Mini-Grid Emissions Tool

Cover note

Universal Energy Facility | C/O Sustainable Energy for All
Andromeda Tower 15th floor, Donau City Strasse 6, 1220, Vienna Austria
UEF@SEforALL.org

BACKGROUND

The mini-grid emissions tool was originally designed to calculate the climatic impact of the Universal Energy Facility (UEF). The Universal Energy Facility is a multi-donor results-based financing facility that provides incentive payments to eligible organizations that deploy energy solutions and provide verified end-user energy connections. The facility's mission is to significantly speed up and scale up access to energy across Africa by providing results-based financing for verified connections for electricity and solutions for clean cooking. The facility was established by Sustainable Energy for All (SEforALL), in collaboration with several other donors and partners, including The Rockefeller Foundation, Shell Foundation, Power Africa, Good Energies, UK Aid/Carbon Trust and Africa Minigrid Developers Association (AMDA).

This mini-grid emissions tool has been developed by SEforALL with development led by Naomi Wagura with contributions from Ruchi Soni and Sisana Farley from SEforALL. SEforALL would like to thank Sam Duby (TFE Energy) whose valuable expertise has ensured that the methodology is not only rigorous but can serve an array of stakeholders to encourage standardization of reporting protocols in the mini-grid sector. SEforALL is also grateful to the following individuals and organisations for providing data, and for their valuable comments and advice: Perumal Arumugam (UNFCCC), Gajanana Hegde (UNFCCC), and Aaron Leopold (AMDA).

Why Is the Mini-Grid Emissions Tool Necessary?

Currently, the mini-grid sector does not have a standardized method of tracking the carbon emissions displaced by renewable energy mini-grids. Although there are current methodologies, most of these calculate the emissions avoided based on energy generated by mini-grids and one default emissions factor. Usually the default emissions factor assumes that the mini-grid consumers previously all used one fuel source, e.g. a diesel generator. However, the consumers connected to mini-grids typically use a variety of energy sources for lighting and other energy services. Additionally, for many mini-grids, 100 percent of the energy generated is not consumed, at least in the first few years, so basing emissions mitigated by the mini-grids using the energy generated over-estimates the mitigation impact.

SEforALL developed the mini-grid emissions tool to help the sector better estimate emissions avoided by taking into consideration:

- different previous energy sources to calculate the baseline emissions
- energy consumed by the mini-grid customers
- different mini-grid generating sources including hybrid mini-grids

A harmonized and detailed approach to estimating the carbon emissions avoided by renewable energy mini-grids enables mini-grid developers, governments, investors, multi-lateral organizations and other sector stakeholders to better quantify the climatic benefits of mini-grids in a consistent manner and report on the sector’s contribution to climate change mitigation.

Using the Mini-Grid Emissions Tool

The mini-grid emissions tool can be used by the mini-grid sector stakeholders to calculate the climatic impact of mini-grid installations. The tool requires some detailed inputs from the mini-grids installed and can be modified to suit a country or regionally-specific context.

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SUMMARY OF INPUTS

The mini-grid emissions tool requires detailed inputs from the mini-grids installed and the customers connected to the mini-grids. However, if detailed information is not available, the tool provides default figures that are based on information collected from various sources including mini-grid developers, sector reports, other widely accepted methodologies and other sources. The default values should only be changed if more reliable and context-specific values are available. Information on default value sources and their limitations is contained in the Annexes.

The tool provides a “dashboard” tab that provides a summary of the emissions calculation results.

Mini-Grid Specific Inputs

Inputs	Use
Solution	The current version of the tool only covers mini-grids but will likely be updated in the future to include other energy access technologies such as solar home systems.
Country/Region	This the country or region the mini-grid(s) is being implemented. This input changes the baseline kerosene emissions and fossil fuel generator inputs. See more in the Annexes.
Funds disbursed to mini-grid developer or CAPEX	Calculate the climatic return on funds invested or disbursed.
Number of mini-grid connections	Estimate the total electricity consumed from the mini-grid and so the total emissions generated from the electricity consumed
Number of Tier 2[2] household connections	The Tier 2 classification references the consumption once the customers are connected to the mini-grid(s). These are households that would likely use the mini-grid electricity for lighting, phone charging and an appliance, e.g. TV or fan. The tool also assumes that before connecting to the mini-grid(s), these households only had access to lighting, phone charging and a small appliance such as a radio (See ANNEX 1: HOUSEHOLD ENERGY ACCESS TIERS for more information). In the baseline emissions section of the inputs, these households are therefore referred to as Tier 1 households. This input is used to estimate the electricity consumed by Tier 2

