Approved baseline and monitoring methodology AM0046

"Distribution of efficient light bulbs to households"

I. SOURCE AND APPLICABILITY

Source

This methodology is based on the project activity "Ghana efficient lighting retrofit project", whose baseline and monitoring methodology and project design document were prepared by Perspectives Climate Change GmbH, Hamburg, Germany.

For more information regarding the proposal and its consideration by the Executive Board please refer to case NM0150-rev: "Ghana efficient lighting retrofit project" on http://cdm.unfccc.int/goto/ARpropmeth

This methodology also refers to the latest version of the "Tool for the demonstration and assessment of additionality" and the latest version of approved methodology ACM0002.[1]

Selected approach from paragraph 48 of the CDM modalities and procedures

"Existing actual or historical emissions, as applicable".

Definitions

For the purpose of this methodology, the following definitions apply:

Light bulb: a replaceable component that is designed to produce light from electricity and that can be connected to a lamp socket. The different groups of light bulbs are: incandescent lamps (which include halogen lamps), gas discharge lamps, fluorescent lamps, compact fluorescent lamps and LED lamps (solid state lighting).

Light appliance: electric appliances that produce light and are connected to the electricity supply of the household, including the light bulb, the lamp socket, and, if applicable, any transformers or electronic control gear to transform the grid voltage (typically 110 V or 230 V) to applicable voltage levels (e.g. 20 V) and any dimmers to regulate the level of light. Appliances that have other purposes but also produce light (e.g. television) are not included.

Project coordinator: entity, which is a project participant, organizing the sale, at a reduced price, or the free distribution of efficient light bulbs to the households participating in the project activity.

Urban area[2]**:** is an area where people live in continuously build-up areas in places with a population of 1,000 or more people and a population density of 400 or more people per km^2.

[1] Please refer to: http://cdm.unfccc.int/goto/MPappmeth
[2] This definition of urban and rural area is extracted from Statistics Canada (2005): http://www.statcan.ca/english/research/21-601-MIE/2002061/appendixa.pdf (9.5.06)

Rural area[2]: is an area where people live in sparsely populated lands lying outside urban areas, i.e. areas where less than 1,000 people live in one place or where the population density is less than 400 people per km^2.

Total project area: total geographical area in which light bulbs are distributed under the project activity.

Project area (*i*): distinct geographical area in which light bulbs are distributed under the project activity. Each project activity area can either be an urban or a rural area. The CDM project activity may encompass one or more project activity areas. All project activity areas together correspond to the total project activity area.

Baseline sample group (BSG): group of households monitored to estimate baseline emissions. The households included in this group do not participate in the project activity but would be eligible to do so and are located in the total project area.

Baseline sample buffer group (BSBG): group of households used to replace households that leave the BSG during the crediting period, e.g. if a household moves elsewhere. The households included in this group do not participate in the project activity but would be eligible to do so and are located in the total project area.

Baseline cross-check group (BCCG): group of households newly established for each monitoring interval *y* and selected randomly among the households that are eligible to participate in the project but that do not yet have received light bulbs from the project coordinator and that do not belong to the BSG or the BSBG.

Project sample group (PSG): group of households monitored to estimate the project emissions. The households included in this group are eligible to participate in the project activity.

Project sample buffer group (PSBG): group of households used to replace the households that leave the PSG during the crediting period, e.g. if a household moves elsewhere. The households included in this group are eligible to participate in the project activity.

Project cross-check group (PCCG): group of households newly established for each monitoring interval *y* and selected randomly among the households that are not in the PSG or PSBG and that have received light bulbs from the project coordinator prior to the start of the spot check (i.e. the date of the first visit of a household during the spot checking period) that was undertaken at the beginning of the monitoring interval *y*.

P-U characteristic curve: curve representing the relation between the net power of the light bulb and the grid voltage. For an example, see
Figure **1**.

Living area: areas within a household in which lighting appliances are typically switched on for a long time during a day. This includes the living room and the kitchen. This does not include the staircase, the basement, storage rooms, bathrooms and bedrooms.

Applicability

This methodology is applicable to project activities that enhance energy-efficient lighting in households. The project activity is implemented by a project coordinator who is the project participant. The project coordinator sells, at a reduced price, or donates compact fluorescent lamps (CFLs) to households within a distinct geographical area, thereby replacing less energy efficient light bulbs. The individual households that use the CFLs that are distributed or sold under the project activity are not the project participants.

The households return the previously used light bulbs to the project coordinator. For each returned and functioning light bulb, the household may purchase or receive a new CFL from the project coordinator. A light bulb that is sold or distributed to a household by the project coordinator should:

(a) Be more efficient (i.e. use less electricity per lumen output) than the light bulb returned by the household, and
(b) Have the same (or a lower) lumen output as the light bulb returned by the household.

The light bulbs returned by the households to the project coordinator should have a rated power consumption of 100 W or less. The maximum number of light bulbs distributed or sold to each household should not exceed four light bulbs.

Light bulbs are sold or distributed in the following manner:

(a) Distribution or sale of light bulbs and recollection of previously used light bulbs directly at each household; and/or
(b) Distribution of light bulbs at dedicated distribution/collection points upon presentation of an invitation to participate in the project, which is sent by the project coordinator to the households.

The project coordinator ensures that the returned light bulbs are destroyed. If the distribution mode (a) is chosen, the light bulbs are collected directly from the households and destroyed immediately. With approach (b), the light bulbs are collected at the dedicated distribution/collection points and stored for centralized or decentralized destruction.

Furthermore, the following conditions apply to the methodology:

- The households are connected to a national or regional electricity grid.
- The power rating of each type of light bulb that is distributed or sold by the project coordinator is known before the start of the project activity and the P-U characteristic curves of these light bulb types have been determined by laboratory measurements.
- The project coordinator implements a social lottery system among all households included in the baseline sample group (BSG) and the project sample group (PSG) which provides a strong incentive for not leaving the sample groups, while ensuring that lottery income does not create a monetary household income that could have an impact on the household's lighting behaviour (e.g. semi-annually 3 awards providing free educational programmes could be advertised among all sample group households). The lottery should be observed by an independent non-profit organisation within the host country (e.g. the church). Lottery results need to be reported semi-annually to all sample group households;
- No other CDM project that may affect the energy efficiency of lighting in households located within the total project area has been registered.

- The geographic and system boundaries for the relevant electricity grid can be clearly identified and the necessary information to calculate the grid emission factor according to the latest approved version of baseline and monitoring methodology ACM0002 is available.
- Metering equipment recording the utilisation hours or the electricity consumption of each light appliance in the PSG and BSG is attached to every lamp socket or the cable leading to the lighting appliance. This means that light bulbs can be replaced by the households without inference with the metering equipment (e.g. in case of autonomous replacement

II. BASELINE METHODOLOGY

Project boundary

The spatial extent of the project boundary encompasses the physical, geographical location of each project area *i* and the spatial extent of the electricity system(s) that the households are connected to. The project boundary includes each lighting appliance replaced under the project activity and all power plants physically connected to the electricity system that the households are connected to. The distinct geographical boundary of each project area *i* should be clearly documented in the CDM-PDD using GPS data.

The spatial extent of the project electricity system, including issues related to the calculation of the combined margin (CM), is as per that defined in ACM0002 "Consolidated baseline methodology for grid-connected electricity generation from renewable sources".

Table 1 below illustrates which emission sources are included in the project boundary.

Table 1: Summary of gases and sources included in the project boundary and justification / explanation where gases and sources are not included

	Source	Gas	Included?	Justification / Explanation
Baseline	Power plants servicing the electricity grid	CO_2	Yes	
		CH_4	No	Minor source.
		N_2O	No	Minor source.
Project Activity	Power plants servicing the electricity grid	CO_2	Yes	
		CH_4	No	Minor source.
		N_2O	No	Minor source.

Procedure for the selection of the most plausible baseline scenario

The baseline scenario is that lighting in the households in the total project area would in the absence of the project activity have occurred:

(a) By utilisation of the currently used light bulbs (these light bulbs may include efficient and not efficient light bulbs); and
(b) By utilisation of new light bulbs with the same or greater efficiency (autonomous replacement).

The use of light bulbs in the absence of the project activity is determined by monitoring a control group of households – the baseline sample group (BSG) – over the whole crediting period.

Since the baseline scenario for utilisation of lightening appliances is determined by monitoring a control group, any policies and measures affecting the use of light appliances are reflected in the baseline scenario.

Additionality

Additionality shall be demonstrated using the latest version of the *"Tool for the demonstration and assessment of additionality"* that is available on the UNFCCC web site. Step 2 (Investment Analysis) shall be used to demonstrate additionality. The *"Tool for the demonstration and assessment of additionality"* should be applied from the perspective of the project coordinator undertaking the project activity.

Emission reductions

The project activity enhances the efficiency of lighting in households and thereby reduces electricity consumption of the households. Emission reductions are calculated based on the grid emission factor ($EF_{CO2,ELEC,y}$) and the quantity of electricity saved by the households as a result of the project activity. The electricity savings by the households are estimated and monitored by establishing two control groups, a baseline sampling group (BSG) and a project sample group (PSG). The households in the BSG do not participate in the project activity, whereas the households in the PSG participate in the same manner in the project activity as all other households. The households in both groups are selected in a statistically representative manner. Electricity consumption for lighting is metered during monitoring and the difference between the two control groups, adjusted for the margin of error at a 95% confidence interval, is used to calculate emission reductions. As a quality assurance measure, the total electricity consumption of households in the BSG and PSG is compared to the total electricity consumption of a random sample of households that have not participated in the project – the baseline cross-check group (BCCG) – and households that have participated in the project – the project cross-check group (PCCG).

