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OFF- AND WEAK-GRID APPLIANCES IMPACT ASSESSMENT FRAMEWORK

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METHODOLOGY AND HOW-TO-USE GUIDE

This Methodology and How-to-Use Guide outlines the work undertaken to develop a standard Impact Assessment Framework for off- and weak-grid 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, Stephanie Hirmer, Thalia Konaris, Josephine Tumwesige, and Ramit Debnath of Rural Senses, Richa Goyal of Energy Saving Trust, Makena Ireri of CLASP, and Sarah Olsen and David Pritchard of SVT.

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Disclaimer

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:

- 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.
- This brief was funded by UK aid and the IKEA Foundation. The views expressed do not necessarily reflect the official policies of Government of the United Kingdom or the IKEA Foundation.

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ABBREVIATIONS

GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit, the German Development Agency
GWPR	Global warming potential of refrigerant
IMP	Impact management project
IRIS+	Impact Reporting and Investment Standards
LMIC	Low- and middle-income country
MCDA	Multi-criteria decision analysis
NGOs	Non-governmental organisations
OPEX	Operational expenditure over the lifetime of a technology
PV	Photovoltaic
RS-SVT	Rural Senses and SVT Group
SDG	Sustainable Development Goal
UNICEF	United Nations Children's Fund
UPV	User-perceived value

DEFINITIONS

Confidence Level	The confidence level was assessed for each value for 'standard variables'. Three stars (***) indicates that a study is 'up to date' (i.e. 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 (**) indicates 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 a small sample size.
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); (c) Rural areas (thinly populated areas) (Eurostat, 2021).
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.[1]
Indicator	The means by which an impact can be gauged.
Input Variables	Variables that the framework user needs to provide data for.
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.[2]
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.
Purposive Sampling	A technique widely used in qualitative research for the identification and selection of information-rich cases, for the most effective use of limited resources.[3]
Shared Value	An approach to impact assessment wherein the parties who have an interest in understanding social, environmental, and economic impact, all share the cost and / or data collection effort required to assess it, and have access to the findings.
Stakeholder Mapping	The process of identifying and categorising key stakeholders that are relevant to the work undertaken.
Standard Variables	Variables provided within the Framework based on existing evidence.
The Framework	The Impact Assessment Framework for off- and weak-grid high performing appliances ,the Framework, describes metrics, indicators, and formulae that are to be used to assess the social, environmental, and economic impacts of the four types of appliances. 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 applies to the appliance users and 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 [people] 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. (Impact Management Project, N/A)
Variables	A quantity which, during the calculation of a formula, is assumed to vary or be capable of varying in value. (Oxford Languages, N/A)
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 Efficiency for Access, The State of the Off-Grid Appliance Market (2019) https://storage.googleapis.com/e4a-website-assets/Clasp-SOGAM-Report-final.pdf

2 Energypedia, Pay-as-you-go Approaches (2021), https://energypedia.info/wiki/Pay-as-you-go_Approaches_(PAYGO)

3 Michael Patton, Qualitative Research in Encyclopedia of Statistics in Behavioral Science (American Cancer Society, 2005), https://doi.org/10.1002/0470013192.bsa514

4 Stephanie Hirmer, Alycia Leonard, Josephine Tumwesige, and Constanza Conforti, Building Representative Corpora from Illiterate Communities: A Review of Challenges and Mitigation Strategies for Developing Countries in Proceedings of the 16th Conference of the European Chapter of the Association for Computational Linguistics: Main Volume, (2021), no. iii, pp. 2176–2189, doi: 10.18653/v1/2021.eacl-main.186.

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This report outlines the work undertaken to develop a standard Impact Assessment Framework for off- and weak-grid high-performing appliances, referred to as 'the Framework'. The high-performing appliances considered in this project are fans, refrigerators, solar water pumps, and TVs. Through the development of evidence-based social, environmental, and economic impact indicators, the Framework 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 report seeks to harmonise existing evidence from a wide range of studies into an easy to use and robust set of impact indicators for high-performing appliances. Some of the suggested indicators can already be used to report impacts, while others are not yet complete, mainly due to data gaps. Indicators that are not yet ready are nevertheless important to develop, in order to provide a framework that captures a holistic set of impacts.

Indicators can have a positive, negative, or positive / negative impact. This level of impact is indicated using the following signs respectively: +, –, + / –. The 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 to use

Acknowledging that assessing impact is an ongoing process, this project aims to provide a system for its own continuous improvement. This is done via an open source approach. We transparently documented the origin of each data point and the data gaps. A modular structure of separated indicators, variables, and formulae helps to support incremental improvements as more data is gathered.

The primary use cases of this Framework are:

- for organisations and programmes to assess the holistic impact that they create by distributing high-performing appliances
- to inform decision-making with regard to providing funding for funding high-performing appliances
- to inform strategies to mitigate the unintended negative impacts of high-performing appliances and
- to guide further research.

EXECUTIVE SUMMARY

This document presents an Impact Assessment Framework for off-and weak-grid high performing appliances, referred to as 'the Framework'. High-performing appliances have significant positive social, environmental, and economic impacts on people and their communities in low and middle income countries (LMICs). This Framework amalgamates evidence on the impacts of four high-performing appliances: refrigerators, TVs, fans, and solar water pumps, and provides a set of formulae that have a common language and structure to help quantify these impacts. The framework and formulae will help facilitate the financing, planning, measuring, and reporting of these impacts, and in doing so help stakeholders identify opportunities and minimise risks.

Four principal methods were used to create the Framework: literature review, stakeholder analysis, end-user research, and multi-criteria decision analysis

The initial literature review identified indicators, data gaps, and quantifiable measures from previous studies. The views of stakeholders who are potential users of the Framework — including companies, donors, and investors — were solicited to guide the development of the Framework. End-user interviews were conducted in Uganda and India, and their perceptions were incorporated into the Framework, especially regarding the selection of impacts to include. Multi-criteria decision analysis was conducted to streamline the Framework, by identifying indicators that were widely applicable, comparable, robust, relevant, timely, specific, and dynamic.

The Framework can be used to assess and quantify access, and social, environmental, and economic impacts of off- and weak-grid high-performing appliances

The Framework comprises a list of social, environmental and economic impacts, some general and some specific, to each of the four high-performing appliances. Each impact has a definition, impact statement, formula, supporting literature, and, where relevant, assumptions and data gaps. The Framework includes available existing evidence on the impacts supplemented with new stakeholder and 'end-user views, for easy reference when planning projects.

How to use the Framework to estimate the impact of off- and weak-grid high-performing appliances

Please follow the below steps:

1. Choose the indicator you wish to use based on the high-performing appliance and the type of impact you wish to measure from the metrics summary table.
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 Excel version of the framework.
3. Check the assumptions are suitable for your use-case.
4. Use the provided formula to calculate the impact. Standard variables are provided where available, but some input variables require the Framework user to provide the data.
5. Use the provided impact statement to explain the impact.
6. Help improve the Framework by challenging parts that seem wrong and sharing your findings and data.

The Framework should be updated as new evidence becomes available

Although extensive primary and secondary research was undertaken to develop the Framework, there are still several gaps in the data where there is insufficient evidence on suspected impacts. (Please refer to Section 5 for further information). In addition, some indicators need improvement, as noted in the indicator tables in Section 3. There are cross-cutting gaps related to: the economic impacts of high-performing appliances on users; the impact of financing arrangements on high-performing appliance usage; the environmental impacts of high-performing appliances; and perceptions of how high-performing appliances affect users' lives. The utility and value of the Framework will increase as further evidence is added.

Motivation for the Framework

The impact of high performing appliances on users is significant, varied, and complex. With the growing prevalence of appliances in off- and weak-grid communities, accurate impact assessment is becoming a fundamental tool for increasing responsible funding and managing risk. Many impact assessment efforts have been conducted in isolation by different stakeholders, resulting in an inefficient allocation of precious impact assessment resources, and suboptimal value captured from those efforts. The main motivation for developing this Impact Assessment Framework for Off- and Weak-Grid High-Performing Appliances (the Framework), is to increase the efficiency and optimise the value of impact assessment efforts.

Each year, tens of thousands of off- and weak-grid high-performing appliances , such as fans, TVs, refrigerators, and solar water pumps, are distributed across off-grid communities in low- and middle-income countries (LMICs). According to the 2021 GOGLA report,[5] 35% growth in high-performing appliances sales was observed between Q2 2018 and Q2 2020. In total, between July and December 2020, GOGLA's affiliate companies reported that a total of 469,000 high-performing appliances were sold globally.[6]

The impact of high-performing appliances on their users and their communities is, and is expected to continue to be, significant and includes effects on social, environmental and economic ecosystems. For example, solar water pumps, one of the appliances considered in this report, help end-users to withstand droughts, by relying less on precipitation for irrigation.[7] These appliances can improve food security in the entire community by increasing the availability of vegetables,[8] and can enhance hygiene and sanitation through improved access to clean water.[9] At the same time, the use of solar water pumps may introduce some new challenges, which were previously unknown to appliance users. These could include, for example, sustainable water use[10] and the need for responsible e-waste management.[11] Understanding the different positive and negative effects of high-performing appliances will allow stakeholders to measure and report on impacts. It can also help identify and minimise risks for the intended users and other stakeholders, increase positive impacts, and identify opportunities to align impact, sustainable income and cost savings.

While the impact of the nascent appliance market is being measured by some organisations, the stakeholder consultation conducted in the course of this project shows that impact assessment of appliances is almost entirely done in isolation, on a case-by-case basis, using different assumptions and standards, without an overarching framework. The consequence is that existing impact data are hard to share, and collective learning by the sector is hindered.

Accurate assessment of the multi-layered impacts of high-performing appliances requires collaboration between distributors, researchers, appliance users, donors, investors, and others. This Framework provides a common language and structure to facilitate a growing body of evidence and insight on the impact of high-performing appliances. By using this Framework, developers, distributors, investors and funders of high-performing appliances will gain a greater understanding of the likely social, environmental, and economic impacts of the products and services that they promote. They can use this information to promote high-performing appliances as well as increase the positive, and reduce the negative impacts of their products.

What the Framework includes and what it does not include

The Framework comprises:

- a list of the most important outcomes that flow to the environment, individuals, families, and communities from the use of four high-performing appliances: TVs, fans, refrigerators, and solar water pumps. The list was developed through a review of literature and consultations with a sample of stakeholders.
- standardised formulae that can be used to estimate the scale and depth of each of these outcomes, for any given set of high-performing appliances in use.
- estimated values of variables used in the formula.[12]
- references to the relevant literature and sources of those values.

Neither the framework nor this report provide:

- guidance on how to collect primary data to use in the formula.
- comprehensive information on all the contextual factors that will influence the impact of any high-performing appliance or group of high-performing appliances.

5 GOGLA, Global Off-Grid Solar Market Report: Semi-Annual Sales and Impact Data, July – December 2021 (2021) https://www.gogla.org/sites/default/files/resource_docs/gogla_sales-and-impact-reporth2-2021_def2.pdf

6 ibid

7 Eshita Gupta, The impact of solar water pumps on energy-water-food nexus: Evidence from Rajasthan, India, Energy Policy, 2019, vol. 129, issue C, 598-609 (2019)

8 ibid

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

10 Efficiency Access , Sustainable expansion of groundwater-based solar water pumping for smallholder farmers in Sub-Saharan Africa, (2021) https://efficiencyforaccess.org/publications/sustainable-expansion-of-groundwater-based-solar-water- pumping-for-smallholder-farmers-in-sub-saharan-africa

11 Stephanie Weckend, Andreas Wade and Garvin Heath,End of life management: solar photovoltaic panels (2017) No. NREL/TP-6A20-73852. National Renewable Energy Lab.(NREL), Golden, CO (United States)

12 The evidence on the impacts of HPAs is, in general, weak; the values we provide are to our knowledge based on the best available evidence but are not necessarily authoritative. Further research is needed to improve the evidence base.

The most important limitation of the Framework is that, by design, it provides generic formulae to estimate the impacts of high-performing appliances rather than formulae that are sensitive to the impact of specific versions or brands of high-performing appliances, the different high-performing appliance users, and the particular context in which the high-performing appliances are used. Thus, the formula can be used to estimate the expected impact of fans, TVs, refrigerators, and solar water pumps. Formulae can be applied tousers (individuals, families and communities) and the environment in general, but they cannot reliably estimate the impact of a specific high-performing appliance used by a particular user (or groups), in a particular time or place.

