



GENERAL GUIDELINES⁺-STANDARD FOR SAMPLING AND SURVEYS FOR SMALL-SCALE CDM PROJECT ACTIVITIES AND PROGRAMME OF ACTIVITIES

(Version 012)

I. BACKGROUND

1. There have been increasing requests for clarification on the applications of statistical approaches and sampling and survey schemes in CDM methodologies and CDM project activities. These concern regular Small-Scale and Large-Scale CDM project activities but notably program of activities (PoAs). Issues related to sampling have also been cited with regard to approaches a Designated Operational Entity (DOE) may take while validating a project activity or CDM Project Activities (CPAs) of a PoA.

2. In order to respond to these requests proactively, the CDM Executive Board (CDM EB), at its 50th meeting took the first step by approving the “General Guidelines for Sampling and Surveys for Small-Scale CDM Project Activities (sampling guideline)”.

3. Further, the CDM EB at its 60th meeting agreed to set up a joint task force comprising of members of the Methodologies Panel and the Small-Scale Working Group to further work on the issue to develop one set of common sampling guidelines and best practices examples covering Large and Small-Scale projects and PoAs. It further agreed that the scope of the guidelines shall include guidance to DOEs how to review sampling and survey designs in Project Design Documents as well as how to apply sampling to validation/verification work.

II. SCOPE AND APPLICABILITY

4. CDM Project Design Documents (PDDs) or CDM Programme of Activities Design Documents (CDM-PoA-DDs, CDM-CPA-DDs) utilising sampling for the determination of parameter values for calculating emission reductions shall include a *sampling plan* with a description of the sampling approach, important assumptions, and justification for the selection of the chosen approach.

5. ~~Several approved CDM methodologies require estimates of parameter values using sampling methods.~~ The purpose of this document is to specify the reliability requirements and provide requirements guidance on appropriate sampling methods and what is expected to be provided in a sampling plan. The general requirements shall be applicable to both small-scale and large-scale CDM project activities as well as PoAs unless different requirements or additional requirements are specified in the applicable methodologies. The document also provides designated operational entities (DOEs) with specific requirements how to validate sampling plans and how to conduct their own sampling/ surveys for validation/verification.

6. This document also covers specific sampling requirements for PoAs for application by a coordinating/managing entity (CME) to estimate parameter values through sampling. It also includes requirements for sampling by DOEs of PoA application.

7. This document only addresses random errors associated with sampling and does not address systematic (non-random) errors associated with topics such as measurement error.

⁺ See EB 49 Annex 31 for the definition of guidance, guidelines and procedures.

III. ESSENTIAL SAMPLING TERMINOLOGY

8. The following definitions are applied in this document:

- (a) A *sample* is a subset of a *population*. The population could be, for example, all households included in a CDM project activity; the sample is a subset of these households. A characteristic of the population such as average number of hours of operating a biogas stove, or proportion of installed refrigerator units still in operation, will be referred to as a *parameter*. The population parameter is unknown unless the whole population is studied, which is often not feasible or possible. A population parameter can however be estimated using data collected from a sample. It is therefore important that the sample is *representative* of the population. The correct choice of sample design can help to achieve this.
- (b) The distinction about different *types of data (mean vs. proportion)* is important when determining the size of the sample. Mean (average) values are derived from data that are often referred to as *continuous variables* whilst proportion (or percentage) values are derived from data that are described as *attributes, yes/no data or binary data*. The following examples reflect different types of data when determining emission reductions achieved by a project activity requires sampling;
- Mean value Obtaining a point estimate for a parameter such as: -the average annual hours of operation of lighting is used to estimate energy savings. It can also be the efficiency of replaced equipment, where savings equal the change in wattage (determined at installation) multiplied by the average hours of operation (based on a sample estimate) to estimate the characteristics of an equipment or a technology or it may be an output/input of an equipment or technology. the efficiency of replaced equipment, such as heating or lighting systems whereas methane avoidance methodologies may require a mean value for the methane content in biogas;
 - Proportion value such as the percent of units still in operation included in a replacement program for estimating the changes of the operating characteristics of an technology or process have changed over time. e.g. a refrigerator replacement program requires an annual survey to estimatesuch as the percent of units still in operation included in a replacement program.
 - Estimating whether a field value is significantly different from a value based on laboratory tests or previous studies. e.g. some methodologies use the rated efficiency of equipment in estimating savings and these may need to be compared with in-situ performance of the equipment.
- (c) The parameter estimates that are calculated from the sample data should be (a) *unbiased* and (b) *reliable estimates* of the population parameters since they will be used in the calculations of greenhouse gas emission reductions.
- An *unbiased* estimate is one that does not systematically underestimate or overestimate the parameter value it is representing. Non-sampling errors are a main cause of estimates being biased, but the choice of sampling design can also have a bearing on whether an estimate is biased or unbiased.
 - *Reliability* of a sample-based estimate is typically expressed in terms of the probability that the population parameter value falls within a specified distance from the sample-based estimate. The probability is called the *confidence*, and the distance is referred to as the *precision*. *Precision* can be expressed in absolute units or in relative (percentage) terms – i.e. as a percentage of the anticipated target value. These

standards use relative units for a proportion value of parameters as well as for the mean value of parameters used in the calculation. *Confidence* is the likelihood that the sampling has resulted in the target value within a certain range of values (i.e., precision).

