EFFICIENCY FOR ACCESS

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IMPACT ASSESSMENT FRAMEWORK

JULY 2022

REFRIGERATORS

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

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

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

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

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

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ABBREVIATIONS

*Please refer to the section, Framework at a Glance, for abbreviations for the variables used in the indicators. Refer to the tables for Input Variables and Standard Variables, as well as the list of IDs used for indicators.

BCG	Bacillus Calmette–Guérin (vaccination for tuberculosis)
DPT	Diphtheria, pertussis (whooping cough) and tetanus vaccination
FAO	Food and Agriculture Organization (UN)
FTE	Full-time equivalent
GWP	Global warming potential
HepB	Hepatitis B
IRENA	International Renewable Energy Agency
MCDA	Multi-Criteria Decision Analysis
NGOs	Non-Governmental Organisations
NREL	National Renewable Energy Laboratory (US)
OPEX	Operational expenditure per litre over the lifetime of a technology
OPV	Oral polio vaccine
PV	Photovoltaic
RS-SVT	Rural Senses and SVT Group
SDG	Sustainable Development Goal
SHS	Solar home system
STAR	Solar Thermal Adsorption Refrigerator
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
UPV	User-Perceived Value
WHO	World Health Organization

DEFINITIONS

Confidence level	The confidence level was assessed for each value for 'standard variables'. Three stars (***) indicate 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 (**) indicate that studies are either 'up to date' or have a 'large sample size', and one star (*) indicates that the studies are not up to date and have 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) and (c) rural areas (thinly populated areas).[1]
End-user	People who use the appliances.
Formula	The specific data points necessary to calculate a given impact metric or indicator and how they should be combined to arrive at the impact indicators result.
High-performing appliances	High-quality and efficient off- and weak grid appliances that are intentionally designed for end-users living in an energy-constrained environment and advertised for use primarily with a PV module or a solar home system.[2]
Indicator	The means by which an impact can be gauged.
Input variables	Variables 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.[3]
Pipeline variables	Variables that are of interest but where data is not yet available. While there is no set plan for these pipeline variables, we invite people to undertake research to close the existing data gap.
Standard variables	Variables provided within the Framework based on existing evidence.
The Framework	The Impact Assessment Framework for off- and weak-grid high performing appliances. The Framework describes metrics, indicators and formula 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: "Formula 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.[5]
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 Eurostat, Applying the Degree of Urbanisation. (2021) OECD. https://doi.org/10.1787/4bc1c502-en

2 Efficiency for Access, 'The State of the Off-Grid Appliance Market (2019) https://storage.googleapis.com/e4a-website-assets/Clasp-SOGAM-Report-final.pdf

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

4 Stephanie Hermer, 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.

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

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Purpose and Context

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

Purpose of the Framework

The Framework aims to facilitate the shared measurement and reporting of the impacts of refrigerators for a variety of stakeholders (e.g., distributors, developers, funders, appliance users and researchers) through the development of evidence-based social, environmental and economic impact indicators. Ultimately, this work seeks to contribute to the creation of an industry-wide consensus for the assessment, reporting and measurement of the impact of refrigerators. For more information on how this and the other three frameworks were developed, you are encouraged to consult the methodology report.

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

Context

A holistic understanding of the impacts of high-performing appliances is important because their use has been growing over the years. GOGLA's 'Global Off-Grid Solar Market Report Semi-Annual Sales and Impact Data' report, recorded sales of 470,000 off-grid solar appliances between July and December 2020.[6] While recorded global sales were less than anticipated due to the impacts of COVID-19, the easing of some countries' lockdown restrictions in the second half of the year may have contributed to an increase in sales for this period. This is despite the additional constraints on cash flows and shows the critical role of high-performing appliances in providing homes and businesses with essential services. While refrigerators only make up 1% of off-grid appliance sales, their importance in varying healthcare and business applications is being recognised increasingly.[7]

In line with the research carried out under Efficiency for Access' 'Off-grid Refrigeration: Technology Roadmap', the indicators are focused on refrigerators defined as follows:[8]

'An insulated cabinet with one or more compartments that are controlled within specific temperature range(s) and suitable for household or small commercial use for the storage of foodstuff and/or generation of ice in off-grid and weak-grid communities, prioritising rural and peri-urban low resource environments.'

The indicators focus on appliances which may include a refrigerator, a freezer or the two combined, with a gross storage volume from 80 to 600 litres for domestic and small commercial use respectively. This aligns with the EU classification of small refrigerators.[9] To use the indicators for refrigerators, it is important to briefly describe the scope of solar-powered refrigerators being considered in this Framework and the technologies they employ compared to conventional refrigeration.

Additionally, the following refrigeration segments of significance are considered in off- and weak- grid markets, where the use of solar energy can compensate for the lack of, or unreliable grid access:[10]

- medical-grade (vaccine) refrigerators
- household refrigerators and freezers, predominantly for food storage
- small commercial refrigerators, predominantly for cooling drinks as well as commercial food freezing, with higher cooling capacity than would be needed for household refrigerators
- small commercial ice-makers for ice-making or thermal packs, for use in commercial activities requiring high freezing capacity

It is important to note that not all indicators will apply to all types of refrigerators. This study does not consider larger refrigerators such as walk-in coolers, which are required for the preservation of large amounts of commercial stock from the agricultural, food, or medical industries.

In the case of solar electric cooling technologies, the use of a

6 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-andimpact-reporth2-2021_def2.pdf

7 ibid

8 Efficiency for Access, Off-Grid Refrigeration Technology Roadmap. (2019): https://storage.googleapis.com/e4a-website-assets/Refrigeration-Roadmap_FINAL.pdf

9 European Union, Supplementing Regulation 2017/1369 of the European Parliament and of the Council with regard to energy labelling of refrigerating appliances with a direct sales function. Official Journal of the European Union. (2019): https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R2018&rid=8

10 ibid

battery for energy storage in combination with the PV system ensures continuous refrigerator operation when there is limited solar energy available. The characteristics of a battery that determine its suitability for an appliance include its power rating, usable storage capacity, roundtrip efficiency, battery lifetime and safety characteristics. These in turn are determined by the type of storage system used. They vary between lithium-ion batteries, lead acid batteries, vanadium flow batteries and other less common types. Each of these batteries also poses a different hazard to the environment and humans during use or disposal.[11] While there are examples of lead-acid batteries in off-grid solar applications due to their wide availability and relatively low cost, the most widely adopted battery type for solar applications is the lithium-ion battery.[12]

Use of the Framework

The primary use cases of this Framework are:

- for organisations to assess the holistic impact they create by distributing refrigerators
- to support funding decision making with regards to refrigerators
- to inform mitigation strategies for unintended negative impacts of refrigerators
- to guide further research

To use the framework to estimate the impact of refrigerators 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:
    - **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.
    - **Standard variables**[13] 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 the results of your calculation. For example, "950 kg of CO_2 emissions was saved through the distribution of solar-powered refrigerators during 2021".

How to challenge the Framework

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

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

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

11 Energysage, Choosing a battery: how to pick the best battery for you. (2021): https://www.energysage.com/energy-storage/how-to-get-storage/choosing-battery/

12 Solar Power World, Common battery types used in solar + storage. (2018): https://www.solarpowerworldonline.com/2018/11/common-battery-types-used-in-solarstorage/

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

The Framework at a Glance

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

The Framework consists of:

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

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

The formulae to measure the impact, which can be positive or negative, is then 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 each compare against desired characteristics, namely widely applicable, comparable, robust, relevant, time-bound / timely, specific and dynamic. The maximum sum for the scores is 14. Please refer to the methodology report for more details.

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

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

Table 1: Refrigerator Framework

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					

ID	INDICATOR	FORMULA	MCDA SCORE	STATUS	IMPACT
Access and inclusion					
A-SOC1	**Number of people who gained access to an off-grid appliance for the first time**	S × (1 – DL) × (1 – DR-Access)	12	●	⊕
A-SOC2	**Number of customers currently accessing off-grid appliances through flexible financing**	SL-PAYGo × (1 – DL) × (1 – DR-Access)	12	●	±
A-SOC4	**Affordability of monthly repayments**	(PAYGoMC / IMAC) × 100	12	●	⊕
Health and wellbeing					
SF-SOC1a	**Number of health facilities offering improved health services due to use of refrigeration**	SL × (1 – DL) × DH × (1 – DR-Access)	11	●	⊕
SF-SOC1b	**Percentage reduction in vaccine waste**	(VUSWC – VUCWS) / 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 in food security and nutrition due to owning a refrigerator**	SL × (1 – DL) × (1 – DR-Access) × H × PFS	13	●	⊕

Variables

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

Input Variables

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

VARIABLES	DEFINITION
DH	Percentage of refrigerators distributed to health facilities (%)
FC	Percentage of commercial refrigerators distributed (within the scope refrigerator type) (%)
FD	Percentage of domestic refrigerators distributed (within the scope refrigerator type) (%)
FB	Percentage of refrigerators distributed to small and medium businesses (%)
FSC	Average commercial food savings per year per business due to the use of refrigeration (kg / litre / year)
IMAC	Average monthly income of the customer base (USD or equivalent)
PAYGoMC	Average monthly PAYGo commitment (USD or equivalent)
SL-PAYGO	Number of units sold through flexible financing currently in use (number of units)
PL	Estimated product lifespan (minimum of 1.5 × financing period, or 1.5 × warranty period in cash payments in years)
S	Number of units sold (cumulative, i.e. ever) (number of units)
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 in number of units)
VC	Average solar-powered refrigerator volume per commercial refrigerator (within the scope refrigerator type in litres)
VD	Average solar-powered refrigerator volume per domestic refrigerator (within the scope refrigerator type in litres)
WRP	Proportional weight of each appliance that will be recycled (%)
WS	Weight of solar-powered appliance (kg)

Standard Variables

Standard variables are those for which a reasonably reliable estimate was found in the literature review and 'end-user' research conducted as part of this project. These values are included 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,[14] to decide which value is most appropriate for their products, as well as the confidence rating[15] of each value. For more information, please consult the Standard Variables section.

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. Please refer here for the corresponding sheet in the Excel version of the Impact Assessment Framework for Off- and Weak-Grid High-Performing Appliances.

VARIABLES	DEFINITION	VALUE
DL	Discount for loss: products not working or not in use, excluding loss in supply chain (%)	**4.50%**
DR-Access	Discount for repeat sales for estimating new access to solar powered appliance (including different companies) (%)	**9%**
DR-GHG	Ratio capturing sales replacing a diesel genset-powered appliance (%)	**9%**
EF	Employment factor (jobs / item sold)	**0.01095**
EFa	The proportion of employment factor relevant to each appliance	**100%**
FSD	Average domestic food savings per year per litre of refrigerator volume per household due to the use of refrigeration (kg / litre / year)	**Pipeline variable**
G	Average amount of greenhouse gases avoided per appliance, due to diesel displacement (kg / CO_2 / year)	**170**
GWPR	Global Warming Potential of Refrigerants (GWP). Benchmark values are available in the Efficiency for Access report Phasing Down HFCs in Off- and Weak-Grid Refrigeration [16]	**Refer to the Kigali factsheet, page 3, table of GWP values for reference.** In case refrigerants are a blend of two or more gases, the final GWP is the weighted average of the GWPs of the individual gases
H	Household size (number of people)	**5.5**
OPEXD	Annual operational fuel cost of a diesel-powered appliance (USD / year)	**176–269.2**
PI	Percentage of people who experienced an annual income increase of any value (%)	**Pipeline variable**
PI-30	Percentage of people who experienced at least a 30% annual income increase (%)	**70%**
PQL	The percentage of people associating the appliance with improved quality of life (%)	**15%**
PFS	The percentage of people associating the appliance with improved food security (%)	**10%**
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)	**1–15%**
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"[17]	**Use know value,** otherwise use: 0

14 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).

15 The confidence level was assessed for each value for 'standard variables'. Three stars (***) indicates that a study is 'up to date' (i.e. was conducted within five years of the assessment) and has, at the same time, a 'large sample size' (meaning that the data came from one study with over 500 samples or several studies with a total of over 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.

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

17 ibid

VARIABLES	DEFINITION	VALUE
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"[18]	Enter measured value by user, or use the following formula: **1. For refrigerators with HCs (R600s or R290) in gms:** RM = 0.1881 × CL + 27.437, or 150 gms whichever is lower where, CL is the capacity of the refrigerator in L **2. For refrigerators with R134a in gms:** RM = 0.5282 × CL + 36.518 where CL is the capacity of the refrigerator in L
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"[19]	Enter measured value by user, or use the following formula: **RS = 0.1 * RM**
VUC	Average vaccine utilisation rate within a defined period or immunisation programme (%)	**60.5%**
VUS	Average vaccine utilisation rate from health facilities with additional solar refrigeration within a defined period or immunisation programme (%)	**Pipeline variable**
WomenT	Percentage of women with access to a [appliance name] who perceive the appliances contributes to 'time benefit', 'time management' or 'unburdening' to the [appliance name] in a representative sample (percentage of women)	**Pipeline variable**

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

19 ibid

Impact Indicators

Below we give a detailed description of the evidence for the indicators and values proposed for refrigerators.