With this in mind, the Framework should not be used as the only method by which investors, manufacturers, distributors, and retailers of high-performing appliances assess the impact of their products.

How to use the Framework

Below is a short guide that explains how to use the Framework practically, including potential users, how often they should use it, what they have to do, what decisions it can inform, and limitations on the Framework's use.

We invite the users of this Framework to:

a. use the Framework to estimate the impact of high-performing appliances.

b. challenge the Framework and identify opportunities for improvement.

c. use the Framework to inform additional research into impacts that are not yet well-evidenced.

These steps are further described below.

Use the Framework to estimate impact

To use this Framework to estimate the impact of high-performing appliances and/or their distribution, please 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 Excel 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:
   a. Input variables are marked as 'Input by user'. These are variables that the user needs to provide values for based on the impact being assessed.
   b. Standard variables 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. You can describe the impact using the phrasing of the impact statement and results of your calculation. For example: "950 kg of CO_2 emissions were saved through the distribution of solar TVs during 2021".
6. Where the value for the standard variable is given as a percentage (e.g. 3%), it will need to be entered in its decimal equivalent when it is used in the indicator formula. e.g. 0.003.

Challenge the Framework

We invite Framework users, researchers, sceptics, appliance users, and others to challenge the Framework and identify opportunities for improvement. Please share evidence with us that could challenge the metrics, variables, assumptions, and data used in the Framework.

This Framework was built over several years through extensive literature reviews and interaction with multiple stakeholders. Through the process of building the Framework, we have tried to answer the following questions:

- What is the impact of high-performing appliances ?
- Which impact areas are most important to different stakeholders?
- How can we assess the most important impact areas?

The Framework is a living document. Therefore, it is very likely that when reviewing and using the Framework, one or many of the following might apply:

- It uses indicators that are no longer important to stakeholders.
- Calculation of the indicator is not accurate.
- data needed are impossible to obtain.
- New evidence suggests improvements to the indicators or the creation of new ones.

The Data Gaps section in this report highlights key modifications that may be addressed in the near future, to improve the framework. We encourage you to send us any necessary modifications that are not already documented in the Data Gaps section.

Please contribute to the development of the Framework by communicating any of the above through this form.

Use the Framework to inform additional research into impacts that are not yet well-evidenced

Related to the above, users of the Framework may also recognise that the Framework points to areas where impact is not yet well-evidenced, and where new research may be helpful. We encourage you to use it to help identify opportunities to flesh out a more complete and detailed picture of the impact of these appliances. Please reach out to us by completing the above form if you:

- identify areas of further investigation that are not already included in the Data Gaps section, or
- want to take part in a new research to address some of the identified Data Gaps

The Framework at a Glance

The Off- and Weak- Grid Appliance Impact Assessment Framework, referred to as Framework, is intended to future-proof funding decisions by providing meaningful information on the social, environmental, and economic impact of four appliances: fans, refrigerators, solar water pumps, and TVs. This Framework was developed between 2020 and 2022, in consultation with end-users, investors, donors, and the Efficiency for Access Secretariat, together with external partners Rural Senses and SVT Group.

The appliance-specific frameworks comprise:

1. A table summarising the relevant indicators and formulae to calculate the indicators. Impact categories (and indicators) were selected based on extensive consultation with stakeholders. (Please refer to Section 4 for more information).
2. A table of variables to be used in the formula. Appropriate values of some variables, namely standard variables. Here, values were identified through the research undertaken for this project. For other variables, namely input variables, the research did not yield appropriate values. For these variables, users of the Framework need to provide appropriate values.

The tables below summarise the Framework for each of the four appliances (i.e. fan, TV, refrigerator, solar water pump). The tables show the ID for each of the indicators that are defined under the 'Indicator Statement' 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 i.e. 'F' for a fan, 'TV' for TV, 'SF' for refrigerator, and 'SWP' for solar water pump. Where the ID starts with an 'A', the indicator is used for all appliances. This is followed by the indicator category: ENV for environmental, ECO for economic, and SOC for social.

The formula used to calculate the indicator is given next. The variables are described in the tables that follow. The MCDA Score refers to the sum of the scores (given to each indicator, according to how well they compare against desired characteristics, namely: widely applicable, comparable, robust, relevant, time-bound / timely, specific, and dynamic (see Appendix 1 for more detail). (The maximum sum is 14). We use a traffic light system in the 'Status' column, to show the readiness level of each indicator. 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. Some indicators reflect impacts that are widely seen as positive (e.g. the number of jobs created) or negative (e.g. tonnes of waste added), while some indicators could be both (e.g. number of customers below the poverty line). This is indicated using the following signs respectively +, –, + / – under 'Impact'.

Table 1: Terminology

TERM	DEFINITION
Variables	A quantity which, during the calculation of a formula, is assumed to vary or be capable of varying in value.
User input	This variable is to be inserted by the user.
Pipeline variables	Variables that are of interest, but data is not yet available. While there is no set plan for these pipeline variables, we urge people to undertake research to close the existing data gap.
Impact	Indicators can have a positive, negative, or positive / negative impact. This is indicated using the following signs respectively: +, –, + / –.
Status	The status indicates the readiness level of the different indicators. This is indicated using a traffic light system, where 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.

Fan-Specific Indicators

Here we have summarised the indicators that apply to fans. These include indicators that apply to all (Indicator ID 'A_'), as well as those specific to a fan (Indicator ID 'F_'). Indicators are also elaborated individually; please refer to the corresponding sheets in the Excel version of this summary sheet here, or the fan-specific report.

Table 2: Fan-Specific Indicators

ID	INDICATOR	FORMULA	MCDA SCORE	STATUS	IMPACT
ENVIRONMENTAL					
Emissions					
A-ENV1	**Tonnes of CO_2 emissions avoided**	(S × (1 – DL) × DR-GHG × PL × G) / 1000	13	●	⊕
E-waste					
A-ENV2a	**Annual tonnes of electric waste added**	S × WS / 1000	14	●	⊖
A-ENV2b	**Annual tonnes of electric waste avoided**	S × WS × WRP / 1000	12	●	⊕
ECONOMIC					
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	●	⊕
Job Opportunity					
A-ECO2	**Number of new jobs created**	S × EF × EFa	13	●	⊕
SOCIAL					
Access and Inclusion					
A-SOC 1	**Number of people who gained access to an off-grid appliance for the first time**	S × (1 – DL) × (1 – DR-Access)	12	●	⊕
A-SOC 2	**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) × RPL	11	●	⊕
Ownership					
A-SOC4	**Affordability of monthly repayments**	(PAYGoMC / IMAC) × 100	14	●	±
Comfort					
F-SOC1a	**Total hours of improved thermal comfort, cumulatively**	S × Ff × (PL – PTsp) × (1 – DL) × (1 – DR-Access)	13	●	⊕
F-SOC1b	**Number of people who are experiencing improved thermal comfort**	SL × (1 – DL) × (1 – DR-Access) × H × PTC	13	●	⊕
Health and Wellbeing					
F-SOC2a	**Number of people who are experiencing improved indoor air quality**	SL × (1 – DL) × (1-DR-Access) × H × PIAQ	13	●	⊕
F-SOC2b	**Number of people who perceived a reduction in carriers of vector-borne diseases, e.g. mosquitos**	SL × (1 – DL) × (1-DR-Access) × PDCV			
F-SOC2c	**Number of people who perceived improved health**	SL × (1 – DL) × (1-DR-Access) × PIH	13	●	⊕
F-SOC3a	**Number of people spending more time together**	SL × (1 – DL) × (1-DR-Access) × H × PSTT	12	●	⊕

TV-Specific Indicators

Here we have summarised indicators that apply to TVs. These include indicators that apply to all (Indicator ID 'A_'), as well as those specific to TVs (Indicator ID 'TV_'). Indicators are also elaborated individually; refer to the corresponding sheets in the Excel version of this summary sheet here, or the TV-specific report.

Table 3: TV-Specific Indicators

ID	INDICATOR	FORMULA	MCDA SCORE	STATUS	IMPACT
ENVIRONMENTAL					
Emissions					
A-ENV1	**Tonnes of CO_2 emissions avoided**	(S × (1 – DL) × DR-GHG × PL × G) / 1000	13	●	⊕
E-waste					
A-ENV2a	**Annual tonnes of electric waste added**	S × WS / 1000	14	●	⊖
A-ENV2b	**Annual tonnes of electric waste avoided**	S × WS × WRP / 1000	12	●	⊕
ECONOMIC					
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	●	⊕
Job Opportunity					
A-ECO2	**Number of new jobs created**	S × EF × EFa	13	●	⊕
SOCIAL					
Access and Inclusion					
A-SOC 1	**Number of people who gained access to an off-grid appliance for the first time**	S × (1 – DL) × (1 – DR-Access)	12	●	⊕
A-SOC 2	**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) × RPL	11	●	⊕
Ownership					
A-SOC4	**Affordability of monthly repayments**	(PAYGoMC / IMAC) × 100	14	●	⊕
Health and Wellbeing					
TV-SOC1a	**Number of people exhibiting an increase in sedentary behaviour**	SL × (1 – DL) × H × PTST	13	●	⊖
TV-SOC1b	**Number of people who experience reduced stress levels**	SL × (1 – DL) × (1 – DR-Access) × PRSL	14	●	⊕
TV-SOC1c	**Number of children who are perceived to be more exposed to violent and other undesired content**	SL × (1 – DL) × PR × PEVP	10	●	⊖
TV-SOC2a	**Number of people spending more time together due to owning a TV**	SL × (1 – DL) × H × PSTT	12	●	⊕
TV-SOC2b	**Number of people who perceive improved quality of life due to owning a TV**	SL × (1 – DL) × (1 – DR-Access) × H × PQL	13	●	⊕
Information Access & Learning					
TV-SOC3a	**Number of people accessing information through a TV**	S × (1 – DL) × (1 – DR-Access) × H × PIW	12	●	⊕
TV-SOC3b	**Number of children accessing education programmes through a TV**	S × (1 – DL) × (1 – DR-Access) × PR × PLTTV	12	●	⊕

Refrigerator-Specific Indicators

Here we have summarised the indicators that apply to refrigerators. These include indicators that apply to all (Indicator ID 'A_'), as well as those specific to a refrigerator (Indicator ID 'SF_'). Indicators are also elaborated individually; refer to the corresponding sheets in the Excel version of this summary sheet here, or the refrigerator-specific report.

Refrigerators and freezers with an indicative gross storage volume of up to 600 litres are considered. Refrigerating appliances have one or more compartments; they are used for storing food or generating ice in off-and weak-grid communities.

Table 4: Refrigerator-Specific Indicators

ID	INDICATOR	FORMULA	MCDA SCORE	STATUS	IMPACT
ENVIRONMENTAL					
Food Spoilage					
SF-ENV1a	**Annual tonnes reduction in food spoilage (domestic refrigerator)**	(S × PL × (1 – DL) × FSD × VD × DD) / 1000	13	🔴	⊕
SF-ENV1b	**Annual tonnes reduction in food spoilage (commercial refrigerator)**	(S × PL × (1 – DL) × FSC × VC × FC) / 1000	13	🔴	⊕
Emissions					
SF-ENV2	**Kg of CO_2e refrigerant-related emissions added**	S × (RM + RS – RD) × GWPR	13	🟢	⊖
A-ENV1	**Tonnes of CO_2 emissions avoided**	(S × (1 – DL) × DR-GHG × PL × G) / 1000	13	🟢	⊕
E-waste					
A-ENV2a	**Annual tonnes of electric waste added**	S × WS / 1000	14	🟢	⊖
A-ENV2b	**Annual tonnes of electric waste avoided**	S × WS × WRP / 1000	12	🟢	⊕
ECONOMIC					
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	🟢	⊕
Job Opportunity					
A-ECO2	**Number of new jobs created**	S × EF × EFa	13	🟢	⊕
Business Income					
SF-ECO1a	**Number of businesses generating at least 30% additional annual income due to owning a refrigerator**	SL × (1 – DL) × (1 – DR-Access) × FB × PI-30	13	🟢	⊕
SF-ECO1b	**Number of businesses generating additional income of any value due to owning a refrigerator**	SL × (1 – DL) × (1 – DR-Access) × FB × PI	13	🔴	⊕
SOCIAL					
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)	12	🟢	⊕
Health and wellbeing					
SF-SOC1a	**Number of health facilities offering improved health services due to their use of refrigeration**	SL × (1 – DL) × DH × (1 – DR-Access)	11	🟢	⊕
SF-SOC1b	**Percentage reduction in vaccine waste**	(VWC – VWS) / SH	14	🔴	⊕
SF-SOC2a+b	**Number of people / women who perceive that a solar-powered refrigerator provides them with more free time**	SL × (1 – DL) × (1 – DR-Access) × PT SL × (1 – DL) × (1 – DR-Access) × WomenT	13	🟠	⊕
SF-SOC3	**Number of people who experience improved quality of life due to owning a refrigerator**	SL × (1 – DL) × (1 – DR-Access) × H × PQL	13	🟢	⊕
Food Security					
SF-SOC4	**Number of people who perceive improved food security and nutrition due to owning a refrigerator**	SL × (1 – DL) × (1 – DR-Access) × H × PFS	13	🟢	⊕

Solar Water Pump-Specific Indicators

Here we have summarised the indicators that apply to solar water pumps. These include indicators that apply to all (Indicator ID 'A_'), as well as those specific to a pump (Indicator ID 'SWP_'). Indicators are also elaborated individually; refer to the corresponding sheets in the Excel version of this summary sheet here, or the solar water pump-specific report.