- A high level of confidence is desirable, and levels of 90% and 95% confidence are commonly used. Equally, small margins of error are desirable, and frequently a precision of $\pm 10\%$ is used. The required reliability (both precision and confidence) determines the sample size.

IV. SAMPLING REQUIREMENTS

9. The purpose of sampling is to obtain (a) *unbiased* and (b) *reliable estimates* of the mean [or proportion] value of parameters used in the calculations of greenhouse gas emission reductions.

10. Requirements for reliability are defined either in the applicable CDM methodology or in paragraph 12 below, with the applicable methodology having precedence.

11. Where there is no specific guidance in the applicable methodology, project proponents shall use 90/10 confidence/precision as the criteria for reliability of sampling efforts for small-scale project activities and 95/10 for large-scale project activities. This reliability specification shall be applied to determine the sampling requirements for each individual parameter value determined through a sampling effort. The largest of these sample sizes shall then be used for the project.²

12. It is important to note that the figure of $\pm 10\%$ in this standard shall be interpreted;

- as a *relative* unit when the parameter of interest is a proportion (or a percentage). For instance, $\pm 10\%$ in relative units means that the interval around a proportion value of 70% is 63% to 77%.
- as a *relative* term when the parameter of interest is a mean. For example, $\pm 10\%$ in relative terms means that the interval around a mean value of 4 is 3.6 to 4.4.

13. The reliability of a sample-based estimate depends on both the numerical size of the sample and the variability associated with the parameter of interest. The larger the sample size the greater the reliability, whereas the relationship with the variability is the opposite, i.e. the more variable the parameter the less reliable the estimate. If a parameter has a large amount of variability, increasing the sample size will help to increase the reliability.

14. When developing a sampling plan, project participants should calculate the sample size required to achieve a required level of reliability. The sample size can be determined manually or sometimes using reliable statistical software. The calculation is dependent on all of the following as well as the target level of confidence and the precision (e.g. 90/10 or 95/10):

- the type of parameter of interest, i.e. mean value or proportion value
- the target value, i.e. the value that the parameter is expected, which can be determined using the project planner's knowledge and experience – e.g.

² If there is more than one parameter to be estimated in a CDM project activity, then a sample size calculation should be done for each of them, and then the largest number shall be chosen for the sampling effort.



- 80% of households will still have an operational cooker
- the average household size is 4.5

(c) the variance (or standard deviation³) that can be expected for that measure in the sample, which can be based on results from similar studies, pilot studies⁴, or from the project planner's own knowledge of the data.⁵

15. It is good practice to employ oversampling at the design stage not only to compensate for any attrition, outliers or non response associated with the sample but also to prevent a situation at the analysis stage where the required reliability is not achieved and additional sampling efforts would be required (see paragraph 21). This would then be expensive, time consuming and inconvenient.

16. As a clarification it is noted that the 90/10 these confidence/precision requirements are not required to be applied to the annual emission reduction (CER) values, only to the parameter(s) used in the calculation of CERs that are determined through a sampling effort⁶.

17. Subject to the two requirements of unbiased estimates and achieving reliability levels for the specific parameter determination, project participants have broad discretion in the sampling approach they propose to use to obtain the estimates. The choice of which sampling approach to use depends on several considerations, including the types of information to be collected through sampling, the known characteristics of the population, the cost of information gathering, and other conditions surrounding the project in question. Some of the most commonly used sampling methods are summarized in this document (in the session of VI), along with typical circumstances where each may be most appropriate to apply.

V. PROCEDURES

18. A sampling plan shall be included in any PDD for CDM projects and PoAs that utilize sampling for determining one or more parameters. This document provides an annotated outline for what should be included in a sampling plan.

19. Some CDM methodologies specify minimum required levels of precision and confidence for various categories of variables estimated by way of sampling. The samples should be chosen so as to meet or exceed these minimum levels. Project proponents may request a revision of these requirements in the methodology or request a deviation from the approved methodology in accordance with the relevant procedures (see <http://cdm.unfccc.int/Reference/Procedures/index.html>) providing sufficient justifications as to why a lower level is suitable for the planned application.

³ The variance is denoted by σ^2 (or s^2), and the standard deviation by σ or s . The standard deviation is the square root of the variance.

⁴ Project participants may conduct a sample campaign before the monitoring period to determine the standard deviation.

⁵ If the parameter of interest is a proportion, or a percentage, then (c) can be derived directly from the target value.

⁶ For example, consider a project activity that has installed household biogas digesters in numerous distributed several locations to displace fossil fuel use for cooking. The number of annually operating biogas digesters directly impacts on the emissions reductions of the project activity; therefore the number of households for the sample should be chosen so as to achieve a 90% confidence with 10% precision for the data on the number of households with operating biogas digesters. However, a 90/10 specification of the parameter value for the number of households does not necessarily imply that the emission reduction calculation is also at the 90/10 confidence/precision reliability.