The project implementation and determination of emission reductions involves the following steps:

Step 1: Determination of the project area(s) *i*
Step 2: Establishment of a project activity implementation plan
Step 3: Determination of the size of the BSG and the PSG
Step 4: Selection of the households to be included in the BSG and the PSG
Step 5: Installation of measurement equipment
Step 6: Allocation of households to the BSG and PSG
Step 7: Establishment of a baseline sample buffer group (BSBG) and project sample buffer group (PSBG) (not mandatory)
Step 8: Establishment of a project database
Step 9: Monitoring of utilization hours / electricity consumption in the BSG and PSG
Step 10: Determination of the power correction factor
Step 11: Calculation of the mean and standard deviation of household electricity consumption for lighting
Step 12: Estimation of technical distribution losses in the electricity grid
Step 13: Cross-check of monitoring results by random sampling of households not included in the BSG, PSG, BSBG and PSBG
Step 14: Calculation of emission reductions

Step 1: Determination of the project area(s) *i*

The total project area should be divided into single project areas *i*. Each project area i should either be an urban area or a rural area. Each project area is restricted to an area of:

- 4 km^2 (a square with 2 km edges length) for urban areas;
- 3,600 km^2 (a square with 60 km edges length) for rural areas.

The distinct geographical boundary of each project area *i* should be clearly documented in the CDM-PDD using GPS data.

Step 2: Establishment of a project activity implementation plan

A project activity implementation plan which specifies how the project is implemented should be established and documented in the CDM-PDD , including, *inter alia*, information on:

- The type of light bulbs that are distributed or sold by the project coordinator, including information on the manufacturer, any label, the product number, the lumen, the power rating, the P-U characteristic curve, etc;
- The number of project activity light bulbs (L_i) that are planned to be distributed by the project activity in each project area *i* over the duration of the crediting period;
- The total number of project activity light bulbs by type that is planned to be distributed by the project activity over the duration of the crediting period;
- Which households are eligible to participate in the project activity (e.g. households that are costumers of an electric utility, households with a certain income, etc);
- How the light bulbs will be distributed or sold to household consumers, including a description of all measures employed under the project and a description how final consumers are motivated to participate in the project;
- How households included in all sample groups (BSG, BSBG, BCCG, PSG, PSBG and PCCG) will be selected randomly in a statistically representative manner.

Step 3: Determination of the size of the household pool to establish the BSG and the PSG

Emission reductions are calculated based on sampling electricity consumption from lighting in a baseline sample group (BSG) and a project sample group (PSG).

The households in the project sample group participate in the same manner in the project activity as all other households. It should be ensured that the households included in the PSG receive the same level of service and information. This means that they should not receive more information than other households and should not be particularly encouraged to participate in the project activity. This implies that in the first year(s) of the crediting period not all households in the PSG may already immediately decide to participate in the project activity but may participate in the project at a similar rate as other households. Since only households that have returned used light bulbs and received efficient light bulbs can be used for sampling, the PSG needs to be large enough to ensure that it contains a sufficiently large number of households that actually participate in the project activity. This may need to be taken into account by project participants in selecting the appropriate size of the BSG and the PSG.

The households in the baseline sample group should also be located in the total project area but do not receive any efficient light bulbs under the project but may autonomously purchase efficient light bulbs.

To yield statistically representative results, these sample groups should have a minimum size. In this methodology, baseline and project emissions are adjusted by the margin of error at a 95% confidence interval from sampling electricity consumption in order to ensure that emission reductions are estimated in a conservative manner. Moreover, emission reductions can only be claimed if ≥ 60 households are sampled from each group. Therefore, project participants may deliberately choose any size ≥ 100 households for the baseline sample group (BSG) and the project sample group (PSG) respectively.[3] As households are distributed to the BSG and PSG by coin toss (see step 6), the minimum size of the pool of households for sampling should be 200.

To select a reasonable size for the BSG and PSB, it is recommended (but not mandatory) to undertake pre-sampling of the electricity consumption in about 100 to 200 households, using the same or similar procedures as outlined in the following steps, with 50% of the households receiving CFLs prior to the start of the pre-sampling. The mean and the standard deviation of the electricity consumption of the household with and without CFLs can provide an indication to project participants on the expected variation in electricity consumption and could be used to pre-estimate the consequences of different sizes for the BSG and PSG on the level of emission reductions achieved.

Step 4: Selection of the households to be included in the BSG and the PSG

Under the project activity, light bulbs may be distributed to households located in different areas, with a different income and with a different household size. Consequently, electricity consumption for lighting will vary from household to household. Therefore, it has to be ensured that the households included in the BSG and the PSG are representative for the households that are eligible to participate in the project. In order to ensure a geographically equal representation, the methodology requires that the households included in the BSG and PSG are distributed over the project areas *i* according to the number of light bulbs that are distributed or sold under the project activity.

The number of households n_i from project area *i* that should be included in the pool of households used for sampling of the BSG and PSG is calculated as follows:

$$n_i = \frac{L_i}{L_t} \times n_{BSG+PSG} \quad \textbf{(1)}$$

Where:

n_i = Number of households from project area *i* to be included in the pool of households used for sampling of the BSG and PSG

L_i = Number of project activity light bulbs to be distributed in project activity area *i* over the whole crediting period as per the project activity plan

[3] According to Sachs (1992), a sample of n>60 is necessary to yield meaningful data for the mean and the standard deviation. As some households may leave the baseline sample group during the crediting period, the minimum size should be 100 households. Note that a large sample size involves higher transaction costs but will result in a low margin of error and thus more CERs, whereas a small sample size involves lower transaction costs for sampling but is likely to result in a higher margin of error and thus less CERs.

L_t = Total number of light bulbs to be distributed over the whole crediting period as per the project activity plan

$n_{BSG+PSG}$ = Total size of the pool of households used for sampling of the BSG and PSG, should be ≥ 200

The households to be included in the pool of households should be selected randomly among the households that are eligible to participate in the project. How the random selection is undertaken should be explained in the CDM-PDD.

Step 5: Installation of measurement equipment

Prior to the start of the distribution or sale of light bulbs under the project activity, all households included in the pool of households should be fitted with measurement equipment to meter the electricity consumption for lighting. The following two options for measurement may be chosen:

Option A: Measurement of the electricity consumption of all electric lighting appliances used by the household

Option B: Measurement of the electricity consumption of all electric lighting appliances in the *living areas* of the household.[4]

Project participants should document their choice in the CDM-PDD and apply the same option to all households throughout all crediting periods. If project participants select option B, all households when receiving the light bulbs should be made aware by the project coordinator that they save money if they use the CFLs in the lighting appliances with most utilization hours in the year. For example, the households could receive as part of the distribution of the CFLs a leaflet which explains why fitting the CFLs in the lighting appliances with most utilization hours will save money. The information to the households should be presented in a simple and comprehensive manner, reflecting the culture and socio-economic circumstances in the host country.

To determine the electricity consumption for lighting in the household (Option A) or in the living area of the household (Option B), the project coordinator should fit **all** lighting appliances found in the household (Option A) or **all** lighting appliances found in the living area of the household (Option B) with measurement equipment. During the installation of the measurement equipment, the households should not receive any efficient light bulbs or lighting appliances and no light bulbs or lighting appliances should be exchanged.

The electricity consumption of a light appliance *j* may be metered in the following ways:

Option 1: Installation of an electricity consumption meter;

Option 2: Installation of a utilization hour meter and identification of the power rating of the light bulb.

[4] If households behave rationally, it can be assumed that they will replace lighting appliances with long utilization hours per year, which applies to lighting appliances in the living areas of households. If households use the efficient lighting appliances elsewhere, the respective reduction of electricity consumption as a result of the project activity is not monitored during sampling. Hence, limiting the sampling to the living areas tends to be a conservative approach, which reduces transaction costs.

Option 1 should be used in case of lighting appliances that have dimmers or that transform the voltage to an applicable level (e.g. 20 V).

In case of option 2, the manufacturer specifications of the power rating of a light bulb can be used to identify the power rating if national legislation in the host country only allows sale of lighting appliances according to the international performance standards IEC60064 (incandescent lamps) and IEC60901 (CFLs). If national legislation in the host country also allows for sale of lighting appliance that do not perform to the above-mentioned standards or if the manufacturer specification of the power rating of a light bulb cannot be identified, project participants should:

(a) directly meter the electricity consumption of that light appliance (option 1); or
(b) measure the power rating of the light bulb on-site, using portable accurate measurement equipment[5]; or
(c) use, as a conservative approach, the lowest power rating among all other light bulbs found in the BSG in case the household is included the BSG in step 6 below or use the highest power rating among all other light bulbs found in the PSG in case the household is included in the PSG in step 6 below.

Step 6: Allocation of households to the BSG and PSG

After the installation of the measurement equipment and prior to the start of the distribution or sale of light bulbs by the project coordinator, project participants should allocate the households included in the pool of households by coin toss to the BSG and PSG.