Table 5: Solar Water Pump-Specific Indicators

ID	INDICATOR	FORMULA	MCDA SCORE	STATUS	IMPACT
ENVIRONMENTAL					
Emissions					
A-ENV1	**Tonnes of CO_2 emissions avoided**	(S × (1 – DL) × DR-GHG × PL × G) /1000	13	●	⊕
E-waste					
A-ENV2a	**Annual tonnes of electric waste added**	S × WS / 1000	14	●	⊖
A-ENV2b	**Annual tonnes of electric waste avoided**	S × WS × WRP / 1000	12	●	⊕
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 SL × (1 – DL) × (1 – DR-Access) × PI_50	13	●	⊕
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	●	⊕
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	●	⊕
Job Opportunity					
A-ECO2	**Number of new jobs created**	S × EF × EFa	13	●	⊕
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	●	⊕
SWP-SOC2a+b	**Number of people / women who perceive that a solar water pump provides them with more free time**	SL × (1 – DL) × (1 – DR-Access) × PT SL × (1 – DL) × (1 – DR-Access) × WomenT	13	●	⊕
SWP-SOC3	**Number of people who perceive enhanced quality of life through using a solar water pump**	SL × (1 – DL) × (1 – DR-Access) × H × PQL	13	●	⊕
Food Security					
SWP-SOC4	**Number of people who attribute the use of the appliance to improved food security**	SL × (1 – DL) × (1 – DR-Access) × H × PFS	13	●	⊕
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)	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) × RPL	11	●	⊕
Ownership					
A-SOC4	**Affordability of monthly repayments**	(PAYGoMC / IMAC) × 100	14	●	±

Variables

Below a summary of the variables used in the formula are presented. These are separated into 'Input Variables' and 'Standard Variables'.

Input Variables

Input variables need to be entered into the Framework by the user, as a reliable source for their value was not found in the literature review. Please refer here for the corresponding sheet in the Excel version of this Framework.

Table 6: Input Variables

VARIABLES	DEFINITION
C	The average retail price of the solar product (capital cost to customer) (USD or equivalent)
CM	Monthly cost of a solar-powered appliance for a household (USD or equivalent)
DH	Percentage of refrigerators distributed to health facilities (%)
DosesIM	Total doses immunised (used) (number of vaccines)
DosesIS	Total net doses issued to facility (number of vaccines)
DWASH	Percentage of people who use a solar water pump for improved water and hygiene
EFw	Percentage of women employed in supply chain
FB	Percentage of refrigerators distributed to small and medium businesses (%)
FC	Percentage of commercial refrigerators distributed (within the scope refrigerator type) (%)
FD	Percentage of domestic refrigerators distributed (within the scope refrigerator type) (%)
FSC	Average commercial food savings per year per business due to their use of refrigeration (kg / litre/ year)
GWPR	Global Warming Potential of Refrigerant (GWP). Benchmark values are available in the Efficiency for Access report 'Phasing Down HFCs in Off- and Weak-Grid Refrigeration' (link in usage notes)
HB	Household expenditure on the prevention & cure of mosquito-borne diseases prior to purchasing a fan (USD or equivalent)
HF	Household expenditure on the prevention & cure of mosquito-borne diseases after purchasing a fan (USD or equivalent)
IH	Average annual income of household or business of a representative sample (USD or equivalent)
IMAC	Average monthly income of the customer base (USD or equivalent)
IMD	Average monthly disposable income of a household, defined as the difference between the average monthly income and the average monthly costs of a household (USD or equivalent)
PAYGoMC	Average Monthly PAYGo commitment (USD or equivalent)
PL	Estimated product lifespan (minimum of 1.5 × financing period, or 1.5 × warranty period in cash payments) (years)
PS	Individuals with access to a [Appliance name] in a representative sample (number of people)
PSa	Appliance Popularity Score — percentage of people who rank the appliance in their top five most valuable items in a representative sample of a community (% of people)
PSU	Percentage of solar water pump users who received sustainable water usage training, or SWPs that are sold as a package with information on water-saving measures (% of people)
PTsp	Average number of days per year in which the temperature is above 26 °C (# of days / year).[13]
RD	Refrigerant recovered during disposal (kg). Benchmark values are available in the Efficiency for Access report "Phasing Down HFCs in Off- and Weak-Grid Refrigeration" (link in usage notes)
RM	Refrigerant charge mass at manufacturing stage (kg). Benchmark values are available in the Efficiency for Access report "Phasing Down HFCs in Off- and Weak-Grid Refrigeration" (link in usage notes)
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.[14]
RS	Refrigerant charge mass used to service refrigerators during use phase (kg). Benchmark values are available in the Efficiency for Access report "Phasing Down HFCs in Off- and Weak-Grid Refrigeration" (link in usage notes)
S	Number of units sold (cumulative, i.e. ever) (number of units)

13 Data for different geographies is accessible here: Data for PTsp can be accessed via: https://weather-and-climate.com/

14 World Population review, Median income rankings by country (2022) https://worldpopulationreview.com/country-rankings/median-income-by-country

VARIABLES	DEFINITION
SH	Total number of solar-powered refrigerators in operation in the facilities under consideration
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)
VC	Average solar-powered refrigerator volume per commercial refrigerator (within the scope refrigerator type) (litre)
VD	Average solar-powered refrigerator volume per domestic refrigerator (within the scope refrigerator type) (litre)
WRP	Proportional weight of each appliance that will be recycled (%)
WS-RC	Weight of components of solar-powered appliance that can be recycled / reused (kg)
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 with 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 degree of urbanisation[15], to decide which value is most appropriate for their products, as well as the confidence rating[16] of each value. Those variables marked as 'Pipeline Variables' are of interest, but relevant 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 of this Framework in the Excel version.

Table 7: Standard Variables

VARIABLE (LINKED TO DETAILED TABLE)	DEFINITION	FAN	TV	REFRIGERATOR	SOLAR WATER PUMP
CCC	**Cost of equivalent type of non-solar-powered appliance in the target region (USD)**	5–100	105–200	135–270	300–1,500
DL	**Discount for loss: products not working or not in use, excluding loss in supply chain (%)**	3%	3%	4.50%	8.50%
DR-Access	**Discount for repeat sales for estimating new access to solar-powered appliances (including different companies) (%)**	5%	16%	9%	1%
DR-GHG	**Ratio capturing sales replacing a diesel genset-powered appliance (%)**	3%	16%	9%	35%
EF	**Employment factor (jobs / item sold)**	0.0082	0.0082	0.01095	0.0197
EFA	**Proportion of employment factor relevant to each appliance**	25%	60%	100%	100%
Ff	**Operating time fraction for a fan as hours per day (hours / day)**	4–8.5	N/A	N/A	N/A
FSD	**Average domestic food savings per year per litre of refrigerator volume per household due to the use of refrigeration (kg / litre / year)**	N/A	N/A	Pipeline Variable	N/A
G	**Average amount of greenhouse gases avoided per appliance, due to diesel displacement (kg CO_2 / year)**	84	59	25,384	8,834
H	**Household size (number of people)**	5.5	5.5	5.5	5.5
OPEXD	**Annual operational fuel cost of a diesel-powered appliance (USD / year)**	34–58.17	18–23.214	176–269.2	4,563
PDCV	**Percentage of people who report using a fan to deter mosquitos (%)**	75%	N/A	N/A	N/A
PEVP	**Percentage of people who associate exposure to violence and any other undesired content to using a TV (%)**	N/A	27%	N/A	N/A

15 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).

16 The confidence level was assessed for each value for 'standard variables'. Three stars (***) indicates that a study is 'up to date' (i.e. conducted within 5 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 (**) indicates 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.

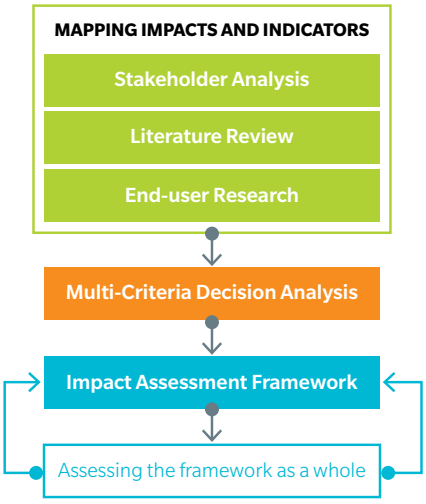
VARIABLE (LINKED TO DETAILED TABLE)	DEFINITION	FAN	TV	REFRIGERATOR	SOLAR WATER PUMP
PI	**Percentage of people who experienced an annual income increase of any value (%)**	N/A	N/A	Pipeline Variable	N/A
PI-30	**Percentage of people who experienced an annual income increase of at least 30% (%)**	N/A	N/A	70%	65%
PI-50	**Percentage of people who experienced an annual income increase of at least 50% (%)**	N/A	N/A	N/A	45%
PIAQ	**Percentage of people who associate their fan with improved indoor air quality (IAQ) (%)**	9%	N/A	N/A	N/A
PIH	**The percentage of people with access to the appliance who perceive the appliance contributes to health and wellbeing**	75%	75-78%	69%	Pipeline Variable
PIW	**Percentage of people associating TVs with improved access to information (%)**	N/A	86%	N/A	N/A
PLTTV	**Percentage of children under the age of 18 with access to a TV who relate it to learning (%)**	N/A	60%	N/A	N/A
PQL	**Percentage of people associating the appliance with improved quality of life (%)**	N/A	10-49%	15%	64-90%
PR	**The multiplier for the number of children under the age of 18 in a household accessing the appliance (Ratio)**	2.3-2.8	2.3-2.8	2.3-2.8	2.3-2.8
PRSL	**Percentage of people who associate reduction in stress levels and relaxation with using a TV (%)**	N/A	76%	N/A	N/A
PSTT	**Percentage of people who associate an appliance with spending time with family and community (%)**	Pipeline Variable	76%	N/A	N/A
PFS	**Percentage of people who associate the appliance with improved food security (%)**	N/A	N/A	10%	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)**	N/A	N/A	1-15%	29-36%
PTC	**Percentage of people who associate their fan with improved thermal comfort (%)**	94%	N/A	N/A	N/A
PTST	**Percentage of people reporting watching TV for more than two hours (%)**	N/A	95%	N/A	N/A
PY-30	**Percentage of people who experienced at least a 30% annual yield increase (%)**	N/A	N/A	N/A	39%
TAHW	**Average time spent watching comforting programmes (hours)**	N/A	5	N/A	N/A
TSP	**Indoor set temperature above which cooling using a fan is required (°C)**	26 °C	N/A	N/A	N/A
VUC	**Average vaccine utilisation rate within a defined period or immunisation programme (%)**	N/A	N/A	60.5%	N/A
VUS	**Average vaccine utilisation rate from health facilities with additional refrigeration within a defined period or immunisation programme (%)**	N/A	N/A	Pipeline Variable	N/A
VWC	**Average vaccine wastage rate from health facilities without refrigeration within a defined period or immunisation programme (%)**	N/A	N/A	39.5%	N/A
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 (% of women)**	N/A	N/A	Pipeline Variable	Pipeline Variable
VWS	**Average vaccine waste rate from a health facility with refrigeration within a defined period or immunisation programme (%)**	N/A	N/A	Pipeline Variable	N/A
WC	**Weight of non-solar-powered appliance (kg)**	10	N/A	85	Pipeline Variable

Methodology

Below is a summary of the four principal methods used to create the Framework. Each section clearly lists some of the limitations and how these were mitigated.

