The Voice of the Off-Grid Solar Energy Industry

Standardized Impact Metrics for the Off-Grid Solar Energy Sector

GOGLA

GOGLA is the global association for the off-grid solar energy industry. Established in 2012, GOGLA now represents over 135 members as a neutral, independent, not-for-profit industry association. Its mission is to help its members build sustainable markets, delivering quality, affordable products and services to as many households, businesses and communities as possible across the developing world. The products and solutions that GOGLA members sell transform lives. They improve health and education, create jobs and income opportunities and help consumers save money.

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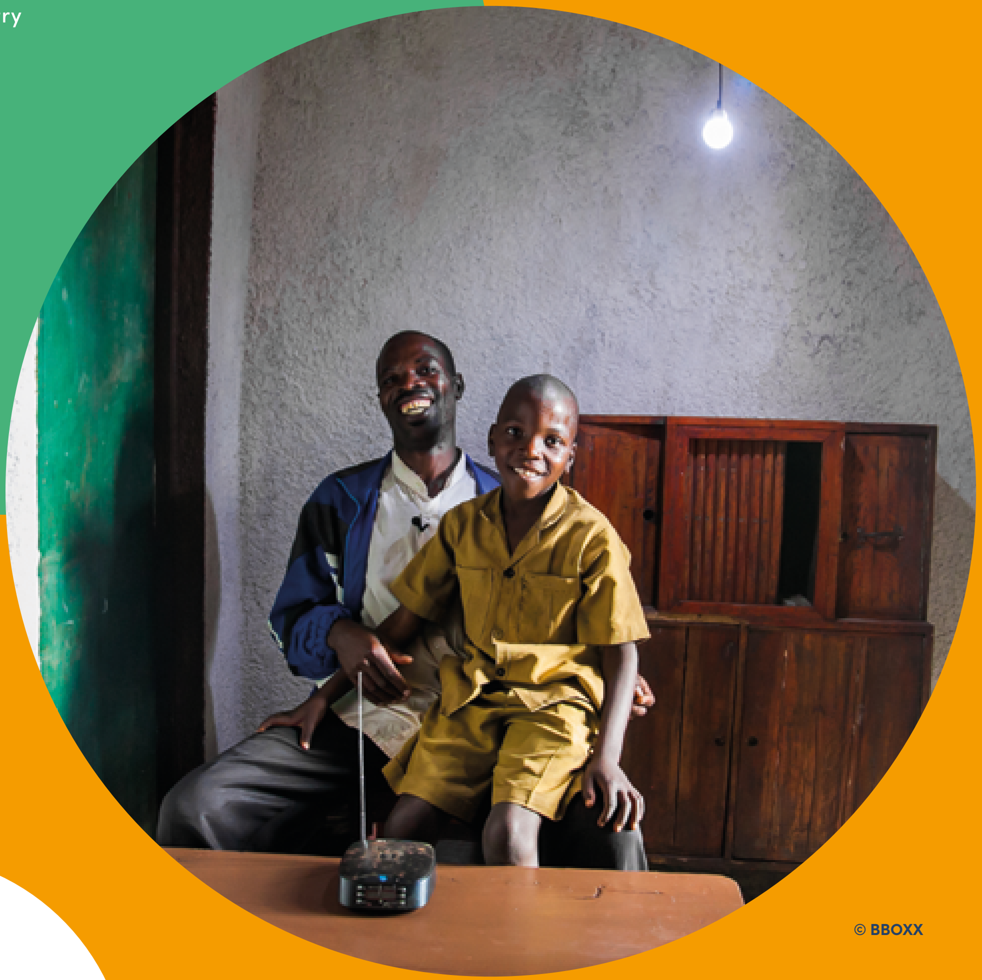

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1. Why Impact Metrics Matter

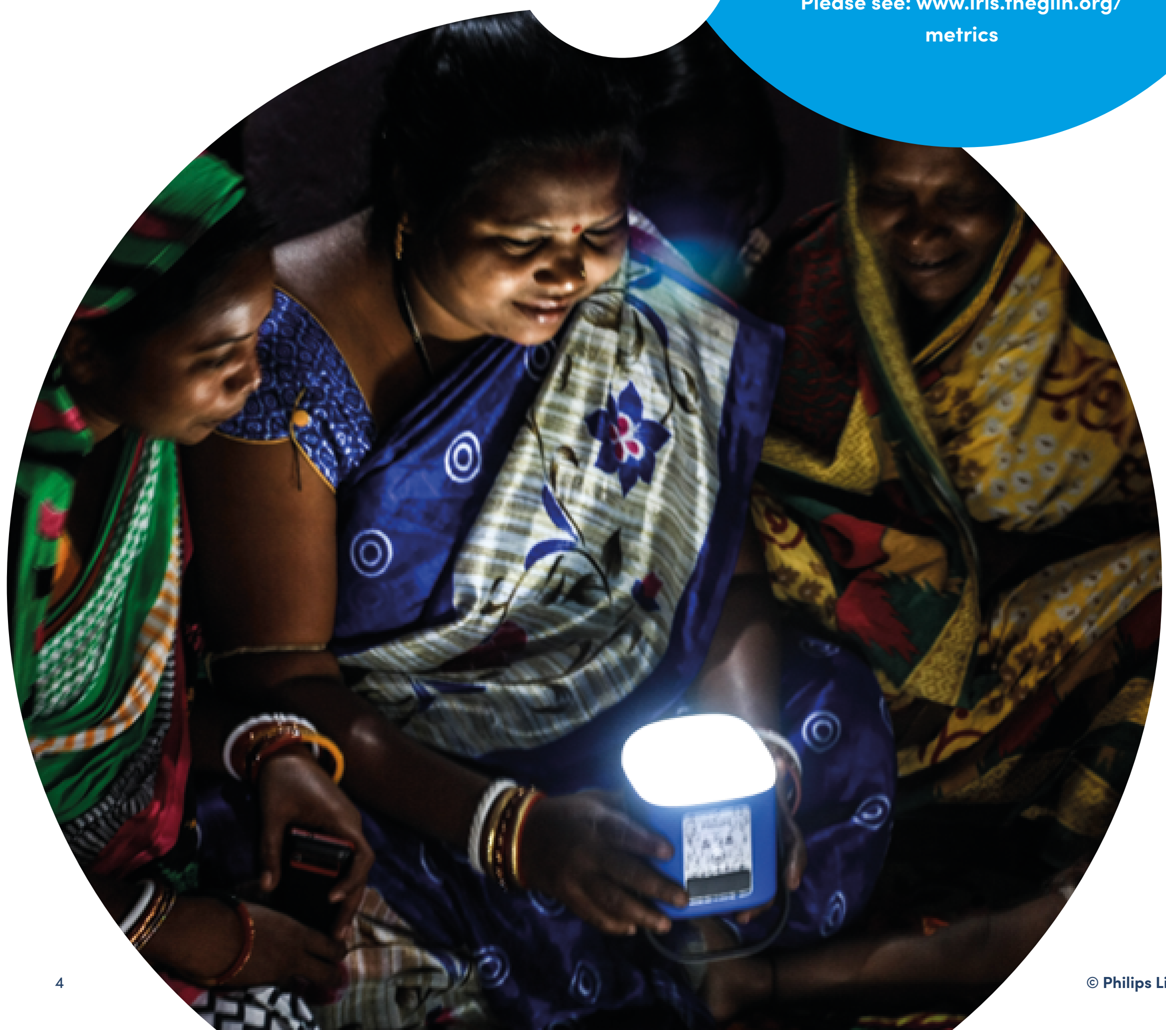
A consistent approach to impact measurement allows companies, investors, policy-makers, multi-lateral institutions, non-government organizations and other sector stakeholders to comprehensively estimate the impacts created by off-grid solar. For this reason, the GOGLA Impact Working Group was established in 2013, with the goal of creating the first standardized impact metrics for the off-grid industry. These metrics were designed to enhance knowledge, streamline reporting and attract investment, working capital, and regulatory support. The first standardized impact metrics were launched in 2015.

This document presents Version 3.0 of those metrics, which have been updated and expanded using the best available data from across the off-grid solar industry and research community. The updated metrics also enable users to measure the impact of different categories of off-grid technology – from solar lanterns to large solar home systems.

Individual organizations can use these metrics to estimate the impact of their products, services or market supporting activities. GOGLA also uses the metrics to calculate the impact of all GOGLA Members and IFC Associate companies twice yearly in its Off-Grid Solar Global Sales and Impact Reports – enabling aggregated impact insights to be shared with key decision-makers.

As with the previous version, version 3.0 of the Standardized Impact Metrics for the Off-Grid Solar Sector has been aligned with the IRIS Metrics.

IRIS is an initiative of the Global Impact Investing Network (GIIN), a non-profit organization dedicated to increasing the scale and effectiveness of impact investing. Please see: www.iris.thegiin.org/metrics



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2. How to use the Metrics

The off-grid solar industry and sector stakeholders can:

1. Adopt the GOGLA metrics framework
Organizations including manufacturers, distributors, investors, multilateral programs, and industry groups are strongly encouraged to adopt this set of core metrics as a key input to estimating and reporting impact. When organizations report impact on one or more of the dimensions included in this framework, the GOGLA methodology should be applied.

2. Go beyond the framework
There are a range of development outcomes that may be specific to a region, product, or company. Users are encouraged to go beyond the framework to collect targeted data. Research by individual organizations helps to increase the knowledge base, provide contextually specific data-points and allows for a greater awareness of, and solutions to, any challenges identified. The GOGLA framework is meant as a foundation, not a ceiling, on social impact reporting.

3. Broadcast results
Organizations and coalitions that adopt the GOGLA framework are encouraged to speak with a unified language about the estimated impact being created by the off-grid solar industry.

When using the impact metrics, please be aware that:

Specific metrics or variables apply to specific technology types and sizes. For example, certain variables might be specific to Pay-As-You-Go (PAYG) companies only, while different variables may apply to solar lanterns versus large solar home systems. Please ensure you review the metrics carefully and only use those metrics that relate to the relevant product(s) or service(s).

The metrics apply to solar products sold in off-grid or underserved communities only. Therefore, only off-grid solar products sold in the developing world should be included when using the metrics to measure impact.

These metrics apply to high-quality solar products. The metrics have been created using data and evidence from high-quality solar products. As such, these metrics should only be used to calculate the impact of GOGLA Members or organizations selling Lighting Global / IEC quality-verified solar products, or products that deliver comparable performance.

Results calculated using these metrics should be described as estimates. It is important to note that, while these metrics have been created using the best available data, when describing results created by using the metrics these should always be referred to as estimates as the data represents research done with specific companies or organizations which may not be representative of all GOGLA Member impact.