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

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

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

Table 2: Environment
A-ENV1: Tonnes of CO_2 emissions avoided

METRIC	TONNES OF CO_2 EMISSIONS AVOIDED		
			STATUS
ID	A-ENV1		●
			IMPACT
Appliance name	All		⊕
Unit of measurement	Tonnes CO_2e / year		
Definition	CO_2 emissions saved during operation, for households or businesses replacing a diesel-powered appliance with a solar-powered appliance.		
Usefulness of metric	Quantifying the benefit of replacing diesel-powered appliances with solar-powered appliances in terms of CO_2 emissions.		
Impact statement	X tonnes of CO_2 emissions were saved through the distribution of [appliance name] since [start date of distribution].		
Calculation	(S × (1 – DL) × DR-GHG × PL × G) / 1000		
Variables	**VARIABLES**	**DEFINITION**	**VALUE**
	S	Number of units sold (cumulative, i.e. ever) (number of units)	This variable is to be inserted by the user
	DL	Discount for loss: products not working or not in use, excluding loss in supply chain (%)	4.5%
	DR-GHG	Ratio capturing sales replacing a diesel gen set-powered appliance (%)	9%
	PL	Estimated product lifespan (minimum of 1.5 × financing period, or 1.5 × warranty period in cash payments) (years)	This variable is to be inserted by the user
	G	Average amount of greenhouse gases avoided per appliance, due to diesel displacement (kg CO_2/year)	170
Assumptions	• The operational CO_2 emissions of a solar appliance are assumed to be zero. • Nonetheless, the US National Renewable Energy Laboratory (NREL) conducted a harmonisation study[20] on all published lifecycle analyses of residential and utility-scale solar PV systems, harmonising the lifecycle emissions of PVs at 40gCO_2e / kWh (Stages, 2012), with operational emissions estimated at 8.4 – 10.4gCO_2e / kWh. • In the case of solar-powered refrigerators, this indicator does not consider emissions due to refrigerant use. If any refrigerant-related emissions are shown in the above equation, they should be subtracted as they reduce the savings made.		
Supporting literature	• The International Renewable Energy Agency (IRENA) estimates that accelerated deployment of solar PV alone can lead to significant emission reductions of 4.9 gigatonnes of carbon dioxide (Gt CO_2) in 2050.		

20 Stephanie Weckend, Andreas Wade and Garvin Heath, End of life management: solar photovoltaic panels" (No.NREL/TP-6A20-73852, 2018). National Renewable Energy Lab.(NREL), Golden, CO (United States)

METRIC	TONNES OF CO_2 EMISSIONS AVOIDED

Supporting literature	• A global study[21] showed that successfully replacing a conventional refrigerator with a Solar Thermal Adsorption Refrigerator (STAR) can annually reduce:
	  • 292 ~ 1170 kg CO_2-eq of global warming potential (GWP)
	  • 104 ~ 418 H+ moles-eq. of acidification
	  • 1.15 ~ 4.61 kg benzene- eq. of carcinogenic
	  • 6850 ~ 27,400 kg toluene-eq. of non-carcinogenic
	  • 1.2 ~ 4.78 kg N-eq. of eutrophication
	  • 0.556 ~ 2.22 kg PM2.5-eq. of respiratory effects
	  • 0.0078 ~ 0.031 g of CFC-11 eq. of ozone depletion
	  • 0.564 ~ 2.26 g NOx-eq. of smog.
	• Low and high numbers indicate the amount of reduction when compared with average electricity consumption of a modern energy-efficient refrigerator (i.e. 365 kWh / yr) and an old 1990 era refrigerator (i.e. 1095 kWh / yr) respectively. Considering the typical lifetime of a conventional refrigerator of 13 ~ 19 years, the reduction of the aforementioned environmental impacts of the STAR can be scaled significantly.

Data gaps	• Addressing more accurate usage pathways of appliances and especially solar water pumps. In what percentage of the cases a solar-powered appliance is used in addition to the diesel powered appliance. • Identifying lifecycle emissions reduction, also considering production, transportation, maintenance and replacement of solar-powered appliances. • In the case of cooling (fans and refrigerators) – addressing passive methods (e.g. building standards), as benchmarks for emissions avoided. For example,if a building is a metal sheet building and then uses multiple fans to cool it, it will show a higher level of 'emissions avoided' and more efficiency achieved, but it is actually an un-optimised solution.
Usage notes	• Impact insights from other regions in the Global South, especially Sub-Saharan Africa. Impact insights broken down by different appliance access use cases: gender access, actual access level (period), or extent of functionality. • Impact insights broken down into differences of geography, seasonality or differences in time-use.

Table 3: Environment
A-ENV2a: Annual tonnes of electric waste added

METRIC	ANNUAL TONNES OF ELECTRIC WASTE ADDED		
			STATUS
ID	A-ENV2a		●
			IMPACT
Appliance name	All		⊖
Unit of measurement	Tonnes		
Definition	Tonnes of electronic waste added annually due to the ownership and disposal of an off-grid appliance by households or businesses.		
Usefulness of metric	Quantifying the electronic waste added to the environment when off-grid appliances are disposed of in the absence of a disposal plan.		
Impact statement	Since [start date of distribution], X tonnes of electronic waste was added to the environment due to the distribution of off-grid appliances, in the absence of a recycling or reuse plan.		
Calculation	S × WS / 1000		
Variables	**VARIABLES**	**DEFINITION**	**VALUE**
	S	Number of units sold (cumulative, i.e. ever) (number of units)	This variable is to be inserted by the user
	WS	Weight of solar-powered appliance (kg)	This variable is to be inserted by the user
Assumptions	• It is assumed that the entire appliances, whether solar-powered or non-solar-powered, will be disposed of in full, in the absence of recycling or reuse. • The indicator does not address the difference in environmental impact of different mass elements (all kgs are equal).		

21 Chris Denzinger, Gretchen Berkemeier, Oliver Winter, Matthew Worsham, Claudia Labrador, Katie Willard, Amnah Altaher, JackSchuleter,, Amy Ciric,Jun-Ki Choi, Toward sustainable refrigeration systems: Life cycle assessment of a bench-scale solar-thermal adsorption refrigerator. (2021): International Journal of Refrigeration, 121, 105–113. https://doi.org/10.1016/j.ijrefrig.2020.09.022

METRIC	ANNUAL TONNES OF ELECTRIC WASTE ADDED
Supporting literature	• E-waste is defined as "all types of electrical and electronic equipment that have been discarded".[22] For our purposes, we include all parts in the appliance including all electrical components, as well as metal and plastic fractions and excluding packaging and external power source. • Appliances that include a majority of mechanical components (such as water pumps) are also considered e-waste as described in Psomopoulos, Barkas, & Ioannidis' report "The Recycling Potential of Submersible Sewage Pumps in the EU".[23] "The expected quantity of e-waste going to landfill as a result of using solar appliances is 78 million tonnes by 2050 (Weckend et al., 2016). No appliance-specific data currently exist. • A two-fold increase in the global sales of small-scale solar devices, including PV-based solar lanterns, solar water pumps, solar-powered refrigerators and solar home systems, was predicted between 2010 and 2022. Sales reached 130 million units between 2010 and 2017 and were expected to increase up to 250 million units in 2017 and 2022.[24] These sales were concentrated geographically in developing countries located in Sub-Saharan Africa, especially in East Africa, and to a lesser extent in South Asia and Latin America. • Recent research highlighted an 'emerging disposal problem' associated with the exponential rise in sales of small-scale and off-grid solar devices.[25] The World Bank estimated that of the 130 million off-grid solar devices sold in 2017, 26 million off-grid solar devices went out of use.[26] Estimates show that solar e-waste represented less than 0.5% of the overall e-waste stream in 14 Sub-Saharan African countries in 2014. In 2014, an estimated 2,500 tonnes of off- grid solar products were put on the market of which 800 tonnes were present in the waste stream. Solar e-waste disposal was expected to increase up to 10,000 tonnes by 2020 with Kenya leading the share with 3,800 tonnes, followed by Nigeria (530 tonnes) and Rwanda (350 tonnes).[27] • The International Renewable Energy Agency estimated that by 2050, cumulative global solar e-waste volume could reach 78 million metric tonnes).[28]
Data gaps	Addressing different components according to their environmental impact (e.g., battery vs cables).
Usage notes	WS includes only the appliance and inbuilt battery. It excludes packaging and external power source, but includes any other part of the appliance.

Table 4: Environment
A-ENV2b: Annual tonnes of electric waste avoided

METRIC	ANNUAL TONNES OF ELECTRIC WASTE AVOIDED		
			STATUS
ID	A-ENV2b		●
			IMPACT
Appliance name	All		⊕
Unit of measurement	Tonnes		
Definition	Tonnes of electronic waste avoided annually due to the existence of a recycling plan.		
Usefulness of metric	This metric rewards organisations that promote recycling and raise awareness of e-waste recycling.		
Impact statement	Since [start date of distribution], X tonnes of electronic waste was avoided thanks to recycling plans.		
Calculation	S × WS × WRP / 1000		
Variables	**VARIABLES**	**DEFINITION**	**VALUE**
	S	Number of units sold (cumulative, i.e. ever) (number of units)	This variable is to be inserted by the user
	WS	Weight of solar-powered appliance (kg)	This variable is to be inserted by the user

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

23 Constantinos S. Psomopoulos, Dimitrios Barkas and George Ch. Ioannidis, The Recycling Potential of Submersible Sewage Pumps in the EU. (2018): doi: 10.3390/recycling3020014

24 Lighting Global, Off-grid solar market trend report 2018. International Finance Corporation., (2018): https://www.lightingglobal.org/wp-content/uploads/2018/02/2018_Off_Grid_Solar_Market_Trends_Report_Summary.pdf

25 Gunther Bensch, Jorg Peters, and Maximiliene Sievert 2017, The lighting transition in rural Africa—From kerosene to battery-powered LED and the emerging disposal problem (2017) Energy for Sustainable Development,39, 13-20.

26 Lighting Global, Off-grid solar market trend report 2018. International Finance Corporation., (2018): https://www.lightingglobal.org/wp-content/uploads/2018/02/2018_Off_Grid_Solar_Market_Trends_Report_Summary.pdf

27 Federico Magalini, Deepali Sinha Khetriwal, David Rochat and Jaco Huisman, Electronic Waste (E-waste) Impacts and Mitigation Options in the Off-grid Renewable Energy Sector" (p. 62, 2016). UK Department for International Development (DFID). https://www.gov.uk/research-for-development-outputs/electronic-waste-e-waste-impacts-and-mitigation-options-in-the-off-grid-renewable-energy-sector-in-the-off-grid-renewable-energy-sector

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

METRIC	ANNUAL TONNES OF ELECTRIC WASTE AVOIDED		
Variables	**VARIABLES**	**DEFINITION**	**VALUE**
	WRP	Proportional weight of each appliance that will be recycled (%)	This variable is to be inserted by the user
Assumptions	• It is assumed that the entire appliance, whether solar-powered or non-solar-powered, will be disposed of in full, in the absence of recycling or reuse plans. • The indicator does not address the difference in the environmental impact of different mass elements (all kgs are equal).		
Supporting literature	See A-ENV2a.		
Input from stakeholders	Input from people / investors / donors.		
Data gaps	• Solar appliance recycling potential in East Africa and Asia. • Including the e-waste saved through using reused materials in the manufacturing process.		
Usage notes	• WS includes only the appliance and inbuilt battery. It excludes packaging and external power source, but includes any other part of the appliance. • WRP is determined during the project/intervention depending on the recycling / reuse plan available. • The above indicator could be improved or added to in order to incorporate reduction in e-wastage.		

Table 5: Environment
SF-ENV1a: Annual tonnes reduction in food spoilage (domestic refrigerator)

METRIC	ANNUAL TONNES REDUCTION IN FOOD SPOILAGE (DOMESTIC REFRIGERATOR)		
			STATUS
ID	SF-ENV1a		●
			IMPACT
Appliance name	Refrigerator		⊕
Unit of measurement	Tonnes		
Definition	Reduction in waste from food spoilage, for households previously without a refrigerator.		
Usefulness of metric	The indicator enables determination of the amount of food saved due to the ability to preserve it for longer with the use of a refrigerator.		
Impact statement	X tonnes of food per year has been saved since [start date of distribution] from households due to their purchase of a solar-powered refrigerator.		
Calculation	(S × PL × (1 – DL) × FSD × VD × FD) / 1000		
Variables	**VARIABLES**	**DEFINITION**	**VALUE**
	S	Number of units sold (cumulative, i.e. ever) (number of units)	This variable is to be inserted by the user
	PL	Estimated product lifespan (minimum of 1.5 × financing period, or 1.5 × warranty period in cash payments) (years)	This variable is to be inserted by the user
	DL	Discount for loss: products not working or not in use, excluding loss in supply chain (%)	4.5%
	FSD	Average domestic food savings per year per litre of refrigerator volume per household due to use of refrigeration (kg / litre / year)	Pipeline variable
	FD	Percentage of domestic refrigerators distributed (within the scope refrigerator type) (%)	This variable is to be inserted by the user
	VD	Average solar-powered refrigerator volume per domestic refrigerator (within the scope refrigerator type) (litre)	This variable is to be inserted by the user
Assumptions	• The equation focuses on food waste due to lack of refrigeration rather than general food waste, which may include food purchased but not consumed by customers. • 'Food' includes both food and perishable drinks (such as milk, fresh juice, etc.). • Litres are converted to kg.		