We drew on the following four key methods to inform the development of the Framework and the indicators therein: literature review, key stakeholder interviews, end-user research, and multi-criteria decision analysis. The process and interplay of these methods is summarised in Figure 1, and further discussed in the section below.

Figure 1. Process of framework development for High-Performing Appliances



Literature Review

The literature review focused on identifying studies and methods for measuring the environmental, social,and economic impacts of four types of appliances in low- and middle- income countries (LMICs): refrigerators, TVs, fans, and solar water pumps. Specifically, the purpose of this literature review was to:

- incorporate the literature review previously done by the Secretariat
- check for other indicators that were not previously identified but are also important, with an emphasis on the environment and gender, or inclusion-related impacts
- identify data gaps
- where possible, identify quantifiable measures.

As part of the literature review, we:

- examined literature consisting of academic literature, reports from institutions specialising in the sector, books and websites
- noted differences between rural and urban
- focused on the most recent studies available
- noted regional differences and applicability, with a special focus on East Africa and India
- covered both positive and negative impacts.

Literature Review limitations

We identified a number of core limitations and potential mitigation strategies as follows:

- **Absence of available literature:** Where there is no literature on solar-powered appliances, we looked at alternatives. For example, diesel and grid water pumps can share some impacts with solar water pumps. When alternatives were used, these are clearly noted.
- **Geographic bias:** A large majority of studies used in the literature review have a clear geographical focus. While we endeavoured to find evidence that tested the differences across geographies, in other words, studies that found similar results in different geographies, this was not always possible. In response, we clearly noted the geographical focus of each study. In the future, Efficiency for Access may want to refine the Framework's evidence base by identifying countries with similarities, e.g. find areas with similar climatic conditions.
- **Lack of statistical significance:** We found that many studies were not based on statistical analysis and / or have a small sample size.
- **Inconsistency across research:** Most studies that we found are highly local and context-specific;their methods of data collection differ and ultimately the reporting is different and intended for different purposes. This makes it difficult to compare and collate. While a more systematic approach to data collection is needed, in this literature review we clearly note these differences to be able to account for them accurately in our assessment.

Key Stakeholder Engagement

Our approach to the Framework's development centred around stakeholder mapping and stakeholder engagement, including firstly those stakeholders who will ultimately use the Framework, and secondly the appliance users. The aim was to build a sense of ownership, increase likely uptake, ensure the Framework is fit-for-purpose and relevant to people intend to use the Framework, while also adequately representing the diverse positive and negative impacts of appliances on their users. This section will focus on people ultimately using the Framework (private sector, academia, international organisations, and NGOs). The end-users of appliances are discussed in the following section.

The data from key stakeholders that informed the Framework included specifically: (a) data collected from companies, primarily by the Efficiency for Access Secretariat ; (b) public donor and investor data; and (c) data gathered through ten semi-structured interviews with donors and investors from Efficiency for Access , conducted by RS-SVT during November and December 2020. Information provided by these stakeholders was incorporated with the benefit of frequent conversation with the Efficiency for Access Secretariat.

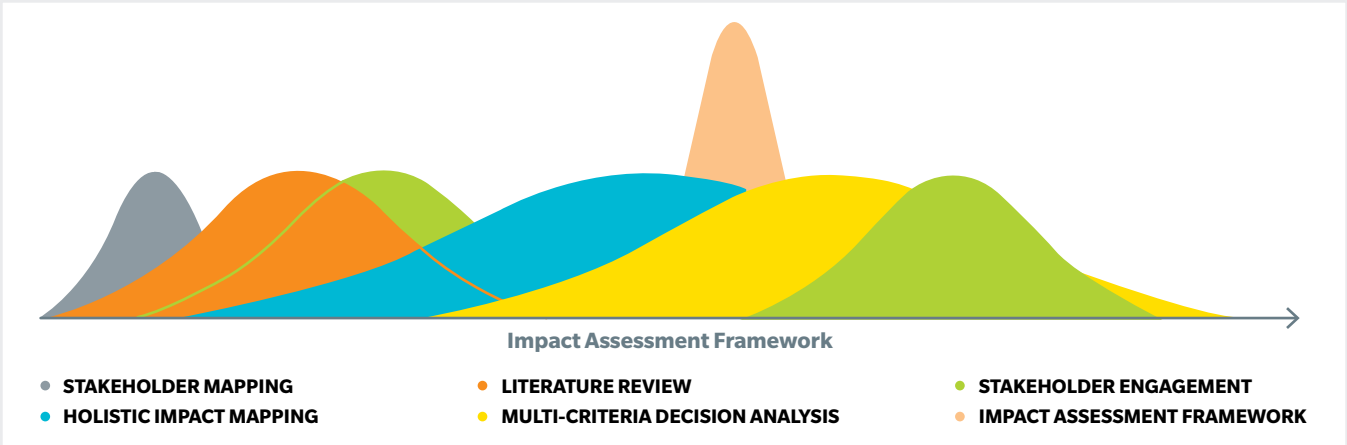
Our approach to stakeholders was informed by Social Value International's Social Value Principles which seek to understand (Social Value International, 2011):

1. Who is affected by high-performing appliances?
2. What resources do they invest (including time, skill, etc.) to enable the successful development and deployment of high-performing appliances?
3. What roles do they play in the successful development and deployment of high-performing appliances?
4. What changes for them as a result of the successful deployment and development of high-performing appliances?
5. How important are these changes in their eyes?
6. How do they perceive these changes?
7. What information about these changes are the main influences on their decisions?
8. How can we improve users' buy-in to the Framework?

Items (I–III) were primarily investigated through initial interviews with Efficiency for Access and the review of relevant literature. Items (IV–VIII) were investigated by seeking interviews with Efficiency for Access donor members and members of the Efficiency for Access Investor Network , and surveys of end-users in India and Uganda. We conducted 10 semi-structured interviews with investors and funders, and over 200 surveys with end-users.

From those initially interviewed, we identified 10 key stakeholders (e.g. representatives from the Rockefeller Foundation and IFC) who were then invited to review the Framework, to provide further insight into their motivations for use of the Framework, and to recommend means to increase buy-in via (viii) ongoing stakeholder engagement (SE). The direct intelligence resulting from the work summarised in this report will be used in Efficiency for Access' outreach and continuous engagement of organisations. The process of key stakeholder engagement along the development of the Framework is shown in Figure 2.

Figure 2: Use of different methodologies within the Framework development process



Once developed, we validated the impact metrics and variables with key stakeholders. We ran multiple focus groups with technical working groups of the specific appliances. These included the GOGLA Impact Working Group for validating metrics related to TVs and fans, the Efficiency for Access Refrigeration Technical Working Group for refrigerator metrics, the Efficiency for Access Solar Water Pump Technical Working Group for pump metrics, as well as the Efficiency for Access Investor Network. In the focus groups, we presented the metrics and received feedback through an open discussion. At the end of the discussion, participants were asked to vote to either approve or continue the discussion on any of the metrics and associated variables. When needed, a follow up session was scheduled to continue the discussion. The summary of the engagements that were conducted is summarised in table 16 below.

Table 8: Summary of Engagement with Key Stakeholders

DATE	TYPE OF ENGAGEMENT	DETAILS
7 October 2020	Efficiency for Access Investor Network	**A focus group activity to probe what key impact topics are most important and useful to the Efficiency for Access Investor Network**
November – December 2020	One-to-one semi-structured interviews	**Semi-structured discussion about appliance impact data with Efficiency for Access donor members and representatives from the Efficiency for Access Investor Network. Specifically, we spoke to the following personnel:** **Efficiency for Access donor members** • Good Energies Foundation • IFC • DOEN Foundation • IKEA Foundation • Acumen • Rockefeller Foundation **Efficiency for Access Investor Network members** • Charm Impact • SunFunder • KawiSafi Ventures • FINCA **Topics that were discussed:** 1. Accessibility, availability, and use of impact data on off- and weak-grid appliances 2. Importance of impact data (of off- and weak-grid appliances) 3. Types of impact data 4. Attributes of impact (of off- and weak-grid appliances) framework as a whole 5. Challenges 6. Appliance-specific impacts 7. Trends
29 April 2021	Focus group	**Presenting impact metrics to the Efficiency for Access Investor Network** **31 attendees from the following organisations:** • Project Maji • Simusolar Ltd • Bonergie in Senegal • Futurepump • World Bank ESMAP • Lighting Global • GIZ • Water and Energy for Food • Sunken Limited • KickStart International • Grundfos • Ignite Power • Impact Pumps
18 May 2021	Focus group	**Presenting refrigerator indicators to Efficiency for Access Refrigeration Technical Working Group**
14 July 2021	Focus group	**Presenting TV and fans indicators to the GOGLA Impact Working Group**
10 August 2021	Focus group	**Presenting final solar water pump impact metrics to the Quality Solar Solutions Working Group**
28 September 2021	Focus group	**Presenting final solar water pump impact metrics to the Efficiency for Access Solar Water Pump Technical Working Group**
7 October 2021	Focus group	**Final presentation on the SWP Impact Metrics to the Quality Solar Solutions Working Group**
1 November –December 2021	Peer review	**One month detailed peer review of the final framework.** **Six peer reviewers from the following organisations:** • Acumen • Energy for Impact • GOGLA • SEforAll • SELCO • Energy 4 Impact
23 December 2021	Discussion on integrating indicators in GOGLA's platform	**A meeting with team members from GOGLA regarding comments on the indicators and their integration in GOGLA's platform**
11 January 2022	Discussion on integrating indicators in GOGLA's platform	**A meeting with team members from GOGLA and Energy Saving Trust regarding comments on the indicators and their integration in GOGLA's platform**

End-User Research

The purpose of the end-user research was to provide insights into the 'unknown unknowns' and to start identifying some of the existing 'known unknowns' (data gaps), particularly pertaining to appliance users' perception of impacts.

RS-SVT conducted 'end-user' interviews in Uganda and India between February–June 2021.

The objective of the research was to include the users' perceptions of appliance impact as they themselves experience it. Ultimately, the goal of donors, investors and all other off- and weak-grid stakeholders is to serve the end-user. Therefore, end-user research was critical to the development of the Framework. More specifically it helped inform its assessment of changes, how these are measured, and how important they are to the diverse voices of appliance end-users.

Selection Criteria for the Research Location

Uganda and India were selected as the representative countries for the Sub-Saharan Africa and South Asia regions. Uganda was chosen because of the consultant's presence in the country and experience working with local rural communities in the country. Similarly, India was selected due to the consultant's collaborations in the country and partnerships with other local organisations. Furthermore, other studies had been undertaken in these two countries, providing comparable data sets. In Uganda, research was conducted across 16 districts, and in India in the Rajasthan region.

Participant Selection Criteria

Sampling was done using the purposive sampling technique. Purposive sampling is a technique that is widely used in qualitative research, for the identification and selection of information-rich cases, for the most effective use of limited resources.[17] The technique involves identifying and selecting individuals, or groups of individuals, who are especially knowledgeable about or experienced with a phenomenon of interest.[18] Two purposive sampling strategies were used; criterion-i and maximum variation. Criterion-i means that participants were identified and selected because they met the predetermined criteria for the study, that is, they used one of the following off-grid and weak-grid appliances: TVs, fans, refrigerators, and solar water pumps. In Uganda, off-grid appliance owners in urban, semi-urban and rural areas across the 16 districts were selected to capture maximum variation in location. The maximum variation strategy was used because of its strength in documenting unique or diverse variations that have emerged in adapting different conditions. In addition, the selection aimed to get an equal representation of men and women.