Metrics should not be used when it is clear specific products and services do not have the estimated impact. While applicable in most cases, there may be instances where a specific product type, location or use-case may not lead to a commonly observed impact. For example, in a region with a high density of torch use, little kerosene reduction will be seen, while systems sold specifically to light an educational facility are less likely to lead to new business creation. A common-sense approach should be taken to use and application of the impact metrics.

3. Background

In 2013 the GOGLA Impact Working Group was established to conservatively construct calculations for modelling a set of priority impact metrics. The Impact Working Group brought together off-grid practitioners, researchers and data experts to co-create these metrics. This resulted in Version 1.0 of the Standardized Impact Metrics, launched in June 2015 and piloted by the GOGLA membership. Following the pilot, the Impact Working Group published Version 2.0 of the metrics in January 2016.

In Version 3.0, outlined in this paper, the Impact Working Group has further refined and updated the standardized impact metrics, with data gathering and synthesis support provided by the GOGLA Secretariat and researchers from the Schatz Energy Research Center.

Between 2016-18 the GOGLA Impact Working Group:

- reconfirmed priority metrics relevant to the impact of off-grid energy access on end-users
- verified or updated appropriate formulae for calculating metric values
- sourced available data to confirm or update coefficient default values, with references, assumptions and limitations outlined
- split the Impact Metrics so they can better represent Pay-As-You-Go (PAYG) and Solar Home Systems (SHS)
- created seven new impact metrics

This Paper was developed to:

- update and replace Version 2.0
- provide specific metrics relevant for the impact of solar lanterns, multi-light kits, small solar home systems and large solar home systems
- expand the impact metrics to include income generation and economic activity
- enable and encourage more off-grid organizations and stakeholder to use these standardized metrics to calculate estimated impact

Impact Metrics: An Iterative Approach

As the ongoing review and expansion of the impact metrics indicates, GOGLA's approach to measuring the impact of off-grid solar products has been iterative – and will continue to be so as new data and evidence become available. GOGLA aims to review and revise these metrics every 18-24 months to ensure that they are in line with the latest research. Please note that a conservative approach has been taken to all metrics. In a small number of cases, assumptions have been made due to limited data / smaller sample sizes. In instances where this has been necessary, an even more conservative approach has been applied.

In addition, while these metrics lay the foundations for calculating estimated impact, many critical social development benefits from off-grid solar also remain difficult to track. For example, improvements in health and safety. Therefore, these metrics should be seen a starting point, not an end, to the exploration of socio-economic impacts by the off-grid sector and new metrics may be added as new data becomes available. GOGLA welcomes input from its Members and other stakeholders in the sector on future enhancements to these metrics.

4. At a Glance

The overview of formulas and variables in the tables on the following pages summarize the harmonized framework detailed in the rest of this document. **Blue coefficients are to be inputted by users of the metrics** (e.g. GOGLA Member companies) whilst **green coefficients have default values** that should be inputted– outlined in detail later in this document.

The primary basis used for counting and scaling estimates of social impact is number of products sold or deployed to end-users (product specifications are also used for certain metrics). In some cases, it makes sense to count all products ever sold [S], while in others the estimated number of currently operating systems [S_L] (i.e., within the lifetime of the product) is a more appropriate basis.

For sales and deployment estimates for cash sales business models, sales numbers should be discounted by a channel loss discount factor [D_L] that is the fraction of products that are damaged or lost and never reach end users. This discount factor has been added as typically the sales data available for cash sales business models are at the wholesale level. However, if retail sales totals are accounted for, these could be used directly, without the sales channel loss factors.

For PAYG sales where retail account totals are available, the number of total retail sales should be discounted by a channel loss discount factor [D_F] that estimates the fraction of customers for whom the impact of a product is not fully realized. This could be due to a variety of potential reasons e.g. product loss or breakdown, churn, repossession or default. As PAYG discount factors will vary widely between different companies, programs and regions, organizations are asked to input their own, appropriate and conservative PAYG discount factor based on their specific experience. (Please note that GOGLA applies a conservative PAYG discount factor to all publicly shared industry-level data, as well as impact estimates shared directly with GOGLA Member companies.)

The formulas within the tables on the following pages have been split by cash sales and PAYG to reflect these different discount factors.

As with the PAYG discount factor, if more specific company or organizational-level impact data has been gathered through robust research, other relevant variables can be updated with this data to best represent organizational impact. However, we strongly recommend that the harmonized metric formulas are used in all cases to enable consistency of reporting. Any organization using their own impact data to replace a variable is advised to take a conservative approach and to transparently communicate if they deviate from the GOGLA default variables.

Please note that variables used in the Impact metrics are primarily based on research that uses self-reported customer data.

Impact Metrics – Overview of Formulas

Metric		Business Model	Formula
Energy Access			
1ai	Number of people with improved energy access, cumulatively	Cash	$(S) * (1 - D_L) * (1 - D_R) * H$
		PAYG	$(S) * (1 - D_F) * (1 - D_R) * H$
1aii	Number of people with improved energy access, currently	Cash	$(S_L) * (1 - D_L) * (1 - D_R) * H$
		PAYG	$(S_L) * (1 - D_F) * (1 - D_R) * H$
1bi	Number of people with access to Tier 1 energy services	Cash	$(S_L) * (1 - D_L) * (1 - D_R) * H * D_{T1}$
		PAYG	$(S_L) * (1 - D_F) * (1 - D_R) * H * D_{T1}$
1bii	Number of people with access to Tier 2 energy services	Cash	$(S_L) * (1 - D_L) * (1 - D_R) * H * D_{T2}$
		PAYG	$(S_L) * (1 - D_F) * (1 - D_R) * H * D_{T2}$
Economic Activity			
2a	People undertaking more economic activity	Cash	$(S_L) * (1 - D_L) * EA$
		PAYG	$(S_L) * (1 - D_F) * EA$
2b	People using products to support enterprise	Cash	$(S_L) * (1 - D_L) * E$
		PAYG	$(S_L) * (1 - D_F) * E$
2c	People that spend more time working	Cash	$(S_L) * (1 - D_L) * T$
		PAYG	$(S_L) * (1 - D_F) * T$
2d	People that have opened a new business	Cash	$(S) * (1 - D_L) * NB$
		PAYG	$(S) * (1 - D_F) * NB$
Income Generation			
3a	People generating additional income	Cash	$(S_L) * (1 - D_L) * IG$
		PAYG	$(S_L) * (1 - D_F) * IG$
3b	Additional income generated, cumulatively	Cash	$S * (1 - D_L) * (IG * AI * P_L)$
		PAYG	$S * (1 - D_F) * (IG * AI * P_L)$
Kerosene Replacement & CO2e Reduction			
4	Kerosene lanterns replaced	Cash	$S_L * (1 - D_L) * R$
		PAYG	$S_L * (1 - D_F) * R$
5	CO2e emissions avoided	Cash	$S * (1 - D_L) * R * G * P_L$
		PAYG	$S * (1 - D_F) * R * G * P_L$
Light Availability and Quality			
6ai	Additional light hours used, by household	Cash	$(L_F - L_B) * L_D * P_L$
		PAYG	As Cash
6aii	Additional light hours used, cumulatively	Cash	$S * (1 - D_L) * ((L_F - L_B) * L_D * P_L)$
		PAYG	$S * (1 - D_F) * ((L_F - L_B) * L_D * P_L)$
6b	Change in quality of light, by household	Cash	$B_F - B_B$
		PAYG	As Cash
Energy Spending			
7ai	Savings on energy expenditure, by household	Cash	$((E_F - E_B) * P_L) - C$
		PAYG	$((E_F - E_B) * P_L) - TCO$
7aii	Savings on energy expenditure, cumulatively	Cash	$S * (1 - D_L) * ((E_F - E_B) * P_L) - C$
		PAYG	$S * (1 - D_F) * ((E_F - E_B) * P_L) - TCO$
Financial Inclusion			
8	Number of adults currently benefitting from clean energy financing (PAYG only)	PAYG	$S_L * (1 - D_F)$

Impact Metrics – Overview of Variables

Variable		0.5 – 3.999 Wp	4 – 10. 999 Wp	11 – 49.999 Wp	50+ Wp
S	number of units sold (cumulative i.e. ever)				
S_L	number of units sold within lifespan of product (1.5 x warranty period)				
P_L	estimated solar product lifespan (1.5 x warranty)				
B_F	average post-purchase lumens (brightness) of household lighting				
C	average retail price of solar product (cost to customer), in US$ (Cash only)				
D_F	discount for loss factor: products for which full usage is not received (PAYG only)				
TCO	average total cost of ownership of solar product (cost to customer), in US$ (PAYG only)				
D_L	discount for loss: products not working or not in use, excluding loss in supply chain (Cash only)	3%	3%	3%	3%
D_R	discount for repeat sales: to avoid double counting of customers, but does not try to estimate proportion of customers who owned solar more generally before	10%	3%	3%	3%
H	household size	5	5	5	5
D_{T1}	Tier 1 Factor	Annex 1	Annex 1	Annex 1	Annex 1
D_{T2}	Tier 2 Factor	Annex 1	Annex 1	Annex 1	Annex 1
EA	percentage of customers undertaking more economic activity (including a household member doing one or more of: spending more time working, using their system to support enterprise or getting a new job)	14%	48%	38%	38%
E	percentage of customers using products to support enterprise (including those that have opened a new business)	10%	16%	16%	16%
T	Percentage of customers that spend more time working	5%	37%	29%	26%
NB	percentage of customers that have opened a new business	5%	9%	7%	7%
IG	percentage of customers creating additional income	10%	30%	25%	17%
AI	average additional income generated, per household (annual)	$170	$288	$300	$384
R	replacement ratio of kerosene lanterns per solar product	1	1	1	1
G	average annual carbon dioxide and black carbon (CO2e) emissions per kerosene lantern	370g	370g	370g	370g
L_B	average baseline hours of light used, per day/night (24 hours) per household	4	4	4	4
L_F	average post-purchase hours of light used, per day/night (24 hours), per household	5	5	5	5
L_D	Average number of days per year that off-grid solar product is used for lighting	350	350	350	350
B_B	average baseline lumens (brightness) of household lighting use	35	45	45	45
E_B	average annual expenditure on energy baseline (lighting and phone charging), per household	$95	$127	n/a	n/a
E_F	average annual expenditure on energy post-purchase (lighting and phone charging), per household	$22	$38	n/a	n/a

5. Impact Metrics

For each metric, the following pages outline the:
- Definition
- Message to share
- Calculation
- Assumptions

To calculate impact, users should input sales units and other relevant off-grid solar product information into each metric formula. The assumptions and calculations for coefficients that make up the metric formulas are outlined in the section below.