METRIC	ANNUAL TONNES REDUCTION IN FOOD SPOILAGE (DOMESTIC REFRIGERATOR)
Supporting literature	• Food preservation is important for rural households and especially for subsistence farmers who rely on harvested fruit and vegetables, both for consumption at home (rather than expending valuable income to purchase from the market due to spoilage) and for sales of said produce for income. Unfortunately, there are currently no data publicly available on average domestic or commercial (small business) food wastage per year per household/business due to the absence of refrigeration. • A recent study by NAAS showed that in India 16% of food waste (fruits and vegetables) can be saved annually by using off-grid solar-powered refrigerators.[29] • According to the Birmingham Energy Institute[30], food loss reduces income by at least 15% for 470 million smallholder farmers, most of whom also sit within the 1.2 billion people who are food insecure. 90% of food waste in developing countries is caused by losses in the supply chain rather than consumers discarding edible food. Tackling food waste in the supply chain would benefit the poorest by simultaneously raising farmers' incomes and reducing food prices.
Data gaps	Missing data on the average refrigerator-related food savings and wastage per year for households in regions and countries in Asia and East Africa.

Table 6: Environment

SF-ENV1b: Annual tonnes reduction in food spoilage (commercial refrigerator)

METRIC	ANNUAL TONNES REDUCTION IN FOOD SPOILAGE (COMMERCIAL REFRIGERATOR)		
			STATUS
ID	SF-ENV1b		●
			IMPACT
Appliance name	Refrigerator		⊕
Unit of measurement	Tonnes		
Definition	Reduction in waste from food spoilage for businesses previously without a refrigerator.		
Usefulness of metric	The indicator enables determination of the amount of food saved due to the ability to preserve it for longer with the use of a refrigerator. This obviously results in business income savings.		
Impact statement	X tonnes of food per year has been saved since [start date of distribution] from businesses due to their purchase of a solar-powered refrigerator.		
Calculation	(S × PL × (1 – DL) × FSC × VC × FC) / 1000		
Variables	**VARIABLES**	**DEFINITION**	**VALUE**
	S	Number of units sold (cumulative, i.e. ever) (number of units)	This variable is to be inserted by the user
	PL	Estimated product lifespan (minimum of 1.5 × financing period, or 1.5 × warranty period in cash payments) (years)	This variable is to be inserted by the user
	DL	Discount for loss: products not working or not in use, excluding loss in supply chain (%)	4.5%
	FSC	Average commercial food savings per year per business due to use of refrigeration (kg / litre / year)	This variable is to be inserted by the user
	VC	Average solar-powered refrigerator volume per commercial refrigerator (within the scope refrigerator type) (litre)	This variable is to be inserted by the user
	FC	Percentage of commercial refrigerators distributed (within the scope refrigerator type) (%)	This variable is to be inserted by the user
Assumptions	• The equation focuses on food waste due to a lack of refrigeration rather than general food waste, which may include food purchased but not consumed by customers. • 'Food' includes both food and perishable drinks (such as milk, fresh juice, etc.) collectively.		

29 NAAS, Saving the Harvest: Reducing the Food Loss and Waste (No. 5; Policy Brief, p. 10). National Academy of Agricultural Sciences. (2019): http://naasindia.org/documents/Saving%20the%20Harvest.pdf

30 Birmingham Energy Institute and University of Birmingham, Clean Cold and the Global Goals (2016) https://www.birmingham.ac.uk/documents/college-eps/energy/publications/clean-cold-and-the-global-goals.pdf

METRIC	ANNUAL TONNES REDUCTION IN FOOD SPOILAGE (COMMERCIAL REFRIGERATOR)
Supporting literature	• Food preservation is important for rural households, especially for subsistence farmers who rely on harvested fruit and vegetables both for consumption at home (rather than expending valuable income to purchase from the market due to spoilage) and for sales of said produce for income. Unfortunately, there are currently no data publicly available on average domestic or commercial (small business) food wastage per year per household/business due to the absence of refrigeration. • A recent study by NAAS showed that in India 16% of food waste (fruits and vegetables) could be saved annually through the use of off-grid solar-powered refrigerators.[31] Although cold rooms are out of scope for this study, it is worth noting the following studies. It was shown that by improving refrigeration conditions using cold rooms, USD 8.4 billion per annum could be saved in India by avoiding food waste.[32] Similarly, off-grid solar-powered milk chillers in India can reduce the 3% annual milk / dairy wastage.[33] While in Tanzania, 10 to 20% of fish loss could be prevented through cold storage.[34] • In Uganda, it was found that farmers could reduce food losses by 80% if they utilised ColdHubs solar-powered walk-in cold rooms, which can also extend the life of food up to 21 days.[35] The same study found that fruit and vegetable vendors and farmers were able to increase their income by an average of 25%. Furthermore, the dairy industry is highly sensitive to refrigeration, with a global estimation showing that cold storage can enable and empower the economic transformation of the lives of 780 million smallholder farmers, who bear the brunt of food waste and are also the most vulnerable to climate change.[36]
Data gaps	Missing data on the average refrigerator-related food savings and wastage per year for businesses in regions and countries in Asia and East Africa.

Table 7: Environment
SF-ENV2: Kg of CO_2e refrigerant-related emissions added

METRIC	KG OF CO_2E REFRIGERANT-RELATED EMISSIONS ADDED		
			STATUS
ID	SF-ENV2		●
			IMPACT
Appliance name	Refrigerator		⊖
Unit of measurement	kg of CO_2e		
Definition	The number of kg of CO_2e refrigerant-related emissions additionally generated due to households or businesses purchasing and operating a solar-powered refrigerator with fluorinated gases.		
Usefulness of metric	This indicator enables entities to calculate the additional emissions generated due to refrigerant use in new solar-powered refrigerators sold and also calculate the cumulative benefit of switching to refrigerants that have a lower global warming potential. The indicator applies both to customers who had not previously owned a refrigerator and those replacing a conventional refrigerator.		
Impact statement	X kg of CO_2 equivalent emissions were generated from solar-powered refrigerators sold since [start date of distribution].		
Calculation	S × (RM + RS – RD) × GWPR		
Variables	**VARIABLES**	**DEFINITION**	**VALUE**
	S	Number of units sold (cumulative, i.e. ever) (number of units)	This variable is to be inserted by the user

31 NAAS, Saving the Harvest: Reducing the Food Loss and Waste (No. 5; Policy Brief, p. 10). National Academy of Agricultural Sciences. (2019): http://naasindia.org/documents/Saving%20the%20Harvest.pdf
32 Kieran Pandey, Poor post-harvest storage, transportation facilities to cost farmers dearly. Down to Earth. (2018): https://www.downtoearth.org.in/news/agriculture/poor-post-harvest-storagetransportation-facilities-to-cost-farmers-dearly-61047
33 Nanda Kasabe, Solar cold storage and other solutions preventing milk wastage in India. Financial Express. (2019): https://www.financialexpress.com/lifestyle/science/solar-cold-storage-and-othersolutions-preventing-milk-wastage-in-india/1760450/
34 Power for All, Powering Agriculture eBooklet: A Knowledge Resource for the Productive Use of Renewable Energy in Food Systems. (2020): https://www.powerforall.org/application/files/5216/0578/6043/Powering_Agriculture_eBooklet.pdf
35 Kate Hodal, How the sun's rays can keep food chilled: Fighting waste in Africa. The Guardian. (2017) https://www.theguardian.com/global-development/2017/dec/28/fighting-food-waste-in-africa
36 Roberto Ridolfi and Olivier Dubois, How powering food storage could end hunger. World Economic Forum. (2019) https://www.weforum.org/agenda/2019/12/how-to-reduce-food-waste-endhunger/

METRIC	KG OF CO_2E REFRIGERANT-RELATED EMISSIONS ADDED		
Variables	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".[37]	Enter measured value by user, or use the following formula: **1. For refrigerators with HCs (R600s or R290) in gms:** RM = 0.1881 × CL + 27.437, or 150 gms whichever is lower where, CL is the capacity of the refrigerator in L. **2. For refrigerators with R134a in gms:** RM = 0.5282xCL +36.518 where CL is the capacity of the refrigerator in L.
	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".[38]	4.5%
	RD	Refrigerant recovered during disposal (kg). Benchmark values are available at the Efficiency for Access report "Phasing Down HFCs in Off- and Weak-Grid Refrigeration" (link in usage notes).	This variable is to be inserted by the user
	GWPR	Global Warming Potential of Refrigerants (GWP). Benchmark values are available in the Efficiency for Access report "Phasing Down HFCs in Off- and Weak-Grid Refrigeration" (link in usage notes).	This variable is to be inserted by the user
Assumptions	• It is assumed that all units sold result in refrigerant emissions. Therefore, there are no considerations for products lost or not in use. • The formula should only be used for refrigerators that contain fluorinated gases.		
Supporting literature	Formulae based on the Efficiency for Access report on "Phasing Down HFCs in Off- and Weak-Grid Refrigeration", suggested values for RM, RS, RD and GWPR for different models are available in the report.[39] The report was produced to raise awareness of the harmful effects of using fluorinated gases in refrigerators under 600L capacity, enable the calculation of the extent of this harmful effect on the environment and climate change and inform the development of low GWP refrigerants and high-performing off-grid refrigerator technologies. The report also recommends formulas for estimating the mass of refrigerant R134a and natural refrigerants like R600a and R290 to facilitate the calculation where refrigerant mass information is absent.[40] The report advocates that it is possible to achieve a near 100% natural refrigerant coverage for off- and weak-grid settings by 2030 if appropriate measures are put in place.[41]		
Usage notes	• Benchmark values are available in the Efficiency for Access report "Phasing Down HFCs in Off- and Weak-Grid Refrigeration".[42] • Table of GWP values.[43]		
Data gaps	• Enhancing access to data on types of refrigerants used. • Estimating emissions avoided from hydrocarbon. • Estimate emissions from use of HFCs as refrigerants in cold rooms and as blowing agents.		

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

38 ibid

39 ibid

40 ibid

41 ibid

42 ibid

43 United Nations Environment Program., GWP, $CO_2(e)$ and the Basket of HFCs, OzonAction Kigali Fact Sheet 3. (2017): https://wedocs.unep.org/bitstream/handle/20.500.11822/26866/7878FS03GWPCO_EN.pdf

Table 8: Economic
A-ECO1: USD savings in fuel costs

METRIC	USD SAVINGS IN FUEL COSTS (SOLAR-POWERED APPLIANCE REPLACING A NON-SOLAR-POWERED APPLIANCE)		
			STATUS
ID	A-ECO1		●
			IMPACT
Appliance name	All		⊕
Unit of measurement	USD		
Definition	Total USD saved in fuel-related operational costs for households or businesses replacing a diesel-powered appliance with a solar-powered appliance, throughout the solar-powered appliance's lifetime.		
Usefulness of metric	The indicator provides an economic business case for solar appliances by highlighting the amount of operational costs that a household or business saves throughout its lifetime.		
Impact statement	Since [start date of distribution], people saved x USD in operational costs due to moving from diesel-powered [appliance name] to a solar-powered appliance.		
Calculation	S × (1 – DL) × DR-GHG × PL × OPEXD		
Variables	**VARIABLES**	**DEFINITION**	**VALUE**
	S	Number of units sold (cumulative, i.e. ever) (number of units)	This variable is to be inserted by the user
	DL	Discount for loss: products not working or not in use, excluding loss in supply chain (%)	4.5%
	DR-GHG	Ratio capturing sales replacing a diesel genset-powered appliance (%)	9%
	PL	Estimated product lifespan (minimum of 1.5 × financing period, or 1.5 × warranty period in cash payments) (years)	This variable is to be inserted by the user
	OPEXD	Annual operational fuel cost of a diesel-powered appliance (USD / year)	176–269.2
Assumptions	• The annual operational expenditure of a solar appliance is assumed to be zero. • Only fuel cost reduction is accounted for i.e. costs such as seeds, fertiliser and labour are not considered.		
Supporting literature	• Solar-powered refrigerators can bring about significant financial savings for businesses and households alike. Research carried out by M-KOPA found four main areas of time and cost savings from refrigerator ownership in Kenya.[44] • Cost savings through bulk purchasing food on the weekly market day, when wholesalers are selling at lower per-unit prices than the re-sellers who operate the rest of the week. • Cost and time savings by reducing the total number of times a household has to shop for food weekly. • Cost and time savings by enabling more efficient bulk cooking, storage of prepared food and reheating, meaning less time and fuel spent on cooking. • Cost savings through avoiding food spoilage. • A further study found that households in Kenya and Uganda saved ~USD 4.83 a week (on average) by reducing food spoilage and costs incurred on trips to the market. Some households reported savings up to 50% of their total income.[45] • In India, a restaurant in Karnataka increased its profit by 26.66% per month by reducing the wastage of perishable produce and expanding its product range.[46] • Furthermore, a study by Gender Toolkit recorded a 30–40% cost saving per month in households due to the ability to buy in bulk, reductions in cooking fuel costs and less food waste due to spoilage in Kenya.[47] Research by GOGLA in north-east India found that cooperatives can save up to 40.33% per month by avoiding usage of diesel generators in Sikkim, India.		
Data gaps	• Include other expenses that are not fuel. • Magnitude of replacement market for solar appliances. • The operational costs of solar appliances.		
Usage notes	Values for OPEXD vary depending on the geography. To find the most suitable value please refer to the elaborated variable sheet (click on the variable name).		