The main challenge with the technique of purposive sampling is the identification and application of appropriate sampling strategies in the study. For instance, the range of variation in a sample from which the sample selection was made was not known at the outset of the study. To sample information-rich informants that cover the range of variation, an iterative approach of sampling and resampling was necessary. This was time and resource-intensive.

Sample Size

In total, 316 participants were selected from Uganda (116) and India (200). The table 17 below shows the sample sizes in Uganda and India by appliance type.

In the India sample, 40 users of each appliance (TV, fan, refrigerator, solar water pump) were selected. An additional 40 participants who had none of these appliances were also interviewed. The purpose of this was to compare the findings between the participants whose the appliances and those who have no access to the appliances.

In Uganda, 30 users for each of the appliances (TV, fan, refrigerator, solar water pump) were selected. A representative sample of fan end-users could not be identified in Uganda. It should also be noted that although 30 off-grid solar water pump users had been identified, only 25 could be contacted for the interview.

Table 9: Summary of Sample Sizes in Uganda and India

	FAN	TV	REFRIGERATOR	WATER PUMP	NO APPLIANCE	TOTAL
Uganda	0	30	31	25	30	**116**
India	40	40	40	40	40	**200**
Total	40	70	71	65	70	**316**

17 Michael Quinn Patton, Qualitative Research, in Encyclopedia of Statistics in Behavioral Science (American Cancer Society, 2005), https://doi.org/10.1002/0470013192.bsa514

18 Laurence A. Palinkas, Sarah M. Horwitz, Carla A. Green et all, Purposeful Sampling for Qualitative Data Collection and Analysis in Mixed Method Implementation (2015) Research, Administration and Policy in Mental Health 42, no. 5: 533–44, https://doi.org/10.1007/s10488-013-0528-y

Method

The end-user research consisted of a User-Perceived Value[19] (UPV) Game and a socio-economic survey.

User-Perceived Value Game

The UPV game was used to uncover known and unknown impacts of appliances for appliance users and non-users. The UPV game is framed as a semi-structured interview. For both the general and the appliance-specific version of the game, a similar approach was followed. In the general version of the UPV game, interviewees were asked to:

1. select five out of 45 presented items;[20]
2. rank the items in order of importance
3. For each item, explain why the item was selected. At this last stage, 'why-probing' is used to capture multiple layers of reasoning.

In the appliance-specific version of the UPV game, only four cards are presented: TV, fan, refrigerator, and solar water pump. Following this, the interviewees were asked to:

1. rank the items in order of importance
2. For each item, explain its advantages and disadvantages. At this last stage, 'why-probing' is used to capture multiple layers of reasoning.

Socio-Economic Survey

The socio-economic survey was used to contextualise the data collected from the UPV game. The survey consisted of multiple sections and varied according to the level of appliance ownership (i.e. appliance owner or non-owner), as well as type of appliance ownership (i.e. refrigerator, TV, solar water pump, fan), and demographic data.

Ethical Considerations

Interviews followed the country's COVID-19 guidance: data collectors and participants were provided with the necessary safety equipment. We also followed the recommendations of Hirmer et al.[21] for respectfully contacting and interacting with community members. Each interview lasted between one – two hours. Interviewees were compensated for the financial equivalent of one day of labour.

Following data collection, interviews were translated into English. This step was necessary to ensure the protection of participants' identity. As illiterate and isolated rural communities tend to display a high degree of language fragmentation,[22] precise geographic information could implicitly be released by sharing linguistic data.

Use of End-User Research

The data obtained from the study was used in two ways; i) as end-user input in the MCDA and therefore used to generate the priority scores, and ii) to provide specific data points for the different metric variables.

Limitations of the Study

1. The primary downside of purposive sampling is that it is prone to researcher bias, due to the fact that the researcher makes subjective or generalised assumptions when choosing participants. However, researcher bias is only a real threat to a study's credibility when the researcher's judgements are poorly considered, or when they have not been based on clear criteria. This was not the case in this study because the selection criteria were clearly stated.
2. Data was collected at specific points in time and may have been affected by seasonal factors such as the agricultural calendar, political events, currency variations, fuel price variations, and the ongoing COVID-19 pandemic more generally. Through consultation with companies that provided the participant information at the time of initial data collection, it seemed that no specific conditions required special treatment of the sample during the research period.
3. Due to the multi-country aspect of the research, cultural understanding and interpretation of certain questions may have differed between the interviewer and interviewees. To mitigate this effect, in Uganda, the survey was deployed in English and the data collector asked the question in the participants' respective local languages. In India, the survey was translated to Hindu by our partners in India, and all translations were reviewed by our field team of data collectors to ensure the questions would be understood by interviewees.

19 User-Perceived Value 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 [people] themselves at a given time". (Hirmer, 2017).

20 Cards depicted everyday items found in rural areas in LMICs and were adapted to the local context with the help of local experts. Indian and Ugandan interviewees were therefore exposed to slightly different, culturally specific cards.

21 Stephanie Hirmer, Alycia Leonard, Josephine Tumwesige, and Constanza Conforti, Building Representative Corpora from Illiterate Communities: A Review of Challenges and Mitigation Strategies for Developing Countries (2021) in Proceedings of the 16th Conference of the European Chapter of the Association for Computational Linguistics: Main Volume, 2021, no. iii, pp. 2176–2189, doi: 10.18653/v1/2021.eacl-main.186

22 Kirk Hazen, Identity and language variation in a rural community, (2002) Language, pages 240–257

Multi-Criteria Decision Analysis

The purpose of the Multi-Criteria Decision Analysis (MCDA) was to propose a structured process for assessing and selecting (i) impacts to be measured; (ii) indicators to assess those impacts; and (iii) the Framework as a whole.

To prioritise impacts, we sought to assess those that were considered most important by the following key stakeholder groups:

- Appliance users
- Companies
- Investors
- Donors

As noted above, through the stakeholder engagement phase, we collected views from a sample of investors and donors on which types of impact were most important. To help future-proof the Framework, we also asked about the importance of each impact for today, and for the foreseeable future. We also sought the views of companies who produce and market high-performing appliances. The end-user research provided the views of the users (or potential users) of appliances.

With this information, and from the literature review for TVs, fans, refrigerators, and solar water pumps, we identified a long list of outcomes. These were filtered based on which were most directly related to the use of the four high-performing appliances. This led to:

- Seven direct and indirect outcomes and 20 potential indicators for TVs;
- Eight direct and indirect outcomes and 23 potential indicators for fans;
- 11 direct and indirect outcomes and 35 potential indicators for refrigerators; and
- 16 direct and indirect outcomes and 23 potential indicators for solar water pumps.

To streamline the number of outcomes and remove unnecessary indicators, we assessed the indicators against the following set of characteristics that make for useful measures:

- **widely applicable:** the outcomes or indicators would be comprehensible to people from different nations, rural and urban settings, cultural and religious traditions, etc.
- **comparable:** measurement of the outcomes in different locations (countries, regions, etc.), environments (e.g. urban vs rural), and time periods reflect meaningful differences in the underlying impact, rather than differences due to other factors affecting the outcome.
- **robust:** measurement of the outcomes are not significantly affected by small changes in the method or timing of data collection or the presence of outliers.
- **relevant:** indicators closely reflect the intended outcome.
- **time-bound / timely:** indicators capture changes in an appropriate window of time.
- **specific:** outcomes and indicators are detailed enough to be measurable and meaningful.
- **dynamic:** outcomes can be increased or decreased by changes in the adoption of appliances.

To avoid the classic problem of ignoring impacts that are difficult to measure, we excluded the ease or cost of measuring impacts as a criteria for a useful measure. Accordingly, the Framework includes outcomes for which data are not readily available (i.e. data gaps). We recommend that users of this Framework collectively focus on closing these data gaps.

In addition to consulting the literature on the measurement of the impacts, we looked at other indicator frameworks, notably the United Nations Sustainable Development Goals (SDGs) and IRIS+ [23] (produced by the Global Impact Investing Network). We compared the long list of indicators that relate to the SDGs to reduce the risk of omitting relevant impacts and assess the breadth of impacts for high-performing appliances across the SDGs. For example, in this mapping only one of the 17 SDGs (SDG 17, Life On Land) did not have a related indicator.

Following this assessment, some outcomes and indicators were rejected, while other outcomes and indicators were refined to improve their assessment scores. This led to the final set of outcomes and indicators presented in this report.

We also assessed each of the sets of indicators that correspond with the four types of appliances as a whole, by answering the questions in table 18 below.

23 Impact Reporting and Investment Standards, developed by the Global Impact Investing Network

Table 10: The Correspondence of Indicators to the Four Types of Appliances

QUESTION TO ASSESS THE FRAMEWORK AS A WHOLE	ASSESSMENT
Does the Framework reflect appliance users' perspectives on the impact of appliances?	**Yes:** the end-user research played an important role in the choice of outcomes and indicators. Ongoing input from appliance users is needed to keep the Framework up-to-date.
Does it cover the important outcomes?	**Most likely:** what is most important is subjective and there cannot be a definitive answer to this question. The stakeholder consultation, literature review, and end-user research should provide confidence that the Framework includes the most important outcomes, though this should continue to be validated through ongoing use and development of the Framework.
Is it considered useful to those who must produce the data to populate it?	**Unknown:** whether the Framework is useful to those who produced data to populate it (primarily users) depends on how the Framework is used in practice.
Does it inform links between different outcomes?	**No:** the interactions between different outcomes are complex. Adding maps that show the outcomes link to each other would improve the Framework.
Does it recognise that impact may change over time?	**Yes:** the Framework can and should be adapted over time as the market and products change, impacts change, and new data on impacts become available.
Does it align with good practises, such as the Impact Management Project (IMP) and the GOGLA Standardised Impact Metrics for the Off-Grid Solar Energy Sector?	**Yes:** the structure of the Framework was based on GOGLA's set of standardised impact metrics, and the IMP and IRIS+ were referred to in the development of the framework.
Are the costs of collected data as low as possible, without negatively affecting the validity and utility of the Framework?	**Unknown:** the Framework, by design, did not prioritise impact data that are least costly to collect, but it does include values for formula variables that are currently available, thus helping minimise costs to those who use the Framework to assess the impact of high-performing appliances.

Overall, we believe the Framework is helpful in assessing the impact of high-performing appliances, even though like any impact assessment framework it has limitations.

MCDA Limitations

The main limitations of the MCDA are:

- Stakeholder feedback was limited. It was difficult to get input from some stakeholders on their priorities for assessing impact. While there is interest in having a robust framework, few investors, donors and companies took up the opportunity to provide their views on what impacts and measures are most important. Even though the end-user research was robust, the literature review was broad, and while we were open to adding new outcomes at any point in the process, we cannot be fully confident that the choices of impacts and indicators reflect a broad consensus among stakeholders. We are unsure that such a consensus exists.
- Lack of available literature. For some outcomes and / or impacts, there was no or limited literature on the experience of measurement for use in the assessment. In such cases, we used our judgement and experience to assess potential indicators against the desired characteristics. The indicators and formulae can be improved going forward based on the experience of use. The system for scoring the indicators (see Appendix 1) was simple and included subjective as well as objective elements. It provided a useful and transparent, but not a foolproof, method of selecting measures.
- Translating into practice. For many indicators, whether they are good indicators depends on how they are implemented in practice. Data collection practices are very important to the integrity and utility of the Framework, but it is complicated to prescribe data collection practices to fit all contexts.

Data Gaps

Below is a summary of data gaps identified through the process of collecting evidence for the indicators. These data gaps should inform future research to improve the Framework.

This report recognises three types of data gaps:

1. Pipeline Variables – specific variables for which not enough data were found. The Pipeline Variables are highlighted in the Standard Variables table.
2. Indicator Improvement – comments on how specific indicators can be improved. The Indicator improvements are detailed in the below table (Indicator improvement data gap table).
3. Pipeline Indicators – general suggestions for new indicators that should be developed for the framework to be comprehensive. The Pipeline Indicators appear in the bulleted list below (Pipeline Indicators).