5.1 Energy Access

Metric	1ai. Improved energy access, cumulatively
Unit of measurement	Number of people
Definition	Cumulative number of people who have ever lived in a house with an improved off-grid energy source (i.e. solar)
Usefulness of metric	Enables us to estimate the number of people that have benefited from using off-grid solar products
Message to share	The off-grid solar industry has helped to improve energy access for an estimated X number of people
Calculation	Cash Sales: (S) * (1 – D_L) * (1 – D_R) * H PAYG Sales: (S) * (1 – D_F) * (1 – D_R) * H Number of products sold (S) x discount for loss (D_L or D_F) x discount for repeat sales (D_R) x household size (H)
Assumptions	• Solar products are used in the home • All members in the household have access to the solar product • Solar products are being used in households with a 'worse' source of energy before (except for discounted repeat sales)
Other notes	• In this context, 'improved' is used to reflect lighting and energy provided by appropriate (less expensive, less dangerous, better quality) technologies such as solar, instead of baseline technologies such as kerosene lanterns, battery lights, candles, or even poor-quality solar products etc.
Future improvements	• Discounts for assumptions i.e. products used outside the home, back up generation and intrahousehold usage across all members

Metric	1aii. Improved energy access, currently
Unit of measurement	Number of people
Definition	Number of people who currently live in a house with an improved off-grid energy source (i.e. solar)
Usefulness of metric	Enables us to estimate the number of people using off-grid solar products
Message to share	The off-grid solar industry is helping to improve energy access for an estimated X number of people
Calculation	Cash Sales: (S_L) * (1 – D_L) * (1 – D_R) * H PAYG Sales: (S_L) * (1 – D_F) * (1 – D_R) * H Number of products sold that are still in lifetime (S_L) x discount for loss (D_L or D_F) x discount for repeat sales (D_R) x household size (H) Number of products still in lifetime = sold within last: 1.5 x warranty years
Assumptions	• As 1ai
Other notes	• As 1ai
Future improvements	• As 1ai

Metric	1bi. People with access to Tier 1 energy services
Unit of measurement	Number of people
Definition	Number of people with Tier 1 energy access currently, based on the SEforAll Global Tracking Framework
Usefulness of metric	Enables understanding of the level of energy service enabled due to off-grid solar and allows for comparisons between energy service enabled by off-grid solar and all other energy sources (e.g. mini-grids, unreliable / reliable grid access etc.)
Message to share	The off-grid solar industry is helping to meet the basic energy needs of X people
Calculation	Cash Sales: (S_L) * (1 – D_L) * (1 – D_R) * H * D_{T1} PAYG Sales: (S_L) * (1 – D_F) * (1 – D_R) * H * D_{T1} Number of products sold that are still in lifetime (S_L) x discount for loss (D_L or D_F) x discount for repeat sales (D_R) x household size (H) x reduction factor from Tier 1 SEforAll framework (D_{T1}), where the reduction factor is based on typical energy service level available See Annex 1 for more details of D_{T1}
Assumptions	• As per SEforAll Global Tracking framework
Other notes	• An illustrative example of the framework mapped to off-grid system size / service level can be found in Annex 1. This can be used to establish the number of people, per household, who have had their basic energy needs met by various off-grid products and services
Future improvements	• Continued engagement in the maintenance and utilization of the SEforAll Global Tracking Framework

Metric	1bii. People with access to Tier 2 energy services
Unit of measurement	Number of people
Definition	Number of people with Tier 2 energy access currently, based on the SEforAll Global Tracking Framework
Usefulness of metric	Enables understanding of the level of energy service enabled due to off-grid solar and allows for comparisons between energy service enabled by off-grid solar and all other energy sources (e.g. off-grid solar, mini-grids, unreliable/reliable grid access etc.)
Message to share	The off-grid solar industry is helping to meet the basic energy needs of X people
Calculation	Cash Sales: $(S_L) * (1 - D_L) * (1 - D_R) * H * D_{T2}$ PAYG Sales: $(S_L) * (1 - D_F) * (1 - D_R) * H * D_{T2}$ Number of products sold that are still in lifetime (S_L) x discount for loss (D_L or D_F) x discount for repeat sales (D_R) x household size (H) x reduction factor from Tier 1 SEforAll framework (D_{T2}), where the reduction factor is based on typical energy service level available See Annex 1 for more details of D_{T2}
Assumptions	• As per SEforAll Global Tracking framework
Other notes	• As 1bi
Future improvements	• As 1bi

5.2 Economic Activity

Metric	2a. People undertaking more economic activity
Unit of measurement	Number of people
Definition	Number of off-grid solar customers who are undertaking more economic activity as a result of using off-grid solar
Usefulness of metric	Enables us to estimate the number of people undertaking more economic activity as a result of using off-grid solar e.g. a household member is doing one or more of: spending more time working, using their system to support enterprise or has got a new job
Message to share	Off-grid solar products and services are estimated to be enabling X number of people to undertake more economic activity
Calculation	Cash Sales: $(S_L) * (1 - D_L) * EA$ PAYG Sales: $(S_L) * (1 - D_F) * EA$ Number of products sold that are still in lifetime (S_L) x discount for loss (D_L or D_F) x proportion of people undertaking more economic activity (EA)
Assumptions	• Increase in economic activity is a result of using off-grid solar • No change over time
Other notes	• Economic activity is broadly defined in this metric. This includes customers who pursue more income generating activities or support their business with off-grid solar, as well those who use time more productively e.g. undertake household-level agricultural activities
Future improvements	• Explore change over time

Metric	2b. People using products to support enterprise
Unit of measurement	Number of people
Definition	Number of off-grid solar customers using their system to support an enterprise, or income generating activities e.g. charging phones for a fee or opening a stall at night
Usefulness of metric	Enables us to estimate the number of people directly using their off-grid solar product to support enterprise (e.g. the lights, phone charging capacity, TV, power to run a fan or fridge etc.)
Message to share	Off-grid solar products are used by an estimated X people to support enterprise
Calculation	Cash Sales: $(S_L) * (1 - D_L) * E$ PAYG Sales: $(S_L) * (1 - D_F) * E$ Number of products sold that are still in lifetime (S_L) x discount for loss (D_L or D_F) x proportion of people using products to support enterprise or income generating activities in the home (E)
Assumptions	• No change over time
Other notes	• This metric includes new businesses opened (NB) • This metric is focused on the enterprise being supported due to the ownership of off-grid solar only. Please note it excludes all enterprise created by the industry rather than the products e.g. it does not include solar agents selling off-grid solar products
Future improvements	• Explore change over time

Metric	2c. People that spend more time working
Unit of measurement	Number of people
Definition	Number of off-grid solar customers spending more time working as a result of using off-grid solar e.g. as a household member can shift tasks to the evening time due to increased light hours available or as they spend less time travelling to buy fuel
Usefulness of metric	Enables us to show the impact of off-grid solar ownership on the amount of time that can be spent working
Message to share	Off-grid solar products and services are unlocking previously unproductive time and enabling people to work for longer
Calculation	Cash Sales: $(S_L) * (1 - D_L) * T$ PAYG Sales: $(S_L) * (1 - D_F) * T$ Number of products sold that are still in lifetime (S_L) x discount for loss (D_L or D_F) x proportion of customer base able to spend more time working outside the home (T)
Assumptions	• More time spent working is a result of using off-grid solar • No change over time
Other notes	• As 2a, work undertaken with additional time is broadly defined. This includes productive activities such as household-level agriculture, as well as direct income generating activities
Future improvements	• Explore change over time

Metric	2d. People that have opened a new business
Unit of measurement	Number of people
Definition	Number of people who have opened a new business as a result of off-grid system ownership e.g. a mobile phone charging business or a solar powered video hall
Usefulness of metric	Enables us to highlight how off-grid solar is helping customers to create new business opportunities
Message to share	Off-grid solar products and services have enabled an estimated X people to open new businesses, such as a phone charging enterprises or solar powered video halls
Calculation	Cash Sales: (S) * (1 – D_L) * NB PAYG Sales: (S) * (1 – D_F) * NB Number of products sold (S) x discount for loss (D_L or D_F) x proportion of customer base able to open a new business (NB)
Assumptions	• People have opened a new business due to their access to off-grid solar • No change over time
Other notes	• New businesses highlighted by this metric are primarily micro-enterprises. Care should be taken when using this metric to ensure that the type of new businesses (e.g. small scale) is understood
Future improvements	• Explore change over time

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5.3 Income Generation

Metric	3b. Additional income generated, cumulatively
Unit of measurement	USD$
Definition	Cumulative amount of additional income generated as a result of off-grid system ownership; over the expected lifetime of the solar products
Usefulness of metric	Enables us to estimate how much additional income has been created by households using off-grid solar
Message to share	The off-grid solar industry has helped households to generate an estimated $X in additional income over the lifetime of their solar products
Calculation	Cash Sales: (S_L) * (1 – D_L) * IG PAYG Sales: (S_L) * (1 – D_F) * IG Number of products sold that are still in lifetime (S_L) x discount for loss (D_L or D_F) x proportion of customer base generating additional income (IG)
Assumptions	• Additional income generated is a result of using off-grid solar • Households continue to generate additional income at a constant rate throughout the lifetime of their solar product
Other notes	• This metric does not take into account any change in the value of the dollar vs local currency
Future improvements	• Explore change over time

Metric	3a. People generating additional income
Unit of measurement	Number of people
Definition	Number of people who are generating additional income as a result of off-grid system ownership e.g. as they can open a business for longer, use their system to generate income or get a new job
Usefulness of metric	Enables us to estimate how many people have been able to create additional income as a result of using off-grid solar
Message to share	Off-grid solar products and services have enabled an estimated X people to generate additional income
Calculation	Cash Sales: (S_L) * (1 – D_L) * IG PAYG Sales: (S_L) * (1 – D_F) * IG Number of products sold that are still in lifetime (S_L) x discount for loss (D_L or D_F) x proportion of customer base generating additional income (IG)
Assumptions	• People are generating additional income as a result of using off-grid solar • No change over time
Other notes	–
Future improvements	• Explore change over time