20. In addition to the parameters specifically indicated in CDM methodologies that are to be determined through sampling, project implementers may propose to obtain estimates of other variables using sampling techniques if that is the only practical or cost effective means to obtain them. In those instances project proponents shall request a revision of methodology or request deviation from the methodology or request a clarification using the approved procedures before ~~undertaking~~ ~~developing~~ a sampling ~~effort~~ plan.
21. ~~As noted in paragraph 6,~~ if the estimates from the actual samples fail to achieve the target minimum levels of precision, project participants shall perform additional data collection that is a supplemental or new sample ~~to reach the required precision level.~~
22. When sampling is undertaken, unless differently specified in the methodology applied, the sample mean (or proportion) value will be used for the emissions reduction calculation, ~~not the lower or upper bound of the confidence interval.~~
23. In a sampling plan, the sample size chosen shall be justified. In particular it shall be explained how the target level of reliability specified in the applicable methodology (or in ~~paragraph 12~~ above) will be achieved. Appropriate references shall be made to previous studies or sound engineering judgments where necessary to explain expected variability. The detail documentation requirements for a sampling plan are specified below. The sampling plan shall contain information relating to (a) sampling design, (b) data to be collected and (c) implementation plan.
- (a) Sampling Design
- **Objectives and Reliability Requirements:** Describe the objective of the sampling effort, the time frame, and the estimated parameter value(s). Identify the sampling requirements (applicable CDM methodology or sampling standards) and the confidence/precision criteria to be met. For example, the objective is determining the mean monthly value of parameter “X” during the crediting period, and with a 90/10 confidence/precision.
 - **Target Population:** Define the target population, and describe any particular features associated with it.
 - **Sampling Method:** Select and describe the sampling method – e.g. simple random sampling, stratified sampling, cluster sampling etc. Strata or clusters shall be clearly identified if sampling other than simple random sampling is to be used.
 - **Sample Size:** Address and justify the target number of “units” – pieces of equipment, solar cookers, buildings, motors, log-books, etc. – which are to be studied (i.e. the sample size). The justification shall include the parameter of interest, the value it is expected to take and an estimate of the variance associated with the data, as well as the level of confidence and precision. (Note that if the parameter of interest is a proportion, or a percentage, then there is no need to specify a variance estimate).
 - **Sampling Frame:** Identify or describe the sampling frame to be used. This shall agree with the information about the Target Population and Sampling Design above. For instance if cluster sampling is to be used in a study of equipment in buildings, then the frame should be a listing of the buildings from which the sample will be selected.

- (b) Data

- **Field Measurements:** Identify all the variables to be measured, and the timing and frequency of the measurements. Methods of measurement shall be described as appropriate.
- **QA/QC:** Describe how to achieve good quality data, e.g. describe the procedures for conducting the data collection and/or field measurements including training of field personnel, provisions for maximizing response rates, documenting out-of-population cases, refusals and other sources of non-response, and related issues. An overall quality control and assurance strategy shall be documented in the plan. This shall include a procedure for defining outliers and under what circumstances outlier data/measurements may be excluded and/or replaced.
- **Analysis:** Describe how the data will be used.

(c) **Implementation**

- **Implementation Plan:** Define the schedule for implementing the sampling effort and identify who will conduct the actual data collection and the analyses. Include qualifications, experience and any potential conflicts of interest of those involved in the data collection and analyses.

Review of sampling and survey designs in PDDs by DOEs during validation

24. This following paragraphs 25 and 26 provides requirements for DOEs to review sampling plans during validation.

25. The proposed sampling plans shall be validated by DOEs whether they adequately address all of the issues and topics required in paragraph 23 and whether they will provide parameter value estimates in an unbiased and reliable manner. The validation includes whether the proposed approach to sample is practical and likely to provide usable results given the available information about the population and the feasibility of developing the sample frame. The sampling approach shall be evaluated for its adequacy in dealing with the range of sampling and non-sampling errors that may arise. The basis for the forecasts of parameter value's variance shall be assessed, along with the sufficiency of the proposed sample size given the minimum precision/confidence levels. DOEs shall reproduce the sample size calculation in order to validate the proposed sample size.

26. The following questions and evaluation criteria can be utilized for DOEs to validate the proposed sampling plans:

(a) **Does the sampling plan present a reasonable approach for obtaining unbiased, reliable estimates of the variables?**

- In terms of assessing reliability, are the elements of Objectives and Reliability in the Section on Requirements for Sampling Plans complete? Do the requirements specified agree with those stated in the appropriate standards? If not is there a reason why not.
- From all the different elements of the Design, is there any obvious reason to suspect that the results from the activity will be biased? For instance, is the population under consideration only urban households with two or more individuals?. What about rural households ? Might this cause a bias when the data are extrapolated to emission reductions?