44 MKOPA and CDC, How Innovation in Off-Grid Refrigeration Impacts Lives in Kenya. (2019): https://assets.cdcgroup.com/wp-content/uploads/2019/10/29165356/How-innovation-in-off-grid-refrigeration-impacts-lives-in-Kenya.pdf

45 Adele Peters, Youmma's pay-as-you-go solar fridge helps poor African families. (2020): https://www.fastcompany.com/90489600/this-pay-as-you-go-solar-fridge-helps-poor-african-families-savemoney-and-food

46 SELCO, Innovation solar projects. SELCO Foundation. (2017): https://www.selco-india.com/public/pdf/livelihoods.pdf

47 CDC, M-KOPA case study | CDC Gender Toolkit. (2021): https://gendertoolkit.cdcgroup.com/case-studies/m-kopa-case-study/

Table 9: Economic
A-ECO2: Number of new jobs created

METRIC	NUMBER OF NEW JOBS CREATED		
			STATUS
ID	A-ECO2		●
			IMPACT
Appliance name	All		⊕
Unit of measurement	Number of jobs		
Definition	Increase in job opportunities within the business (manufacturing, assembly, distribution).		
Usefulness of metric	Enables demonstration of the contribution of the high-performing appliance supply chain to the local job market.		
Impact statement	A total of x jobs have been created in local markets through the high-performing appliance supply chain.		
Calculation	S × EF × EFA		
Variables	**VARIABLES**	**DEFINITION**	**VALUE**
	S	Number of units sold (cumulative, i.e. ever) (number of units)	This variable is to be inserted by the user
	EF	Employment factor (jobs / item sold)	0.01095
	EFA	Proportion of employment factor relevant to each appliance	100%
Assumptions	The jobs are created within the geographical area being served.		
Supporting literature	The values for EF and EFA are taken from the Power for All report "Powering Jobs Census 2019".[48] Evidence from the same publication and others suggests that the off-grid solar value chain could generate up to 1.3 million full-time equivalent (FTE) jobs by 2022, excluding manufacturing).[49] For further details, we recommend consulting the original report.		
Data gaps	Explore indirect jobs from upstream sectors and potential job displacement from traditional energy sectors.		
Usage notes	• The above indicators would be applied to a specific geographical region that is the area of interest. • The jobs being counted are those generated within that geographical region. • The formula should not be used for appliances sold as a bundle with SHS.		

Table 10: Economic
SF-ECO1a: Number of end-users experiencing an annual increase in business income of at least 30%

METRIC	NUMBER OF BUSINESSES GENERATING AT LEAST A 30% ADDITIONAL ANNUAL INCOME DUE TO OWNING A REFRIGERATOR
	STATUS
ID	SF-ECO1a ●
	IMPACT
Appliance name	Refrigerator ⊕
Unit of measurement	Number of people
Definition	Number of businesses without previous access to a refrigerator, benefiting from an increase in income due to ownership of a solar-powered refrigerator.
Usefulness of metric	Capturing the number of businesses with a significant (30%) increase in income due to owning solar-powered refrigerators.
Impact statement	X number of businesses are achieving, or expected to achieve in the following year, at least a 30% increase in income due to gaining new access to solar-powered refrigerators.
Calculation	SL × (1 – DL) × (1 – DR-Access) × FB × PI-30

48 Power for All, Powering Jobs Census 2019: The Energy Access Workforce. (2019): https://www.powerforall.org/resources/reports/powering-jobs-census-2019-energy-access-workforce
49 Lighting Global, Off-grid solar market trend report 2018. International Finance Corporation., (2018): https://www.lightingglobal.org/wp-content/uploads/2018/02/2018_Off_Grid_Solar_Market_Trends_Report_Summary.pdf

METRIC	NUMBER OF BUSINESSES GENERATING AT LEAST A 30% ADDITIONAL ANNUAL INCOME DUE TO OWNING A REFRIGERATOR		
	VARIABLES	DEFINITION	VALUE
Variables	SL	Number of units sold which are estimated to currently be in use (based on the products estimated lifespan being 1.5 × financing period, or 1.5 × warranty period in cash payments) (number of units)	This variable is to be inserted by the user
	FB	Percentage of refrigerators distributed to small and medium businesses (%)	This variable is to be inserted by the user
	DL	Discount for loss: products not working or not in use, excluding loss in supply chain (%)	4.5%
	DR-Access	Discount for repeat sales for estimating new access to solar powered appliances (including different companies) (%)	9%
	PI-30	Percentage of people who experienced at least a 30% annual income increase (%)	70%
Assumptions	That businesses used purchased refrigerators to generate income. A survey across rural Uganda showed that 44% of refrigerator owners perceived the appliance to be a source of business opportunities.		
Supporting literature	• Businesses without previous access to a refrigerator benefit in two ways from the ownership of a solar-powered refrigerator. Firstly, they benefit from the reduction in perishability of products linked to their existing services, such as dairy products, food, drinks (dairy-based drinks, juices, etc.), as well as a reduction in staff time spent on food preparation or shopping and a reduction in fuel costs, i.e. an overall reduction of operational expenses. Secondly, they benefit from diversification of income sources through expanding services to incorporate the offering of chilled or frozen products (cold drinks, ice-cream, ice, frozen food, etc.). • For example, from a pilot study of 45 stand-alone solar-powered refrigerators in India conducted by a product distributor, more than 70% of participants reported an increased profit of more than Rs. 4,000 per month (USD 57 per month); the average customer reporting a profit increase of Rs. 8,000 (USD 114 per month). Additionally, customer surveys by Global LEAP in Kenya and Uganda reported that businesses experienced an average gross sales increase in the range of 40–60% per week. • Refrigeration is especially critical for dairy products and consequently could have larger productive impacts on these items than other fresh produce. With solar direct drive milk chillers, off-grid dairy farmers in Kenya were able to store greater quantities of milk overnight, resulting in a 30% increase in income. • Rural entrepreneurs in India increased revenue by selling chilled juice and cold drinks in a hot and humid climate, while off-grid solar-powered refrigerators in Western India led to an increase in the income of petty shop owners by 60% during the summer months. This technology directly benefited more than 100 families in rural areas in Rajasthan, India. Another study found a 40% increase in the profits of smallholder farmers in Maharashtra, India due to refrigeration.[50] • While in Uganda, Efficiency for Access and CLASP data reveals that thanks to off-grid refrigerators, small and medium sized enterprises increased their daily incomes by 2.5 on average (from USD 29 to USD 70) by venturing into new business lines (i.e. food and drink sales).[51]		
Data gaps	Missing more robust data regarding income increase of end-users due to solar-powered refrigeration use, specifically for East Asia.		

Table 11: Economic

SF-ECO1b: Number of businesses generating additional income of any value due to owning a refrigerator

METRIC	NUMBER OF BUSINESSES GENERATING ADDITIONAL INCOME OF ANY VALUE DUE TO OWNING A REFRIGERATOR	
		STATUS
ID	SF-ECO1b	●
		IMPACT
Appliance name	Refrigerator	⊕

50 World Bank, Ecozen case study. The World Bank Group. (2017): https://www.innovationpolicyplatform.org/www.innovationpolicyplatform.org/system/files/8-Storage%20Solutions_Agri_Profile%20Ecozen/index.pdf

51 Elisa Lai, Stewart Muir and Yasemin Erboy-Ruff, Off-grid appliance performance testing: Results and trends for early-stage market development. Energy Efficiency, 13(2), 323–347. (2020): https://doi.org/10.1007/s12053-019-09793-z

METRIC	NUMBER OF BUSINESSES GENERATING ADDITIONAL INCOME OF ANY VALUE DUE TO OWNING A REFRIGERATOR		
Unit of measurement	Number of business owners		
Definition	Number of business owners, without previous access to a refrigerator, benefiting from an increase in income due to the ownership of a solar-powered refrigerator.		
Usefulness of metric	This indicator aims to capture the number of businesses with a 30% increase in income due to solar-powered refrigerator use.		
Impact statement	X number of businesses without previous use of a refrigerator, achieved at least a 30% increase in income from owning a solar-powered refrigerator.		
Calculation	SL × (1 – DL) × (1 – DR-Access) × FB × PI		
Variables	**VARIABLES**	**DEFINITION**	**VALUE**
	SL	Number of units sold which are estimated to currently be in use (based on the products' estimated lifespan being 1.5 × financing period, or 1.5 × warranty period in cash payments) (number of units)	This variable is to be inserted by the user
	FB	Percentage of refrigerators distributed to small and medium businesses (%)	This variable is to be inserted by the user
	DL	Discount for loss: products not working or not in use, excluding loss in supply chain (%)	4.5%
	DR-Access	Discount for repeat sales for estimating new access to solar powered appliances (including different companies) (%)	9%
	PI	Percentage of people who experienced an annual income increase of any value (%)	Pipeline variable
Assumptions	That businesses use purchased refrigerators to generate income. A survey across rural Uganda showed that 44% of refrigerator owners perceived the appliance to be a source of business opportunities.		
Supporting literature	• Businesses without previous access to a refrigerator benefit in two ways from the ownership of a solar-powered refrigerators. Firstly, they benefit from the reduction in perishability of products linked to their existing services, such as dairy products, food, drinks (dairy-based drinks, juices, etc.), as well as a reduction in staff time spent on food preparation or shopping and a reduction in fuel costs, i.e. overall reduction of operational expenses. Secondly, they benefit from diversification of income sources through expanding services to incorporate the offering of chilled or frozen products (cold drinks, ice-cream, ice, frozen food, etc.). • For example, from a pilot study of 45 stand-alone solar-powered refrigerators in India conducted by a product distributor, more than 70% of participants reported increased profit of more than Rs. 4,000 per month (USD 57 per month); the average customer reporting a profit increase of Rs. 8,000 (USD 114 per month). Additionally, customer surveys by Global LEAP in Kenya and Uganda reported that businesses experienced an average gross sales increase in the range of 40–60% per week. • Refrigeration is especially critical for dairy products and consequently could have larger productive impacts on these items than other fresh produce. With solar direct drive milk chillers, off-grid dairy farmers in Kenya were able to store larger quantities of milk overnight, resulting in a 30% increase in income. • Rural entrepreneurs in India increased revenue by selling chilled juice and cold drinks in a hot and humid climate, while off-grid solar-powered refrigerators in Western India led to an increase in the income of petty shop owners by 60% during the summer months.[52] This technology directly benefited more than 100 families in rural areas in Rajasthan, India. Another study found a 40% increase in the profits of smallholder farmers in Maharashtra, India due to refrigeration.[53] • While in Uganda, Efficiency for Access and CLASP data reveal that thanks to off-grid refrigerators, small and medium sized enterprises (SMEs) increased their daily incomes 2.5-fold on average (from USD 29 – USD 70) by venturing into new business lines (i.e. food and drink sales).[54]		
Data gaps	Data is missing regarding the increase in income as a result of access to a refrigerator.		

52 SELCO., GIZ-SELCO innovation and replication. SELCO Foundation. (2015) https://energypedia.info/images/0/08/Innovation_and_Replication_GIZ_2015.pdf

53 World Bank, Ecozen case study. The World Bank Group. (2017): https://www.innovationpolicyplatform.org/www.innovationpolicyplatform.org/system/files/8-Storage%20Solutions_Agri_Profile%20Ecozen/index.pdf

54 Elisa Lai, Stewart Muir and Yasemin Erboy-Ruff, Off-grid appliance performance testing: Results and trends for early-stage market development. Energy Efficiency, 13(2), 323–347. (2020): https://doi.org/10.1007/s12053-019-09793-z

Table 12: Social / Health Impact

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

METRIC	NUMBER OF PEOPLE WHO GAINED FIRST TIME ACCESS TO AN OFF-GRID APPLIANCE		
			STATUS
ID	A-SOC1		●
			IMPACT
Appliance name	All		⊕
Unit of measurement	Number of people		
Definition	Number of people engaging and benefiting from the off-grid market due to access to high-performing [appliance name].		
Usefulness of metric	Enables demonstration of the number of people who have benefited from clean energy using appliances.		
Impact statement	High-performing appliances are enabling an estimated x people to access and use clean energy. This will allow them to build up assets which could help them to access more products and services in the future.		
Calculation	S × (1 – DL) × (1 – DR-Access) × H		
Variables	**VARIABLES**	**DEFINITION**	**VALUE**
	S	Number of units sold (cumulative, i.e., ever) (number of units)	This variable is to be inserted by the user
	DL	Discount for loss: products not working or not in use, excluding loss in supply chain (%)	4.5%
	H	Household size (number of people)	5.5
	DR-Access	Discount for repeat sales for estimating new access to solar powered appliances (including different companies) (%)	9%
Assumptions	That the majority of the customers are first-time owners and the appliance is not only allowing them to benefit from its functionality, but also enabling them to become more financially included.		
Supporting literature	• The "Powering Opportunity in South Asia" report found that 39% of respondents, the SHS owners, had their first experience of access to clean, modern power. [55] • "M-KOPA's 'Pay-As-You-Go' solar model has helped open up exciting new consumer markets. As off-grid energy connections increase, we are seeing millions of new consumers with greater financial stability and, for the first time, access to power".[56]		
Data gaps	• Explore the impacts of access on financial inclusion and further engagement in the appliance market (e.g., customer upgrades, use of PAYGo to purchase other products and services). • Disaggregate this indicator for gender and income levels.		
Usage notes	• This metric is equal to the number of currently active appliances and is definitional. • The number does not include those who may have purchased a product previously or appliances that are currently not being used due to several reasons.		