Pipeline Indicators

- Indicators that capture financial data about users, before and after purchasing appliances. Economic indicators tend to get the most interest from stakeholders, yet valuable data are still not available. For example, these could be indicators that capture the income of end-users on the day of purchase, and the change in income levels post-purchase. Further effort is needed to facilitate the collection and sharing of such data.
- Indicators that measure the affordability of appliances. Financing and remote payment mechanisms (such as PAYGo) have revolutionised the off-grid appliance sector, enabling distribution at scale. However, important data points regarding the financial behaviour of appliance users post-purchase (e.g. default rates), are still not widely shared. This lack of data sharing limits off-grid appliance sector stakeholders' ability to understand the true affordability and accessibility factors of new appliances.
- Indicators that measure the environmental impact of appliances. These include the impact of uncontrolled disposal of multiple components of appliances and the impact of solar water pumps on underground water levels. Since high levels of appliance distribution are only recent, evidence on long-term environmental impacts is still scarce. Further indicators are needed to accurately account for the environmental consequences associated with appliances. These will hopefully enable mitigation mechanisms that will allow net-positive effects on the planet.
- Disaggregated indicators for gender equality and social inclusion. Understanding the impacts of appliances on marginalised groups is important. This is currently not well understood. While reporting on gender is becoming more mainstream.[24] There is a need to look beyond and consider other demographic features (e.g. income level, gender, household head), their intersection, and how these contribute to inequality.
- Indicators that capture the impact of circular appliances and business models. A set of new environmental and social indicators can help capture the impact of new circular appliances and business models. These include repairable appliances, "pro-repair" business models, and interoperable appliances.

Indicator Improvement Data Gap Table

The table below summarises the notes on individual data gaps identified through the process of collecting evidence for the indicators. These are working notes that should be read in that context of each indicator.

24 Stephanie Hirmer, Alycia Leonard and Constanza Conforti, The power of language: Exploring values, empowerment dynamics and communication strategies for gender-inclusive energy service design in rural Uganda. (2022) Energy Res. Soc. Sci., vol. 85, no. October 2021, p. 102379, 2022, doi: 10.1016/j.erss.2021.102379.

Table 11: All Appliances

ID	INDICATOR	FORMULA
ENVIRONMENTAL		
Emissions		
A-ENV1	**Tonnes of CO_2 emissions avoided**	• Addressing more accurate usage pathways of appliances and especially solar water pumps. The percentage of cases that a solar-powered appliance is used in addition to the diesel-powered appliance. • Identifying lifecycle emissions reduction, considering also production, transportation, maintenance, and the replacement of solar-powered appliances. • In the case of cooling (fan and refrigerator), addressing passive methods (e.g. building standards) as a benchmark for avoided emissions. For example, if a building is a metal sheet building, and then has multiple fans to cool it, it will show higher levels of 'avoided emissions' and greater efficiency achieved, but is actually an un-optimised solution.
E-waste		
A-ENV2a	**Annual tonnes of electric waste added**	Addressing different components according to their environmental impact (e.g. battery vs cables)
A-ENV2b	**Annual tonnes of electric waste avoided**	• Solar-powered appliance recycling potential in East Africa and Asia. • Including the e-waste saved through using reused materials in the manufacturing process
ECONOMIC		
Expenditure		
A-ECO1	**USD savings in fuel costs (solar-powered appliance replacing a non-solar-powered appliance)**	• Includes other expenses that are not fuel. • Size of replacement market for solar-powered appliances. • The operational costs for solar-powered appliances.
Job opportunity		
A-ECO2	**Number of new jobs created**	Explore indirect jobs from upstream sectors and potential job displacement from traditional energy sectors
SOCIAL		
Access and inclusion		
A-SOC 1	**Number of people who gained access to an off-grid appliance for the first time**	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).Disaggregate this indicator for gender and income levels.
A-SOC 2	**Number of customers currently accessing off-grid appliances through flexible financing**	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). Disaggregate this indicator for gender and income levels. Gather data about number of customers with access to flexible financing beyond PAYGo.
A-SOC3	**Number of people below the poverty line with access to an appliance**	
Ownership		
A-SOC4	**Affordability of monthly repayments**	More work on how to include changes in income post-purchase in the case of productive use of energy (e.g. irrigation).Including the income increase post-purchase.Measure the default rates of appliances as a more accurate proxy to affordability. Disaggregate this indicator for gender.

Table 12: Fans only

ID	INDICATOR	FORMULA
SOCIAL		
Comfort		
F-SOC1a	**Total hours of improved thermal comfort, cumulatively**	None
F-SOC1b	**Number of people who are experiencing improved thermal comfort**	Better understanding the accessibility of household members, especially women, to fans used at home.
Health and wellbeing		
F-SOC2a	**Number of people experiencing improved indoor air quality**	• The Rural Senses (2021) survey of fan users in India found that 47.8 % of the respondents associated fan use with improved air quality. • A study conducted in Peru has found that fans can be 70–80% more effective in disinfecting air.[25] • 81% of respondents of CLASP's survey of fan users in Bangladesh associated fan use with improvements in quality of life. 7% was attributed to less dust, a strong indicator for improved air quality.[26] • All the respondents in the Zhai et al (2015) study of Human Comfort and Perceived Air Quality in Warm and Humid Environments reported improved thermal comfort and perceived air quality (PAQ) when using a fan (Zhai et al., 2015).
F-SOC2b	**Number of people who perceived a reduction in carriers of vector-borne disease, e.g. mosquitos**	More evidence regarding the efficacy of fans for reducing mosquito-transmitted diseases.
F-SOC2c	**Number of people who perceived improved health**	More evidence regarding the impact of fans on health.
F-SOC3a	**Number of people spending more time together**	More evidence regarding the impact of fans on spending more time together.

Table 13: TVs only

ID	INDICATOR	FORMULA
SOCIAL		
Health and wellbeing		
TV-SOC1a	**Number of people exhibiting an increase in sedentary behaviour**	The impact of using high-performing off-grid TVs on the increase of sedentary behaviours, physical inactivity and associated risks. The current literature has a strong Global North and higher income groups focus. Impact insights broken down by different appliance access use cases: gender access, actual watching time with different energy systems.
TV-SOC1b	**Number of people who experience reduced stress levels**	More evidence about the impact of TVs on mental health.
TV-SOC1c	**Number of children who are perceived to be more exposed to violent and other undesired content**	It is unknown if the TV suppliers offer any form of appliance use training that educate users about measures to prevent other household members from being exposed to violent and other undesired content.
TV-SOC2a	**Number of people spending more time together due to TV ownership**	Impact insights from other Global South regions, especially Sub-Saharan Africa. Impact insights broken down by different appliance access use cases: gender access and age. Impact insights broken down into differences of geography, seasonality or differences in time-use.
TV-SOC2b	**Number of people who perceive improved quality of life due to TV ownership**	• More accurate definition of quality of life with regards to a TV. • Gender-disaggregated data.
Information access & learning		
TV-SOC3a	**Number of people accessing information through a TV**	More evidence regarding the value of the information accessed via a TV
TV-SOC3b	**Number of children accessing education programmes through a TV**	Evidence from TV-enabled remote learning during the COVID-19 pandemic.

25 Shengwei Zhu et al, Numerical Modeling of Indoor Environment with a Ceiling Fan and an Upper-Room Ultraviolet Germicidal Irradiation System, (2014), Building and Environment 72: 116–24, https://doi.org/10.1016/j.buildenv.2013.10.019

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

Table 14: Refrigerators only

ID	INDICATOR	FORMULA
ENVIRONMENTAL		
Food spoilage		
SF-ENV1a	**Annual tonnes reduction in food spoilage (domestic refrigerators)**	Missing data on the average refrigerator-related food savings and waste per year for households in regions and countries in Asia and East Africa.
SF-ENV1b	**Annual tonnes reduction in food spoilage (commercial refrigerators)**	Missing data on the average refrigerator-related food savings and spoilage per year for businesses in regions and countries in Asia and East Africa.
Emissions		
SF-ENV2	**Kg of CO_2e refrigerant-related emissions added**	• Enhancing access to data on the types of refrigerants used • Estimating avoided emissions from hydrocarbons • Estimate emissions from the use of HFCs as refrigerants in cold rooms, and as blowing agents
ECONOMIC		
Business income		
SF-ECO1a	**Number of businesses generating at least 30% additional annual income due to refrigerator ownership**	Missing more robust data regarding growth in incomes for en- users as a result of using solar-powered refrigeration, specifically for East Asia.
SF-ECO1b	**Number of businesses generating additional income of any value due to owning a refrigerator**	Data is missing regarding the increase in income as a result of a refrigerator.
SOCIAL		
Health and wellbeing		
SF-SOC1a	**Number of health facilities offering improved health services due to the use of refrigeration**	Researching the effect on health facilities purchasing more than one solar-powered refrigerator.
SF-SOC1b	**Percentage reduction in vaccine waste**	Gaining more information on vaccine waste rates due to a lack of refrigeration.
SF-SOC2a+b	**Number of people / women who perceive that a solar-powered refrigerator provides them with more free time**	More evidence about the link between the use of a refrigerator and time saved, especially for women.
SF-SOC3	**Number of people who experience improved quality of life due to owning a refrigerator**	Impact of a solar-powered refrigerator on individual stress and well-being levels.
Food security		
SF-SOC4	**Number of people who perceive improvement in food security and nutrition due to owning a refrigerator**	More data into the influence of a refrigerator on food security, including quantity and variety of food.

Table 15: Solar Water Pumps only

ID	INDICATOR	FORMULA
SOCIAL		
Health and wellbeing		
SWP-SOC1	**Number of people benefiting from improved access to water, sanitation & hygiene**	Missing data about the percentage of cases where a household is using more than one solar water pump, or that a few households share a pump.
SWP-SOC2a+b	**Number of people / women who perceive that a solar water pump provides them with more free time**	More data on the gender-specific impact of solar water pumps.
SWP-SOC3	**Number of people who perceive enhanced quality of life through using a solar water pump**	Evidence of the impact of solar-powered appliances on individual stress and wellbeing levels.
Food security		
SWP-SOC4	**Number of people who attribute the use of the appliance to improved food security**	Better definition and evidence regarding food security, including parameters of variety, continuity and resilience of food supply.
ECONOMIC		
Business income		
SWP-ECO1	**Number of people experiencing an annual increase in business income of at least x% (30% or 50% increase)**	The different impact for different types of businesses and for farm size. Different types of yield for different types of crops and context as a variable for increase in income.
SWP-ECO2	**Number of households experiencing an annual increase in agricultural yields of at least 30%**	The different impact for different types of businesses and for farm size. Different types of yield for different types of crops and context as a variable for increase in income.

Summary and Recommendations

Summary

The development of this framework illustrated four high-level findings:

- The impact of high-performing appliances goes beyond SDG 7 (Affordable and Clean Energy). The research shows evidence for measurable positive impacts across many areas of end-users' lives. For example, the indicators in the Framework relate to SDG 3, (Health and Well-Being), SDG 4 (Quality Education), SDG 8 (Decent Work and Economic Growth), and SDG 13 (Climate Action), among others.
- High-performing appliances also introduce potential negative impact and risks that should be mitigated. These include negative impacts on the environment in the form of e-waste and potential risks to groundwater level. Measuring and reporting on these measures is essential for enabling the development of mitigation practices that will reduce negative impact.
- Data on the impact of high-performing appliances are fragmented and of variable quality. While many studies are available, comparing and harmonising them is challenging due to different measurement and reporting standards, as well as restrictions on sharing. This inhibits collective learning and evidence growth needed to accurately report the impact of the sector.
- There is a proven interest in assessing impact accurately, but more needs to be done. While there was an interest to measure impact more accurately, there is insufficient interest to invest time in the research needed. For instance, we found it hard to engage foundations and investors in the interviews.

These findings lead to our recommendations.

Recommendations

1. **Use this framework to manage and increase your positive impact.** We invite the multiple stakeholders in the off-grid appliance sector to utilise this Framework to identify where they may be able to mitigate negative impacts and and increase positive impacts in the sale, distribution, and service of high-performing appliances. Adopting this Framework will help improve the global awareness of the magnitude and breadth of impact created by high-performing appliances. This will support investment in and responsible growth of this sector.
2. **Conduct follow up research to cover identified data gaps.** There are gaps in the evidence about the impact of high-performing appliances. Ensuring the responsible growth of the sector requires filling in these evidence and data gaps.
3. **Support evidence and consensus building.** One of the key objectives of this Framework is to enable consensus creation around the impact of high-performing appliances. This can only be done through an ongoing debate and feedback. We invite the users of this Framework to contribute to the creation of impact counsensue by suggesting supporting evidence that can increase the accuracy of the Framework.
4. **Develop digital tools and standards for sharing impact data easily across organisations.** Existing data technologies can be utilised to improve the collective learning in the sector and to offer a more robust evidence-building process. We call for a collaborative creation of impact data sharing protocols and the required Application Programming Interface that will enable cross-stakeholder data sharing without compromising data privacy or competitive advantage.