[1] Please reach out to Stephen.kent@seforall.org for attribution.
[2] Based on SEforALL/ESMAP’s multi-tier framework - Tier 2 are connections with more than 200Wh daily consumption while Tier 3 are connections with more than 1kWh daily consumption

	households on the mini-grid(s) and so the emissions generated from their electricity use. It is also used to calculate the baseline emissions from these households.
Number of Tier 3[2] households, businesses/productive use and public connections	It is assumed that these three mini-grid connection types would have one energy source to power all their loads which is why they are grouped together in the tool. The Tier 3 households classification refers to consumption once the households are connected to a mini-grid. It is assumed that these households, prior to connecting to the mini-grid(s), had a lower level of access (Tier 2). This input is used to estimate the electricity consumed by these consumer groups and their baseline emissions.
Growth in connections per annum	Used to project how the baseline and mini-grid emissions would change over the life of the mini-grid(s).
Initial average monthly consumption/consumer - all consumers	Used to estimate the total amount of electricity consumed on the mini-grid(s) in the first year after customer connection.
Maximum average monthly consumption (Plateau) - all consumers	Consumption on mini-grids typically increases during the first few years but would likely not increase past a certain amount (referred to as a plateau here). The tool uses the equation below to estimate the annual consumption in the years before the consumption plateaus: [a*log (year)+c] where: $a = \frac{consumption\ in\ plateau\ year - consumption\ in\ intial\ year}{LN\ plateau\ year}$ $year = the\ year\ under\ consideration$ $c = plateau\ consumption$ Used to estimate the increase in electricity consumption by all mini-grid(s) consumers.
Initial average monthly consumption/Tier 2 household	Used to estimate the total amount of electricity consumed by the Tier 2 households in year 1.
Maximum monthly consumption/Tier 2 household (plateau)	Used to estimate the increase in electricity consumption by Tier 2 households connected to the mini-grid(s).
Time period to get to plateau	Used to estimate the increase in energy consumption for all consumers.
Mini-grid lifespan	Used to project the emissions avoided over the life of the mini-grid.

Baseline Emissions Inputs

The inputs in this section are based on the previous energy sources of the mini-grid connections. They are split into two categories: Households that had Tier 1[3] energy access and households that had Tier 2[3] access or businesses or productive use or public connections.

Inputs	Use
Households that had Tier 1 energy access	
Previous energy supply technology	The user needs to input the technology used to provide the energy supply used for lighting and other non-lighting energy services. Used to calculate the baseline emissions from this consumer type.

[3] As indicated above in the mini-grid specific inputs, the households that had Tier 1 access would now have Tier 2 access when connected to the mini-grid while those that had Tier 2 access would now have Tier 3 access.

	The tool contains default factors for kerosene lamps (see ANNEX 2: BASELINE KEROSENE EMISSION), solar PV, petrol and diesel generators (see ANNEX 3: FOSSIL FUEL GENERATORS EMISSION FACTORS). For candles, the default factor is based on an estimated emissions factor of 5.5 g CO_2/h[i]. For rechargeable battery torches, the user would need to input either the main grid emissions factor or the relevant emissions factor based on which energy supply was used to charge the torches.
Percentage of consumers that used that energy supply technology	The tool allows the user to provide the percentage of consumers of this type that used each energy supply technology. The total percentage points across each energy service should add up to 100 percent. Used to calculate the baseline emissions from this consumer type.
Households that had >Tier 2 access or businesses or productive use or public connections	
Previous energy supply technology	The tool allows the user to input up to five energy supply technologies. Used to calculate the baseline emissions based on the technology type selected.
Percentage of consumers that used that energy supply technology	The tool allows the user to provide the percentage of consumers of this type that used each energy supply technology. The total percentage points across each energy service should add up to 100. Used to calculate the baseline emissions from this consumer type.
Baseline consumption as a percentage of consumption on mini-grid	The tool assumes that for this consumer type, there was suppressed demand and therefore these consumers were only able to meet a portion of their energy needs using the previous sources, e.g. by only running a generator for a few hours every day. The tool then assumes that the previous energy used by this consumer type is a percentage of their energy consumption after connecting to the mini-grid(s). This value is an estimate since data on previous energy consumption for this consumer type is scarce. The default value for this is 70 percent and the user should change this if better data is available.

Replacement Technology Inputs

Inputs	Use
Generating technology	Used to estimate the emissions generated by the mini-grid(s). The tool currently accommodates solar PV, diesel generator or a hybrid of these. In future this will be expanded to include other generating types such as biomass, hydroelectric and wind.
Percentage of total energy supplied by technology	Used to calculate the mini-grid emissions from each generating technology type.