(b) **Is the population clearly defined and how well does the proposed approach to developing the sampling frame represent that population?**

- The population should be clear from the Target Population description. Whether or not the sampling frame is possible or appropriate will depend on the detail and the particular situation – e.g. if a map is going to be used, a question would be whether or not a map already exists, and how reliable it is. If a map doesn't exist, then who is going to create it.
- (c) Is the sampling approach suitable, given the nature of the parameters, the data collection method and the information in the sampling frame?**
- Is it clear which sampling method is being proposed – e.g. is it simple random sampling, or some other method of sampling?
 - Does the method agree with the description of the population? Are there clusters or strata, and if so does it state what they are –e.g. are they buildings, villages, etc.
 - Is there another better approach available - e.g. would stratified sampling be more appropriate than simple random sampling? Is the population large?
 - Is there anything in the description of the Target Population that suggests that another method may be better?⁷
- (d) Is the proposed sample size adequate to achieve the minimum confidence/precision requirements? Is the *ex ante* estimate of the population variance needed for the calculation of the sample size adequately justified?**
- All of the information set out in the section on Sampling Plans should help answer this question. If not all information is provided then the question cannot be answered.
 - Is the target value for the population parameter reasonably anticipated?
 - Does the estimate of variability seem reasonable?
- (e) Is the sample representative?**
- Is it clear how the sample is to be selected? e.g. from the sampling frame, and is it selected randomly?
 - Does the Plan indicate that the sampling frame will be kept (e.g. in an Excel spreadsheet), and that random numbers will be generated and these random numbers will then be used to select the sample?
- (f) Is the data collection/measurement method likely to provide reliable data given the nature of the parameters of interest and project, or is it subject to measurement errors?**
- Are the methods of data collection clear and unambiguous? Are there questions which could be subject to respondent error due to sensitivity (e.g. how much money do you spend on heating?), lack of recall etc. (e.g. how many times did you buy fuel last year?)
 - Are there questions that could be subject to measurement error? e.g. Is a particular measurement method known to under-record key data, e.g. the weight of bricks?
- (g) Are the procedures for the data measurements well defined and do they adequately provide for minimizing non-sampling errors?**
- Is the quality control and assurance strategy adequate?
 - Are there mechanisms⁸ for avoiding bias in the answer[, including possible fraud]?

⁷ For example, if the target population is large then simple random sampling may not be the appropriate sampling method.



(h) Does the frame contain the information necessary to implement the sampling approach?

- [Are the persons conducting the sampling activities qualified?] [Has everyone received training on how to collect the data in this study?] [Have the persons conducting the activities got experience of this kind of work?]

Review of implementation of sampling plans by DOEs during verification

27. DOEs shall verify whether PPs have implemented the sampling and surveys properly according to the validated sampling plans.

VI. SAMPLING DESIGN REQUIREMENTS

28. The following subsections provide a summary of some of the most common types of sampling approaches and typical situations where each is recommended. Formulas for calculating standard errors of estimates from each sampling technique, confidence intervals and associated sample sizes are provided in the reference texts cited at the end of this report. The provided sampling information primarily relates to determining point estimates of average (mean) values of a parameter. Other potentially useful statistical modeling approaches, such as regression analysis are not covered.

Simple Random Sample

29. A *simple random sample* is a subset of a population (e.g. villages, individuals, buildings, pieces of equipment) chosen randomly, such that each element (or unit) of the population has the same probability of being selected. The sample-based estimate (mean or proportion) is an unbiased estimate of the population parameter.

30. Simple random sampling is conceptually straightforward and easy to implement – provided that a sampling frame of all elements of the population exists. Its simplicity makes it relatively easy to analyze the collected data. It is also appropriate when only minimum knowledge of the population is known in advance of the data collection.

31. Simple random sampling is suited to relatively homogeneous populations. Consequently, since large populations are usually less homogeneous than small ones, simple random sampling tends not to be suitable for large populations. It may also not be appropriate for populations that are geographically dispersed. In such cases, the costs of data collection associated with the distance between sampled elements (travel, time) may make other methods more cost effective.

Stratified Random Sample

32. When the population under study consists of several sub-populations which are known (or thought) to vary, then it is better to take a simple random sample from each of these sub-populations separately. This is called *stratified random sampling*. The sub-populations are called the strata. When considering stratified random sampling it is important to note that when identifying the strata no population element can be excluded and every element must be assigned to

⁸ Mechanisms for avoiding non-sampling errors (bias) include good questionnaire design, well-tested questionnaires, possibly pilot testing the data collection.

only one stratum. For example, the population of participants in a commercial lighting program might be grouped according to building type (e.g. restaurants, food stores, and offices).

33. Stratified random sampling is most applicable to situations where there are obvious groupings of population elements whose characteristics are more similar within group than across groups (e.g. restaurants are likely to be more similar to one another in terms of lighting use than they are to offices or food stores). It requires that the grouping variable be known for all elements in the sampling frame. For example, the sampling frame would require information on the building type for each case in the population to allow stratification by that characteristic.

34. Stratification helps to ensure that estimates of a population characteristic are accurate, especially if there are differences amongst the strata. For example if lighting use within office buildings tends to be lower (on average) than in food stores then this can be taken into account when estimating the overall average number of hours of operation. Equally, if the cases within each stratum are more homogeneous than across strata then the estimated number of hours of operation will be more precise than if simple random sample of the same size had been taken.

Systematic Sampling

35. *Systematic sampling* is a statistical method involving the selection of elements from an ordered sampling frame. The most common form of systematic sampling is an equal-probability method, in which every k^{th} element in the frame is selected, where k , the sampling interval (sometimes known as the ‘skip’), is calculated as:

$$k = \text{population size } (N) / \text{sample size } (n)$$

36. Using this procedure each element in the population has a known and equal probability of selection. The project participant shall ensure that the chosen sampling interval does not hide a pattern. Any pattern would threaten randomness. A random starting point must also be selected. Systematic sampling is to be applied only if the given population is logically homogeneous, because systematic sample units are uniformly distributed over the population.

