNDP, Solar empowerment: Solar-powered solutions promoting climate-resilient livelihoods across five countries, Reliefweb (2016), https://reliefweb.int/report/mali/solar-empowerment-solar-powered-solutions-promoting-climate-resilient-livelihoods-across

94 Rural Senses, Impact Assessment Framework End-User Research in Uganda & India' (End-User research unpublished) (2021)

95 UNDP, Solar empowerment: Solar-powered solutions promoting climate-resilient livelihoods across five countries, Reliefweb (2016), https://reliefweb.int/report/mali/solar-empowerment-solar-powered-solutions-promoting-climate-resilient-livelihoods-across

| PT | PERCENTAGE OF PEOPLE WITH ACCESS TO A [APPLIANCE NAME] WHO PERCEIVE THAT THE APPLIANCE CONTRIBUTES TO 'TIME BENEFIT', 'TIME MANAGEMENT' OR 'UNBURDENING' (% OF PEOPLE) |
|---|---|
| **Limitations / biases** | A perception variable is highly dependent on the specific community and additional factors. |
| **Data gaps** | Individuals who own a solar water pump and relate or assign the User-Perceived Values of 'time benefit', 'time management' or 'unburdening' to the appliance within a representative sample of solar water pump owners. |

**Table 30: PY-30: Percentage of people who experienced at least a 30% annual yield increase**

| PY-30 | PERCENTAGE OF PEOPLE WHO EXPERIENCED AT LEAST A 30% ANNUAL YIELD INCREASE (%) | | | |
|---|---|---|---|---|
| **Unit** | % | | | |
| **Appliance** | Solar water pump | | | |
| **Applicability** | **GEOGRAPHY** | **DEGREE OF URBANISATION** | **CONFIDENCE** | **VALUE** |
| | North Benin | Rural | ** | 40% |
| | Central India | Rural | ** | 36% |
| **Supporting literature** | A study in Central India of 200 farmers found that they experienced a 36% increase in crop yields and a 66% increase in crop cycles because of the efficient irrigation potential.[96] Additionally, a nationwide assessment in India found that overall, one million solar pumps had the potential to deliver a 10% yield improvement (farmer perception if the required volume of water is available when required). This figure is not included in the table above as it is based on a hypothetical scenario rather than actual measurement.[97] A study found that solar powered drip irrigation in northern Benin helped two village women's agricultural groups (400 women) increase their vegetable and fruit production by 26% and 55% respectively.[98] From the Central India and North Benin studies, an average increase in yield of 39% can be assumed.[99] | | | |
| **Limitations / biases** | The sample size of studies is relatively small, with the study in Benin focused on women-led agriculture.[100] | | | |
| **Data gaps** | Robust, large-scale study on yield effects arising from the use of solar water pumps only. | | | |

96 Shikha Suman, Evaluation and Impact Assessment of the Solar Irrigation Pumps Program in Andhra Pradesh and Chhattisgarh Report, Shri Shakti Alternative Energy Limited (2018), https://www.ssael.co.in/images/Library/files/Solar-Pumps-Impact--SSAEL-Report.pdf

97 KPMG, Feasibility analysis for solar agricultural water pumps in India. KPMG India (2014), https://shaktifoundation.in/wp-content/uploads/2014/02/feasibility-analysis-for-solar-High-Res-1.pdf

98 KPMG, Feasibility analysis for solar agricultural water pumps in India. KPMG India (2014), https://shaktifoundation.in/wp-content/uploads/2014/02/feasibility-analysis-for-solar-High-Res-1.pdf

99 UNFCCC. (n.d.). Self's Solar Market Gardens | Benin | UNFCCC. Retrieved October 31, 2021, from https://unfccc.int/climate-action/momentum-for-change/women-for-results/selfs-solar-market-gardens

100 UNFCCC. (n.d.). Self's Solar Market Gardens | Benin | UNFCCC. Retrieved October 31, 2021, from https://unfccc.int/climate-action/momentum-for-change/women-for-results/selfs-solar-market-gardens