Appendix 1: Decision Points in Selecting the Indicators

There was a structured process to select the indicators for TVs, fans, solar water pumps, and refrigerators. The process was iterative rather than linear. At different points in refining the indicators we referred to the literature and the end-user research. The process comprised:

- Literature review of the impacts of high-performing appliances. This provided an initial set of indicators based on impacts that had been researched or otherwise reported.
- Input from funders and investors. We interviewed 10 donors and investors to learn what types of impacts they were most concerned about, based on their understanding of the research and issues. Table 3 shows the frequency with which different issues were raised in these interviews.
- Development of initial indicators. From the research and funders, we developed an initial list of indicators that corresponded to the research and funder and donor views of what was important.
- Preliminary assessment of initial indicators. The indicators were assessed against seven characteristics to determine which indicators would be most appropriate for an impact assessment framework used by multiple organisations in different countries and contexts. Each indicator was given a score of 0, 1 or 2 for each of the following:
    - widely applicable: would be comprehensible to parties from different nations, rural and urban settings, and cultural and religious traditions, etc.
    - comparable: results from different locations (countries, regions, etc.), environments (e.g. urban vs rural) and time periods reflect meaningful differences in the underlying impact, rather than differences due to other factors affecting the outcome.
    - robust: results are not significantly affected by small changes in the method or timing of data collection or the presence of outliers.
    - relevant: closely reflects the intended outcome.
    - time-bound / timely: captures changes in an appropriate window of time.
    - specific: detailed enough to be measurable and meaningful.
    - dynamic: can be increased or decreased by changes in adoption of appliances.
    - These findings lead to our recommendations.

Table 3 below shows how the criteria were scored. The assessment was based on judgement and research of the strengths and weaknesses of different types of indicators. Accordingly, some of the assessment can be disputed. The results of the assessment are shown in Table 3 for the sake of transparency and are included in the corresponding spreadsheet of indicators.

- refinement of initial indicators: The preliminary assessment revealed some weaknesses in some indicators that could be improved by refining how the indicators were defined or articulated. Indicators that scored low and could not be easily improved were removed from consideration. The final set of indicators are those that scored highest.
- assessment of indicators based on review of end-user research: The preliminary assessment had not included the perspective of end-users or consumers of high-performing appliances, except to the extent these were already reflected in the research or funder or donor views. After the end-user research had been conducted, the indicators were assessed against two additional criteria, namely:
    - supported by literature review: the literature review suggests the impact is significant / common / important enough to include.
    - supported by end-user research: end-user research suggests the impact is significant / common / important enough to include.
- final selection: The indicators that achieved the highest scores were selected for inclusion into the impact assessment framework.

Table 16: Factors Most Frequently Raised in Donor and Investor Interviews (N=10)

META-CATEGORIES	INVESTORS	INVESTOR REASONING	DONORS	DONOR REASONING	WEIGHTED AVG*	COMBINED REASONING
Affordability / Poverty (Increase or Decrease in Costs)	🟢	**2/4 investors mentioned** • poverty focus • 'affordability' & 'income savings on energy costs' **note:** 'don't look at the socio-economic impacts because we don't have a framework'	🟢	**4/6 donors mentioned** • 'addressing poverty' • 'income and asset increase' (2x) • affordability • 'increased income quality, equity'	🟢	**6/10 interviewees mentioned**
Food	🟠	**1/4 investors mentioned** • 'reduction in spoilage'	🟢	**5/6 donors mentioned** **note:** specific reference to fridges • food 'waste' / 'loss' • 'nutrition' • food cleanliness • dedicated food team	🟢	**6/10 interviewees mentioned** **note:** most responses in favour of this area came from donors
Gender	🟠	**3/4 investors mentioned** • gender equality • impact framework inclusive of gender	🟠	**2/6 donors mentioned** • impact framework 'inclusive of gender' • 'well being of women' and 'gender-related awareness'	🟢	**5/10 interviewees mentioned**
Productivity	🟠	**3/4 investors mentioned** • 'improved productivity' • 'productivity of appliances' • want to 'unpack the impact of productive use of energy' • 'Economic productivity'	🟠	**2/6 donors mentioned** • 'productive use' • 'livelihood productivity'	🟢	**5/10 interviewees mentioned**
Climate Change	🟢	**2/4 investors mentioned** • 'CO_2 emission reduction corresponding to those social human services (SHS) connections' • 'GHG emissions'	🟢	**3/6 donors mentioned** • 'GHG decreases' (2x) • 'ground-water levels' (2x) and 'water spillage' (**note:** specific to SWP) • 'climate change' • dedicated 'climate team'	🟢	**5/10 interviewees mentioned**
Access	🟢	**3/4 investors mentioned** • 'number of people'	🟠	**2/6 donors mentioned** • 'number of people'	🟢	**5/10 interviewees mentioned**
Livelihood (Additional Income Sources or Livelihood Improvement)	🟠	**1/4 investors mentioned** • 'accessible income-generating activities'	🟢	**3/6 donors mentioned** • 'livelihood creation' • 'jobs created' • 'income generation / livelihoods improvement' • 'increasing revenue [of mini-grids]'	🟠	**4/10 interviewees mentioned**
Environmental Effects	🟠	**1/4 investors mentioned** • 'recycling'	🟠	**2/6 donors mentioned** • 'recycling' (2x) • 'environmental impact'	🟠	**3/10 interviewees mentioned**
Cooling / Indoor Climate	🔴	**0/4 investors mentioned**	🟠	**2/6 donors mentioned** • 'cooling' • 'better indoor climate'	🟠	**2/10 interviewees mentioned**
Health Effects	🔴	**0/4 investors mentioned**	🔴	**1/6 donors mentioned** • 'nutrition' **note:** specific to fridges	🟠	**1/10 interviewees mentioned**
Behavioural Effects	🔴	**0/4 investors mentioned**	🔴	**1/6 donors mentioned** • 'entertainment' • 'informed'	🟠	**1/10 interviewees mentioned**

🟢 **HIGH IMPORTANCE:** mentioned by half or more than half of interviewees
🟠 **MEDIUM IMPORTANCE:** mentioned by a third or less of interviewees
🔴 **LOW IMPORTANCE:** not mentioned at all

Table 17: Criteria for Assessing Indicators

INDICATOR CRITERIA			
Widely applicable: would be comprehensible to parties from different nations, rural and urban settings, and cultural and religious traditions, etc.	All, nearly all	Some / many	None / few
Comparable: results from different locations (countries, regions, etc.), environments (e.g. urban vs rural) and time periods reflect meaningful differences in the underlying impact, rather than differences due to other factors affecting the outcome	Yes, with minimal or no accounting for differences in context	Yes, with some accounting for differences in context	No, without significant accounting for differences in context
Robust: results are not significantly affected by small changes in the method or timing of data collection or the presence of outliers	Mostly	Sometimes	Unlikely
Relevant: closely reflects the intended outcome	Zero or one assumption must be made	Two or three assumptions must be made	Four or more assumptions must be made
Time-bound / timely: captures changes in an appropriate window of time	Yes	-	No
Specific: detailed enough to be measurable and meaningful	Yes	Potentially yes, if clear definitions or standardised ways of measuring used	No
Dynamic: can be increased or decreased by changes in adoption of appliances	Measure is sensitive to adoption of appliances	Measure only partially sensitive to adoption of appliances	Will not change much or at all as appliances are adopted

- **HIGH IMPORTANCE:** mentioned by half or more than half of interviewees
- **MEDIUM IMPORTANCE:** mentioned by a third or less of interviewees
- **LOW IMPORTANCE:** not mentioned at all

Table 18: Solar Refrigeration Technologies

REFRIGERATION TECHNOLOGY		APPLICATION	WORKING FLUID/REFRIGERANT	ADVANTAGES & DISADVANTAGES
Solar Electric Cooling [31]	Vapour Compression System Life expectancy: 15 years	Freezing, refrigeration for food storage & vaccine storage	In the off-grid market, three refrigerants dominate the market for refrigerators under 600 litre capacity. These are: • Natural refrigerants (Hydrocarbons – HCs): 1. Propane (R2900); 2. Isobutane (R600a); • Hydrofluorocarbons (HFC): • 1,1,1,2-tetrafluoroethane R134a; with a global warming potential (GWP) of 1,430 on a 100-year timescale. Used by more than 50% of manufacturers targeting off-grid areas. • The net greenhouse gas mitigation potential that a 50L HC-based rather than a HFC-based fridge can claim is approximately 89.9 kg of CO_2e avoided emissions.	✓ This type of system dominates the off-grid refrigeration market.[27] May facilitate rapid penetration of solar refrigeration through adaptation. ✓ Substantial industry experience and benefit from economies of scale. ✓ High Coefficient of Performance (COP),[28] a metric of refrigerating efficiency, of 2–4. ⊖ High cost of PVs ⊖ Space required for PVs ⊖ Battery required for storage and back-up ⊖ Vulnerable to leaks ⊖ Environmental impact associated with associated refrigerant emissions or method of disposal; ⊖ Substantial energy required to drive the compressor
	Stirling Refrigerator System Life expectancy: 15 years	Freezing (up to -80° Celsius), suitable for medical applications such as storage of COVID -19 vaccines	Typical working fluids are Hydrogen, Nitrogen or Helium	✓ High COP of around 3; ✓ No adverse environmental impacts from working fluid ✓ Light-weight ⊖ High production cost ⊖ Expertise required in manufacture; ⊖ Space required for solar PVs
	Thermoelectric (Peltier) System Life expectancy: 23 years	Freezing, refrigeration for food storage & vaccine storage	None	✓ No environmental impact from working fluid; ✓ No moving parts hence little wear and tear; ✓ Light-weight and compact; ✓ No risk of leakage. ⊖ Very low COP of around 0.5; ⊖ High cost; ⊖ Does not reach sufficiently low temperature for cooling food easily; ⊖ Low reliability
Solar Thermal Cooling	Absorption System Life expectancy: 10 years	Refrigeration for food storage & vaccine storage	• Absorbent: Lithium bromide (LiBr) as the absorbent, Refrigerant: water; • Absorbent: Water, Refrigerant: Ammonia.	✓ Lower environmental impact of refrigerants: Ammonia does not deplete the ozone nor contribute to global warming.[29] Water has no environmental impact; ✓ Low cost compared to vapour compression system; ✓ Lower system pressure than vapour compression system, hence reduced chance of leakage; ✓ Little energy required to drive the circulation pump; ✓ Low running cost; ✓ NH3 / HO system even more affordable than Vapour compression system; ✓ Solar collectors or waste heat from other processes can be used. ⊖ Low COP of between 0.8 and 1.1; ⊖ High costs for LiBr / H_2O system; ⊖ In case of water as the refrigerant, it cannot cool below 5 degrees Celsius. More research is being conducted to reduce this further.[30] ⊖ Lithium bromide is corrosive in nature.
	Absorption System Life expectancy: 30 years	Refrigeration for food storage & vaccine storage	• Water vapour adsorbed by silica gel; • Ammonia vapour adsorbed by charcoal	✓ Lower environmental impact of coolants: Ammonia does not deplete the ozone nor contribute to global warming.[31] Water has no environmental impact; ✓ Solar collectors or waste heat from other processes can be used. ⊖ High cost of system; ⊖ Very low COP between 0.7 and 0.8.