5.4 Kerosene Replacement and CO2e Reduction

Metric	4. Kerosene lanterns replaced
Unit of measurement	Number of kerosene lanterns
Definition	Number of kerosene lanterns no longer in use because customers have replaced them with solar lighting
Usefulness of metric	Enables us to estimate the impact of reducing the use of dangerous and polluting kerosene lanterns
Message to share	The solar lighting industry is contributing to the reduction of an estimated X expensive, dangerous, polluting kerosene lanterns
Calculation	Cash Sales: $S_L * (1 - D_L) * R$ PAYG Sales: $S_L * (1 - D_F) * R$ Number of products sold that are still in lifetime (S_L) x discount for loss (D_L or D_F) x replacement ratio of kerosene lanterns (R)
Assumptions	• Kerosene lanterns are no longer used because of access to new solar products
Other notes	• Please note, the kerosene replacement rate is averaged from research that includes homes with no kerosene lamps as well as households with more than one. This means that households using kerosene lamps will have a higher replacement ratio than the average, while households with no kerosene lamps will see zero change • This metric previously included data on the replacement of additional lighting sources such as torch batteries and candles, but these are no longer included; the metric focuses solely on kerosene replacement and should only be used in countries / contexts where there is significant kerosene use for lighting • This metric was previously based on all sales but has been updated to current sales to avoid any potential for overestimation should kerosene lanterns come back into use after the end of a product's lifetime
Future improvements	• Explore replacement of polluting diesel generators and / or dangerous candles with off-grid solar

Metric	5. CO2e emissions avoided
Unit of measurement	Tons of carbon dioxide and black carbon (in carbon dioxide equivalent, CO2e)
Definition	Tons of carbon dioxide and black carbon averted due to estimated reduction in kerosene lantern use, per off-grid solar product; over expected lifetime of the product
Usefulness of metric	Enables us to highlight the estimated short-term (20 year) and long-term (100 year) environmental benefits of solar by capturing the immediate effects of reductions in black carbon and the longer-term effects of other greenhouse gases including carbon dioxide compared to baseline kerosene use
Message to share	The off-grid solar industry has helped to avert an estimated X tonnes of CO2e
Calculation	Cash Sales: $S * (1 - D_L) * R * G * P_L$ PAYG Sales: $S * (1 - D_F) * R * G * P_L$ Number of products sold (S) x discount for loss (D_L or D_F) x replacement ratio (R) x annual $CO2_e$ emissions per kerosene lantern (G) x estimated lifespan of solar product (P_L)
Assumptions	• Replacement of kerosene use is as a direct result of access to a new solar product
Other notes	• Does not include embodied energy from manufacturing and transporting products
Future improvements	• Determine the best way to measure and deduct embodied energy

5.5 Light Availability and Quality

Metric	6ai. Additional light hours used, by household
Unit of measurement	Number of hours
Definition	Average additional hours of light usage, per household; over the expected lifetime of their solar product. Change in light hours results from ownership of off-grid solar products / lighting when compared to the typical usage of baseline lighting
Usefulness of metric	Enables us to estimate the change in light usage per day
Message to share	Off-grid solar increases a household's hours of light by an estimated X hours over the average product lifetime
Calculation	Cash & PAYG Sales: $(L_F - L_B) * L_D * P_L$ Post-purchase hours of light used, per day/night per household (L_F) – baseline hours of light used, per day/night per household (L_B) x number of days per year that off-grid solar is used for lighting (L_D) x product lifetime (P_L)
Assumptions	• Light usage in a home is relatively constant • While there will be differences between the capacities of different solar lighting products to provide hours of light, this metric assumes an average change in light usage (calculated using data from various solar lantern and solar home system types and baseline lighting sources) to indicate the actual, rather than potential, additional light usage
Other notes	• As well as replacement of traditional energy sources, this metric captures the change in light hours created by product stacking e.g. where a solar light complements existing lighting sources in a household
Future improvements	• Explore data on different 'types' of off-grid solar users to understand how different light uses impacts change e.g. differences in the light hours used between households using light for leisure vs income generation, security, etc.

Metric	6aii. Additional light hours used, cumulatively
Unit of measurement	Number of hours
Definition	Estimated cumulative number of additional light hours used by all households; over the expected lifetime of their solar products. Change in light hours results from ownership of off-grid solar products / lighting, when compared to the typical usage of baseline lighting
Usefulness of metric	Enables us to show the increase in hours of light usage enabled due to households purchasing an off-grid solar lighting product
Message to share	The solar lighting industry has unlocked an estimated X hours of light for off-grid households
Calculation	Cash Sales: $S * (1 - D_L) * ((L_F - L_B) * L_D * P_L)$ PAYG Sales: $S * (1 - D_F) * ((L_F - L_B) * L_D * P_L)$ Number of products sold x discount for loss (D_L or D_F) x ((post-purchase hours of light used, per night per household (L_F) – baseline hours of light used, per night per household (L_B)) x number of days per year that off-grid solar is used for lighting (L_D) x product lifetime (P_L))
Assumptions	• As 6ai
Other notes	• As 6ai
Future improvements	• As 6ai

Metric	6b. Change in quality of light, by household
Unit of measurement	Number of lumens per household
Definition	Estimated change in lumens of light used, per household per day (on average)
Usefulness of metric	Enables us to show the potential quality improvement (i.e. newly available opportunity of light brightness) of solar compared to the previous household lighting mix
Message to share	The solar lighting industry is enabling customers to experience brighter lighting; an estimated X lumens more than previously, per household, on average
Calculation	Cash & PAYG Sales: $B_F - B_B$ Post-purchase lumens of household lighting use (B_F) – baseline lumens of household lighting use [B_B]
Assumptions	• Light quality households receive from their product is, on average, on a par with use of the mid-range setting of their product (see below)
Other notes	• When adding the post-purchase lumen output of a product the mid-range or average lumen output (of lowest and highest settings) should be used to provide a reasonable estimate of the actual lumen output received by a household • To avoid over or underestimating the change in brightness received by a household, unless actual setting usage data is known, using the highest or lowest product setting is not advised
Future improvements	• Explore common usage settings to provide more certainty on the recommendation to use mid-range setting or average lumen output to uncover the average change in brightness

5.6 Energy Spending

Metric	7ai. Savings on energy expenditure, by household
Unit of measurement	US$ over lifetime of solar product
Definition	Estimated amount of US$ savings on energy-related expenditure*; over expected lifetime of product, per household
Usefulness of metric	Enables us to demonstrate the estimated financial benefit of pico-solar at the household level
Message to share	Pico-solar products are helping households save an estimated $X, over their lifetime, by replacing the use of alternatives for lighting and phone charging (e.g. kerosene and batteries)
Calculation	Cash Sales: $((E_F - E_B) * P_L) - C$ PAYG Sales: $((E_F - E_B) * P_L) - TCO$ ((Annual energy expenditure post purchase on traditional lighting sources (E_F) – annual baseline energy expenditure (E_B)) x product lifetime) – Cost of solar product (C) or total cost of ownership of PAYG product (TCO)
Assumptions	• Uniform spending on non-solar energy across product lifetime • Repayment of PAYG products is standard across the repayment period (e.g. costs are not increased / decreased due to early or late payment etc.)
Other notes	• Please note this metric is designed for use with pico-solar products only, where the pre-post energy spending and service is most comparable • Use of this metric is not advised where off-grid systems provide significantly more service, particularly where the cost of appliances such as TVs, radios and fans are included in the cost of the product. In many such cases expenditure will go up, rather than down, after purchasing an off-grid solar product
Future improvements	• Explore total energy expenditure (including transportation and other costs) both before and after purchase • Explore the change in energy cost by kWh

Metric	7aii. Savings on energy expenditure, cumulatively
Unit of measurement	US$ over lifetime of solar products
Definition	Estimated amount of US$ savings on energy-related expenditure*; over expected lifetime of products, in aggregate of all sales ever
Usefulness of metric	Enables us to demonstrate the estimated financial benefit of pico-solar products, cumulatively
Message to share	Pico-solar products have helped off-grid households save an estimated $X, over their lifetime, by replacing the use of alternatives for lighting and phone charging (e.g. kerosene and batteries)
Calculation	Cash Sales: $S * (1 - D_L) * ((E_F - E_B) * P_L) - C$ PAYG Sales: $S * (1 - D_F) * ((E_F - E_B) * P_L) - TCO$ Number of products sold (S) x discount for loss (D_L or D_F) x ((Annual energy expenditure post purchase on traditional lighting sources (E_F) – annual baseline energy expenditure (E_B)) x product lifetime (P_L)) – Cost of solar product (C) or total cost of ownership of PAYG product (TCO)
Assumptions	• As 7ai
Other notes	• As 7ai
Future improvements	• As 7ai

*lighting + phone charging

5.7 Financial Inclusion

Metric	8. Number of adults currently benefitting from clean energy financing (PAYG only)
Unit of measurement	Number of adults
Definition	Number of adults with current access to clean energy financing
Usefulness of metric	Enables us to demonstrate the number of adults who have benefitted from clean energy financing through PAYG solar
Message to share	PAYG solar is enabling an estimated X households to access clean energy 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	PAYG Sales: S_L * (1 – D_F) Number of products sold that are still in lifetime (S_L) x discount for loss (D_F)
Assumptions	• That the majority of PAYG customers are unlikely to have a strong credit history and, as such, PAYG financing is not only providing affordable solar but enabling them to become more financially included
Other notes	• This metric is simply equal to the number of currently active PAYG lighting systems and is definitional • The number does not include those who may have purchased a product previously through PAYG financing and have already benefitted from this level of financial inclusion
Future improvements	• Further explore the impacts of access to PAYG financing on financial inclusion e.g. customer upgrades, use of PAYG to purchase clean cook stoves or the inclusion of health insurance with PAYG Solar

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6. Coefficient Calculations and Default Values

The below tables outline the definitions, assumptions and default value for coefficients that make up the metric formulas.