Step 7: Establishment of a baseline sample buffer group (BSBG) and project sample buffer group (PSBG) (not mandatory)

It is recommended (but not mandatory) that project participants establish a baseline sample buffer group (BSBG) and project sample buffer group (PSBG) of households. At the start of the distribution or sale of light bulbs by the project coordinator, these households are not included in the BSG or PSG, but they can be included at a later stage, if the number of households in the BSG or PSG decreases. Project participants may choose any size for the BSBG and the PSBG, however, the following equations may be useful to estimate a reasonable size:

$$n_{BSBG} = n_{BSG} \times CP \times (1 - r) \quad \textbf{(2)}$$

and

$$n_{PSBG} = n_{PSG} \times CP \times (1 - r) \quad \textbf{(3)}$$

[5] The international performance standard IEC60064 specifies the performance requirements of tungsten filament incandescent lamps for general lighting service (GLS). The normative Annex A "Test procedure" of IEC60064 specifies how the wattage of CFL should be measured. This includes specifications for ageing, test voltage, ambient test temperature and test circuit. The extent possible, this guidance should be applied.

Where:

n_{BSBG} = Number of households to be included in the baseline sample buffer group
n_{PSBG} = Number of households to be included in the project sample buffer group
n_{BSG} = Number of households included in the BSG at the start of the project activity
n_{PSG} = Number of households included in the PSG at the start of the project activity
CP = Duration of the crediting periods for which project participants plan to seek CERs (7, 10, 14 or 21 years)
r = Factor which expresses the percentage of households that on average is lost from the BSG and the PSG in each year (e.g. 10% or 20%)

The households to be included in the BSBG and the PSBG should be identified by coin toss from a respective pool of households prior to the start of the distribution or sale of light bulbs by the project coordinator. The pool of households should be selected randomly and with a representative geographical distribution across the different project areas i, subject to the provisions in step 4 above. The households included in the BSBG should not receive any light bulbs by the program coordinator.
If project participants wish to add households from the BSBG to the BSG or from the PSBG to the PSG, the households should be selected randomly among all households in the BSBG or PSBG. Households from the BSBG and the PSBG may only be added during the period when spot checks are undertaken. Measurement equipment should be installed according to the provisions in step 5 at the point in time when the household is added to the BSG or the PSG, during the first spot check at the household.

Step 8: Establishment of a project database

Prior to the start of the distribution or sale of light bulbs by the project coordinator, the project coordinator should establish a database containing all relevant information for sampling households, including, *inter alia*:

- A list of all project areas *i*, including the name or number of the project area and the GPS data to delineate the area;
- A list of the households included in the BSG, BSBG, PSG and PSBG, including information to identify the household (name, address, GPS data, applicable project area *i*)[6];
- For each household in the BSG and PSG, information of when the household has been added to the BSG or PSG and information of when it has been removed (if applicable);
- For each spot check undertaken at a household in the BSG or PSG, the date of the spot check, information on the place and number of lighting appliances found in the household (Option A) or in the living area of the household (Option B), and information on which lighting appliances have been added or removed by the household since the last spot check (by comparison with data from the previous spot check),
- For each lighting appliance found during a spot check:
    - Information that allows a clear identification of the lighting appliance (preferably a tag number for each lighting appliance or otherwise the installation place, type, colour, etc),
    - Information on the type of measurement equipment installed (utilization hour meter, electricity consumption meter),
    - The date of initial installation of the measurement equipment,

[6] This information may be treated confidential and only be made available to the DOE, the EB and its support structure.

- Information whether the measurement equipment is working appropriately,
- Information on any changes made to the measurement equipment (exchange, repair, etc),
- Information whether the lighting appliance is working and fitted with a working light bulb,
- Information on type of light bulb / lighting appliance used,
- Information on measurement results obtained (e.g. power rating of the light bulb, utilization hours, electricity consumption),
- Any other relevant information;

- For each household that receives efficient light bulbs from the project coordinator, information to identify the household[6], the date of return and distribution or sale of efficient light bulbs, information on the number and power rating of the returned light bulbs and of the efficient lighting bulbs distributed or sold to the household;
- For each household included in the PSG and BSG, information on the total electricity consumption according to electricity invoices;
- For each monitoring interval y, a list of households included in the BCCG or PCCG (name, address, applicable project area *i*) [6] and information on the total electricity consumption of these households.

The initial installation of measurement equipment according to step 5 is regarded as the first spot check undertaken in the household. An extract of the database should be attached to the CDM-PDD and to each monitoring report.

Step 9: Monitoring of utilization hours / electricity consumption in the BSG and PSG

After the start of the distribution or sale of light bulbs by the project coordinator, the project coordinator should monitor the electricity consumption/the utilization hours for lighting of the BSG and PSG households by undertaking spot checks at all households included in the BSG and at all households included in the PSG that have received light bulbs from the project coordinator prior to the start of the spot check (i.e. the date of the first visit of a household during the spot checking period) that was undertaken at the beginning of the monitoring interval *y*. Note that this means that in the first year(s) of the crediting period the number of households in the PSG that can be used for sampling is likely to be smaller than the total number of households included in the PSG.

Project participants may deliberately determine the frequency of these spot checks. Since incandescent light bulbs have a lifetime of only about 1000 hours, it is recommended (but not mandatory) to undertake spot checks every three to six months or at least annually.

When undertaking a spot check, all households should be visited within a distinct short time period not longer than three weeks, i.e. the last household should not be visited later than three weeks after the first household has been visited. During the spot checks, no additional written or oral information or recommendations on the use of the light bulbs should be provided to the households.[7]

All results of the spot check should be entered in the project database. For the purpose of calculating emission reductions, **the monitoring interval *y* is defined as the time between two spot checks**. As a

[7] This provision is required to ensure that the households in the BSG and PSB behave in a manner that is representative for all households.

simplification, the day in the middle between the first and the last visit to a household should be assumed as the point in time when the spot check has been undertaken in all households.

For a spot check at a household, the following provisions apply:

- The project coordinator should check in the whole household (Option A) or in the living area of the household (Option B) whether the lighting appliances found at the last spot check are still there and whether new light appliances have been installed since the last spot check. If a lighting appliance cannot be found anymore, this should be noted in the database and the electricity consumption of the relevant lighting appliances should, as a simplification, not be taken into account for this monitoring interval (i.e. this appliance is not included in equations (5) and (6) below). If a new lighting appliance is found, it should be fitted with measurement equipment, subject to the guidance in step 5 above, and entered into the database. The electricity consumption of new lighting appliances will, as a simplification, only be taken into account in the subsequent monitoring interval (the time period between the current and the next spot check).[8]
- The project coordinator should check and document in the database whether each measurement equipment (electricity consumption meters and/or utilization hour meters) installed at the household is working appropriately. If a measurement equipment is not working appropriately, it should be exchanged by new measurement equipment, and, as a simplified approach, the electricity consumption from that lighting appliance should not be considered for this monitoring interval y (i.e. this appliance is not included in equations (5) and (6) below).
- The electricity consumption meter or the utilization hour meter should be read and the results should be entered into the database for each light appliance where the measurement equipment is working or has been installed during the spot visit. Where measurement equipment has been installed during the spot visit, the meter should be set to zero.
- For lighting appliances where utilization hour meters are used (i.e. where option 2 is used to determine electricity consumption), the program coordinator should determine the power rating of the light bulb currently used, subject to the guidance in step 5 above, and enter it into the database. Similarly, if the light bulb is broken or if no light bulb is installed in the lighting appliance, this should be noted in the database respectively.
- If the household cannot be found anymore, this should be noted in the database. If the household has moved elsewhere within the total project area, the household may either remain in the BSG or PSG or may be removed from the BSG or PSG. If the household has moved outside the total project area or does not exist anymore, it should be removed from the PSG or PSG (effective from the previous spot check undertaken).

Step 10: Determination of the power correction factor

The electricity consumption of lighting appliances depends on the grid voltage. According to measurements undertaken by the proponents of this methodology, it can be observed that the electricity consumption of compact fluorescent lamps (CFLs) is more stable with varying grid voltage compared with incandescent lamps. This effect is considered in the calculation of emission reductions by introducing a

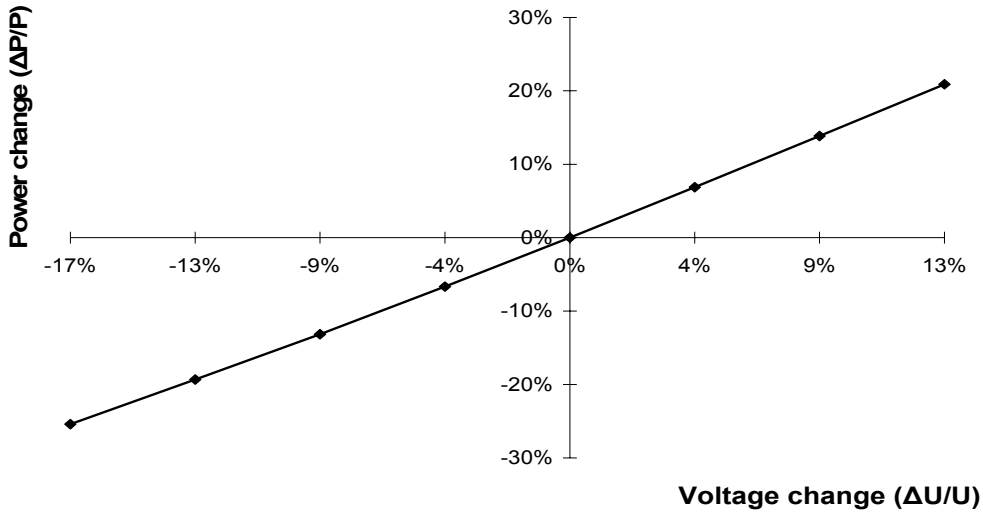
[8] Note that this is not a conservative assumption since households included the PSG could, as a result of rebound effects, install more new lighting appliances than households included the BSG. However, several other conservative assumptions are made in this methodology so that overall emission reductions are estimated in a conservative manner.

power correction factor (*PCF*). The power correction factor is defined as the relative decrease in power consumption of the lighting appliance to a relative decrease of grid voltage.