37. Systematic sampling is applicable in a number of situations. If there is a natural ordering or flow of subjects in the population, such as output of bricks in a manufacturing process, then it is typically easier to sample every k^{th} unit to test for quality as they are produced. In all cases, it is important that the list of subjects or the process is naturally random, in the sense that there is no pattern to its order.

Cluster Sampling

38. *Clustered sampling* refers to a technique where the population is divided into sub-groups (clusters), and the sub-groups are randomly selected (sampled), rather than the individual elements which are to be studied. The data are then collected on all the individual elements in the selected sub-groups.

Cluster sampling is used when “hierarchical/natural” groupings are evident in a population – e.g. villages and households within villages, or buildings and appliances within buildings. In this technique, the total population is divided into sub-groups (clusters), and a sample of the groups is selected. For example, suppose a project installs high efficiency motors in new apartment buildings, with several motors typically in each building. If one is interested in estimating the operating hours of the motors, one might take a sample of the buildings instead of the motors, and then meter all of the motors in the selected buildings.

In contrast to stratified sampling, where the equipment of interest is grouped into a relatively small number of homogeneous segments, there are many clusters of motors (i.e., apartment buildings),

and there is no expectation that the motors in each building are more homogeneous than the overall population of efficient motors.

39. Cluster sampling is useful when there is no sampling frame at the lowest level of the hierarchy but there is one at the cluster level – as in the case above where a ready list of all motors would not be available, but a list of all new apartment buildings would be.

40. In many applications of cluster sampling to monitor efficient equipment, the subgroupings of units occur naturally in clusters, with a different number of elements per cluster. For example, a building or plant location might constitute a natural cluster, with varying numbers of pieces of equipment/motors per location.

41. One version of cluster sampling is area sampling or geographical cluster sampling. Clusters consist of geographical areas. Because a geographically dispersed population can be expensive to survey, greater economy than simple random sampling can be achieved by treating several respondents within a local area as a cluster.

42. A clustered sampling approach to collect data may offer cost advantages in certain instances. If a significant component of the cost of data collection is travel time between sites, then it may make sense to monitor all of the equipment at individual locations to reduce that cost component. Under that approach, it will typically be necessary to meter more pieces of equipment than under random sampling to achieve a given level of precision. But the reduction in cost may more than offset any negative effects on sample precision, allowing one to take a larger sample for a given budget, with an increase in accuracy.

43. A cluster sampling approach can offer cost advantages. For instance, if a significant component of the cost of data collection is travel time between buildings, but there is minimal cost to collect data on units within a building, then it is more cost effective to collect data on all units within a sample of buildings than to take a simple random sample across all units in the study. It will, however, usually be necessary to meter more pieces of equipment (sample more clusters) to achieve the same level of precision as the simple random sampling, but the reduction in cost etc. may more than offset this apparent increase in effort.

Multi-Stage Sampling

44. Multistage sampling is a more complex form of cluster sampling. Measuring all the sample elements in all the selected clusters may be prohibitively expensive, or not even necessary. Under those circumstances, multistage cluster sampling becomes useful. In multi-stage sampling, the cluster units are often (referred to as primary sampling units and the elements within the clusters secondary sampling units.) in the population are divided into smaller sub-units (referred to as secondary units), similar to cluster sampling. In contrast to cluster sampling where all of the secondary units (elements) are measured, in multi-stage sampling data are collected for only a sample of the secondary units.

For example, in a study of efficient lighting, if the operation hours of motors within any one building are thought likely to be similar across all motors then – especially if the cost of measuring them is relatively high – there is not much to be gained by metering all of them. It might be better to first draw a sample of buildings, and then only measure take a sample of motors from within lighting fixtures in each selected building. If the characteristics of the fixtures in a given building are very similar and the costs of measuring them is relatively high, then taking a sample of fixtures may be sufficient to achieve a target level of precision at lower cost. On the other hand, if the measurements are inexpensive once a technician is on-site, then it may make sense to monitor all of the fixtures.

45. Multi-stage sampling can be extended further to three or more stages. For example, one might group the population into building complexes, then buildings, and finally fixtures.

46. So far most of the methods above have been based on simple random sampling. Another option is to sample with probability proportional to size, and this is sometimes used in cluster sampling where clusters are of different sizes, or in multistage sampling.

47. There are **therefore** many variations in methods in applying multi-stage sampling. If the number of secondary units in each primary unit is not known in the sampling frame, then one approach is to draw a sample of primary units at random, count the number of secondary units in each selected primary unit, and then take detailed measurements for a sample of secondary units. **If the number of secondary units is known in the sampling frame and varies only moderately across units, then one can stratify the primary unit population by size and draw successive random samples of primary and secondary units. The standard formulas for random sampling apply to the secondary unit means, and the formulas for stratified sampling apply to the grand mean.** Another option is to sample the primary units with probability proportional to size, and to draw a random sample of the secondary units in the selected primary units. The relative performance of these alternatives depends on the population characteristics, the costs of data collection, and the availability of information on the primary and secondary units in the sample frame.