6.1 Standard Coefficients with Default Values

Coefficient	D_L: discount for loss (Use for cash sales only)			
Definition	The percentage of solar products sold that do not end up in customer homes, due to theft, damage, loss, non-adoption etc.			
System Size	0.5 – 3.999 Wp	4 – 10.999 Wp	11 – 49.999 Wp	50+ Wp
Default value	3%	3%	3%	3%
Justification	Conservative estimate by companies involved in the supply chain			
Limitations	Not validated by any data			
Sources	• GOGLA member companies			
Relevant metrics where coefficient is used	1ai. Number of people with improved energy access, cumulatively 1aii. Number of people with improved energy access, currently 1bi. Number of people with access to Tier 1 energy services 1bii. Number of people with access to Tier 2 energy services 2a. People undertaking more economic activity 2b. People using products to support enterprise 2c. People spending more time working outside the home 2d. People that have opened a new business 3a. People generating additional income 3b. Additional income generated, cumulatively 4. Kerosene lanterns replaced 5. CO2e avoided 6aii. Additional light hours used, cumulatively 7aii. Savings on energy expenditure, cumulatively			
Future improvements	• Collect better data from member companies or identify third party research source			

Coefficient	D_R: discount for repeat sales			
Definition	The percentage of units sold that are repeated sales to a household with solar already due to replacement or additional purchases while first product is still in use. Intention is to avoid double-counting within number of people affected			
System Size	0.5 – 3.999 Wp	4 – 10.999 Wp	11 – 49.999 Wp	50+ Wp
Default value	10%	3%	3%	3%
Justification	• Solar lanterns (0.5 – 3.999 Wp): Estimate by companies involved in the supply chain • Larger systems sizes (4 – 50+ Wp): Data drawn from research and represents customers that upgraded their SHS within the same brand			
Limitations	• Does not include movement between solar lanterns and SHS, or unbranded SHS and quality SHS			
Sources	• GOGLA member companies • Altai and GOGLA (2018). *Powering Opportunity: The Economic Impact of Off-Grid Solar. (Unpublished data set from research).* Data gathered from Kenya, Mozambique, Rwanda, Tanzania and Uganda			
Relevant metrics where coefficient is used	1ai. Number of people with improved energy access, cumulatively 1aii. Number of people with improved energy access, currently 1bi. Number of people with access to Tier 1 energy services 1bii. Number of people with access to Tier 2 energy services 2a. People undertaking more economic activity 2b. People using products to support enterprise 2c. People spending more time working outside the home 2d. People that have opened a new business 3a. People generating additional income 3b. Additional income generated, cumulatively 4. Kerosene lanterns replaced 5. CO2e avoided 6aii. Additional light hours used, cumulatively 7aii. Savings on energy expenditure, cumulatively 8. Number of adults currently benefitting from clean energy financing (PAYG only)			
Future improvements	• Continue to review and enhance data on product upgrades			

Coefficient	H: household size			
Definition	The number of people living in a household			
System Size	0.5 – 3.999 Wp	4 – 10.999 Wp	11 – 49.999 Wp	50+ Wp
Default value	5%	5%	5%	5%
Justification	• High-quality external source; the average for developing countries in Asia and Africa is 5			
Limitations	• Off-grid household data can show larger household sizes but GOGLA advises using a value of 5 people per household to maintain a standard and conservative approach to estimating household size			
Sources	• UN DESA Population Division (2017). *Population Facts.* • UNEP/GEF en.lighten initiative (2013). *Off-Grid Country Lighting Assessments*			
Relevant metrics where coefficient is used	1ai. Number of people with improved energy access, cumulatively 1aii. Number of people with improved energy access, currently 1bi. Number of people with access to Tier 1 energy services 1bii. Number of people with access to Tier 2 energy services			
Future improvements	• Metric to be reviewed should significantly more off-grid specific household size data become available • Explore the differences in household size between rural, urban and peri-urban locations			

Coefficient	D_{T1} & D_{T2}: Tier 1 & Tier 2 energy service level			
Definition	Based on the SEforALL Global Tracking Framework, an estimate of the number of persons who achieve Tier 1 or Tier 2 access to electricity through standalone solar lighting systems. These are specific to each model of solar product that is offered in the market, with calculation based on verified test results			
System Size	0.5 – 3.999 Wp	4 – 10.999 Wp	11 – 49.999 Wp	50+ Wp
Default value	• See Annex 1 for more details on system size / service Tier values			
Justification	• High-quality external framework			
Limitations	• This coefficient is the result of a global effort towards harmonization on the definition for energy access classifications. These Tier levels are based on specific performance parameters for off-grid solar products that will be reported by companies and / or verified by third-party testing of products			
Sources	• As per SEforAll Global Tracking framework • An illustrative example of the framework mapped to off-grid solar system size / service level can be found in Annex 1			
Relevant metrics where coefficient is used	1bi. Number of people with access to Tier 1 energy services 1bii. Number of people with access to Tier 2 energy services			
Future improvements	• Updates to made in line with any changes to the SEforALL Framework			

Coefficient	EA: percentage of customers undertaking economic activity			
Definition	The percentage of customers undertaking more economic activity (including a household member doing one or more of: spending more time working, using their system to support enterprise or getting a new job			
System Size	0.5 – 3.999 Wp	4 – 10.999 Wp	11 – 49.999 Wp	50+ Wp
Default value	14%	48%	38%	38%
Justification	• High-quality data sources, including thousands of interviews with off-grid customers • Customers have reported that purchase or ownership of an off-grid system has led to the specific effect noted			
Limitations	• Data is from a limited number of countries • 'Economic activity' is not well-defined and includes a range of activities. As such, some assumptions have been used when combining relevant data sets • Data for solar lanterns is drawn from a variety of sources, many of which did not have specific data on customers who are now able to spend more time working outside the home or are able to gain a new job. Therefore, the value for solar lanterns only assumes a very slight increase for any such activity and may be particularly conservative			
Sources	• Aevarsdottir A., et al. (2017). *The impacts of rural electrification on labour supply, income, and health. Experimental evidence with solar lamps in Tanzania.* • Altai and GOGLA (2018). *Powering Opportunity: The Economic Impact of Off-Grid Solar.* Data gathered from Kenya, Mozambique, Rwanda, Uganda, Tanzania • Azimoh C., et al. (2015). *Illuminated but not electrified: An assessment of the impact of Solar Home System on rural households in South Africa.* • FINCA International. *Internal data.* (To be published in late 2018). Data from Uganda • Hassan H. & Lucchino, P. (2016). *Entrepreneurship, gender and the constraints of time: a randomised experiment on the role of access to light.* Data gathered from Kenya			
Relevant metrics where coefficient is used	2a. People undertaking more economic activity			
Future improvements	• Expand data collection to more geographic regions • Expand data collection to gather more specific insights on solar lanterns • Work with research partners to better align data sets and capture more information on time spent working / new jobs			

Coefficient	E: percentage of customers using products to support enterprise			
Definition	The percentage of off-grid solar customers using their products to support an enterprise, or income generating activities in the home e.g. charging phones for a fee or opening a stall, bar or restaurant at night			
System Size	0.5 – 3.999 Wp	4 – 10.999 Wp	11 – 49.999 Wp	50+ Wp
Default value	10%	16%	16%	16%
Justification	• High-quality data sources, including thousands of interviews with off-grid customers			
Limitations	• SHS system size variations are not currently possible as data has been used to create this metric from data sets that used different approaches to categorizing product size / types			
Sources	• Acumen. (2015-18). *Internal data.* Data gathered from Cote d'Ivoire, Ghana, Haiti, India, Kenya, Nigeria, Pakistan, Rwanda, Senegal, Sierra Leone and Uganda • Aevarsdottir A., et al. (2017). *The impacts of rural electrification on labour supply, income, and health. Experimental evidence with solar lamps in Tanzania.* • Altai and GOGLA (2018). *Powering Opportunity: The Economic Impact of Off-Grid Solar.* Data gathered from Kenya, Mozambique, Rwanda, Uganda, Tanzania • Azimoh C., et al. (2015). *Illuminated but not electrified: An assessment of the impact of Solar Home System on rural households in South Africa.* • FINCA International. *Internal data.* (To be published in late 2018). Data from Uganda • Gray L., et al. (2016). *Turning on the Lights: Transcending Energy Poverty Through the Power of Women Entrepreneurs. Miller Center for Social Entrepreneurship.* Data from Tanzania • GSMA. (2016). *Mobisol: Pay-As-You-Go Solar for Entrepreneurs in Rwanda* • GSMA. (2015). *Fenix International: Scaling Pay-As-You-Go Solar in Uganda* • Hassan H. & Lucchino, P. (2016). *Entrepreneurship, gender and the constraints of time: a randomised experiment on the role of access to light.* Data gathered from Kenya • IDInsight. (2014). *d.light Solar Home System Impact Evaluation.* Data gathered from Uganda • Mishra, P. et al. (2016). *Socio-economic and environmental implications of solar electrification: Experience of rural Odisha* • SolarAid. *Internal data.* (2012-4). Data gathered from Kenya, Malawi, Tanzania and Zambia • Urmee and Harries. (2011). *Determinants of the success and sustainability of Bangladesh's SHS program*			
Relevant metrics where coefficient is used	2b. People using products to support enterprise			
Future improvements	• Review, recode and expand data to uncover more nuanced insights by different sizes of solar home system / solar lantern types			

Coefficient	T: percentage of customers that spend more time working			
Definition	The percentage of customers spending more time working as a result of using off-grid solar e.g. due to shifting tasks to the evening time as they have more light hours available or as they spend less time travelling to buy fuel			
System Size	0.5 – 3.999 Wp	4 – 10.999 Wp	11 – 49.999 Wp	50+ Wp
Default value	5%	37%	29%	26%
Justification	• High-quality data sources, including thousands of interviews with off-grid customers			
Limitations	• Data is from a limited number of countries			
Sources	• Adkins, E. (2009) *Off-grid energy services for the poor: Introducing LED lighting in the Millennium Villages Project in Malawi* • Aevarsdottir, A., et al. (2017). *The impacts of rural electrification on labour supply, income, and health. Experimental evidence with solar lamps in Tanzania.* • Altai and GOGLA (2018). *Powering Opportunity: The Economic Impact of Off-Grid Solar.* Data gathered from Kenya, Mozambique, Rwanda, Uganda, Tanzania • FINCA International. *Internal data.* (To be published in late 2018). Data from Uganda • Hassan, F. & Lucchino, P. (2016). *Entrepreneurship, gender and the constraints of time: a randomised experiment on the role of access to light.* Data gathered from Kenya • Hassan, F., Lucchino, P. (2014). *Powering Education. Enel Foundation: Working paper 17/2014.* Data gathered from Kenya			
Relevant metrics where coefficient is used	2a. People undertaking more economic activity			
Future improvements	• Expand data collection to more geographic regions • Work with research partners to better align data sets and capture more information on time spent working			