If electricity consumption is determined by metering the utilization time and identifying the power rating of the light bulb (Option 2), the power rating of the light bulb is multiplied with the power correction factor for the type of light bulb in order to reflect the effect of varying grid voltage on electricity consumption (see equations 5 and 6 in step 11 below). If electricity consumption is metered directly (Option 1), the effect of varying grid voltage is included in the measurement results and the power correction factor does not need to be considered.

Project participants should determine for all relevant types of light bulbs used in the BSG and in the PSG the P-U characteristic curve by laboratory measurements and determine the factor expressing the relative slope of the P-U characteristic curve ($f_{PU,j}$) for each type of light bulb. Based on the measurements undertaken by the proponents of this methodology, a linear relation between the percentage change in power consumption and the percentage change in voltage can be reasonably assumed.
Figure 1 illustrates an example of measurement results for a 100 W incandescent light bulb. A value of $f_{PU,j} = 1.5$ can be derived from this measurements. $f_{PU,j}$ only needs to be determined once for each type of light bulb. For incandescent light bulbs and 230 V grids, project participants may assume a default value of $f_{PU,j} = 1.5$.

Figure 1: P-U characteristic curve for a 100 W incandescent lamp in a 230 V grid[9]



The curve above is not plotted between power and voltage but I presume between percentage difference from 230 V v/s percentage change in power rating.

The power correction factor should be calculated for each monitoring interval *y*, taking into account the actual average grid voltage during the monitoring interval, as follows:

[9] The data in this curve is calculated based on measurements undertaken by the proponents of this methodology.

$$PCF_{j,y} = 1 + \frac{\left(U_{grid,y} - U_{grid,nominal}\right)}{U_{grid,nominal}} \cdot f_{PU,j} \quad (4)$$

Where:

$PCF_{j,y}$ = Power correction factor for light bulb *j* and monitoring interval *y*

$U_{grid,y}$ = Average grid voltage in the low voltage part of the grid serving the households that are eligible to participate in the project during the monitoring interval *y* (V)

$U_{grid,nominal}$ = Nominal grid voltage in the low voltage part of the grid (typically 230 V or 110 V) (V)

$f_{PU,j}$ = Slope of the PU characteristic curve for light bulb type j, expressing the marginal increase of power consumption of the light bulb (ΔP/P) as a result of a marginal increase of grid voltage (ΔU/U)

The average grid voltage should be calculated as the mean grid voltage during the monitoring interval *y*, excluding time periods with no electricity supply (black outs). If the average grid voltage is above 230 V, the PCF should be assumed as 1.0 for all light bulbs.

Step 11: Calculation of the mean and standard deviation of household electricity consumption for lighting

After undertaking spot checks at all households included in the BSG and the PSG, the mean and standard deviation of household electricity consumption for lighting during the monitoring interval *y* (the time period between two spot checks) for the baseline and the project activity should be calculated. In case of the PSG, only those households should be considered that have received light bulbs from the project coordinator prior to the start of the spot check (i.e. the date of the first visit of a household during the spot checking period) that was undertaken at the beginning of the monitoring interval *y*.

The electricity consumption for lighting of household *k* included in the BSG ($EC_{BSG,k,y}$) or household *l* included in the PSG ($EC_{PSG,l,y}$) is calculated for each monitoring interval *y* based on the measurement of the utilization time ($h_{BSG,k,m,y}$, $h_{PSG,l,m,y}$) and the power rating ($P_{BSG,k,m,y}$, $P_{PSG,l,m,y}$) of each lighting appliance *m*, adjusted with the power correction factor ($PCF_{m,y}$), where a utilization meter is installed, and based on the direct measurement of the electricity consumption ($EC_{BSG,k,n,y}$, $EC_{PSG,l,n,y}$) of each appliance *n* where an electricity meter is installed, as follows:

$$EC_{BSG,k,y} = \frac{\sum_{m} h_{BSG,k,m,y} \times P_{BSG,k,m,y} \times PCF_{m,y}}{1000} + \sum_{n} EC_{BSG,k,n,y} \quad (5)$$

and

$$EC_{PSG,l,y} = \frac{\sum_{m} h_{PSG,l,m,y} \times P_{PSG,l,m,y} \times PCF_{m,y}}{1000} + \sum_{n} EC_{PSG,l,n,y} \quad (6)$$

Since P-U is estimated for each light bulb type j, the first term should be a double summation over j and mj (j type light bulb used in household l)

Where:

$EC_{BSG,k,y}$ = Electricity consumption for lighting in household *k* (Option A) or in the living areas of household *k* (Option B) during the monitoring interval *y* (kWh)

$EC_{PSG,l,y}$ = Electricity consumption for lighting in household *l* (Option A) or in the living areas of household *l* (Option B) during the monitoring interval *y* (kWh)

$h_{BSG,k,m,y}$ = Measured utilization hours of lighting appliance *m* installed in household *k* during the monitoring interval *y* (h)

$h_{PSG,l,m,y}$ = Measured utilization hours of lighting appliance *m* installed in household *l* during the monitoring interval *y* (h)

$P_{BSG,k,m,y}$ = Power rating of the light bulb used in lighting appliance *m* in household *k* during the monitoring interval *y* (see the guidance below and in step 9) (W)

$P_{PSG,l,m,y}$ = Power rating of the light bulb used in lighting appliance *m* in household *l* during the monitoring interval *y* (see the guidance below and in step 9) (W)

$PCF_{m,y}$ = Power correction factor for light bulb *m* and monitoring interval *y*

$EC_{BSG,k,n,y}$ Electricity consumption of lighting appliance *n* in the household *k* during the monitoring interval *y* (see the guidance in step 9) (kWh)

$EC_{PSG,l,n,y}$ Electricity consumption of lighting appliance *n* in the household *l* during the monitoring interval *y* (see the guidance in step 9) (kWh)

k = Households included in the BSG (see the guidance in step 9)

l = Households included in the PSG that have received light bulbs from the project coordinator prior to the start of the spot check (i.e. the date of the first visit of a household during the spot checking period) that was undertaken at the beginning of the monitoring interval *y* (see the guidance in step 9)

m = Lighting appliances installed in household *k* or *l* (Option A) or in the living areas of household *k* or *l* (Option B) during the monitoring interval *y* and fitted with a utilization hour meter (see the guidance in step 9)

n = Lighting appliances installed in household *k* or *l* (Option A) or in the living areas of household *k* or *l* (Option B) during the monitoring interval *y* and fitted with an electricity consumption meter (see the guidance in step 9)

For lighting appliances where utilization hour meters are used (i.e. where option 2 is used to determine electricity consumption), as a conservative approach, the following guidance applies when applying equations (5) and (6) above:

- If the power rating of the light bulb found at the spot check that was undertaken at the end of the monitoring interval *y* is lower than the power rating of the light bulb found at the spot check that was undertaken at the beginning of the monitoring interval *y*, it should be assumed that:
    - In case the household belongs to the BSG that the light bulb was exchanged immediately after the spot check that was undertaken at the beginning of the monitoring interval *y* (i.e. use the power rating of the light bulb found at the spot check that was undertaken at the end of the monitoring interval *y* for $P_{BSG,k,m,y}$).
    - In case the household belongs to the PSG that the light bulb was exchanged directly prior to the spot check that was undertaken at the end of the monitoring interval *y* (i.e. use the

power rating of the light bulb found at the spot check that was undertaken at the beginning of the monitoring interval *y* for $P_{PSG,l,m,y}$).

- If the power rating of the light bulb found at the spot check that is undertaken at the end of the monitoring interval *y* is higher than the power rating of the light bulb found at the spot check that was undertaken at the beginning of the monitoring interval *y*, it should be assumed that:
  - In case the household belongs to the PSG that the light bulb was exchanged immediately after the spot check that was undertaken at the beginning of the monitoring interval *y* (i.e. use the light power rating of the light bulb found at the spot check that was undertaken at the end of the monitoring interval *y* for $P_{PSG,l,m,y}$).
  - In case the household belongs to the BSG that the light bulb was exchanged directly prior to the spot check that was undertaken at the end of the monitoring interval *y* (i.e. use the power rating of the light bulb found at the spot check that was undertaken at the beginning of the monitoring interval *y* for $P_{BSG,k,m,y}$).
- If a light bulb is found to be broken or if no light bulb is installed in the lighting appliance at the spot check that was undertaken at the end of the monitoring interval *y*, the electricity consumption of the relevant lighting appliances should, as a simplification, not be taken into account for this monitoring interval (i.e. $P_{PSG,l,m,y}$ or $P_{BSG,k,m,y}$ for that light bulb are assumed to be zero).