Table 13: Social / Health Impact

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

METRIC	NUMBER OF CUSTOMERS CURRENTLY ACCESSING OFF-GRID APPLIANCES THROUGH FLEXIBLE FINANCING
	STATUS
ID	A-SOC2 ●
	IMPACT
Appliance name	All ⊕
Unit of measurement	Number of people
Definition	Number of people with current access to high-performing clean energy appliances through financing

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

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

METRIC	NUMBER OF CUSTOMERS CURRENTLY ACCESSING OFF-GRID APPLIANCES THROUGH FLEXIBLE FINANCING		
Usefulness of metric	Enables demonstration of the number of people who have benefited from high-performing clean energy appliance financing through flexible financing.		
Impact statement	PAYGo appliance financing is enabling an estimated x people access to high-performing clean energy appliances financing. This will allow them to build up a credit history which could help them to access more products and services in the future.		
Calculation	SL-PAYGO × (1 – DL) × (1 – DR-Access)		
Variables	**VARIABLES**	**DEFINITION**	**VALUE**
	SL-PAYGO	Number of units sold through flexible financing currently in use (number of units)	This variable is to be inserted by the user
	DL	Discount for loss: products not working or not in use, excluding loss in supply chain (%)	4.5%
	DR-Access	Discount for repeat sales for estimating new access to solar powered appliances (including different companies) (%)	9%
Assumptions	• Currently most of the information about flexible financing comes from PAYGo systems and does not include other micro financing options. • That the majority of PAYGo customers are unlikely to have a strong credit history and, as such, PAYGo financing is providing more affordable high-performing appliances and enabling them to become more financially included. • Most sales are PAYGo and therefore, the discount for loss is approximately equal to the discount for loss for all sold appliances.		
Supporting literature	• The "Powering Opportunity in South Asia" report found that 39% of respondents, the SHS owners, had their first experience of access to clean, modern power.[57] • The "Socio-Economic Impact of Super-Efficient Off-Grid Fans in Bangladesh" report noted that "..for many Bangladeshi customers, super-efficient off-grid fans create an opportunity to test solar technology for the first time. Super-efficient off-grid fans, therefore, have the potential to support a technological leap towards efficiency and wider use of solar.".[58]		
Data gaps	• Explore the impacts of access on financial inclusion and further engagement in the appliance market (e.g., customer upgrades, use of PAYGo to purchase other products and services). • Disaggregate this indicator for gender and income levels. • Gather data about number of customers with access to flexible financing beyond PAYGo.		
Usage notes	• This metric is simply equal to the number of people currently financing their appliance through PAYGo. • The number does not include those who may have purchased a product previously through PAYGo financing and have already benefited from this level of financial inclusion.		

Table 14: Social / Health Impact
A-SOC4: Affordability of monthly repayments

METRIC	AFFORDABILITY OF MONTHLY REPAYMENTS	
		STATUS
ID	A-SOC4	●
		IMPACT
Appliance name	All	±
Unit of measurement	Percentage	
Definition	The affordability of the monthly instalments	
Usefulness of metric	Enables understanding of the affordability of high-performing appliances for the end-user	
Impact statement	At [point in time] the average monthly payment for [appliance name] is x percent of the average monthly income of our target customers.	
Calculation	(PAYGoMC / IMAC) × 100	

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

58 Efficiency for Access, The Socio-Economic Impact of Super-Efficient Off-Grid Fans in Bangladesh. (2020): https://efficiencyforaccess.org/publications/the-socio-economic-impact-of-super-efficient-fans-in-bangladesh

METRIC	AFFORDABILITY OF MONTHLY REPAYMENTS		
	VARIABLES	DEFINITION	VALUE
Variables	PAYGoMC	Average Monthly PAYGo commitment (USD or equivalent)	This variable is to be inserted by the user
	IMAC	Average monthly income of the customer base (USD or equivalent)	This variable is to be inserted by the user
Assumptions	That the majority of PAYGo customers struggle to meet the monthly PAYGo repayments. This implies that the access to the high-performing appliances presents an 'unreasonable burden' to the individual or household.		
Supporting literature	• ALTAI and GOGLA's report "Powering Opportunity in East Africa: Proving Off-Grid Solar is a Power Tool for Change" found that 4% of respondents reported negative effects with the most common being feeling more stressed, likely related to repayments.[59] • For example, regarding to solar-powered TVs, Efficiency for Access & 60 Decibels' survey on the use and impact of the appliances found that 61% of the respondents reported that they have to make unacceptable sacrifices to make repayments. 2% had to cut back on consumption to make repayments.[60]		
Data gaps	• 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 for affordability. • Disaggregate this indicator for gender.		
Usage notes	• This metric defines and measures the affordability to a household, using the payment method which is based on the ratio of the payment for a particular commodity to a household's total resources. • In case IMAC is unavailable, please use National household surveys or the FAO estimates here. • PAYGoMC includes everything that is included in the monthly, including anything in the bundle. • IMAC is calculated as yearly income divided by 12 recognising that there is a seasonal effect in monthly incomes. • In case and for PAYGo payments that are not monthly, or not equal every month, PAYGoMC is calculated as the monthly equivalent.		

Table 15: Social / Health Impact

SF-SOC1a: Number of health facilities offering improved health services due to use of refrigeration

METRIC	NUMBER OF HEALTH FACILITIES OFFERING IMPROVED HEALTH SERVICES DUE TO USE OF REFRIGERATION		
			STATUS
ID	SF-SOC1a		●
			IMPACT
Appliance name	Refrigerator		⊕
Unit of measurement	Number of health facilities		
Definition	The number of health facilities offering improved refrigeration-related health services as a result of using solar-powered refrigeration.		
Usefulness of metric	The capability to store blood and vaccines improves the capacity of health facilities to provide lifesaving care to community members.		
Impact statement	The introduction of solar refrigeration has helped to improve the health services provided in X health facilities.		
Calculation	SL × (1 – DL) × DH × (1 – DR-Access)		
	VARIABLES	DEFINITION	VALUE
Variables	SL	Number of units sold which are estimated to currently be in use (based on the products' estimated lifespan being 1.5 × financing period, or 1.5 × warranty period in cash payments) (number of units)	This variable is to be inserted by the use

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

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

METRIC	NUMBER OF HEALTH FACILITIES OFFERING IMPROVED HEALTH SERVICES DUE TO USE OF REFRIGERATION		
	VARIABLES	DEFINITION	VALUE
Variables	DL	Discount for loss: products not working or not in use, excluding loss in supply chain (%)	4.5%
	DH	Percentage of refrigerators distributed to health facilities (%)	This variable is to be inserted by the use
	DR-Access	Discount for repeat sales for estimating new access to solar powered appliances (including different companies) (%)	9%
Assumptions	• That refrigeration, whether used to store vaccines, blood, or other medication, leads to improved health services. • Facilities purchasing solar-powered refrigerators did not previously use any other refrigerator.		
Supporting literature	• The total addressable market for off-grid solar vaccine storage is around USD 811 million in the healthcare segment. An estimated 25% of vaccine waste could be prevented through off-grid refrigeration in rural areas of India.[61] • The Solar for Health initiative by the UNDP has supported over 900 health centres and storage facilities in Sub-Saharan Africa that have helped reduce complications in pregnancy and childbirth.[62] It improved supply and management of medical and surgical consumables as a result of to cold storage. Access to vaccines saw a significant improvement, increasing by 30%. It also contributed to extended hours of operation and better retention and recruitment of healthcare workers in remote settings, ensuring effective, safe healthcare 24 hours per day, seven days per week. • Solar power helped health facilities save money in Sub-Saharan Africa by up to 40%, which could be reinvested to support other priority health programmes.[63] • The UNDP estimates a 100% return on investment within two – five years when health facilities with unreliable energy sources install solar systems. Additional savings may also be achieved through reduction in waste of pharmaceutical products as a result of temperature control and broader efficiency gains in the procurement and supply management system.[64] • Solar energy also contributes to more resilient health systems. A reliable power supply ensures that core systems for the management of health programmes can function effectively. Uninterrupted systems for data input and analysis contribute to efficient and accurate quantification and distribution of medicines, patient tracking and monitoring of overall health system performance. The Solar for Health initiative improved the resilience of the health information system, the cold chain, the maternity and the pathology lab.[65]		
Data gaps	Researching the effect on health facilities purchasing more than one solar-powered refrigerator.		
Usage notes	• DH can be attained through refrigerators' technical characteristics. For example: • The majority of WHO solar vaccine refrigerators are solar direct drive (SDDs) and are battery free, but not all SDD refrigerators are vaccine refrigerators.		

Table 16: Social / Health Impact
SF-SOC1b: Percentage reduction in vaccine waste

METRIC	PERCENTAGE REDUCTION IN VACCINE WASTAGE
	STATUS
ID	SF-SOC1b
	IMPACT
Appliance name	Refrigerator
Unit of measurement	Percentage of vaccine waste
Definition	Calculation of vaccine waste at the service delivery level for a single facility
Usefulness of metric	Gives a measure of the extent to which vaccines are saved in a vaccination programme and hence the programme's increased cost-effectiveness in reaching a vast population.
Impact statement	The use of a solar-powered refrigerators has given rise to a reduction of x% in vaccine waste for a health facility without previous reliable access to refrigeration.

61 UNICEF, Vaccine Wastage Assessment. (2010): https://www.mofa.go.jp/mofaj/gaiko/oda/seisaku/kanmin/chusho_h24/pdfs/a20-12.pdf
62 Tracey Burton, & Marcel Alers, Solar for Health: Five Ways Solar Power Can Make Universal Healthcare a Reality. (2019) UN Chronicles. https://www.un.org/en/un-chronicle/solar-health-five-ways-solar-power-can-make-universal-healthcare-reality
63 Tracey Burton, & Marcel Alers, Solar for Health: Five Ways Solar Power Can Make Universal Healthcare a Reality. (2019) UN Chronicles. https://www.un.org/en/un-chronicle/solar-health-five-ways-solar-power-can-make-universal-healthcare-reality
64 ibid
65 ibid

METRIC	PERCENTAGE REDUCTION IN VACCINE WASTAGE		
Calculation	(VUS – VUC) / SH		
Variables	**VARIABLES**	**DEFINITION**	**VALUE**
	VUC	Average vaccine utilisation rate within a defined period or immunisation programme (%)	60.50%
	VUS	Average vaccine utilisation rate from health facilities with additional solar refrigeration within a defined period or immunisation programme (%)	Pipeline variable
	SH	Total number of solar-powered refrigerators in operation in the facilities under consideration	This variable is to be inserted by the user
Assumptions	• This metric focuses on waste at the service delivery level, which is the last vaccine storage point (rather than through the vaccine supply chain network). • Focus on waste of vaccines due to exposure to high temperature, as a result of a lack of access to cooling, rather than due to freezing or other types of damage. • Vaccine waste rates vary between different types of vaccines. This is partly due to the sensitivities of different vaccines as well as the way they are administered (over single or multiple sessions) and stored (in single or multiple vials). A study of vaccine wastage across areas of India found the average wastage rate to be 61% (for BCG vaccine), 47% (OPV), 35% (Measles), 34% (TT), 33% (Hepatitis B) and 27% (DPT). The same study also found these wastage rates differing between districts, with less wastage observed in more highly populated areas.		
Supporting literature	• It is recognised that there are insufficient data collected in off- and weak-grid settings of vaccine wastage rates due to lack of refrigeration. However, this is important in estimating needs and restocking to ensure that each health facility is able to carry out effective immunisation. • According to UNICEF, in the healthcare sector, the total addressable market for off-grid solar vaccine storage is around USD 811 million.[66] Reduction of waste is important to maximise the benefit from such investments. For example, an estimated 25% of vaccine wastage could be prevented through off-grid refrigeration in rural areas in India.[67] • Therefore, this metric aims to capture the reduction in the rate of vaccine waste at health facilities (i.e., at the service delivery level), which is the point at which solar-powered refrigerators of the size being discussed in this report would be used. • The Solar for Health initiative by the UNDP, which supported over 900 health centres and storage facilities in Sub-Saharan Africa, improved supply and management of medical and surgical consumables due to cold storage. Access to vaccines saw a significant improvement, increasing by 30%.[68] • Solar power helped health facilities save money in Sub-Saharan Africa by up to 40%, which can be reinvested to support other priority health programmes.[69] • More generally, the UNDP estimates a 100% return on investment within two – five years when health facilities with unreliable energy sources install solar systems. Solar energy contributes to more resilient health systems. A reliable power supply ensures that core systems for the management of health programmes can function effectively. Uninterrupted data input and analysis systems contribute to the efficient and accurate quantification and distribution of medicines, patient tracking and monitoring of overall health system performance.[70]		
Data gaps	Gaining more information on vaccine waste rates due to a lack of refrigeration.		