VII. SAMPLING REQUIREMENTS TO HELP ACHIEVE UNBIASED AND RELIABLE RESULTS

48. In all of the approaches, care must be taken to ensure that the samples are drawn in a manner that avoids any bias and that the data collection minimizes non-sampling (non-random, systematic) errors. In order to achieve those goals, practitioners are expected to observe sound practices in designing samples and administering surveys and field measurements⁹. Those practices include:

- (a) **Defining precisely the sampling objectives and target population and the measurements to be taken and/or data collected.** The sampling objectives will, for the most part, be concerned with estimation – i.e. estimating a characteristic (e.g. mean or percentage) of a population. Occasionally the objective will be one of comparison – e.g. to compare the uptake in rural areas compared to urban areas.
- **The target population is the “greater entity” to which the results from the survey sample are to be generalized e.g. all new light fittings/suministros that are installed in new buildings in Singapore. from which the sample will be drawn.**
 - **The information that will be collected will depend on the objectives – e.g. if a project needs to estimate the average number of hours of operation of a new efficient motor, then the data to be collected on each sampling units is its the number of hours of operation that it operates for. Other measurements to be made may relate to the characteristics of the strata, or clusters, or any other variable that may be relevant to the project objectives, and the methods of measurements should be clearly specified, see Section IV.**
 - **Deciding on the sampling design and the size of the sample.** This decision is based on the information in Sections II and III.
- (b) **Developing the sampling frame.** A *Sampling frame* is a complete listing of all individual units (elements, members) that can be considered as a representation of the

⁹For a very comprehensive treatment of issues surrounding sample/survey design, see *Household Sample Surveys in Developing and Transition Countries*, United Nations, 2005, ISBN 92-1-161481-3.

wholea population, and which can be used as a basis for selecting a sample – e.g. a list of all households in an area that have had solar cookers installed. In the case of cluster sampling or multi-stage sampling, the sampling frame is a complete listing of sub-groups of the study area/population¹⁰ which constitutes all the clusters or primary sampling units.

- Without such a frame, or its equivalent, methods of sampling with assured properties such as unbiasedness are not available. The implementer of the survey effort shall compile a clear description of the target population, including those characteristics of the population which define membership. From the description and characteristic the implementer can then select a sampling frame.
- (c) **Randomizing cases and drawing sample.** The implementer should ensure that the sample is drawn at random from the sampling frame. This can be done using random number tables or using the random number generator in Excel or some other software. If a systematic sampling is chosen, then the ordering of subjects on the sample should be random and free of any trend or cyclical pattern.
- (d) **Selecting the most effective information gathering method.** The implementer should decide on what would be the most reliable and cost effective method for collecting the data, depending on the variables of interest. Alternative methods include visual inspections, physical measurements, respondent self-reports, and operational logs. For example, equipment retention rates may be determined by inspections or self-reports. Estimates of electric consumption could be based on different metering technologies depending on the characteristics of the equipment. Vehicle travel miles or equipment operating schedules could be drawn from odometers or operation logs.
- (e) **Conducting surveys/measurements.** The project implementer is expected to establish and implement procedures to ensure that the field data collection is performed properly and that any potential intentional errors or unintentional errors are minimized and documented. Such procedures include developing field measurement protocols, training personnel, establishing contact procedures, documenting coverage problems, missing cases, and non-response, minimizing non-sampling measurement errors, and quality control for data coding errors.
- (f) **Minimizing non-response and adjusting for its effects.** The project implementer is expected to make all reasonable efforts to minimize non-response, to analyze potential bias arising from non-response, and to correct for any detected biases or losses in precision due to non-response. Field data collection protocols should specify procedures for multiple contacts to minimize non-response, require documentation of reasons for non-response, and prescribe corrective measures to compensate for its occurrence. Corrective measures may include over-sampling, replacing non-respondents with similar subjects, applying “correction factors” and imputing responses.

VIII. SAMPLING REQUIREMENTS FOR DOEs

Application of sampling to validation and verification work

49. This subsection elaborates requirements for DOEs when they apply their own sampling/survey approach to validation and verification.

50. There are three scenarios:

¹⁰ A suitable map with the sampling units marked on it and properly delineated may also be regarded as a sampling frame and be used in drawing samples.



- i) the DOE draws a sample from the project sample selected by PPs
- ii) the DOE draws a separate sample which is independent from the project sample selected by PPs.
- iii) the PP did not apply a sampling approach and monitored all parameter values while the DOE verifies the parameter values based on samples.

51. In situation (i) where the DOE draws a sample from the project sample selected by PPs, the DOE should meet one of the following two options:

- a) In the first option, the objective is for the DOE is to assure that the sample utilized by the project participant can be relied on for emission reduction (ER) calculations. The DOE is required to check the records for each element of his sample – cook stoves, CFLs, etc. Using this approach, the DOE can determine the size of the validation/verification sample using 90/10 reliability criteria and a high target value for the proportion of records that meet the assurance criteria. The appropriate formula to use is one for a proportionate parameter. A project activity will only be deemed to be fully assured if a target value of [90%] is achieved. The validation/verification sample could contain as many as half of the elements in the project sample.
- b) In the second option, the DOE should sample [25%] of project samples units, provided that there are more than 100 project sample units. Otherwise, sample a minimum of [25] of them. If there are less than [25] units in the project sample, then look at all of them.