The mean of household electricity consumption for lighting of households included in the BSG and the PSG ($\mu_{EC,BSG,y}$ and $\mu_{EC,PSG,y}$) is calculated for each monitoring interval *y* as follows:

$$\mu_{EC,BSG,y} = \frac{\sum_{k=1}^{n_{BSG,y}} EC_{BSG,k,y}}{n_{BSG,y}} \quad \textbf{(7)}$$

and

$$\mu_{EC,PSG,y} = \frac{\sum_{l=1}^{n_{PSG,y}} EC_{PSG,l,y}}{n_{PSG,y}} \quad \textbf{(8)}$$

Where:

$\mu_{EC,BSG,y}$ = Mean household electricity consumption for lighting of households included in the BSG for the monitoring interval *y* (kWh)

$\mu_{EC,PSG,y}$ = Mean household electricity consumption for lighting during the monitoring interval *y* of households included in the PSG that have received light bulbs from the project coordinator prior to the start of the spot check (i.e. the date of the first visit of a household during the spot checking period) that was undertaken at the beginning of the monitoring interval *y* (kWh)

$EC_{BSG,k,y}$ = Electricity consumption for lighting in household *k* (Option A) or in the living areas of household *k* (Option B) during the monitoring interval *y* (kWh)

$EC_{PSG,l,y}$ = Electricity consumption for lighting in household *l* (Option A) or in the living areas of household *l* (Option B) during the monitoring interval *y* (kWh)

$n_{BSG,y}$ = Total number of households *k* included in the BSG during the monitoring interval y (see the guidance in step 9)

$n_{PSG,y}$ = Total number of households *l* included in the PSG during the monitoring interval y,

corresponding to the number of households included in the PSG that have received light bulbs from the project coordinator prior to the start of the spot check (i.e. the date of the first visit of a household during the spot checking period) that was undertaken at the beginning of the monitoring interval *y* (see the guidance in step 9)

k = Households included in the BSG (see the guidance in step 9)

l = Households included in the PSG that have received light bulbs from the project coordinator prior to the start of the spot check (i.e. the date of the first visit of a household during the spot checking period) that was undertaken at the beginning of the monitoring interval *y* (see the guidance in step 9)

The standard deviation of household electricity consumption for lighting of households included in the BSG and the PSG ($\sigma_{EC,BSG,y}$ and $\sigma_{EC,PSG,y}$) is calculated for each a monitoring interval *y* as follows:

$$\sigma_{EC,BSG,y} = \sqrt{\frac{\sum_{k=1}^{n_{BSG,y}} (EC_{BSG,k,y} - \mu_{EC,BSG,y})^2}{n_{BSG,y} - 1}} \quad \textbf{(9)}$$

and

$$\sigma_{EC,PSG,y} = \sqrt{\frac{\sum_{l=1}^{n_{PSG,y}} (EC_{PSG,l,y} - \mu_{EC,PSG,y})^2}{n_{PSG,y} - 1}} \quad \textbf{(10)}$$

Where:

$\sigma_{EC,BSG,y}$ = Standard deviation of household electricity consumption for lighting of households included in the BSG for the monitoring interval *y* (kWh)

$\sigma_{EC,PSG,y}$ = Standard deviation of household electricity consumption for lighting for the monitoring interval *y* of households included in the PSG that have received light bulbs from the project coordinator prior to the start of the spot check (i.e. the date of the first visit of a household during the spot checking period) that was undertaken at the beginning of the monitoring interval *y* (kWh)

$EC_{BSG,k,y}$ = Electricity consumption for lighting in household *k* (Option A) or in the living areas of household *k* (Option B) during the monitoring interval *y* (kWh)

$EC_{PSG,l,y}$ = Electricity consumption for lighting in household *l* (Option A) or in the living areas of household *l* (Option B) during the monitoring interval *y* (kWh)

$\mu_{EC,BSG,y}$ = Mean household electricity consumption for lighting of households included in the BSG for the monitoring interval *y* (kWh)

$\mu_{EC,PSG,y}$ = Mean household electricity consumption for lighting during the monitoring interval *y* of households included in the PSG that have received light bulbs from the project coordinator prior to the start of the spot check (i.e. the date of the first visit of a household during the spot checking period) that was undertaken at the beginning of the monitoring interval *y* (kWh)

$n_{BSG,y}$ = Total number of households *k* included in the BSG during the monitoring interval *y* (see the guidance in step 9)

$n_{PSG,y}$ = Total number of households *l* included in the PSG during the monitoring interval y, corresponding to the number of households included in the PSG that have received light bulbs from the project coordinator prior to the start of the spot check (i.e. the date of the first visit of a household during the spot checking period) that was undertaken at the beginning of the monitoring interval *y* (see the guidance in step 9)

k = Households included in the BSG (see the guidance in step 9)

l = Households included in the PSG that have received light bulbs from the project coordinator prior to the start of the spot check (i.e. the date of the first visit of a household during the spot checking period) that was undertaken at the beginning of the monitoring interval *y* (see the guidance in step 9)

Step 12: Estimation of technical distribution losses in the electricity grid

Technical distribution losses in the electricity grid serving the households that are eligible to participate in the project (TDL_y), expressed as kilowatt hours of technical electric losses in the electricity grid per kilowatt hours of electricity supplied to final consumers, should be estimated using recent, accurate and reliable data available within the host country. The technical distribution losses should not contain other types of grid losses (e.g. commercial losses/theft). The distribution losses can either be calculated by a (national) utility or an official governmental body or by project participants. The appropriateness, accuracy/uncertainty and reliability of the data should be checked by project participants and the Designated Operation Entity (DOE) upon verification – especially with regard to the exclusion of other potential grid losses. A default value of 5% may be used for technical grid losses, if no recent data is available or the data cannot be regarded accurate and reliable.

Step 13 Cross-check of monitoring results by random sampling of households not included in the BSG, PSB, BSBG and PSBG

In this methodology, a key prerequisite for achieving statistically representative sampling results is that the households in the BSG and PSG are not directly or indirectly influenced by project participants. As a safeguard and quality assurance measure, project participants should sample also the total electricity consumption of the households in the BSG and PSG and compare it with the total electricity consumption of randomly selected households that do neither belong to the BSG nor to the PSG. For this purpose, project participants should apply the following steps:

1. For each monitoring interval *y*, project participants should establish a new baseline cross-check group (BCCG) and a new project cross-check group (PCCG). Both groups should be established after the end of the monitoring interval by selecting randomly households that do neither belong to the BSG or BSBG nor to the PSG or PSBG. The households should be stratified in the same manner as the households in the BSG and PSG following the guidance as provided in step 4 (distribution across project areas *i*).
   - The BCCG should consist of at least $n_{BSG,y}$ households selected randomly among the households that are eligible to participate in the program but that do not yet have received light bulbs from the project coordinator and do not belong to the BSG, where $n_{BSG,y}$ is the number of households included in the BSG during the monitoring interval *y*; and
   - The PCCG should consist of at least $n_{PSG,y}$ households selected randomly among the households that are not in the PSG or PSBG and that have received light bulbs from the project coordinator prior to the start of the spot check (i.e. the date of the first visit of a household during the spot

checking period) that was undertaken at the beginning of the monitoring interval *y*, where $n_{PSG,y}$ is the number of households included in the PSG that have received light bulbs from the project coordinator prior to the start of the spot check (i.e. the date of the first visit of a household during the spot checking period) that was undertaken at the beginning of the monitoring interval y.

2. Collect information on the total electricity consumption of all households in the BSG, all households in the PSG that have received light bulbs from the project coordinator prior to the start of the spot check (i.e. the date of the first visit of a household during the spot checking period) that was undertaken at the beginning of the monitoring interval *y*, all households in the BCCG and all households in the PCCG, using electricity invoices, provided either by the households or by the electricity supply company. Adjust the total electricity consumption from the time period indicated in the electricity invoices to the monitoring interval *y*, using the adjustment methods as regularly applied by the electricity supply company for invoicing. In the absence of such an adjustment method, the mean daily electricity consumption can be derived from the electricity invoices and be applied to the monitoring interval *y*. The result of this step is the total electricity consumption during the monitoring interval *y* of
   - Each household *k* included in the BSG ($EC_{TOT,BSG,k,y}$),
   - Each household *l* included in the PSG that has received light bulbs from the project coordinator prior to the start of the spot check (i.e. the date of the first visit of a household during the spot checking period) that was undertaken at the beginning of the monitoring interval *y* ($EC_{TOT,PSG,l,y}$),
   - Each household *s* included the BCCG ($EC_{TOT,BCCG,s,y}$), and
   - Each household *t* included in the PCCG ($EC_{TOT,PCCG,t,y}$).
3. Calculate the mean (μ) of the total electricity consumption of households in the PSG, the BSG, the BCCG and the PCCG, as follows:

$$\mu_{EC,TOT,BSG,y} = \frac{\sum_{k=1}^{n_{BSG,y}} EC_{TOT,BSG,k,y}}{n_{BSG,y}} \quad \textbf{(11)}$$

$$\mu_{EC,TOT,PSG,y} = \frac{\sum_{l=1}^{n_{PSG,y}} EC_{TOT,PSG,l,y}}{n_{PSG,y}} \quad \textbf{(12)}$$

$$\mu_{EC,TOT,BCCG,y} = \frac{\sum_{s=1}^{n_{BCCG,y}} EC_{TOT,BCCG,s,y}}{n_{BCCG,y}} \quad \textbf{(13)}$$

$$\mu_{EC,TOT,PCCG,y} = \frac{\sum_{t=1}^{n_{PCCG,y}} EC_{TOT,PCCG,t,y}}{n_{PCCG,y}} \quad \textbf{(14)}$$

Where:

$\mu_{EC,TOT,BSG,y}$ = Mean total electricity consumption of households included in the BSG for the monitoring interval *y* (kWh)