Table 17: Social / Health Impact

SF-SOC4: Number of end-users who perceive that the use of the refrigerator improves food security

METRIC	NUMBER OF PEOPLE WHO PERCEIVE AN IMPROVEMENT IN FOOD SECURITY AND NUTRITION DUE TO OWNING A REFRIGERATOR	
		STATUS
ID	SF-SOC4	●
		IMPACT
Appliance name	Refrigerator	⊕

66 UNICEF, Vaccine Wastage Assessment. (2010): https://www.mofa.go.jp/mofaj/gaiko/oda/seisaku/kanmin/chusho_h24/pdfs/a20-12.pdf

67 ibid

68 Tracey Burton, & Marcel Alers, Solar for Health: Five Ways Solar Power Can Make Universal Healthcare a Reality. (2019) UN Chronicles. https://www.un.org/en/un-chronicle/solar-health-five-ways-solar-power-can-make-universal-healthcare-reality

69 ibid

70 UN, Solar for Health: Five Ways Solar Power Can Make Universal Healthcare a Reality. (2019) United Nations; United Nations. https://www.un.org/en/un-chronicle/solar-health-five-ways-solar-power-can-make-universal-healthcare-reality

METRIC	NUMBER OF PEOPLE WHO PERCEIVE AN IMPROVEMENT IN FOOD SECURITY AND NUTRITION DUE TO OWNING A REFRIGERATOR		
Unit of measurement	Number of people		
Definition	The number of people who perceive an increase in food security as a result of accessing a solar-powered refrigerator.		
Usefulness of metric	To capture the benefit of improved food security and hence the advantages that this brings due to having access to a solar-powered refrigerator.		
Impact statement	X number of people are benefiting from an increased sense of food security due to the use of a solar-powered refrigerators.		
Calculation	SL × (1 – DL) × (1 – DR-Access) × H × PFS		
Variables	**VARIABLES**	**DEFINITION**	**VALUE**
	S	Number of units sold (cumulative, i.e. ever) (number of units)	This variable is to be inserted by the user
	DL	Discount for loss: products not working or not in use, excluding loss in supply chain (%)	4.5%
	DR-Access	Discount for repeat sales for estimating new access to solar powered appliances (including different companies) (%)	9%
	H	Household size (number of people)	5.5
	PFS	The percentage of people associating the appliance with improved food security (%)	10%
Assumptions	That individuals within a household have equal access to the use of the solar-powered refrigerator. This may not always be the case. For example, in countries where menstruation taboos still exist in rural communities, such as in India in Nepal, women are not permitted to use their kitchen, or handle food available to the family during their periods each month.		
Supporting literature	• Solar-powered refrigeration undoubtedly leads to an increase in food security for households that previously did not have access to any form of refrigeration. • Firstly, refrigeration leads to a reduction in expenditure due to food lasting longer, reduced waste, the ability to buy perishables in bulk, time savings by reducing the number of times a household has to purchase perishables and a reduction in fuel costs due to the ability to cook in bulk. • Secondly, it also reduces the risk of food poisoning and improves micronutrient uptake by increasing the variety and quality of the diet of adults and children, providing long-term health benefits.[71] Thirdly, it can also lead to an increase in income, due to smallholder farmers being able to store food more efficiently at home, thus having more produce to sell to the market as well as reducing post-harvest wastage. This reduction in expenditure and increase in income allows households to diversify the abundance and variety of food. • A study in rural Masaka, Uganda, for example, found that 77% of off-grid refrigerator owners modified their diet to incorporate more fresh fruit, juice and dairy products.[72] Another study in Kenya, taking evidence from 2.6 million supermarket customers in Nairobi, found that 30% of solar-powered refrigerator owners were more likely to purchase fresh fruit and vegetables, rather than non-perishable goods.[73] • A food security study in 13 sites across 11 low-income countries in East Africa, West Africa and South Asia found that solar-powered refrigeration provided more than a 10% reduction in the average number of months of food insecurity within households.[74] Research in Ghana found households with solar-powered refrigeration had greater access to clean water, due to the storage of sachet water in the refrigerator.[75] • A Rural Senses study of refrigerator users in Uganda and India found that 63.0% and 52.3% of respondents associated use of refrigerators with food security and longevity. Most references were made to the ability to store food for longer periods.[76]		
Input from stakeholders	Input from people / investors / donors.		
Data gaps	More data into the influence of a refrigerator on food security, including quantity and variety of food.		
Usage notes	PFS determined through a UPV game or questionnaire.		

71 Stephanie Hirmer, and Peter Guthrie, The benefits of energy appliances in the off-grid energy sector based on seven off-grid initiatives in rural Uganda. Renewable and Sustainable Energy Reviews, 79, 924–934. (2017): https://doi.org/10.1016/j.rser.2017.05.152

72 Cool Coalition, Do off-grid refrigerators benefit consumers long-term? (2020): https://coolcoalition.org/do-off-grid-refrigerators-benefit-consumers-long-term/

73 David Neven, Thomas Reardon, Jonathan Chege, & Honglin Wang, Supermarkets and Consumers in Africa. Journal of International Food & Agribusiness Marketing, 18(1–2), 103–123. (2006): https://doi.org/10.1300/J047v18n01_06

74 Meredith Niles, Jessica Rudnick, Mark Lubell, & Laura Cramer, Household and Community Social Capital Links to Smallholder Food Security. Frontiers in Sustainable Food Systems, 5. (2021): https://doi.org/10.3389/fsufs.2021.583353

75 Jude Nuru, Jason Rhoades, & James Gruber, Evidence of adaptation, mitigation, and development co-benefits of solar mini-grids in rural Ghana. Energy and Climate Change, 2, 100024. (2021): https://doi.org/10.1016/j.egycc.2021.100024

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

Table 18: Social / Health Impact

SF-SOC2a+b: Number of new end-users (and women specifically) who perceive that using an appliance saves time

METRIC	NUMBER OF PEOPLE / WOMEN WHO PERCEIVE THAT A SOLAR-POWERED REFRIGERATOR PROVIDES THEM WITH MORE FREE TIME		
			STATUS
ID	SF-SOC2a, SF-SOC2b (women only)		●
			IMPACT
Appliance name	Refrigerator		⊕
Unit of measurement	Number of people / women		
Definition	The number of people / women who perceive that a solar-powered refrigerator provides them with more free time.		
Usefulness of metric	The indicator estimates the proportion of people especially women, who benefit from having more free time in their daily lives to engage in other income-generating activities as a result of owning a refrigerator.		
Impact statement	X number of individuals or women experience an increase in free time and reduction in drudgery as a result of using a solar-powered refrigerator.		
Calculation	SL × (1 – DL) × (1 – DR-Access) × PT (SF-SCO2a) SL × (1 – DL) × (1 – DR-Access) × WomenT (SF-SCO2b)		
Variables	**VARIABLES**	**DEFINITION**	**VALUE**
	S	Number of units sold (cumulative, i.e. ever) (number of units)	This variable is to be inserted by the user
	DL	Discount for loss: products not working or not in use, excluding loss in supply chain (%)	4.5%
	DR-Access	Discount for repeat sales for estimating new access to solar powered appliances (including different companies) (%)	9%
	PT	Percentage of people with access to a [appliance name] that perceive the appliance contributes to 'time benefit', 'time management' or 'unburdening' (% of people)	1-15%
	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)	Pipeline variable
Assumptions	That solar-powered refrigeration disproportionately benefits women in terms of unburdening them of daily tasks.		
Supporting literature	• Studies have shown that owning modern appliances, especially refrigerators and washing machines, improves household welfare among those living in poverty by reducing drudgery and saving their time on daily activities like washing, cooking and cleaning.[77] The kinds of tasks being unburdened, such as cooking, shopping, fetching water or fetching fuel, disproportionally affect women. As such, it is important to capture the proportion of women benefiting from more free time due to the ownership of a solar-powered refrigerator, as this also seems to offer benefits in gender equality and female empowerment. • For example, in South Africa, female employment in new off-grid electrified communities rose by almost 10% because of the improved efficiency in carrying out domestic tasks. • A national-level income-expenditure survey in India found that within households with access to refrigeration, women derive greater utility through time saving that in turn reduces the cost of refrigerator ownership in the long run. Additional studies in India have shown that refrigerators can improve household welfare by reducing time poverty for women in low-income communities. Additionally, the time saved is used for income-generating activities in such communities that in turn, have extended health and well-being benefits. • A report by M-KOPA & CDC found that off-grid solar-powered refrigerators could save over KES 480 and two hours in wasted time every week. 61% of the interviewees saw the main beneficiary as the female head of the household – with time benefits disproportionately accruing to women, who are the primary shoppers in 91% of households in the survey. Refrigerators are shown to help make the shopper's role less stressful, with fewer trips to the market, less money spent on cooking fuel and food preserved for longer.[78]		

77 Ramit Debnath, Ronita Bardhan, and Minna Sunikka-Blank, Discomfort and distress in slum rehabilitation: Investigating a rebound phenomenon using a backcasting approach. Habitat International, 87, 75–90. (2019): https://doi.org/10.1016/j.habitatint.2019.03.010

78 M-KOPA and CDC, How Innovation in Off-Grid Refrigeration Impacts Lives in Kenya. (2019): https://assets.cdcgroup.com/wp-content/uploads/2019/10/29165356/How-innovation-in-off-grid-refrigeration-impacts-lives-in-Kenya.pdf

METRIC	NUMBER OF PEOPLE / WOMEN WHO PERCEIVE THAT A SOLAR-POWERED REFRIGERATOR PROVIDES THEM WITH MORE FREE TIME
Supporting literature	• Village Energy and CLASP followed up with off-grid refrigerator end-users to better understand product performance over time and the long-term impacts of the products on the entrepreneurs' lives and livelihoods. The study found that 83% of respondents reported that their business had evolved because of their refrigerator and 44% used additional funds from the refrigerator to pay for their children's education. The surveys also demonstrated that refrigerators improved consumers' nutrition as 77% had modified their diet with fresh fruit, juice and dairy products.[79] • In Uganda, a Rural Senses study of refrigerator users refrigerators found that 15.2 % of the respondents associated using their refrigerator use with time savings, unburdening and improved time management.[80]
Data gaps	More evidence about the link between the use of a refrigerator and time saving, especially for women.
Usage notes	Values for PT vary depending on the geography. To find the most suitable value, please refer to the elaborated variable sheet (click on the variable name).

Table 19: Social / Health Impact
SF-SOC3: Number of end-users who perceive improved quality of life

METRIC	NUMBER OF PEOPLE WHO EXPERIENCE IMPROVED QUALITY OF LIFE DUE TO OWNING A REFRIGERATOR		
			STATUS
ID	SF-SOC3		●
			IMPACT
Appliance name	Refrigerator		⊕
Unit of measurement	Number of people		
Definition	The number of people benefiting from an increased sense of quality of life due to the use of a solar-powered refrigerator.		
Usefulness of metric	The indicator gives an indication of people who use solar-powered refrigerators who perceive it to be a source of improved quality of life.		
Impact statement	X number of people are benefiting from an improved quality of life due to the use of a solar-powered refrigerator.		
Calculation	SL × (1 – DL) × (1 – DR-Access) × H × PQL		
Variables	**VARIABLES**	**DEFINITION**	**VALUE**
	S	Number of units sold (cumulative, i.e. ever) (number of units)	This variable is to be inserted by the user
	DL	Discount for loss: products not working or not in use, excluding loss in supply chain (%)	4.5%
	DR-Access	Discount for repeat sales for estimating new access to solar powered appliances (including different companies) (%)	9%
	H	Household size (number of people)	5.5
	PQL	The percentage of people associating the appliance with improved quality of life (%)	15%
Assumptions	None		
Supporting literature	• A Rural Senses survey of off-grid refrigerator users found that 78.30% and 59.10% of respondents in Uganda and India respectively associated the use of a refrigerator with improved quality of life with proxies, such as, food security, time benefit, unburdening, preventative healthcare and income generation.[81]		

79 Michael Maina, Siena Hacker, & Hannah Blair, Do Off-Grid Refrigerators Benefit Consumers Long-Term? - Cool Coalition. (2020): https://coolcoalition.org/do-off-grid-refrigerators-benefit-consumers-long-term/
80 Rural Senses. Impact Assessment Framework End-User Research in Uganda & India'. (2021) (End-User research unpublished).
81 ibid

METRIC	NUMBER OF PEOPLE WHO EXPERIENCE IMPROVED QUALITY OF LIFE DUE TO OWNING A REFRIGERATOR
Supporting literature	• A report by M-KOPA & CDC found that off-grid solar-powered refrigerators could save over KES 480 and two hours in wasted time every week. 61% of interviewees saw the main beneficiary as the female head of the household – with time benefits disproportionately accruing to women who are the primary shoppers in 91% of households in the survey. Refrigerators are shown to help make the shopper's role less stressful, with fewer trips to the market, less money spent on cooking fuel and food preserved for longer.[82] • Village Energy and CLASP followed up with off-grid refrigerator field test users to better understand product performance over time and the long-term impacts of the products on the entrepreneurs' lives and livelihoods. They found that 83% of respondents reported that their business had evolved because of the refrigerator and 44% used additional funds from the refrigerator to pay for their children's education. The surveys also showed that refrigerators improved consumers' nutrition, as 77% of respondents had modified their diet with fresh fruit, juice and dairy products.[83]
Data gaps	Impact of a solar-powered refrigerator on individual stress and wellbeing levels.
Usage notes	PQL determined through a UPV game or questionnaire.