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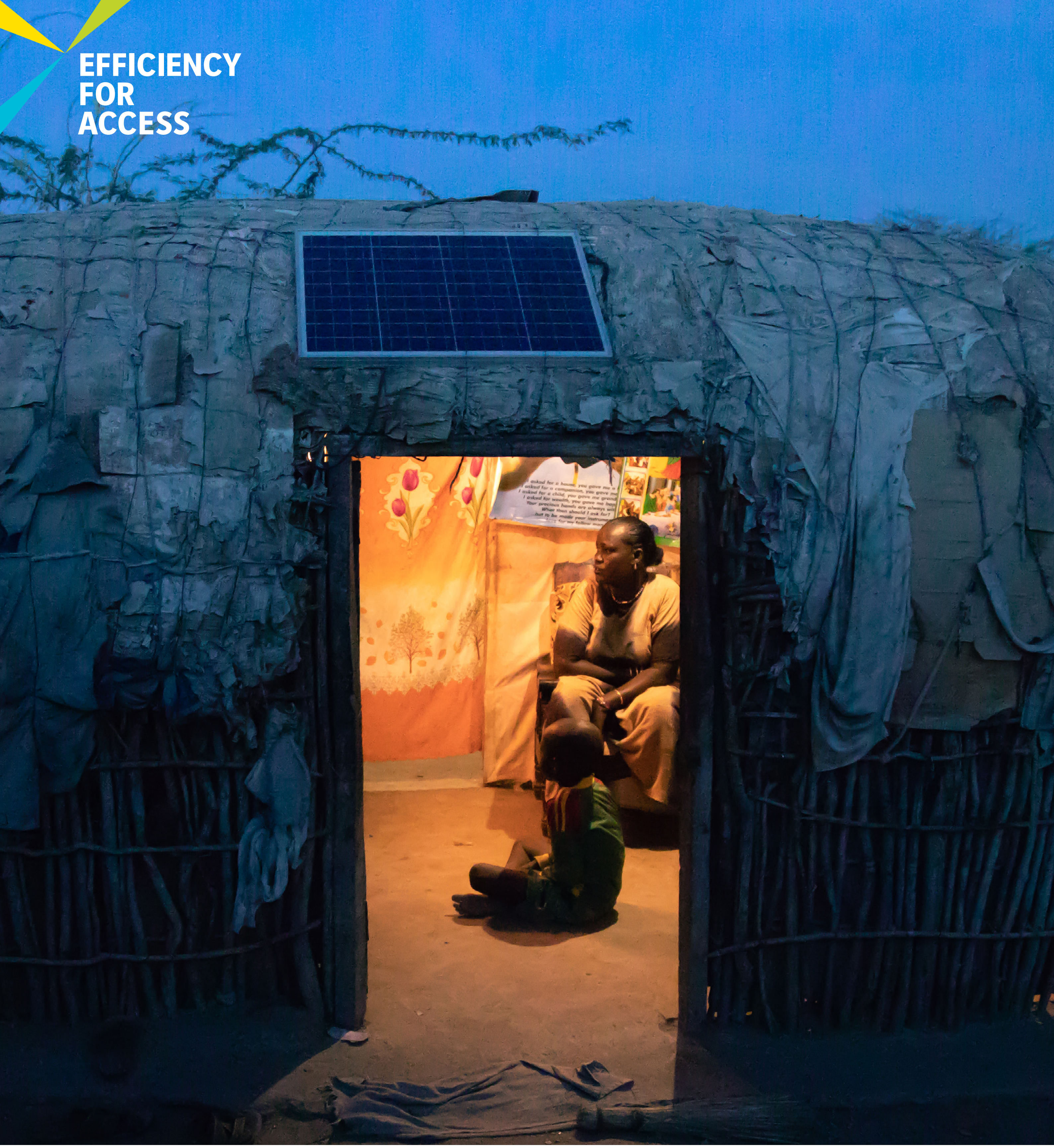


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