$\mu_{EC,TOT,PSG,y}$ = Mean total electricity consumption during the monitoring interval *y* of households included in the PSG that have received light bulbs from the project coordinator prior to the start of the spot check (i.e. the date of the first visit of a household during the spot checking period) that was undertaken at the beginning of the monitoring interval *y* (kWh)

$\mu_{EC,TOT,BCCG,y}$ = Mean total electricity consumption of households included in the BCCG for the monitoring interval *y* (kWh)

$\mu_{EC,TOT,PCCG,y}$ = Mean total electricity consumption of households included in the PCCG for the monitoring interval *y* (kWh)

$EC_{TOT,BSG,k,y}$ = Total electricity consumption of household *k* during the monitoring interval *y* (kWh)

$EC_{TOT,PSG,l,y}$ = Total electricity consumption of household *l* during the monitoring interval *y* (kWh)

$EC_{TOT,BCCG,s,y}$ = Total electricity consumption of household *s* during the monitoring interval *y* (kWh)

$EC_{TOT,PCCG,t,y}$ = Total electricity consumption of household *t* during the monitoring interval *y* (kWh)

$n_{BSG,y}$ = Total number of households *k* included in the BSG during the monitoring interval y (see the guidance in step 9)

$n_{PSG,y}$ = Total number of households *l* included in the PSG during the monitoring interval y, corresponding to the number of households included in the PSG that have received light bulbs from the project coordinator prior to the start of the spot check (i.e. the date of the first visit of a household during the spot checking period) that was undertaken at the beginning of the monitoring interval *y* (see the guidance in step 9)

$n_{BCCG,y}$ = Total number of households *s* included in the BCCG during the monitoring interval *y*

$n_{PCCG,y}$ = Total number of households *t* included in the PCCG during the monitoring interval *y*

k = Households included in the BSG (see the guidance in step 9)

l = Households included in the PSG that have received light bulbs from the project coordinator prior to the start of the spot check (i.e. the date of the first visit of a household during the spot checking period) that was undertaken at the beginning of the monitoring interval *y* (see the guidance in step 9)

s = Households included in the BCCG during the monitoring interval *y*

t = Households included in the PCCG during the monitoring interval *y*

4. Compare the mean total electricity consumption of households included in the BSG ($\mu_{EC,TOT,BSG,y}$) with the mean total electricity consumption of households included in the BCCG ($\mu_{EC,TOT,BCCG,y}$). Apply a T-test for the two independent samples to assess whether the means are statistically different, using a 50% risk level. Calculate an adjustment factor for the baseline sample group ($f_{BSG,y}$), as follows:

   - If the risk that the two means are statistically different is < 50%, then f = 1.0;
   - If the risk that the two means are statistically different is ≥ 50% and if $\mu_{EC,TOT,BSG,y} \leq \mu_{EC,TOT,BCCG,y}$, then f = 1.0;
   - If the risk that the two means are statistically different is ≥ 50% and if $\mu_{EC,TOT,BSG,y} > \mu_{EC,TOT,BCCG,y}$, then

$$f_{BSG,y} = 1 - \frac{\mu_{EC,TOT,BSG,y} - \mu_{EC,TOT,BCCG,y}}{\mu_{EC,BSG,y}} \quad \textbf{(15)}$$

Where:

$f_{BSG,y}$ = Adjustment factor for the BSG for the monitoring interval *y*

$\mu_{EC,TOT,BSG,y}$ = Mean total electricity consumption of households included in the BSG for the monitoring interval *y* (kWh)

$\mu_{EC,TOT,BCCG,y}$ = Mean total electricity consumption of households included in the BCCG for the monitoring interval *y* (kWh)

$\mu_{EC,BSG,y}$ = Mean household electricity consumption for lighting of households included in the BSG for the monitoring interval *y* (kWh)

5. Compare the mean total electricity consumption of households included in the PSG ($\mu_{EC,TOT,PSG,y}$) with the mean total electricity consumption of households included in the PCCG ($\mu_{EC,TOT,PCCG,y}$). Apply a T-test for the two independent samples to assess whether the means are statistically different, using a 50% risk level. Calculate an adjustment factor for the project sample group ($f_{PSG,y}$), as follows:

- If the risk that the two means are statistically different is < 50%, then f = 1.0;
- If the risk that the two means are statistically different is ≥ 50% and if $\mu_{EC,TOT,PSG,y} \geq \mu_{EC,TOT,PCCG,y}$, then f = 1.0;
- If the risk that the two means are statistically different is ≥ 50% and if $\mu_{EC,TOT,PSG,y} < \mu_{EC,TOT,PCCG,y}$, then

$$f_{PSG,y} = 1 + \frac{\mu_{EC,TOT,PCCG,y} - \mu_{EC,TOT,PSG,y}}{\mu_{EC,PSG,y}} \quad \textbf{(16)}$$

Where:

$f_{PSG,y}$ = Adjustment factor for the PSG for the monitoring interval *y*

$\mu_{EC,TOT,PCCG,y}$ = Mean total electricity consumption of households included in the PCCG for the monitoring interval *y* (kWh)

$\mu_{EC,TOT,PSG,y}$ = Mean total electricity consumption during the monitoring interval *y* of households included in the PSG that have received light bulbs from the project coordinator prior to the start of the spot check (i.e. the date of the first visit of a household during the spot checking period) that was undertaken at the beginning of the monitoring interval *y* (kWh)

$\mu_{EC,PSG,y}$ = Mean household electricity consumption for lighting during the monitoring interval *y* of households included in the PSG that have received light bulbs from the project coordinator prior to the start of the spot check (i.e. the date of the first visit of a household during the spot checking period) that was undertaken at the beginning of the monitoring interval *y* (kWh)

Step 14: Calculation of emission reductions

Emission reductions are calculated based on the sampling results and adjusted with the statistical margin of error at a 95% confidence level and, if the sampling results from the sampling the BCCG and PCCG differ, by applying an adjustment factor. The electricity savings as a result of the project are calculated as the

difference of the mean household electricity consumption for lighting of the BSG and the PSG, multiplied with the number of households actually participating in the project. The CO_2 grid emission factor for the monitoring interval *y* ($EF_{CO2,ELEC,y}$) should be calculated following the guidance in the latest approved version of baseline and monitoring methodology ACM0002. Emission reductions are calculated as follows:

$$ER_y = \frac{n_{HH,y} \times \left[\left(\mu_{EC,BSG,y} \times f_{BSG,y} - z \times \frac{\sigma_{EC,BSG,y}}{\sqrt{n_{BSG,y}}} \right) - \left(\mu_{EC,PSG,y} \times f_{PSG,y} + z \times \frac{\sigma_{EC,PSG,y}}{\sqrt{n_{PSG,y}}} \right) \right] \times EF_{CO2,ELEC,y}}{1 - TDL_y} \quad \textbf{(17)}$$

Where:

ER_y = Emission reductions during the monitoring interval *y* (t CO_2)

$n_{HH,y}$ = Number of households eligible for calculating emission reductions for the monitoring interval y

$\mu_{EC,BSG,y}$ = Mean household electricity consumption for lighting of households included in the BSG for the monitoring interval *y* (kWh)

$\mu_{EC,PSG,y}$ = Mean household electricity consumption for lighting during the monitoring interval *y* of households included in the PSG that have received light bulbs from the project coordinator prior to the start of the spot check (i.e. the date of the first visit of a household during the spot checking period) that was undertaken at the beginning of the monitoring interval *y* (kWh)

$f_{BSG,y}$ = Adjustment factor for the BSG for the monitoring interval *y*

$f_{PSG,y}$ = Adjustment factor for the PSG for the monitoring interval *y*

z = Standard normal for a confidence level of 95% (1.96 for n > 200)

$\sigma_{EC,BSG,y}$ = Standard deviation of household electricity consumption for lighting of households included in the BSG for the monitoring interval *y* (kWh)

$\sigma_{EC,PSG,y}$ = Standard deviation of household electricity consumption for lighting for the monitoring interval *y* of households included in the PSG that have received light bulbs from the project coordinator prior to the start of the spot check (i.e. the date of the first visit of a household during the spot checking period) that was undertaken at the beginning of the monitoring interval *y* (kWh)

$n_{BSG,y}$ = Total number of households *k* included in the BSG during the monitoring interval y (see the guidance in step 9)

$n_{PSG,y}$ = Total number of households *l* included in the PSG during the monitoring interval y, corresponding to the number of households included in the PSG that have received light bulbs from the project coordinator prior to the start of the spot check (i.e. the date of the first visit of a household during the spot checking period) that was undertaken at the beginning of the monitoring interval *y* (see the guidance in step 9)

$EF_{CO2,ELEC,y}$ = CO_2 emission factor for displacement of electricity in the grid serving the household consumers that participate in the project during the monitoring interval *y*, calculated according to the latest approved version of baseline and monitoring methodology ACM0002 (t CO_2 / kWh)

TDL_y = Technical distribution losses in the electricity grid serving the household consumers that participate in the project during the monitoring interval *y* (kWh of technical electric losses in the electricity grid / kWh of electricity supplied to final consumers)

The number of households that are eligible for calculating emission reductions for the monitoring interval *y* corresponds to the number of households that have received efficient light bulbs in return for incandescent light bulbs from the project coordinator in the time period between the start of the project activity until the start of the spot check (i.e. the date of the first visit of a household during the spot checking period) that was undertaken at the beginning of the monitoring interval *y*. This means that households that have received efficient light bulbs from the project coordinator during the monitoring interval *y* are only eligible for crediting for the subsequent monitoring interval.