Future Improvements

The tool will be a living document that will be reviewed and updated based on data collected or recommendations received. SEforALL will collect data from the UEF and other sources to validate and update the default values as necessary. Some possible future changes include:

1. Updating the list of previous energy sources based on data from mini grids installed
2. Updating the default initial and maximum energy consumption for the different customer segments
3. Modelling the possible change in baseline emissions over the mini-grid lifespan, e.g. change in kerosene consumption year-on-year in different countries in Sub Saharan Africa (SSA).

SEforALL would be interested in hearing from users of the tool on recommended changes or country/region-specific inputs that can be used to improve the tool.

ANNEX 1: HOUSEHOLD ENERGY ACCESS TIERS

The default values on the average consumption per connection on a mini-grid are based on data collected from mini-grid installed across SSA from reports such as the AMDA "Benchmarking Africa's Minigrids"[ii] report and SEforALL's calculations. The calculations and assumptions behind the estimated consumption of households that previously only had Tier 1 energy access and now have tier 2 access are included in the "Household consumption" tab in the tool.

Based on widely published data, households in areas without access to electricity have access to, at a minimum, some lighting sources (electric or non-electric), mobile phone charging and a radio (Tier 0 - 1 access). The monthly consumption (rounded up) in Table 1 below is used as the default figure for the "Initial average monthly consumption/Tier 2 household" input in the "Inputs" tab.

Table 1: Initial (Yr 1 after mini-grid connection) household electricity access – Tier 1

Typical load	**Consumption**	**Loads**
Lighting	52.56 kWh/annum	2 9W LED lamps run for 4 hours a day every day
Mobile phone charging	3.64 kWh/annum	2 mobile phones per household, each mobile phone charge requires 0.01 kWh & that each phone is charged every other day so total 182 times per annum
Radio	2.19 kWh/annum	1 10W radio powered for 6 hours a day, every day
Total annual consumption per household	58.39 kWh/annum	
Monthly consumption /month	4.86 kWh/month	

Once the mini-grid is installed, anecdotal data suggests that some, if not all, households upgrade their energy services to included appliances such as a fan or a TV (Tier 2). SEforALL made conservative assumptions that in the year the mini-grid is installed, all households that were previously Tier 1 and upgrading to Tier 2 only use the mini-grid electricity for lighting (2 LED lamps), charging two phones every other day and powering a radio. By the consumption plateau year, we assume that all previous Tier 1 households have increased their consumption to include powering a TV or similar appliance. The monthly consumption (rounded dowm) in Table 2 below is used as the default figure for the "Maximum monthly consumption/Tier 2 household (plateau)" input in the "Inputs" tab.

Table 2: Maximum household consumption – Tier 2

Typical load	**Consumption**	**Loads**
Lighting	52.56 kWh/annum	2 9W LED lamps run for 4 hours a day every day
Mobile phone charging	3.64 kWh/annum	2 mobile phones per household, each mobile phone charge requires 0.01 kWh & that each phone is charged every other day so total 182 times per annum
Radio	2.19 kWh/annum	1 10W radio powered for 6 hours a day, every day
TV or other small appliance	65.7 kWh/annum	Average power (Nominal Conditions: Maximum On Mode Power)[4]
Total annual consumption per household	124.09 kWh/annum	
Monthly consumption /month	10 kWh/month	

[4] Verasol Product Database https://data.verasol.org/products/tv

ANNEX 2: BASELINE KEROSENE EMISSION FACTORS

In order to arrive at the default values included in the SEforALL mini-grid emissions tool for kerosene-based baseline emissions, two sources were referenced: the UNFCCC AMS-III.AR. methodology "Substituting fossil fuel-based lighting with LED/CFL lighting systems"[iii] and the GOGLA Standardised Impact Metrics for the Off-Grid Solar Energy Sector[iv]. A summary of the recommendations from these sources and the default values included in SEforALL's tool is provided below.

Baseline assumptions

	UNFCCCC CDM	GOGLA	SEforALL mini-grid emissions tool
Fuel use rate/burn rate (litres/hr)	0.03 litres/hour	Weighted depending on lamp type i.e. 0.018, 0.019, 0.021 for single wick, pressurised and hurricane respectively	Used the GOGLA figures since they take into consideration different kerosene lamp types
Utilization	3.5 hours/day	3.5 hours/day	3.5 hours/day
Fuel emissions factor - Carbon Dioxide (kg CO_2/litre)	2.4 kgCO_2/litre	Dependent on kerosene lamp type: 2.4 for single wick lamps, 2.5 kg for hurricane and pressurised lamps	Used the GOGLA figures since they take into consideration different kerosene lamp types
Fuel emissions factor - Black Carbon (kg CO_2equivalent/litre[5])	None	Dependent on kerosene lamp type: 45.360 kgCO_2e/litre for single wick lamps, 1.134 kgCO_2e/litre for hurricane lamps and 0 pressurised lamps	Used the GOGLA figure since BC is an important short-lived pollutant to take into consideration when calculating the climatic impact of kerosene lamps.
Prevalence of each kerosene lamp type	None	• 11% Pressurised Lamps • 45% Hurricane Lamps • 44% Single Wick Lights	Used the GOGLA weightings as the default for the "kerosene-general" technology option but the user can provide different lamp type weightings by selecting each kerosene lamp type separately and putting in the percentage of households in the project area