82 M-KOPA and CDC, How Innovation in Off-Grid Refrigeration Impacts Lives in Kenya. (2019): https://assets.cdcgroup.com/wp-content/uploads/2019/10/29165356/How-innovation-in-off-grid-refrigeration-impacts-lives-in-Kenya.pdf

83 Michael Maina, Siena Hacker, & Hannah Blair, Do Off-Grid Refrigerators Benefit Consumers Long-Term? - Cool Coalition. (2020): https://coolcoalition.org/do-off-grid-refrigerators-benefit-consumers-long-term/

Standard Variables – Elaborated

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

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

In the section of the table related to applicability for each variable, the 'degree of urbanisation' factor indicates which of three different categories of urbanisation the variable is appropriate for: (a) cities (densely populated areas), (b) towns and suburbs (intermediate density areas) and (c) rural areas (thinly populated areas).[84]

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

Table 20: DL: Discount for loss: products not working or not in use, excluding loss in supply chain (%)

DL	DISCOUNT FOR LOSS: PRODUCTS NOT WORKING OR NOT IN USE, EXCLUDING LOSS IN SUPPLY CHAIN (%)			
Unit	%			
Appliance	Refrigerator			
Applicability	**GEOGRAPHY**	**DEGREE OF URBANISATION**	**CONFIDENCE**	**VALUE**
	East Africa	Rural	***	4.5%
Supporting literature	Efficiency for Access and 60 Decibels' study on the "Use and Impacts of Refrigerators" found that on average 4.5% of 1,104 refrigerator owners did not use their product after 19 months.[85]			
Limitations / biases	It is not clear what proportion of refrigerator owners face issues that have not been resolved.			
Data gaps	The proportion of solar-powered refrigerators bought are lost or fall into disrepair and are not used.			

Table 21: DR-Access: Discount for repeat sales for estimating new access to solar-powered appliances (including different companies) (%)

DR-ACCESS	DISCOUNT FOR REPEAT SALES FOR ESTIMATING NEW ACCESS TO SOLAR APPLIANCE (INCLUDING DIFFERENT COMPANIES) (%)			
Unit	%			
Appliance	Refrigerator			
Applicability	**GEOGRAPHY**	**DEGREE OF URBANISATION**	**CONFIDENCE**	**VALUE**
	N|A	N|A	**	9%
Supporting literature	According to our discussions with stakeholders, repeat sales for solar-powered refrigerators account for 9% of all solar-powered refrigerator sales.			
Limitations / biases	N|A			
Data gaps	How this figure of 9% varies across geographies			

84 Eurostat, Applying the Degree of Urbanisation. OECD; 2021. (2021): https://doi.org/10.1787/4bc1c502-en

85 Efficiency for Access and 60_Decibels, Use and Impacts of Fridges (to be published August 2022)

Table 22: DR-GHG: Ratio capturing sales replacing a diesel genset-powered appliance (%)

DR-GHG	RATIO CAPTURING SALES REPLACING A DIESEL GENSET-POWERED APPLIANCE (%)			
Unit	%			
Appliance	Refrigerator			
Applicability	**GEOGRAPHY**	**DEGREE OF URBANISATION**	**CONFIDENCE**	**VALUE**
	N|A	N|A	**	9%
Supporting literature	According to our discussions with stakeholders, repeat sales for solar-powered refrigerators account for 9% of all solar-powered refrigerator sales, all of which involve replacement of diesel genset-powered appliances.			
Limitations / biases	There is an assumption that all repeat sales relate to the replacement of diesel genset-powered appliances.			
Data gaps	• Verifying the assumption that all repeat sales relate to replacement of diesel genset-powered appliances. • Exploring how this figure of 9% varies across geographies.			

Table 23: EF-Employment factor (jobs/item sold)

EF	EMPLOYMENT FACTOR (JOBS / ITEM SOLD)			
Unit	%			
Appliance	Jobs / item sold			
	GEOGRAPHY	**DEGREE OF URBANISATION**	**CONFIDENCE**	**VALUE**
Applicability	Nigeria	Nationwide	**	0.0188
	Kenya	Nationwide	**	0.0082
	India	Nationwide	**	0.0137
Supporting literature	• According to Power for All's "Powering Jobs Census 2019", the employment factors for pico solar appliances and SHSs in Nigeria, Kenya and India for 2017–2018 were 18.8 jobs, 8.2 jobs and 13.7 jobs per 1,000 items sold respectively. • The information is based on a survey carried out across 150 companies in India, Kenya and Nigeria. These companies were surveyed across the decentralised renewable energy (DRE) technology spectrum and the survey covers the supply chain, from manufacturing and wholesale imports to sales, installation and operations. This included DRE companies working in off-and weak-grid or on-grid contexts.[86]			
Limitations / biases	• The above figures relate to jobs created in the pico solar appliances market used to power solar refrigerators, rather than jobs in the solar-powered refrigerator market itself. • Furthermore, the above figures relate to formal jobs created along the supply chain of the appliance and do not consider the large number of informal jobs created, of which women occupy a large proportion.			
Data gaps	Employment factor specifically for the entire supply chain of solar-powered refrigerators.			

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

Table 24: EFA: Proportion of employment factor relevant to each appliance

EFA	PROPORTION OF EMPLOYMENT FACTOR RELEVANT TO EACH APPLIANCE			
Unit	%			
Appliance	Refrigerator			
Applicability	**GEOGRAPHY**	**DEGREE OF URBANISATION**	**CONFIDENCE**	**VALUE**
	Global	Nationwide	***	100%
Supporting literature	According to the "Powering Jobs census 2019",[87] discount ratios are assigned based on the average appliance-to-total-SHS-cost ratios from the VeraSol database. These values equate to 100% of refrigerators.			
Limitations / biases	The above figures relate to pico solar appliances as a whole, including systems for powering solar-powered refrigerators. They do not refer to jobs created specifically in the solar-powered refrigerator market.			
Data gaps	Percentage of the employment factor specifically dedicated to the solar-powered refrigerator market.			

Table 25: FSD: Average domestic food savings per year per litre of refrigerator volume per household due to the use of refrigeration (kg / litre / year)

FSD	AVERAGE DOMESTIC FOOD SAVINGS PER YEAR PER LITRE OF REFRIGERATOR VOLUME PER HOUSEHOLD DUE TO THE USE OF REFRIGERATION (KG / LITRE / YEAR)			
Unit	kg / litre / year			
Appliance	Refrigerator			
Applicability	**GEOGRAPHY**	**DEGREE OF URBANISATION**	**CONFIDENCE**	**VALUE**
	N|A	N|A	N|A	N|A
Supporting literature	There is currently no literature providing an estimate of domestic food savings per year per litre of refrigerator volume, due to refrigeration. Research shows that off-grid refrigeration is mainly used in business settings to cool drinks, dairy or fisheries.[88]			
Limitations / biases	N|A			
Data gaps	Domestic food savings per year per litre of refrigerator volume, due to refrigeration, in the areas of interest.			

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

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

Table 26: G: Average amount of greenhouse gases avoided per appliance, due to diesel displacement (kg CO_2 / year)

G	AVERAGE AMOUNT OF GREENHOUSE GASES AVOIDED PER APPLIANCE, DUE TO DIESEL DISPLACEMENT (KG CO_2 / YEAR)			
Unit	kg CO_2e / year			
Appliance	Refrigerator			
Applicability	**GEOGRAPHY**	**DEGREE OF URBANISATION**	**CONFIDENCE**	**VALUE**
	Internationally	N/A	***	170
Supporting literature	Assuming that the solar equivalent appliance will have zero end-use emissions, the emissions of a single appliance equal:[89] • (Required energy / 10^12) × Emissions Factor of a Diesel Generator; Where the required energy equals: • (Delivered Energy × 3600 × 1 / Generator efficiency) Assuming a generator efficiency of 25% and the following: • Run-time of three hours / day; • Refrigerator energy consumption: 0.075; • Daily energy consumption of 1.8 kWh / day; • Annual operating days of 365; Then the required annual Delivered Energy is 55 kWh / year and the annual Required Energy is 0.0023 TJ / year. As such, CO_2e emissions saved from using a solar powered TV equal 59 kgCO_2e / year. Diesel Emission Factor: 74100 kgCO_2 / TJ [90]			
Limitations / biases	The above figures assume that solar-powered refrigerators run for 24 hours for 365 days per year. However, it is common practice in locations where electricity is unreliable for refrigerators to be switched off at night or during out of season periods to save on electricity costs			
Data gaps	Whether behaviour related to switching off refrigerators during cooler hours of the day or off-season periods changes with ownership of a solar-powered refrigerator should be investigated			

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

90 ibid

Table 27: H: Household size (number of people)

H	HOUSEHOLD SIZE (NUMBER OF PEOPLE)			
Unit	Number of people			
Appliance	All			
	GEOGRAPHY	**DEGREE OF URBANISATION**	**CONFIDENCE**	**VALUE**
Applicability	South Asia	General	***	5.5
	West Africa	Urban	***	6
	West Africa	Rural	***	8
	East Africa	Urban	***	5.3
	East Africa	Rural	***	5.5
Supporting literature	• 60 Decibels interviewed 25,497 individuals in its study on "Why Off-Grid Energy Matters" in East Africa (61%), West Africa (16%) and South Asia (14%) and recorded an average household size of 5.9.[91] • The Efficiency for Access publication, "Socio-Economic Impacts of Super-Efficient Off-Grid fans in Bangladesh"[92] reported that the average household size of the sample was 5.3 people, with two-thirds of the household size falling into the range of three to six people. • ALTAI and GOGLA's "Powering Opportunity in East Africa: Proving Off-Grid Solar is a Power Tool for Change"[93] report recorded an average household size of 5.7; ALTAI and GOGLA's "Powering Opportunity in West Africa: Improving Lives, Powering Livelihoods with Off-Grid Solar"[94] report highlighted that "while the average household size was seven across the research, urban households tend to be closer to six members while rural households are closer to eight members". • ALTAI and GOGLA's "Powering Opportunity in South Asia: From Work to Well-being, the Important Role of Small Scale Solar"[95] report stated that the average household size among pre-purchase interviewees is 6.9. • The United Nations "Household Size and Composition Around the World 2017" study reported average household size of 4.8 in India and 6.8 in Pakistan.[96]			
Limitations / biases	Off-grid household data show larger household sizes than the national averages; this needs to be further investigated.			

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

92 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/

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

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

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

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

Table 28: OPEXD: Annual operating fuel cost of a diesel-powered appliance (USD / year)

OPEXD	ANNUAL OPERATIONAL FUEL COST OF A DIESEL-POWERED APPLIANCE (USD / YEAR)			
Unit	USD / year			
Appliance	Refrigerator			
Applicability	**GEOGRAPHY**	**DEGREE OF URBANISATION**	**CONFIDENCE**	**VALUE**
	India	Nationwide	***	176 (households) 269.2 (micro-enterprises)
Supporting literature	• According to a study carried out by Intellecap and GOGLA[97], the annual operational expenditure (OPEX) of different refrigerators in India are as follows: Household refrigerator, running on: • A diesel generator — USD 176 / year • The grid — USD 47.6 / year. A microenterprise refrigerator, running on: • A diesel generator — USD 269.2 / year.			
Limitations / biases	The OPEX for enterprises assumes a yearly cost of energy consumption of USD 262.5. This consumption can vary depending on the nature of the business.			

Table 29: PFS: The percentage of people associating the appliance with improved food security (%)

PFS	PERCENTAGE OF PEOPLE ASSOCIATING THE APPLIANCE WITH IMPROVED FOOD SECURITY (%)			
Unit	%			
Appliance	Refrigerator			
Applicability	**GEOGRAPHY**	**DEGREE OF URBANISATION**	**CONFIDENCE**	**VALUE**
	Sub-Saharan Africa	General	**	10%
	South Asia	General	**	10%
Supporting literature	• A study in rural Masaka, Uganda, found that 77% of off-grid refrigerator owners modified their diet to incorporate more fresh fruit, juice and dairy products.[98] • Another study in Kenya, taking evidence from 2.6 million supermarket customers in Nairobi, found that 30% of solar-powered refrigerator owners were more likely to purchase fresh fruit and vegetables, rather than non-perishable goods.[99] • A food security study in 13 sites across 11 low-income countries in East Africa, West Africa and South Asia found solar-powered refrigeration provided more than a 10% reduction in average months of food insecurity within households.[100] Research in Ghana found that households with a solar-powered refrigeration had greater access to clean water, due to the storage of sachet water in the refrigerator.[101] • Rural Senses' study of people with access to refrigerator users in Uganda and India found that 63.0 % and 52.3 % of the participants associated use of refrigerators with food security and longevity.[102]			
Limitations / biases	• We use the data points from the study of 11 sites across 11 countries in Sub-Saharan Africa and South Asia because that is a good sample. However, we understand that generalising a single data point over regions introduces biases. • The Rural Senses data point is not used because the sample size is small and is not comparable to the other data points.			
Data gaps	The proxies for food security need to be clearly defined. Country and regional independent studies with comparable indicators and quantitative scales are required.			