52. In situation (ii) where the DOE takes a separate sample which is independent from the project sample selected by PPs, the DOE should meet one of the following two options:

- a) In the first option, the objective is to compare the estimated population parameter from the validation/verification sample with the estimated population parameter from the project sample selected by PPs. This is equivalent to comparing the ER calculated value from both samples, since all other components of the equation will be constant. Using the project sample value as the “target value”, and a variance (or standard deviation) which has been derived from the project sample, the DOE could use 90/10 reliability criteria to determine the size of his independent sample. The appropriate formula would depend on the type of parameter of interest. For instance, if project is looking at the proportion of solar cookers still in operation after 3 years, then the formula will be for a proportion, whereas if the project is interested in the average daily duration of a cook stove then the formula will be for a numeric value. The sample is likely to be similar in size to the original project sample, unless the project parameter estimate is very different from the original target value in the project plan, or the estimate of the variance is very different.
- b) In the second option, the DOE should draw an independent sample that is [25%] the size of the project sample, provided that the project sample contains between [100 and 200], otherwise draw an independent sample of size [25]. If the project sample size is more than [200], then the validation/verification sample should be of size [50]. If the project sample has less than [25] units then the validation/verification sample should be the same size as the project sample.

53. In situation (iii), the DOE should follow the sampling approach in paragraph 52(a).

IX. SAMPLING REQUIREMENTS FOR PoAs

54. This section covers specific sampling requirements for PoAs for application by a coordinating/managing entity (CME) to estimate parameter values through sampling. It also includes requirements for sampling by DOEs of PoA application¹¹.

Simplified Sampling Requirements for Homogeneous PoAs

55. Parameter values shall be estimated by sampling in accordance with the requirements in the applied methodology separately and independently for each of the CPAs included in a PoA unless the CME demonstrates that the PoA confirms to the definition of homogeneous PoA per paragraph 56 and meets the applicability conditions (size threshold) as specified in paragraph 57 below.

56. A homogeneous PoA is defined when all CPAs included in a PoA implement technologies/measures only with high degree of standardisation¹². The high degree of standardisation of technology/measures shall be demonstrated [in relation to] [using applicable criteria from the following]:

- baseline and project technology/measure,
- where relevant fuel/feed stock inputs,
- type and capacity of service,
- geographic location particularly the ambient/weather conditions of interest.
- Combinations of technologies/measures and/or methodologies are applied as per paragraph 11.a to 11.d of STANDARD FOR APPLICATION OF MULTIPLE CDM METHODOLOGIES FOR A PoA¹³

57. Homogeneous PoAs can apply a simplified sampling approach when each independent subsystem/measure in the CPA is equal to or smaller than a threshold value which is 1% of Small Scale CDM thresholds¹⁴.

58. For homogeneous PoAs, to determine parameters for PoA-DD/CPA-DD preparation (i.e. before implementation of CPAs) or for monitoring reports, a common sampling plan can be undertaken if it is implemented during the specified period under the following conditions:

- (a) It is demonstrated that values of parameter of interest are proved not changed significantly over the time period specified (e.g. usage hours of light bulbs in a PoA for efficient lighting or household fossil fuel consumption in a PoA for efficient cookstoves are unlikely to change significantly within a period of about 3 years), or
- (b) If the values of parameter of interest are expected change significantly over time such as a failure rate or retention rate of project equipment (e.g. CFL), group of CPAs covered under the common sampling plan shall have [been started and commissioned within a specified period defined by CMEs (e.g. overlap with +/- 2 months)] [been

¹¹ See paragraph 6(k) of the PoA procedure “Registration of a programme of activities as a single CDM project activity and issuance of CERs for a PoA”

¹² For example, efficient lighting technologies such as CFLs or LEDs replace incandescent lamps in grid connected households

¹³ It is less likely that type of combinations indicated in paragraph 11.d qualify whereas types of combinations indicated in para 11.a may be more conducive for standardisation

¹⁴ PoAs applying large scale methodologies are not excluded if they satisfy these requirements



implemented during an overlapping time periods for the major part] [been implemented around the same time].

(c) [95/10] [95/5] confidence/precision shall be applied to determine sample size.

(d) As required in the Procedures (Section V), the common sampling plan shall be included in CDM-PoA-DD/CPA-DD along with necessary justifications indicated above which will be validated by a DOE.

Sampling Requirements for DOE validation and verification for PoAs

59. When DOEs select a validation and verification method that uses sampling approach i.e. without verifying all CPAs, a statistically sound sampling method/procedure shall be used.

60. Statistically sound method shall meet the following sampling requirements:

(a) For homogeneous PoAs satisfying the paragraph 56 and 57 conditions, DOEs shall follow options available in paragraph 51 and 52¹⁵.

(b) For PoAs that do not confirm to the definition of homogeneous PoA per paragraph 55 but consist of only subsystem technology/measures that are no greater than [10%]of SSC CDM threshold, DOEs shall follow paragraph 52(a). All project units in the PoA shall be considered as the population for the calculation of sampling size for DOEs¹⁶.