[5] For single wick lamps the black carbon emissions are 56,000 kgCO_2e/kg kerosene, 14000 kgCO_2e/kg kerosene for hurricane lamps and none for pressurized lamps. Assume a kerosene density of 0.81 kg / litre and use a GWP of 700. (Source: GOGLA Impact Metrics)

			that use each lamp type.
Kerosene lamp replacement ratio: The rate at which the new renewable lighting source reduces the regular use of a kerosene lantern.	Assumes a default value of 1.0	Ratio varies depending on region and size of solar system. For the larger solar systems (50W+), the replacement ratio in East Africa is the highest at 1.1 while West Africa's ratio is 0.4, South Asia is 0.3 and Rest of World is 0.4	References the GOGLA replacement ratios, an average of the East and West Africa ratios for sub- Saharan Africa-wide calculations and for region/country-specific calculations the mini-grid emissions tool pulls the country/ regional values as default values.
Dynamic Baseline Factor: change in baseline fuel, fuel use rate, and/or utilization during crediting period.	Calculated as either: Option 1: default of 1.0 in the absence of relevant information. Option 2: value of 1.0+FFg where FFg is the documented national growth rate of kerosene fuel use in lighting from the preceding years (use the most recent available data for a three- or five-years average (fraction))	None	Follows the UNFCCC recommendation leaving it at 1 since information on kerosene use change year on year for countries in SSA is not available. This can be changed if reliable information is available, per country.
Replacement Technology Assumptions			
Service life (years)	2 - 7 years depending on solar lamp sold	1.5 times the solar product warranty.	Not included in the emissions calculation since for mini-grids the energy supply's lifetime is estimated at 20 years unlike solar home systems that have shorter lifespans.

ANNEX 3: FOSSIL FUEL GENERATORS EMISSION FACTORS

The SEforALL mini-grid emissions tool takes into account two types of fossil fuel generators: those used previously by households and businesses before the mini-grid was installed, referred to in the tool as “Diesel generator (previous source) and petrol generators” in the tool, and diesel generators installed as a back-up power source for the new mini-grids, referred to as “Diesel generator (mini-grid)”. Diesel generators are categorized differently because the tool assumes while the previous diesel generators were likely smaller, less efficient units, the ones installed as part of the modern mini-grids will be larger, better-quality generators to minimize the operations and maintenance costs of the grids.

Diesel Generators

For both diesel generators types, the tool assumes that every litre of diesel produces 2.69 kg of CO_2 and the density of diesel as 0.85 kg/litre.

I. Diesel generator (previous source) – Since data on the diesel generators found in rural SSA is hard to find, the default figure was selected based on evaluating data from various reports and sources for diesel generators sold in India[v], Australia[vi], the USA[vii] and a methodology from the Joint Crediting Mechanism (JCM)[viii] and the UNFCCC CDM mini-grid emissions tool AMS-I.F[ix]. Assumptions are made on the loading factor (50 percent) and the size of the previously used generators (<35kW). Based on the data available, emissions factors at 50 percent loading for this generator size range vary from 0.8–1.3 $kgCO_2/kWh$. To make conservative estimates on emissions avoided, the SEforALL tool uses an emissions factor of **1 $kgCO_2/kWh$** for the smaller previously used diesel generators. If this emissions factor needs to be changed to make it more region or country-specific, the user can change the factor in the “Diesel genset emissions” tab in the tool.

II. Diesel generator (mini-grid) – For these larger generators, assumptions are also made on the loading factor (50 percent) and the size of the generator (35–135kW). Based on the data available, emissions factors at 50 percent loading for this generator size range vary from 0.8–1.0804 kgCO2/kWh. The default emissions factor for the larger back-up generators is set at **0.8 $kgCO_2/kWh$** in the mini-grid emissions tool.

Petrol Generators

In most SSA countries, small petrol generators are more prevalent than small diesel generators in the rural areas that will likely be served by a mini-grid as opposed to the main grid. The default factor for these petrol generators in the tool is set at **1.25164 $kgCO_2/kWh$** based on the following assumptions: energy

density of petrol is 46 megajoules per kilogram (MJ/kg); every litre of petrol produces 1.7 kg of CO_2; 20 percent genset efficiency; and genset only does useful work for 70 percent of the time.

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