27 Efficiency for Access, Phasing Down HFCs in Off- and Weak- Grid Refrigeration: An opportunity to reduce greenhouse gas emissions (2021). https://efficiencyforaccess.org/publications/phasingdown-hfcs-in-off-and-weak-grid-refrigeration-an-opportunity-to-reduce-greenhouse-gas-emissions

28 Ayman Jamal Alazazmeh, and Esmail Mokhelmer, Review of Solar Cooling Technologies (2015) Journal of Applied Mechanical Engineering, Volume 4 Issue 5. https://www.walshmedicalmedia.com/open-access/review-of-solar-cooling-technologies-2168-9873-1000180.pdf 22

29 Ashrae, Amonia as a refrigerant (2017) http://www.cold.org.gr/library/downloads/Docs/5875_ASHRAE%20Position%20Document%20on%20Ammonia%20as%20a%20refrigerant%20.pdf

30 Database on Noteworthy Contributions for Science and Technology (Japan). "Development of Water-Lithium Bromide Low-Temperature Absorption Refrigerating Machine". https://dbnst.nii.ac.jp/english/detail/1748

31 Ashrae, Amonia as a refrigerant (2017) http://www.cold.org.gr/library/downloads/Docs/5875_ASHRAE%20Position%20Document%20on%20Ammonia%20as%20a%20refrigerant%20.pdf

GOGLA presents the following variation in capital expenditure, operational expenditure and total cost of operation associated with solar refrigeration technologies in India.

Table 19: Costs Associated with Prevalent Off-Grid Solar Refrigeration Technologies in India [32]

	100-LITRE CAPACITY	150- LITRE CAPACITY	268-LITRE CAPACITY	5 MT CAPACITY	500-LITRE CAPACITY
Solar PV with PCM Thermal Battery	TCO: USD 5,930 OPEX: USD 9/litre CAPEX: USD 50/litre	TCO: USD 1,130 OPEX: USD 2 / litre CAPEX: USD 6 / litre	TCO: USD 1,467 OPEX: USD 1.5 / litre CAPEX: USD 4 / litre	TCO: USD 39,070 OPEX: USD 4,000/MT CAPEX: USD 3,800/MT	TCO: USD 6,130 OPEX: USD 0.8 / litre CAPEX: USD 6 / litre
Solar PV with Battery	TCO: USD 6,100 OPEX: USD 16/litre CAPEX: USD 4.5/litre	TCO: USD 1,225 OPEX: USD 1 / litre CAPEX: USD 7 / litre	TCO: USD 1,492 OPEX: USD 2 / litre CAPEX: USD 4 / litre	TCO: USD 44,330 OPEX: USD 4,200/MT CAPEX: USD 4,600/MT	TCO: USD 6,670 OPEX: USD 2 / litre CAPEX: USD 11 / litre
Solar PV with Biomass	-	-	-	TCO: USD 47,200 OPEX: USD 4,000/MT CAPEX: USD 5,400/MT	-
Solar PV with Battery and Grid	-	TCO: USD 1,143 OPEX: USD 2 / litre CAPEX: USD 5 / litre	TCO: USD 1,846 OPEX: USD 4 / litre CAPEX: USD 3 / litre	-	-
Solar PV with Battery on Grid and Diesel Generator	-	-	-	TCO: USD 59,800 OPEX: USD 9,200 / MT CAPEX: USD 2,700 / MT	-

Lifetime of a Solar Water Pump

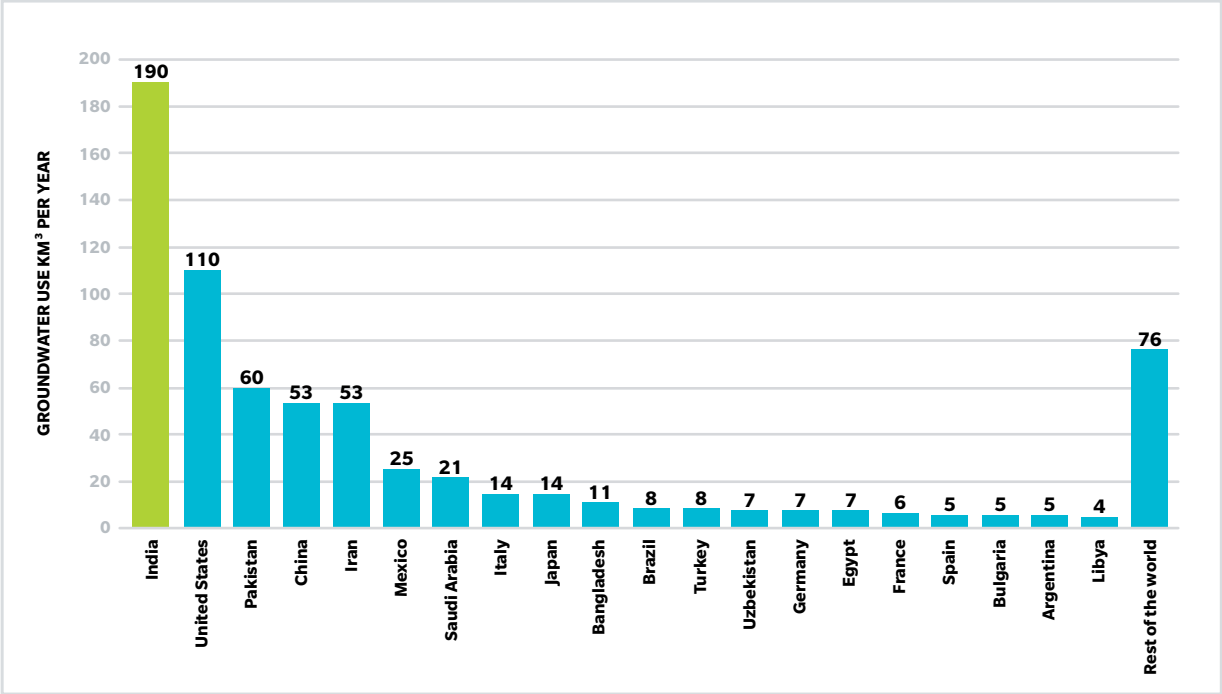
Table 28 below gives an indication of the lifespan of different irrigation technologies, including solar-powered technologies.

Table 20: Irrigation System Component and Typical Lifespan in Years (GiZ, 2016)

IRRIGATION SYSTEM COMPONENT	TYPICAL LIFESPAN (YEARS)
Earthen Weirs / Dams, Farm Ponds	20
Unlined Canals	15
Civil Works Structures (Head portion)	40
Civil Works Structures (Field Level)	20
Underground Primary and Secondary Pipe System	15 – 20
Unburied Pipe System	5 – 10
Fittings, Filter and Metering Devices, etc.	5 – 10
Centre Pivot System	20
Other Travelling Sprinkler Systems	10 – 15
Impact Sprinkler Head	8 – 10
Drip Tape	1 – 2
Drip Tube, Porous Pipes	3 – 5
Drip Emitters, Micro Sprinklers	3 – 5
Electric Motor	7 – 10
PV Generator	15 – 20
PV Controller	3 – 5
PV Pump (Submersible)	5 – 7
PV Pump (Surface)	3 – 5
Lithium-ion batteries	11 – 15

32 GOGLA et al, Global Off-Grid Solar Market Report: Semi-Annual Sales and Impact Data July – December 2021 (2021) https://www.gogla.org/sites/default/files/resource_docs/gogla_sales-and-impact-reporth2-2021_def2.pdf

Figure 3: Groundwater Use by Country, in Cubic Kilometres per Year (Giordano, 2009)



GROUNDWATER LEVELS

Figure 3 shows the groundwater use by country — with India in the global lead. India has become the largest consumer of groundwater at the global scale with an estimated total annual consumption of 190 km^3 per year, or about a quarter of the total global groundwater extraction annually. The annual replenishable groundwater resources of India [33] are estimated as 433 km^3,[34] with net availability of 399 km^3. The exploitation of groundwater in many states of India has expanded over the last five decades through installation of millions of irrigation wells.[35] In the northern state of Punjab, groundwater in 75% of the aquifers is overdrawn; in the western Rajasthan state, the corresponding fraction is 60%.[36]

33 GOGLA , Global Off-Grid Solar Market Report: Semi-Annual Sales and Impact Data July – December 2021 (2021) https://www.gogla.org/sites/default/files/resource_docs/gogla_sales-and-impact-reporth2-2021_def2.pdf

34 Mark Giordano, Global Groundwater? Issues and Solutions (2009). https://www.researchgate.net/figure/Groundwater-use-by-country-a_tbl1_305389873

35 Tushaar Shah, Climate change and groundwater: India's opportunities for mitigation and adaptation. (2009) Environmental Research Letters, 4(3), 035005. https://doi.org/10.1088/1748-9326/4/3/035005

36 World Bank, Deep Wells and Prudence: Towards Pragmatic Action for Addressing Groundwater Overexploitation in India (2010). https://openknowledge.worldbank.org/handle/10986/2835

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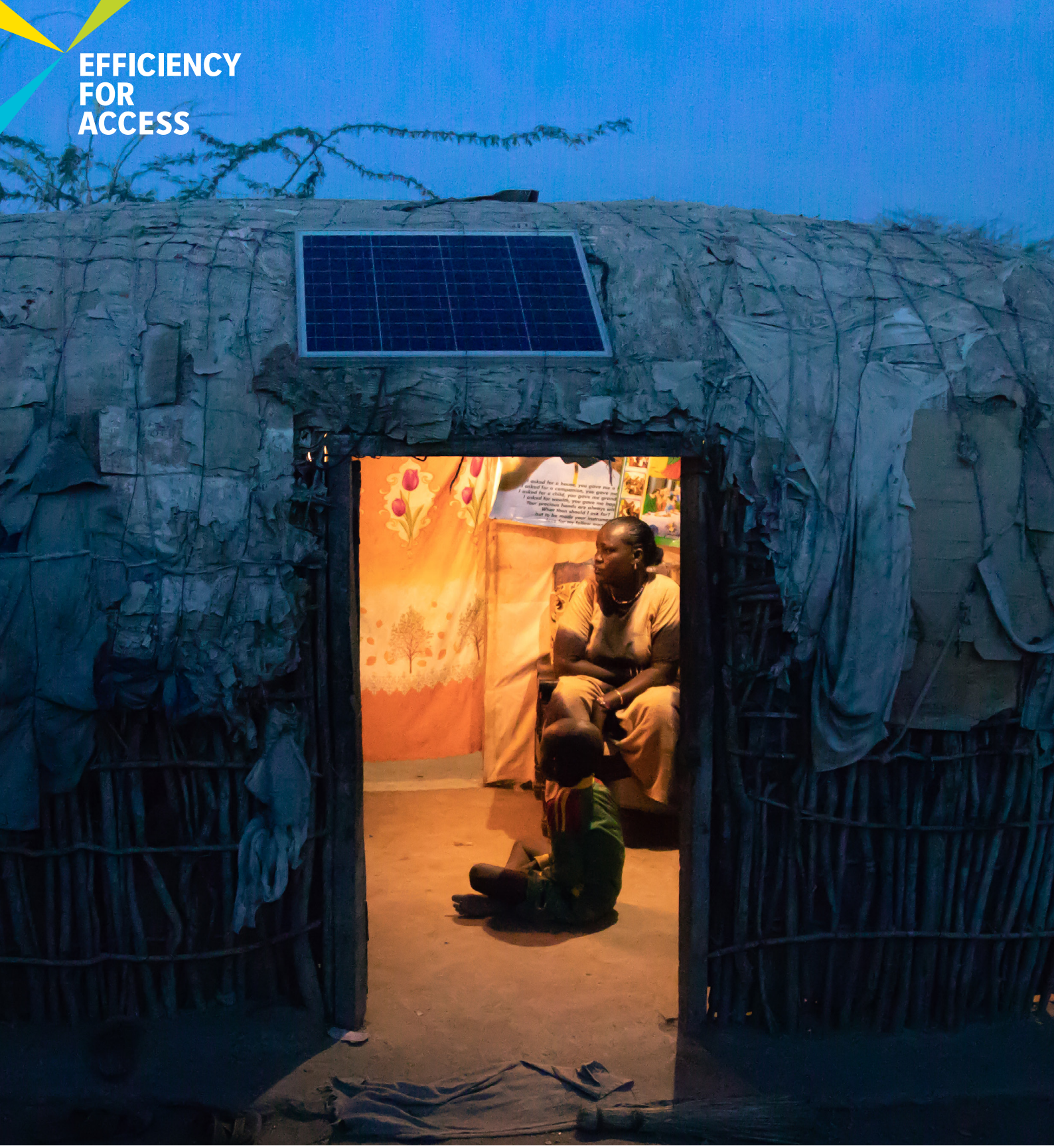

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