Emission reductions for a monitoring interval *y* may only credited if the size of the BSG is ≥ 60 and if the number of households that are included in the PSG and that have received light bulbs from the project coordinator prior to the start of the spot check (i.e. the date of the first visit of a household during the spot checking period) that was undertaken at the beginning of the monitoring interval *y* is ≥ 60. In other cases, no CERs may be issued for that monitoring interval.

In the case that emission reductions calculated with equation 17 above are negative (e.g. due to a small number of sampled households resulting in large statistical uncertainties that outweigh the emission reductions achieved), the emission reductions for that monitoring interval shall be deemed as zero but not as negative.

Leakage

An independent monitoring of scrapping of lighting appliances handed in by the households needs to be implemented. The monitoring should include a check if the number of project activity lighting appliances distributed by the project and the number of scrapped lighting appliances correspond with each other. For this purpose scrapped lighting appliances should be stored until such correspondence has been checked. The scrapping of returned lighting appliances should be documented and independently verified.

Changes required for methodology implementation in 2nd and 3rd crediting periods

At the renewal of the crediting period, project participants should evaluate whether the project activity continues not to be the baseline scenario, i.e. whether it would have been implemented in the absence of the project activity. The procedure outlined under additionality above should be used for that purpose.

Furthermore, all relevant data contained under "Data and parameters not monitored" should be updated. Regarding the grid emission factor, the provisions in the latest approved version of ACM0002 on the update of the emission factor apply.

Data and parameters not monitored

Parameter:	L_i
Data unit:	-
Description:	Number of project activity light bulbs to be distributed by the project coordinator in project activity area *i* over the whole crediting period as per the project activity plan
Source of data:	Deliberate choice by project participants
Measurement procedures (if any):	
Any comment:	

Parameter:	L_t
Data unit:	-
Description:	Total number of light bulbs to be distributed by the project coordinator over the whole crediting period as per the project activity plan
Source of data:	Deliberate choice by project participants
Measurement procedures (if any):	
Any comment:	

Parameter:	$n_{BSG+PSG}$
Data unit:	-
Description:	Total size of the pool of households used for sampling of the BSG and PSG
Source of data:	Project participants may deliberately choose any size ≥ 200 households
Measurement procedures (if any):	
Any comment:	Note that $n_{BSG+PSG} = n_{BSG} + n_{PSG}$

Parameter:	n_{BSG}, n_{PSG}
Data unit:	-
Description:	Number of households included in the BSG / PSG at the start of the project activity
Source of data:	Project participants may deliberately choose any size ≥ 100 households
Measurement procedures (if any):	
Any comment:	Note that n_{BSG} and n_{PSG} should have the same size

Parameter:	$U_{grid,nominal}$
Data unit:	V
Description:	Nominal grid voltage in the low voltage part of the grid (typically 230 V or 110 V)
Source of data:	Electricity utility, documentation by public authorities
Measurement procedures (if any):	
Any comment:	

Parameter:	$f_{PU,j}$
Data unit:	-
Description:	Slope of the PU characteristic curve for light bulb *j*, expressing the marginal increase of power consumption of the light bulb (ΔP/P) as a result of a marginal increase of grid voltage (ΔU/U)
Source of data:	Measurements by project participants once for each type of light bulb. For incandescent light bulbs and 230 V grids, project participants may assume a default value of $f_{PU,j} = 1.5$.
Measurement procedures (if any):	The slope should be derived from measuring the power of the light bulb for different voltage levels. The voltage range used for the measurements should be at least ±10% of $U_{grid,nominal,y}$.
Any comment:	

Parameter:	z
Data unit:	-
Description:	Standard normal for a confidence level of 95%
Source of data:	Tables from statistic books
Measurement procedures (if any):	
Any comment:	Note that the standard normal depends on the sampling size. For example, for more than 200 households z = 1.96 can be assumed.

Parameter:	CP
Data unit:	Number of years
Description:	Duration of the crediting periods for which project participants plan to seek CERs (7, 10, 14 or 21 years)
Source of data:	Deliberate choice by project participants
Measurement procedures (if any):	
Any comment:	Only applicable if step 7 is applied

Parameter:	r
Data unit:	
Description:	Factor which expresses the percentage of households that on average is lost from the BSG and the PSG in each year (e.g. 10% or 20%)
Source of data:	Estimates by project participants
Measurement procedures (if any):	
Any comment:	Only applicable if step 7 is applied

III. MONITORING METHODOLOGY

Monitoring procedures

During monitoring, the provisions as outlined in the baseline methodology, in particular step 9, apply. Monitoring involves, inter alia, the collection of the following data:

- Ex-post determination of the technical distribution losses;
- Ex-post collection of data on the average grid voltage and ex-post calculation of the power correction factor (PCF) for all relevant types of light bulbs;
- Ex-post collection of all data required for calculation of the grid emission factor according to ACM0002;
- Ex-post identification of the number of households that have received efficient light bulbs from the project coordinator in the time period between the start of the project activity until the start of the spot check (i.e. the date of the first visit of a household during the spot checking period) that was undertaken at the beginning of the monitoring interval *y*.
- Spot-checks at all households, according to the provisions in the baseline methodology, and ex-post calculation of the electricity consumption for lighting of each sampled household;
- Ex-post collection of data on the total electricity consumption of households in the PSG, BSG, PCCG and BCCG, comparison of the means, application of a T-test and calculation of the *f*;
- Ex-post calculation of the mean and standard variation of electricity consumption in the BSG and the PSG and ex-post calculation of emission reductions.

All monitored data should be stored in the electronic database. A complete extract of the database should be made available to the DOE and the EB with each monitoring report.

All measurement equipment should be calibrated and regularly maintained and checked for its functioning according to manufacturer's specification and relevant national or international standards.

Data and parameters monitored

Data / Parameter:	$U_{grid,y}$
Data unit:	V
Description:	Average grid voltage in the low voltage part of the grid serving the households that are eligible to participate in the project the during the monitoring interval *y*
Source of data:	(National) utility or an official governmental body
Measurement procedures (if any):	Calculate the man grid voltage during the monitoring interval *y*. Exclude time periods with no electricity supply (black outs).
Monitoring frequency:	Continuously
QA/QC procedures:	Data to be checked by an independent national expert
Any comment:	

Data / Parameter:	$EC_{BSG,k,n,y}$
Data unit:	kWh
Description:	Electricity consumption of lighting appliance *n* in the household *k* during the monitoring interval *y*, where • *n* are the lighting appliances installed in household *k* (Option A) or in the living areas of household *k* (Option B) during the monitoring interval *y* and fitted with an electricity consumption meter, and • *k* are the households included in the BSG during monitoring interval *y*.
Source of data:	Measurements by project participants
Measurement procedures (if any):	Use an electricity consumption meter. Electricity consumption should be measured separately for each lighting appliance *n*. See further guidance in steps 5 and 9.
Monitoring frequency:	Continuous metering, reading of the meter at each spot check
QA/QC procedures:	Check consistency of meter readings with the readings from previous monitoring intervals
Any comment:	Applicable for those lighting appliances *n* where project participants use electricity consumption meters to determine the electricity consumption of the appliance (see further guidance in steps 5 and 9).

Data / Parameter:	$EC_{PSG,l,n,y}$
Data unit:	kWh
Description:	Electricity consumption of lighting appliance *n* in the household *l* during the monitoring interval *y*, where • *n* are the lighting appliances installed in household *l* (Option A) or in the living areas of household *l* (Option B) during the monitoring interval *y* and fitted with an electricity consumption meter, and • *l* are the households included in the PSG that have received light bulbs from the project coordinator prior to the start of the spot check (i.e. the date of the first visit of a household during the spot checking period) that was undertaken at the beginning of the monitoring interval *y*.
Source of data:	Measurements by project participants
Measurement procedures (if any):	Use an electricity consumption meter. Electricity consumption should be measured separately for each lighting appliance *n*. See further guidance in steps 5 and 9.
Monitoring frequency:	Continuous metering, reading of the meter at each spot check
QA/QC procedures:	Check consistency of meter readings with the readings from previous monitoring intervals
Any comment:	Applicable for those lighting appliances *n* where project participants use electricity consumption meters to determine the electricity consumption of the appliance (see further guidance in steps 5 and 9).

Data / Parameter:	$h_{PSG,l,m,y}$
Data unit:	hours
Description:	Utilization hours of lighting appliance *m* installed in household *l* during the monitoring interval *y*, where • *m* are the lighting appliances installed in household *l* (Option A) or in the living areas of household *l* (Option B) during the monitoring interval *y* and fitted with a utilization hour meter (see the guidance in step 9); and • *l* are the households included in the PSG that have received light bulbs from the project coordinator prior to the start of the spot check (i.e. the date of the first visit of a household during the spot checking period) that was undertaken at the beginning of the monitoring interval *y*.
Source of data:	Measurements by project participants
Measurement procedures (if any):	Use a utilization hour meter. The utilization hours should be measured separately for each lighting appliance *m*. See further guidance in steps 5 and 9.
Monitoring frequency:	Continuous metering, reading of the meter at each spot check
QA/QC procedures:	Check consistency of meter readings with the readings from previous monitoring intervals
Any comment:	Applicable for those lighting appliances *m* where project participants use utilization hour meters to determine the electricity consumption of the appliance (see further guidance in steps 5 and 9).