Coefficient	NB: percentage of customers that have opened a new business			
Definition	The percentage of customers that have been able to open a new business as a result of purchasing off-grid solar e.g. a phone charging business or video hall			
System Size	0.5 – 3.999 Wp	4 – 10.999 Wp	11 – 49.999 Wp	50+ Wp
Default value	5%	9%	7%	7%
Justification	• High-quality data sources, including thousands of interviews with off-grid customers			
Limitations	• Data is from a limited number of countries			
Sources	• Adkins, E. (2009) *Off-grid energy services for the poor: Introducing LED lighting in the Millennium Villages Project in Malawi* • Aevarsdottir A., et al. (2017). *The impacts of rural electrification on labour supply, income, and health. Experimental evidence with solar lamps in Tanzania.* • Altai and GOGLA (2018). *Powering Opportunity: The Economic Impact of Off-Grid Solar.* Data gathered from Kenya, Mozambique, Rwanda, Uganda, Tanzania • FINCA International. *Internal data.* (To be published in late 2018). Data from Uganda • Gray L., et al. (2016). *Turning on the Lights: Transcending Energy Poverty Through the Power of Women Entrepreneurs. Miller Center for Social Entrepreneurship.* Data from Tanzania • GSMA. (2016). *Mobisol: Pay-As-You-Go Solar for Entrepreneurs in Rwanda* • GSMA. (2015). *Fenix International: Scaling Pay-As-You-Go Solar in Uganda* • Hassan H. & Lucchino, P. (2016). *Entrepreneurship, gender and the constraints of time: a randomised experiment on the role of access to light.* Data gathered from Kenya			
Relevant metrics where coefficient is used	2d. People that have opened a new business			
Future improvements	• Expand data collection to more geographic regions			

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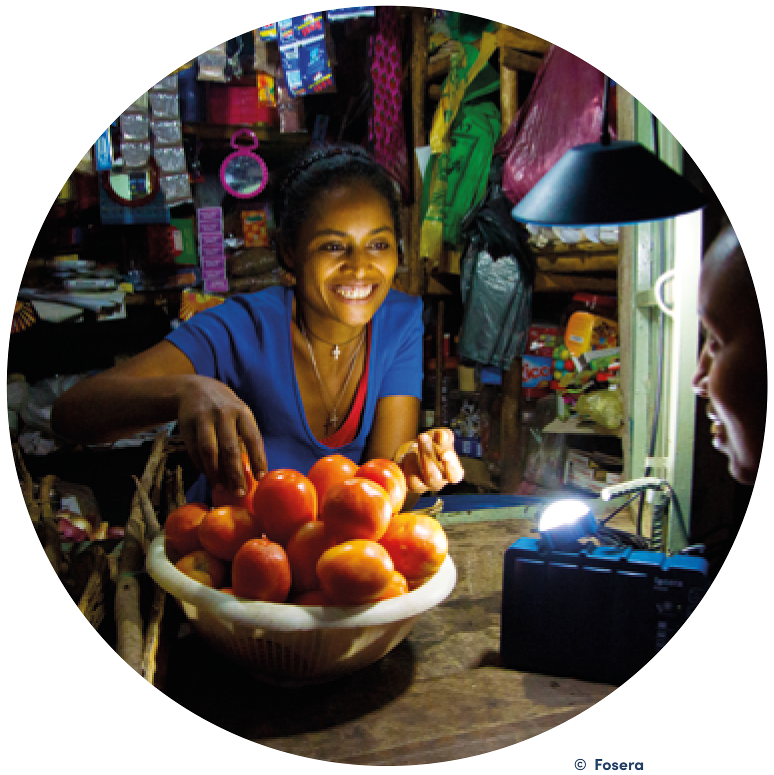
Coefficient	IG: percentage of customers generating additional income			
Definition	Number of people who are generating additional income as a result of off-grid system ownership e.g. due to use of the system to support enterprise, by spending more time at work or by getting a new job			
System Size	0.5 – 3.999 Wp	4 – 10.999 Wp	11 – 49.999 Wp	50+ Wp
Default value	10%	30%	25%	17%
Justification	• High-quality data sources, including thousands of interviews with off-grid customers			
Limitations	• Data used to build these variables is from a limited number of countries • Research for solar lanterns on the percentage of customers generating additional income is more limited than it is for larger systems, as data sets often look at the overall percentage increase in income (across all customers) rather than the specific income-generating group only			
Sources	• Altai and GOGLA (2018). *Powering Opportunity: The Economic Impact of Off-Grid Solar.* Data gathered from Kenya, Mozambique, Rwanda, Uganda, Tanzania • Azimoh C., et al. (2015). *Illuminated but not electrified: An assessment of the impact of Solar Home System on rural households in South Africa.* • FINCA International. *Internal data.* (To be published in late 2018). Data from Uganda • Gray L., et al. (2016). *Turning on the Lights: Transcending Energy Poverty Through the Power of Women Entrepreneurs. Miller Center for Social Entrepreneurship.* Data from Tanzania • GSMA. (2016). *Mobisol: Pay-As-You-Go Solar for Entrepreneurs in Rwanda*			
Relevant metrics where coefficient is used	3a. People generating additional income			
Future improvements	• Work with research partners to better align data sets so that more inputs can be directly used within the variable			



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Coefficient	AI: average additional income generated, per household (annual)			
Definition	Amount of additional income generated as a result of off-grid system ownership; over the expected lifetime of the solar products			
System Size	0.5 – 3.999 Wp	4 – 10.999 Wp	11 – 49.999 Wp	50+ Wp
Default value	$170	$288	$300	$384
Justification	• High-quality data sources, including thousands of interviews with off-grid customers			
Limitations	• Research for solar lanterns on the specific dollar amount of additional income created is more limited than it is for larger systems, as data sets often look at the overall percentage increase in income (across all customers) rather than the specific income-generating group only			
Sources	• Acumen. (2015-18). *Internal data.* Data gathered from Cote d'Ivoire, Ghana, Haiti, India, Kenya, Nigeria, Pakistan, Rwanda, Senegal, Sierra Leone and Uganda • Aevarsdottir A., et al. (2017). *The impacts of rural electrification on labour supply, income, and health.* Experimental evidence with solar lamps in Tanzania. • Altai and GOGLA (2018). *Powering Opportunity: The Economic Impact of Off-Grid Solar.* Data gathered from Kenya, Mozambique, Rwanda, Uganda, Tanzania • FINCA International. *Internal data.* (To be published in late 2018). Data from Uganda • Gray L., et al. (2016). *Turning on the Lights: Transcending Energy Poverty Through the Power of Women Entrepreneurs. Miller Center for Social Entrepreneurship.* Data from Tanzania • GSMA. (2016). *Mobisol: Pay-As-You-Go Solar for Entrepreneurs in Rwanda* • GSMA. (2015). *Fenix International: Scaling Pay-As-You-Go Solar in Uganda* • Hassan H. & Lucchino, P. (2016). *Entrepreneurship, gender and the constraints of time: a randomised experiment on the role of access to light.* Data gathered from Kenya • IDInsight. (2014). *d.light Solar Home System Impact Evaluation.* Data gathered from Uganda • Mishra, P. et al. (2016). *Socio-economic and environmental implications of solar electrification: Experience of rural Odisha* • SolarAid. *Internal data.* (2012-4). Data gathered from Kenya, Malawi, Tanzania and Zambia			
Relevant metrics where coefficient is used	3b. Additional income generated, cumulatively			
Future improvements	• Work with research partners to better align data sets so that more inputs can be directly used within the variable			

Coefficient	R: replacement ratio of kerosene for solar lighting			
Definition	The rate at which the purchase of an improved lighting source i.e. solar product, reduces the regular use of kerosene lanterns			
System Size	0.5 – 3.999 Wp	4 – 10.999 Wp	11 – 49.999 Wp	50+ Wp
Default value	1	1	1	1
Justification	• High-quality data sources, including thousands of interviews with off-grid customers • Data has been averaged out from research that also includes homes with no kerosene lamps (e.g. that use solar, candles, grid or diesel generation), so this metric provides an average kerosene replacement rate across all types of off-grid household			
Limitations	• Regional and sub-regional variations in kerosene usage are not captured			
Sources	• Acumen. (2015-18). *Internal data.* Data gathered from Cote d'Ivoire, Ghana, Haiti, India, Kenya, Nigeria, Pakistan, Rwanda, Senegal, Sierra Leone and Uganda • Altai and GOGLA (2018). *Powering Opportunity: The Economic Impact of Off-Grid Solar.* Data gathered from Kenya, Mozambique, Rwanda, Uganda, Tanzania • Grimm, M., Munyehirwe, A., Peters, J., Sievert, M. (2014). *A First Step up the Energy Ladder? Low Cost Solar Kits and Household's Welfare in Rural Rwanda.* IZA Discussion Paper Series. • Kudo, Y., Shonchoy, A., Takahashi, K. (2015). *Impacts of Solar Lanterns in Geographically Challenged Locations: Experimental Evidence from Bangladesh.* IDE Discussion Paper No. 502. • Rom, A., Günther, I., Harrison, K. (2016), *Economic Impact of Solar Lighting: A Randomised Field Experiment in Rural Kenya.* NADEL Center for Development and Cooperation, ETH & Acumen/SolarAid • SolarAid. *Internal data.* (2012-4). Data gathered from Kenya, Malawi, Tanzania and Zambia • UNFCCC (2012) *Small-scale Methodology: Substituting fossil fuel-based lighting with LED/CFL lighting systems*			
Relevant metrics where coefficient is used	4. Kerosene lanterns replaced			
Future improvements	• Explore regional data to uncover a better understanding of national variations in kerosene use			

Coefficient	G: average carbon dioxide and black carbon (CO2e) emissions per kerosene lantern			
Definition	The average amount of greenhouse gases, including black carbon, in metric tons, emitted annually by a kerosene lantern			
System Size	0.5 – 3.999 Wp	4 – 10.999 Wp	11 – 49.999 Wp	50+ Wp
Default value	0.37	0.37	0.37	0.37
Justification	• Highest-quality external source data available			
Limitations	• Data uses single-point estimate, while emissions from different types of kerosene lamps (pressurized, hurricane and single wick) differ significantly			
Sources	• UNEP/GEF en.lighten initiative Off-Grid Country Lighting Assessments: 2.6kg CO_2 per litre of kerosene (kerosene lantern) • Analysis incorporating findings on black carbon with support from the author, Dr Nicholas Lam (original source below, details in Annex 2) • Lam, N. L. et al. (2012) Household light makes global heat: high black carbon emissions from kerosene wick lamps. Environmental science & technology 46, 13531–13538 • Current default value is conservative as it assumes only three hours of kerosene use per day. (The general baseline across all types of previous lighting sources, including candles, torches and other solar products, is four hours (LB)). See Annex 2 for more details			
Relevant metrics where coefficient is used	5. CO2e avoided			
Future improvements	• Update and review data on kerosene specific hours of baseline lighting use			