(c) For rest of the PoAs not covered by paragraph 60(a) or 60(b), DOEs shall verify each CPA and each technology/measure within the CPA.

¹⁵ [For the purpose of the calculation of the sample size for the DOEs under the option in paragraph 51(a), (b) and 52(b), the samples chosen by CMEs shall be considered as the population. For the option in paragraph 52(a), all project units in the PoA shall be considered as the population.]

¹⁶ Since it is not a homogeneous CPA, sampling will not be undertaken by the CME in this case.



References

The following are references to textbooks on survey sampling that are generally regarded as authoritative treatments of that subject:

Cochran, W.G. 1977, Sampling Techniques, 3d edn, Wiley, New York.

Dillman, D.A. 2007, Mail and internet surveys: the tailored design method, 2., 2007 update with new internet, visual, a mix-mode guide edn, J. Wiley, Hoboken, N.J.

Groves, R.M. 2004, Survey methodology, J. Wiley, Hoboken, NJ.

Groves, R.M. 1989, Survey errors and survey costs, Wiley, New York.

Hansen, M.H. 1953, Sample survey methods and theory, Wiley, New York.

Harkness, J., de Vijver, F.J.R.v. & Mohler, P.P. 2003, Cross-cultural survey methods, J. Wiley-Interscience, Hoboken, N.J.

O'Sullivan, K., and Barnes, D. 2007, Energy Policies and Multi-topic Household Surveys Guidelines, World Bank.

Kish, L. 1995, Survey sampling, Wiley classics library edn, Wiley, New York.

Levy, P. & Lemeshow, S. 1999, Sampling of populations: methods and applications, New York ; Wiley, c1999.

Thompson, S.K. 2002. Sampling, 2nd ed., Wiley

Household Sample Surveys in Developing and Transition Countries, United Nations, 2005, ISBN 92-1-161481-3

Sampling Software Packages

Most statistical software packages have procedures for drawing samples. Widely used commercial packages include SAS, Stata, and SPSS. The UN report cited above reviews these packages and others. Other resources are summarized at the following websites, along with links to free software.

<http://www.hcp.med.harvard.edu/statistics/survey-soft/#Online>

<http://www.freestatistics.info/stat.php>

History of the document

| Version | Date | Nature of revision(s) |
|---|------------------------------------|-----------------------|
| 02 | EB 63, Annex xx | |
| 01 | EB 50, Annex 30 16 October 2009 | Initial adoption. |
| Decision Class: Regulatory Document Type: Guideline Business Function: Methodology | | |



Stakeholder workshop (7-8 May 2011) recommendations

- a. Elaborate requirements for ‘statistically sound approach’ applied to DOE validation/verification (within CPAs, at PoA level and between CPAs). Provide guidelines to avoid redundant (double) checking by DOEs through repeated surveys; (done)
 - b. Have 90/10 precision for annual surveys and 95/5 precision for less frequent surveys especially when surveying households are appropriate requirements. 90/30 for leakage determination is appropriate; (comment is considered when methodologies are proposed for revision/approval)
 - c. Differentiate sampling requirements for PoAs with homogeneous CPAs applying consistent monitoring plans (e.g. for efficient lighting applying AMS II J) versus PoAs containing CPAs with differing baseline conditions. In the former case explore options to apply sampling at the PoA level or at the level of group of CPAs. Clarify under what circumstances stratification is required keeping in mind it is a more difficult method to implement and it is also expensive than other methods; (done for the major part. Best-practice examples will provide more guidance on stratified sampling)
 - d. Include flexibility for timelines to conduct surveys, sampling methods indicated in the PDD versus actually used for project implementation maintaining the rigour for the key requirements. Provide flexibility for monitoring template e.g. either of the options:
 - i. Stand-alone sampling design/reporting document prepared/checked for each CPA; and
 - ii. Template at PoA level setting the framework of the sampling design, to be expanded by adding sampling information of a specific CPA at the time when it is validated/verified. (to be considered under revision of procedures)
 - e. Incorporate the social aspects in the sampling guidance, as not only technical aspects are part of the sampling procedures; (Considered in the best-practice examples)
 - f. Allow a third party to carry out the sampling which leads to avoid the conflict of interest situation; (Considered in the best-practice examples)
 - g. Simplify the current sampling guidance; and (done)
 - h. Provide guidance on determine traceability of the equipment/measure (e.g. in case of bulbs replaced). (Considered in the best-practice examples)
2. Provide best practice guidance for application of sampling which includes criteria to:
- a. Provide technology specific non binding best practice examples accounting for frequently encountered field situations (e.g. households are averse to intrusiveness, statisticians knowledgeable on CDM are hard to find, traceability of low priced equipment such as stoves/CFLs at specified geographic locations



is hard although overall retention rates could be high therefore innovative approaches may be required for retention rates); (Considered in the best-practice examples being developed)

- b. Include equations in the guidelines/worked examples. (Considered in the best-practice examples)
3. Include conservative default factors and/or standardised baselines in the methodologies. (to be considered at the time of revision of/approval of methodologies)
4. Provide procedures for sampling in respective methodologies. (to be considered at the time of revision of/approval of methodologies)