Data / Parameter:	$h_{BSG,k,m,y}$
Data unit:	hours
Description:	Utilization hours of lighting appliance *m* installed in household *k* during the monitoring interval *y*, where • *m* are the lighting appliances installed in household *l* (Option A) or in the living areas of household *l* (Option B) during the monitoring interval *y* and fitted with a utilization hour meter (see the guidance in step 9); and • *k* are the households included in the BSG during monitoring interval *y*.
Source of data:	Measurements by project participants
Measurement procedures (if any):	Use a utilization hour meter. The utilization hours should be measured separately for each lighting appliance *m*. See further guidance in steps 5 and 9.
Monitoring frequency:	Continuous metering, reading of the meter at each spot check
QA/QC procedures:	Check consistency of meter readings with the readings from previous monitoring intervals
Any comment:	Applicable for those lighting appliances *m* where project participants use utilization hour meters to determine the electricity consumption of the appliance (see further guidance in steps 5 and 9).

Data / Parameter:	$P_{PSG,l,m,y}$
Data unit:	W
Description:	Power rating of the light bulb used in lighting appliance *m* in household *l* during the monitoring interval *y*, where • *m* are the lighting appliances installed in household *l* (Option A) or in the living areas of household *l* (Option B) during the monitoring interval *y* and fitted with a utilization hour meter (see the guidance in step 9); and • *l* are the households included in the PSG that have received light bulbs from the project coordinator prior to the start of the spot check (i.e. the date of the first visit of a household during the spot checking period) that was undertaken at the beginning of the monitoring interval *y*.
Source of data:	Sampling by project participants.
Measurement procedures (if any):	See guidance in steps 5, 9 and 11
Monitoring frequency:	At each spot check
QA/QC procedures:	
Any comment:	Applicable for those lighting appliances *m* where project participants use utilization hour meters to determine the electricity consumption of the appliance (see further guidance in steps 5 and 9).

Data / Parameter:	$P_{BSG,k,m,y}$
Data unit:	W
Description:	Power rating of the light bulb used in lighting appliance *m* in household *k* during the monitoring interval *y*, where • *m* are the lighting appliances installed in household *l* (Option A) or in the living areas of household *l* (Option B) during the monitoring interval *y* and fitted with a utilization hour meter (see the guidance in step 9); and • *k* are the households included in the BSG during monitoring interval *y*.
Source of data:	Lighting appliance sampled (=manufacturers specification)
Measurement procedures (if any):	Sampling by project participants.
Monitoring frequency:	See guidance in steps 5, 9 and 11
QA/QC procedures:	At each spot check
Any comment:	
	Applicable for those lighting appliances *m* where project participants use utilization hour meters to determine the electricity consumption of the appliance (see further guidance in steps 5 and 9).

Data / Parameter:	$n_{PSG,y}$
Data unit:	-
Description:	Total number of households *l* included in the PSG during the monitoring interval y, corresponding to the number of households included in the PSG that have received light bulbs from the project coordinator prior to the start of the spot check (i.e. the date of the first visit of a household during the spot checking period) that was undertaken at the beginning of the monitoring interval *y*
Source of data:	Project participants
Measurement procedures (if any):	See guidance in step 9
Monitoring frequency:	Determination for each monitoring interval *y*
QA/QC procedures:	
Any comment:	

Data / Parameter:	$n_{BSG,y}$
Data unit:	-
Description:	Total number of households *k* included in the BSG during the monitoring interval *y*
Source of data:	Project participants
Measurement procedures (if any):	See guidance in step 9
Monitoring frequency:	Determination for each monitoring interval *y*
QA/QC procedures:	
Any comment:	

Data / Parameter:	$n_{HH,y}$
Data unit:	-
Description:	Number of households eligible for calculating emission reductions for the monitoring interval *y*
Source of data:	Documentation by project participants
Measurement procedures (if any):	
Monitoring frequency:	Continuous recording of the date of distribution of lighting appliance to a household
QA/QC procedures:	
Any comment:	The number of households that are eligible for calculating emission reductions for the monitoring interval *y* corresponds to the number of households that have received efficient light bulbs in return for incandescent light bulbs from the project coordinator in the time period between the start of the project activity until the start of the spot check (i.e. the date of the first visit of a household during the spot checking period) that was undertaken at the beginning of the monitoring interval *y*. This means that households that have received efficient light bulbs from the project coordinator during the monitoring interval *y* are only eligible for crediting for the subsequent monitoring interval.

Data / Parameter:	TDL_y
Data unit:	
Description:	Technical distribution losses in the electricity grid serving the household consumers that participate in the project during the monitoring interval *y* (kWh of technical electric losses in the electricity grid / kWh of electricity supplied to final consumers).
Source of data:	(National) utility or an official governmental body. The data should be recent, accurate and reliable. Otherwise a default value of 5% should be used.
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures:	
Any comment:	Make sure that technical distribution losses do not contain other types of grid losses (e.g. commercial losses/theft).

Data / Parameter:	$EF_{CO2,ELEC,y}$
Data unit:	t CO_2 / kWh
Description:	CO_2 emission factor for displacement of electricity in the grid serving the household consumers that participate in the project during the monitoring interval *y*, calculated according to the latest approved version of baseline and monitoring methodology ACM0002
Source of data:	Calculated according to ACM0002
Measurement procedures (if any):	See ACM0002
Monitoring frequency:	Annually
QA/QC procedures:	QA/QC procedures in ACM0002 need to be applied
Any comment:	

Data / Parameter:	$EC_{TOT,BSG,k,y}$
Data unit:	kWh
Description:	Total electricity consumption of household *k* during the monitoring interval *y*, where *k* are the households included in the BSG during monitoring interval *y*.
Source of data:	Electricity invoices, provided either by the households or by the electricity supply company.
Measurement procedures (if any):	Adjust the total electricity consumption from the time period indicated the electricity invoices to the monitoring interval y, using the adjustment methods as applied by the electricity supply company. In the absence of any adjustment method, the mean daily electricity consumption can be derived from the electricity invoices and be applied to the monitoring interval *y*.
Monitoring frequency:	Collect data for each monitoring interval *y*
QA/QC procedures:	
Any comment:	

Data / Parameter:	$EC_{TOT,PSG,l,y}$
Data unit:	kWh
Description:	Total electricity consumption of household *l* during the monitoring interval *y*, where *l* are the households included in the PSG that have received light bulbs from the project coordinator prior to the start of the spot check (i.e. the date of the first visit of a household during the spot checking period) that was undertaken at the beginning of the monitoring interval *y*.
Source of data:	Electricity invoices, provided either by the households or by the electricity supply company.
Measurement procedures (if any):	Adjust the total electricity consumption from the time period indicated the electricity invoices to the monitoring interval y, using the adjustment methods as applied by the electricity supply company. In the absence of any adjustment method, the mean daily electricity consumption can be derived from the electricity invoices and be applied to the monitoring interval *y*.
Monitoring frequency:	Collect data for each monitoring interval *y*
QA/QC procedures:	
Any comment:	

Data / Parameter:	$EC_{TOT,BCCG,s,y}$
Data unit:	kWh
Description:	Total electricity consumption of household *s* during the monitoring interval *y*, where *s* are the households included in the BCCG during the monitoring interval *y*.
Source of data:	Electricity invoices, provided either by the households or by the electricity supply company.
Measurement procedures (if any):	Adjust the total electricity consumption from the time period indicated the electricity invoices to the monitoring interval y, using the adjustment methods as applied by the electricity supply company. In the absence of any adjustment method, the mean daily electricity consumption can be derived from the electricity invoices and be applied to the monitoring interval *y*.
Monitoring frequency:	Collect data for each monitoring interval *y*
QA/QC procedures:	
Any comment:	

Data / Parameter:	$EC_{TOT,PCCG,t,y}$
Data unit:	kWh
Description:	Total electricity consumption of household *t* during the monitoring interval *y*, where *t* are the households included in the PCCG during the monitoring interval *y*.
Source of data:	Electricity invoices, provided either by the households or by the electricity supply company.
Measurement procedures (if any):	Adjust the total electricity consumption from the time period indicated the electricity invoices to the monitoring interval y, using the adjustment methods as applied by the electricity supply company. In the absence of any adjustment method, the mean daily electricity consumption can be derived from the electricity invoices and be applied to the monitoring interval *y*.

Monitoring frequency:	Collect data for each monitoring interval *y*
QA/QC procedures:	
Any comment:	

Data / Parameter:	$\mathbf{n_{BCCG,y}}$
Data unit:	-
Description:	Total number of households *s* included in the BCCG during the monitoring interval *y*
Source of data:	Deliberate choice by project participants
Measurement procedures (if any):	
Monitoring frequency:	To be decided for each monitoring interval *y*
QA/QC procedures:	
Any comment:	

Data / Parameter:	$\mathbf{n_{PCCG,y}}$
Data unit:	-
Description:	Total number of households *t* included in the PCCG during the monitoring interval *y*
Source of data:	Deliberate choice by project participants
Measurement procedures (if any):	
Monitoring frequency:	To be decided for each monitoring interval *y*
QA/QC procedures:	
Any comment:	

Data / Parameter:	$\mathbf{n_{SCRAP,y}}$
Data unit:	-
Description:	Number of scrapped light bulbs handed in by households
Source of data:	Project participants
Measurement procedures (if any):	
Monitoring frequency:	Continuously
QA/QC procedures:	Compare the number of distributed light bulbs with the number of scrapped light bulbs
Any comment:	

IV. REFERENCES

Sachs, L. (1992): Angewandte Statistik. Anwendung statistischer Methoden. 7. Auflage. Berlin, Heidelberg, New York. Springer Verlag.