Coefficient	L_B: average baseline hours of light used, per day/night per household			
Definition	Baseline hours of light used, per day/night per household (i.e. before purchasing a solar product)			
System Size	0.5 – 3.999 Wp	4 – 10.999 Wp	11 – 49.999 Wp	50+ Wp
Default value	4	4	4	4
Justification	• High-quality data sources, including thousands of interviews with off-grid customers			
Limitations	• Using kerosene lantern run-time as proxy for battery torches and candles			
Sources	• Acumen. (2015-18). *Internal data.* Data gathered from Cote d'Ivoire, Ghana, Haiti, India, Kenya, Nigeria, Pakistan, Rwanda, Senegal, Sierra Leone and Uganda • Altai and GOGLA (2018). *Powering Opportunity: The Economic Impact of Off-Grid Solar.* Data gathered from Kenya, Mozambique, Rwanda, Uganda, Tanzania • SolarAid. *Internal data.* (2012-4). Data gathered from Kenya, Malawi, Senegal, Tanzania and Zambia • UNEP/GEF en.lighten initiative: Off-Grid Country Lighting Assessments			
Relevant metrics where coefficient is used	6ai. Additional light hours used, by household 6aii. Additional light hours used, cumulatively			
Future improvements	• Continue to assess the change in baseline light hours as baseline lighting products evolve			

Coefficient	L_F: average post-purchase hours of light used, per day/night per household			
Definition	Post purchase hours of light used, per day/night per household (i.e. before purchasing a solar product)			
System Size	0.5 – 3.999 Wp	4 – 10.999 Wp	11 – 49.999 Wp	50+ Wp
Default value	5	5	5	5
Justification	• High-quality data sources, including thousands of interviews with off-grid customers			
Limitations	• Some available research does not fully capture the change in light use for some larger systems, that are often used for over 6 hours, or products used as overnight security lights			
Sources	• Acumen. (2015-18). *Internal data.* Data gathered from Cote d'Ivoire, Ghana, Haiti, India, Kenya, Nigeria, Pakistan, Rwanda, Senegal, Sierra Leone and Uganda • Altai and GOGLA (2018). *Powering Opportunity: The Economic Impact of Off-Grid Solar.* Data gathered from Kenya, Mozambique, Rwanda, Uganda, Tanzania • SolarAid. *Internal data.* (2012-4). Data gathered from Kenya, Malawi, Tanzania and Zambia • UNEP/GEF en.lighten initiative: Off-Grid Country Lighting Assessments			
Relevant metrics where coefficient is used	6ai. Additional light hours used, by household 6aii. Additional light hours used, cumulatively			
Future improvements	• Improve data capture on extended light usage and use of solar for security lighting			

Coefficient	L_D: Average number of days per year that off-grid product is used for lighting			
Definition	The number of days in a year that the off-grid solar product is used for lighting			
System Size	0.5 – 3.999 Wp	4 – 10.999 Wp	11 – 49.999 Wp	50+ Wp
Default value	350	350	350	350
Justification	• High-quality data sources, including thousands of interviews with off-grid customers • Data on daily lighting use is averaged across a large sample to capture the average number of days that systems are / are not in use. The average number of days of use is 350			
Limitations	• Data average for solar home systems has been used as a proxy figure for solar lanterns			
Sources	• Altai and GOGLA (2018). *Powering Opportunity: The Economic Impact of Off-Grid Solar.* Data gathered from Kenya, Mozambique, Rwanda, Uganda, Tanzania			
Relevant metrics where coefficient is used	6ai. Additional light hours used, by household 6aii. Additional light hours used, cumulatively			
Future improvements	• Expand data set to better validate this variable and get solar lantern specific data			

Coefficient	B_B: average baseline lumens (brightness) of household lighting use			
Definition	Baseline lumens of household lighting use (i.e. before purchasing a solar product)			
System Size	0.5 – 3.999 Wp	4 – 10.999 Wp	11 – 49.999 Wp	50+ Wp
Default value	35	45	45	45
Justification	• High-quality data sources, including thousands of interviews with off-grid customers			
Limitations	• Average lumen levels • For battery torch, based on Kenya specific data with small sample size			
Sources	**Approximate Lumen Outputs** • 25 lumens (kerosene lantern) • 12 lumens (candle) • 25 lumens (battery torch) • 20-120 lumens (solar light – mid-setting) • 100-300 lumens (small solar home system – mid-setting) **Kerosene Lantern** • Alstone, P., et al. (2014) *High Life Cycle Efficacy Explains Fast Energy Payback for Improved Off-Grid Lighting Systems. Journal of Industrial Ecology* • Mills E. (2003). *Technical and Economic Performance Analysis of Kerosene Lamps and Alternative Approaches to Illumination in Developing Countries. Lawrence Berkeley National Laboratory.* **Candle** • Lighting Global. (2010) *Light Emitting Diode (LED) Lighting Basics. Technical Note Issue 0.* **Battery Torch** • Jacobson A., et al. (2010) *LED Flashlights in the Kenyan Market: Quality Problems Confirmed by Laboratory Testing. Lighting Africa.* **Solar lanterns / Multi-light Solar Kits** • Various mid-range settings: Lighting Global **Ratio of Baseline Lighting Sources** • Acumen. (2015-18). *Internal data.* Data gathered from Cote d'Ivoire, Ghana, Haiti, India, Kenya, Nigeria, Pakistan, Rwanda, Senegal, Sierra Leone and Uganda • Altai and GOGLA (2018). *Powering Opportunity: The Economic Impact of Off-Grid Solar.* Data gathered from Kenya, Mozambique, Rwanda, Uganda, Tanzania • SolarAid. *Internal data.* (2012-4). Data gathered from Kenya, Malawi, Tanzania and Zambia			
Relevant metrics where coefficient is used	6aii. Additional light hours used, cumulatively			
Future improvements	• Continue to assess the change in baseline light hours as the baseline lighting mix evolves			

Coefficient	E_B: average annual baseline expenditure on energy (lighting and phone charging) – pico solar only			
Definition	Baseline spending on energy* per year in US$ (i.e. before purchasing a solar product)			
System Size	0.5 – 3.999 Wp	4 – 10.999 Wp	n/a	n/a
Default value	$95	$127		
Justification	• High-quality data sources, including thousands of interviews with off-grid customers			
Limitations	• Data used to build these variables is from a limited number of countries • Data is drawn from expenditure on lighting and phone charging only and does not include expenditure on transportation costs (for previous energy purchase) or any other fees e.g. paying to watch TV for a fee			
Sources	• Altai and GOGLA (2018). *Powering Opportunity: The Economic Impact of Off-Grid Solar.* Data gathered from Kenya, Mozambique, Rwanda, Uganda, Tanzania • Lighting Africa (2011) *The Off-Grid Lighting Market in Sub-Saharan Africa: Market Research Synthesis Report* • UNEP/GEF en.lighten initiative Off-Grid Country Lighting Assessments • SolarAid. *Internal data.* (2012-4). Data gathered from Kenya, Malawi, Tanzania and Zambia			
Relevant metrics where coefficient is used	7ai. Savings on energy expenditure, by household 7aii. Savings on energy expenditure, cumulatively			
Future improvements	• Expand data collection to more geographic regions			

*lighting + phone charging

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6.2 Coefficient Values to be Inputted by Organizations

Coefficient	S: number of units sold
Definition	The number of off-grid products sold This coefficient aims to record the number of products sold since the beginning of a company/organization's sales began
Guidance	• As the metrics are designed to estimate the impact of good quality solar products on households and communities in the developing world, only products sold in the developing world should be counted • In addition, these metrics should only be applied to those products sold by GOGLA Members or other organizations who distribute Lighting Global Quality assured products, or products that deliver the same performance
Notes	• Please note that this metric should not include products lost in the supply chain or products that never enter a customer's home e.g. used for marketing or display
Relevant metrics where coefficient is used	1ai. Number of people with improved energy access, cumulatively 2d. People that have opened a new business 5. CO_2e avoided 6aii. Additional light hours used, cumulatively 7ai. Savings on energy expenditure, by household 7aii. Savings on energy expenditure, cumulatively

Coefficient	S_L: number of units sold within lifespan of product (1.5 x warranty period)
Definition	The number of off-grid products that are still in use
Guidance	• This coefficient aims to estimate the number of products still in working order, and so conservatively calculates the lifetime of the product as: 1.5 x the product's warranty period • As for S, since the metrics are designed to estimate the impact of good quality solar products on households and communities in the developing world, only products sold in the developing world should be counted • In addition, these metrics should only be applied to those products sold by GOGLA Members or other organizations who distribute Lighting Global Quality assured products, or products that deliver the same performance
Notes	• Please note that this metric should not include products lost in the supply chain or products that never enter a customer's home e.g. used for marketing or display
Relevant metrics where coefficient is used	1aii. Number of people with improved energy access, currently 1bi. Number of people with access to Tier 1 energy services 1bii. Number of people with access to Tier 2 energy services 2a. People undertaking more economic activity 2b. People using products to support enterprise 2c. People spending more time working outside the home 3a. People generating additional income 3b. Additional income generated, cumulatively 4. Kerosene lanterns replaced 8. Number of adults currently benefitting from clean energy financing (PAYG only)

Coefficient	P_L: estimated solar product lifespan (1.5 x warranty)
Definition	The lifetime of the off-grid solar product
Guidance	• This coefficient aims to estimate the number of products still in working order, and so conservatively calculates the lifetime of the product as: 1.5 x the product's warranty period
Notes	• Please note that this metric should not include products lost in the supply chain or products that never enter a customer's home e.g. used for marketing or display
Relevant metrics where coefficient is used	3b. Additional income generated, cumulatively 5. CO_2e avoided 6ai. Additional light hours used, by household 6aii. Additional light hours used, cumulatively)

Coefficient	D_F: discount factor (PAYG only)
Definition	The percentage of solar products sold that do not end up in customer homes, due to product loss, churn, repossession or default
Guidance	• Conservative estimate to be inputted by companies involved in the supply chain
Relevant metrics where coefficient is used	1ai. Number of people with improved energy access, cumulatively 1aii. Number of people with improved energy access, currently 1bi. Number of people with access to Tier 1 energy services 1bii. Number of people with access to Tier 2 energy services 2a. People undertaking more economic activity 2b. People using products to support enterprise 2c. People spending more time working outside the home 2d. People that have opened a new business 3a. People generating additional income 3b. Additional income generated, cumulatively 4. Kerosene lanterns replaced 5. CO_2e avoided 6aii. Additional light hours used, cumulatively 7aii. Savings on energy expenditure, cumulatively 8. Number of adults currently benefitting from clean energy financing (PAYG only)