97 Intellecap and GOGLA,. Decentralised Solar Refrigeration: Opportunities in the Livelihood Appliances Market in India. (2021): https://www.gogla.org/sites/default/files/resource_docs/report_decentralised_solar_refrigeration_opportunities_in_the_livelihood_appliances_market_in_india_gogla_intellecap.pdf

98 Cool Coalition, Do off-grid refrigerators benefit consumers long-term? (2020): https://coolcoalition.org/do-off-grid-refrigerators-benefit-consumers-long-term/

99 David Neven, Thomas Reardon, Jonathan Chege, & Honglin Wang, Supermarkets and Consumers in Africa. Journal of International Food & Agribusiness Marketing, 18(1–2), 103–123. (2006): https://doi.org/10.1300/J047v18n01_06

100 Meredith Niles, Jessica Rudnick, Mark Lubell, & Laura Cramer, Household and Community Social Capital Links to Smallholder Food Security. Frontiers in Sustainable Food Systems, 5. (2021): https://doi.org/10.3389/

101 Jude Nuru, Jason Rhoades, & James Gruber, Evidence of adaptation, mitigation, and development co-benefits of solar mini-grids in rural Ghana. Energy and Climate Change, 2, 100024. (2021): https://doi.org/10.1016/j.egycc.2021.100024

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

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

PI-30	PERCENTAGE OF PEOPLE WHO EXPERIENCED AT LEAST A 30% ANNUAL INCOME INCREASE (%)			
Unit	%			
Appliance	Refrigerator			
Applicability	**GEOGRAPHY**	**DEGREE OF URBANISATION**	**CONFIDENCE**	**VALUE**
	India	Rural	*	70%
Supporting literature	• According to a SELCO pilot study of 45 solar-powered refrigerators in South India, 70% of participants reported increased profit of more than 26%.[103] • Several other literature sources mention significant increases in income from SMEs due to diversification of services enabled due to solar-powered refrigeration ownership, but data to inform this precise variable are scarce.			
Limitations / biases	The above value applies for a 26% rather than a 30% increase in income. It applies to the use of small, medium and large refrigerators by petty shops, mobile canteens, home entrepreneurs and institutes. This is the best that could be found in current literature.			
Data gaps	Additional studies on the percentage of solar-powered refrigerator users who experienced at least a 30% annual income increase as a result of the refrigerator.			

103 SELCO, Energising livelihoods through decentralised solar powered refrigeration solutions. (2019): https://ddsolar.in/wp-content/uploads/2020/04/Energizing-Livelihoods-through-Decentralized-Solar-Refrigerators-COMPRESSED.pdf

Table 31: PQL: Percentage of people who associate the appliance with improved quality of life (%)

PQL	PERCENTAGE OF PEOPLE WHO ASSOCIATE THE APPLIANCE WITH IMPROVED QUALITY OF LIFE (%)			
Unit	%			
Appliance	Refrigerator			
Applicability	**GEOGRAPHY**	**DEGREE OF URBANISATION**	**CONFIDENCE**	**VALUE**
	Uganda	Rural	**	15%
Supporting literature	• Studies have shown that owning modern appliances, especially refrigerators and washing machines, improves household welfare among those living in poverty by reducing drudgery and saving their time on daily activities like washing, cooking and cleaning.[104] The kinds of tasks being unburdened, such as cooking, shopping, fetching water or fetching fuel, disproportionally affect women. As such, it is important to capture the proportion of women benefiting from more free time due to the ownership of a solar-powered refrigerators, as this seems to also offer benefits in gender equality and female empowerment. • For example, in South Africa, female employment in new off-grid electrified communities rose by almost 10% because of the improved efficiency in carrying out domestic tasks. • A national-level income-expenditure survey in India found that within households with refrigeration, women derive greater utility through time saving that in turn reduces the cost of refrigerator ownership in the long run. Additional studies in India have shown that refrigerators could improve household welfare by reducing time poverty for women in low-income communities. Additionally, that extra free time is used for income-generating activities in such communities that, in turn, have extended health and well-being benefits. • A report by M-KOPA & CDC found that off-grid solar-powered refrigerators could save over KES 480 and two hours in wasted time every week. 61% of respondents saw the main beneficiary as the female head of the household – with time benefits disproportionately accruing to women, who are the primary shoppers in 91% of households in the survey. Refrigerators were shown to help make the shopper's role less stressful, with fewer trips to the market, less money spent on cooking fuel and food preserved for longer.[105] • Village Energy and CLASP followed up with off-grid refrigerator end-users to better understand product performance over time and the long-term impacts of the products on the entrepreneurs' lives and livelihoods found that 83% of respondents reported that their business had evolved because of the appliance and 44% used additional funds from the refrigerator to pay for their children's education. The surveys also showed that refrigerators improved consumers' nutrition as 77% had modified their diet with fresh fruit, juice and dairy products.[106] • In Uganda, Rural Senses' study of refrigerator users found that 15.2% of the respondents associated their refrigerator use with more time, unburdening and improved time management.[107]			
Limitations / biases	Only one data point from Uganda is taken into consideration because, despite other off-grid surveys providing evidence of this impact, the extent is not quantified.			
Data gaps	Quantitative evidence on the extent of this impact; the dimension of measurement and the clear definition of the proxies for improved quality of life.			

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105 MKOPA and CDC. How Innovation in Off-Grid Refrigeration Impacts Lives in Kenya, 28 October 2019. (2019): https://assets.cdcgroup.com/wp-content/uploads/2019/10/29165356/How-innovation-in-off-grid-refrigeration-impacts-lives-in-Kenya.pdf

106 Michael Maina, Siena Hacker, & Hannah Blair, Do Off-Grid Refrigerators Benefit Consumers Long-Term? - Cool Coalition. (2020): https://coolcoalition.org/do-off-grid-refrigerators-benefit-consumers-long-term/

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Table 32: 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)

PT	PERCENTAGE OF PEOPLE WITH ACCESS TO A [APPLIANCE NAME] WHO PERCEIVE THAT THE APPLIANCE CONTRIBUTES TO 'TIME BENEFIT', 'TIME MANAGEMENT', OR 'UNBURDENING' (% OF PEOPLE)			
Unit	Number of people			
Appliance	Refrigerator			
Applicability	**GEOGRAPHY**	**DEGREE OF URBANISATION**	**CONFIDENCE**	**VALUE**
	Uganda	Rural	*	15%
	India	Rural	*	1%
Supporting literature	• A report by M-KOPA & CDC found that off-grid solar-powered refrigerators could save over KES 480 and two hours of time every week. 61% of the respondents saw the main beneficiary as the female head of the household – with time benefits disproportionately accruing to women, who are the primary shoppers in 91% of households in the survey. • Refrigerators were shown to help make the shopper's role less stressful, with fewer trips to the market, less money spent on cooking fuel and food preserved for longer.[108] • Village Energy and CLASP followed up with off-grid refrigerator end-users to better understand product performance over time and the long-term impacts of the products on the entrepreneurs' lives and livelihoods. The study found that 83% of respondents reported that their business had evolved because of the appliance and 44% used additional funds from the refrigerator to pay for their children's education. The surveys also showed that refrigerators improved consumers' nutrition as 77% had modified their diet with fresh fruit, juice and dairy products.[109] • In Uganda, Rural Senses' study of 46 and 88 refrigerator users found that 15.2% and 1.1.% of users associated their refrigerator use with time benefit, unburdening, or time management in Uganda and India respectively.[110] However, these benefits did not account for the top five benefits users associated with a refrigerator.			
Limitations / biases	A perception variable is highly dependent on the specific community and additional factors.			
Data gaps	Individuals who own a solar-powered refrigerator and relate or assign the User-Perceived Values of 'time benefit', 'time management', or 'unburdening' to the appliance within a representative sample of solar-powered refrigerator owners.			

108 MKOPA and CDC. How Innovation in Off-Grid Refrigeration Impacts Lives in Kenya, 28 October 2019. (2019): https://assets.cdcgroup.com/wp-content/uploads/2019/10/29165356/How-innovation-in-off-grid-refrigeration-impacts-lives-in-Kenya.pdf

109 Michael Maina, Siena Hacker, & Hannah Blair, Do Off-Grid Refrigerators Benefit Consumers Long-Term? - Cool Coalition. (2020): https://coolcoalition.org/do-off-grid-refrigerators-benefit-consumers-long-term/

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Table 33: VUC: Average vaccine utilisation rate within a defined period or immunisation programme (%)

VUC	AVERAGE VACCINE UTILISATION RATE WITHIN A DEFINED PERIOD OR IMMUNISATION PROGRAMME (%)			
Unit	%			
Appliance	Refrigerator			
Applicability	**GEOGRAPHY**	**DEGREE OF URBANISATION**	**CONFIDENCE**	**VALUE**
	India	Rural & Urban	***	60.50%
Supporting literature	• In India, the wastage rate of COVID-19 vaccinations is estimated to be between 1-15% with a national average of 6.3%.[111] • Before the COVID-19 pandemic, a study of five states in India (Uttar Pradesh, Assam, Maharashtra, Tamil Nadu and Himachal Pradesh) found different levels of vaccine waste for different types of vaccines at the session site over a period of six months (location where the vaccine is being administered, as opposed to the supply chain). This was found to be up to 61% for the BCG vaccine, while it was found to be 47% for OPV, 35% for Measles, 34% for TT, 33% for HepB and 27% for DPT vaccines. This leads to an average of 39.5% across all vaccines — i.e. a vaccine utilisation rate of 60.5% (UNICEF, 2010).			
Limitations / biases	The reduced vaccine utilisation is not purely because of refrigeration issues, but also due to unopened vials, vaccines being frozen, vaccines expiring, missing inventory, breakage, theft and loss. In the case of opened vials (with multiple vaccine doses per vial), additional reasons for wastage include discarding of remaining doses at the end of the session, being unable to draw from the vial the intended number of vaccines, suspected contamination, poor administration processes etc.[112]			
Data gaps	There are insufficient data collected in weak and off-grid settings of vaccine wastage rates due to lack of refrigeration.			

111 VC World Bureau, Off-Grid Solar Refrigeration: Cure to the Growing Vaccine Wastage Crisis – An Intellecap & VCWorld Special Feature: – VCWorld. (2021) https://vc-world.in/2021/07/17/intellecap-vcworld-special-feature-off-grid-solar-refrigeration-cure-to-the-growing-vaccine-wastage-crisis/

112 ibid

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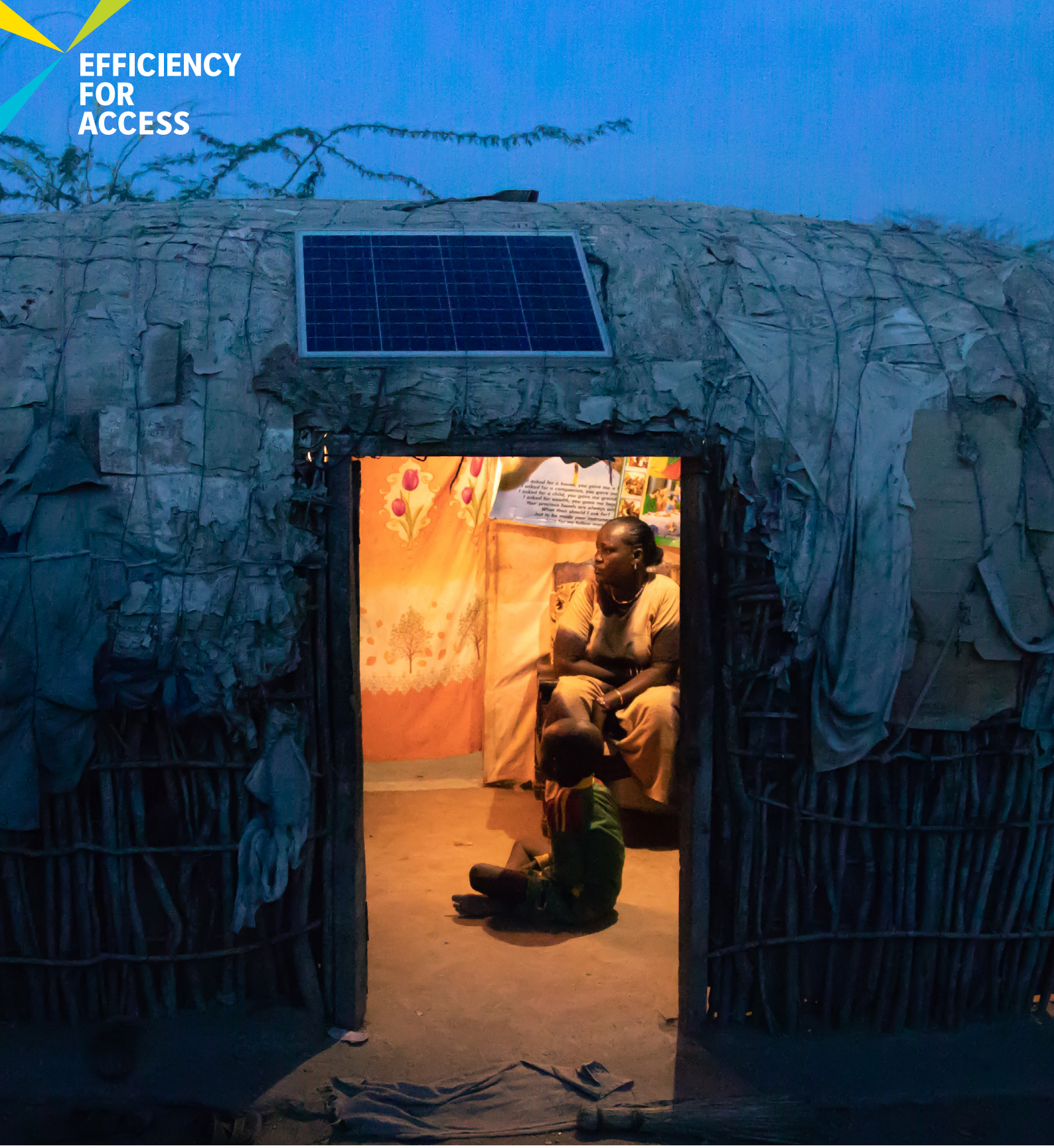

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