Coefficient	B_F: average post-purchase lumens (brightness) of household lighting
Definition	The lumen output of the solar product
Guidance	• Preferred source is third-party verified performance by Lighting Global. If this is not available, manufacturer-provided specification sheets can be used • If there are multiple settings available, the geometric average of the settings or the mid-range setting should be used
Relevant metrics where coefficient is used	6b. Change in quality of light, by household

Coefficient	C: average retail price of solar product; cost to customer (Use for cash sales only)
Definition	The price of the solar product
Guidance	• Organizations calculating their own impact should include the retail cost of their product to the end customer • For GOGLA's central reporting, we calculate averages based on GOGLA Member data provided to ensure consistency of calculating and so that weighting occurs at both organization and aggregate levels. Please note that any data shared with GOGLA is done so under a strict privacy and data protection protocol
Relevant metrics where coefficient is used	7ai. Savings on energy expenditure, by household 7aii Savings on energy expenditure, cumulatively

Coefficient	TCO: total cost of ownership; cost to customer (Use for PAYG only)
Definition	The price of the solar product
Guidance	• Organizations calculating their own impact should include the full cost of ownership of their product to the end customer e.g. including all payments until the product is fully purchased by the customer • For GOGLA's central reporting, we calculate averages based on GOGLA Member data provided to ensure consistency of calculating and so that weighting occurs at both organization and aggregate levels. Please note that any data shared with GOGLA is done so under a strict privacy and data protection protocol
Relevant metrics where coefficient is used	7ai. Savings on energy expenditure, by household 7aii. Savings on energy expenditure, cumulatively

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7. Contributors

These metrics were developed by the GOGLA Impact Working Group, a body of industry practitioners, and academic observers. The revision program was led by the Working Group Chairs and GOGLA's Research Advisor, with the support of researchers from the Schatz Energy Research Center. GOGLA would like to express its thanks to the Working Group Chairs and contributing members and observers noted below.

Working Group Chair:
Kat Harrison, Acumen, October 2013-October 2017
Associate Director of Impact & Lean Data at Acumen, and formerly the Director of Research & Impact at SolarAid, Kat leads the impact work of Acumen's energy portfolio through Lean Data – setting up the sector's first social impact performance benchmarks and building a database of over 10,000 interviews with off-grid solar customers. Chair of the Impact Working Group for four years, Kat's work laid the foundations of the harmonized impact metrics. Her pioneering research provided, and continues to provide, critical data points.

Working Group Co-Chair:
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Paula is responsible for Mobisol's sustainability strategy, environmental management, recycling and social impact reporting. She co-chaired the Impact Working Group for two years, overseeing the expansion of the metrics from pico-solar to solar home systems before undertaking a new role as co-chair of the GOGLA Sustainability Working Group.

Working Group Co-Chair:
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Nabeela is a Manager within CDC Group working on the Impact Accelerator, a direct investment fund focusing on businesses with more challenging risk-return profiles than those typically considered by commercial investors. Nabeela has helped steer the Working Group through the latest revision, bringing with her years of experience on impact investment, measurement and reporting.

Working Group Co-Chair:
Roeland Menger, ZOLA Electric, May 2018 – Present
Although only in the role of co-chair for a few months of this Impact Metric revision, Roeland has been a Working Group Member since June 2017, actively contributing insights from ZOLA's experience gathering data as well his work supporting the Powering Opportunity socioeconomic impact research. Roeland is the Senior Financial Analyst Corporate Finance at ZOLA Electric and leads the organization's impact reporting.

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Peter Alstone, based out of the Schatz Energy Research Center at Humboldt State University, has authored leading research on the off-grid solar market and the impact and efficiency of off-grid products, amongst numerous other topics. Nicholas Lam is an expert in health and environmental impacts of household energy use. His work was among the first to uncover the impacts of fuel based lighting on climate and the risk of exposure to health damaging air pollutants. Their expertise and inputs to key metrics and variables provided valuable insights that have shaped and contributed to this revision.

These updates and Whitepaper were coordinated by GOGLA, with management and input by:
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- Oliver Reynolds, Altai Consulting
- Rebekah Shirley, Power for All / University of California, Berkeley

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This section provides useful resources and links to sources used to inform the Impact Metrics.

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- FINCA International. (2017-18) Research data from Uganda
- SolarAid (2012-5). Research data from public surveys and customer interviews in Kenya, Malawi, Senegal, Tanzania, Uganda, and Zambia

Annex 1: SEforALL Factor

The SEforALL factor can be applied where a specific product or service meets a specific Tier of energy access in the Multi-Tracking Framework. The different Tiers of energy access are noted in the chart below. Products that meet Tier 1 can be attributed a Tier 1 [D_{T1}] factor, while those that meet Tier 2 can be attributed a Tier 2 [D_{T2}] factor.

Where a product provides partial Tier 1 a methodology can be applied to calculate how several products combined can create Tier 1 equivalency. The methodology has been created by SEforALL to account for instances of energy stacking and so that Tier 1 access for an individual is not underrepresented in calculations. This methodology is based on the specific functionality of individual products e.g. (lumen hours, wattage, if mobile charging is possible etc) and can be applied using the SEforALL Calculator Tool.

The approach to calculating Tier 2 is based on an assessment of the wattage (50+ Wp) and / or service provided e.g. whether the product can power a television and fan.

Overall category	Solar module capacity, Watt Peak (Wp)	Categorization by services provided by product	Corresponding level of MTF energy access enabled by use of product
Portable Lanterns	0 – 1.499 Wp (indicative)	Single Light only	Enables partial Tier 1 Electricity Access to a person / household
	1.5 – 3.999 Wp (indicative)	Single Light & Mobile Charging	Enables full Tier 1 Electricity Access to at least one person and contribute to a household
Multi-light Systems	4 – 10.999 Wp (indicative)	Multiple Light & Mobile Charging	Enables full Tier 1 Electricity Access to at least one person, up to a household
	11 – 20.999 Wp	SHS, Entry Level (3-4 lights, phone charging, powering radio, fan etc)	Enables full Tier 1 Electricity Access to a household
Solar Home Systems	21 – 49.999 Wp	SHS, Basic capacity (as above plus power for TV, additional lights, appliances & extended capacity)	Enables full Tier 2 Electricity Access to a household when coupled with high-efficiency appliances
	50 – 99.999 Wp	SHS, Medium capacity (as above but with extended capacities)	Enables full Tier 2 Electricity Access to a household even using conventional appliances
	100 Wp +	SHS, Higher capacity (as above but with extended capacities)	

Annex 2: Avoided Emissions from Replacement of Kerosene Lamps

The avoided pollutant emissions from reduced use of a kerosene lamp is calculated as the difference in annual lighting emissions before and after procurement of the solar product.

Eq. 1: $\text{Emissions}_{avoided}\ (CO2_e\ /\ \text{Year}) = \text{Emissions}_{before}\ (CO2_e\ /\ \text{Year}) - \text{Emissions}_{after}\ (CO2_e\ /\ \text{Year})$

Where $CO2_e$ is the carbon dioxide equivalents of the pollutants from a kerosene lamp exhibiting an effect on the climate. Note that the approach implicitly assumes that emissions from the solar lamp is zero, and so the avoided emissions is represented only by the change kerosene lamp emissions.

For a kerosene lamp, the effect on climate is represented by two pollutants: black carbon (BC) and carbon dioxide (CO_2). When estimating the effect of switching off (on) any emission source, it is important to consider both the pollutants that warm the climate and those that cool it, as switching off (on) sources will influence both. Kerosene lamps emit very little of the pollutants that cool the climate, and the dominant impact of their emissions can be represented by only considering BC and CO_2, both warming pollutants.

The pollutant emissions of a given lamp in either the before or after phase can be estimated as the product of the rate fuel is burned (BR), the duration of lamp use (Runtime), and the pollutant- and lamp type-specific emission factor (EF). Using CO_2 as an example:

Eq. 2: $\text{Emissions}_{phase}\ (gCO2\ /\ \text{Year}) = BR\ (\text{kgKero}\ /\ \text{hr}) \times \text{Runtime}\ (\text{hours}\ /\ \text{day}) \times EF_{CO2}\ (gCO2\ /\ \text{kgKero}) \times 365\ (\text{days}\ /\ \text{year})$

Table 1 outlines the assumptions used in the equation above for various kerosene lamp types. For BC, the emission factor (EFBC) and annual emission can be converted from grams of BC to a CO2 equivalent (CO2e) by multiplying by the BC mass emissions by the global warming potential (GWP) for BC. A conservative 100-year time horizon GWP of 700 is assumed (the energy that one ton of BC will absorb over 100 years, relative to CO2 over that time period). GWP estimates are informed by Bond et al. 2013. The emissions from both BC and CO2 can then be summed to estimate a total emissions from the lamp, in terms of CO2e (i.e. CO2e/lamp-year).

There are large differences in the emission factors for BC and burn rates across the kerosene lamp types. Thus, when estimating avoided emissions for given context, it is important to consider the mix of lamp types in your customer base or population. For the GOGLA Standardized Impact Metrics, an average mix of lamp types is applied, based on a review of kerosene usage gathered through market surveys in several different countries. The mix applied is:

- 11% Pressurised Lamps
- 45% Hurricane Lamps
- 44% Single Wick Lights

Based on the above lamp mix, kerosene burn rate and CO2 / BC (CO2e) emissions factors, and taking a conservative approach to the number of hours of kerosene being avoided (three hours per day), the GOGLA Standardized Impact Metrics default estimate for emissions avoided per solar product is, on average, 370kg per year (0.37 metric tons).

Please note that the GOGLA Standardized Impact Metric for avoided CO2e emissions also considers the solar product replacement ratio for kerosene lamps and the estimated lifetime of each solar product. In Eq. 2, this is effectively represented by a reduction in the runtime of the kerosene lamp.

Table 1. Assumptions used for estimating emissions from kerosene lighting devices. Table values informed by estimates reported in Lam et al. 2012, Apple et al. 2010 and Bond et al. 2013

	Units	Pressurized	Hurricane	Single wick
Kerosene Burn rate (BR)	kgKERO/hr	0.074	0.017	0.015
	LitersKERO/hr[a]	0.091	0.021	0.018
BC emission factor (EF_{BC})	gBC/kgKERO	0	2	80
	gBC/LiterKERO	0	1.62	64.8
	gCO2e/kgKerob	0	1400	56,000
CO_2 emission factor (EF_{CO2})	gCO_2/kgKERO	3,100	3,100	2,900
	gCO_2/LiterKERO	2500	2500	2400

[a] Assuming a density of kerosene of 0.81 kg/liter
[b] Estimated by multiplying the mass emission factor by a GWP of 700, informed by estimates in Bond et al. 2013.

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