Sampling strategy in Nepal for the Multi-Tier Framework Survey

The sample size proposed for the selected countries in the MTF survey, particularly Nepal, is designed to get sufficiently precise estimates of each tier at the national level as well as the zonal (urban and rural) level. This document outlines the strategy followed in all the countries where the MTF survey is carried out and provides a detailed explanation of the steps followed in selecting the sample in Nepal. The first section presents a discussion on the factors that were taken into consideration in the determination of sample size calculation (1.1) and provides a justification for the proposed sample size for the selected countries (1.2). Then, it explains the stratification process (1.3), and finally, the sample weighting calculation (1.4). The last section (1.5) details the methodology undertaken in selecting the sample in Nepal and implementing the sampling process.

1.1. Issues in the determination of the sample size for a survey

The major issues considered in determining the appropriate sample size for a survey are:

1. The precision of the survey estimates (Sampling error);
2. The quality of the data collected by the survey (Non-sampling error); and
3. The cost in time and money of data collection, processing, and dissemination.

The following sub-sections discuss each of these issues in turn.

1. The precision of the survey estimates

The concept of the precision of a sample survey estimate is crucial in determining the sample size. By definition, a sample from a population is not a complete picture of it. However, an appropriately drawn random sample of reasonable size can provide a clear picture of the characteristics of that population, certainly sufficient for policy implication or decision-making purpose. From a sample of households, one can collect data and generate a sample (or survey) estimate of a population parameter. The population parameter value of characteristics of interest is generally unknown.

The formula to calculate the sample size is:

$$n = \frac{z^2 r(1-r) fk}{e^2} = \frac{z^2 r(1-r)[1+\rho(m-1)]k}{e^2} \qquad (1)$$

where:

n = Sample size in terms of number of households to be selected.

z = z-statistics corresponding to the level of confidence desired. The commonly used level of confidence is 95% for which z is 1.96.

r = Estimate of the indicator of interest to be measured by the survey.

f = Sample design effect. It represents how much larger the squared standard error of a two-stage sample is when compared with the squared standard error of a simple random sample of the same size. Its default value for infrastructure interventions is 2.0 or higher, which should be used unless there is supporting empirical data from similar surveys that suggest a different value. The sample design effect has been included in the sample size calculation formula (1) and is defined as: $f = 1 + \rho (m - 1)$.

ρ = Intra-cluster correlation coefficient. It is a number that measures the tendency of households within the same Primary Sampling Unit (PSU) to behave alike in regards to the variable of interest. ρ is almost always positive, normally ranging from 0 (no intra-cluster correlation) to 1 (when all households in the same PSU are exactly alike). For many variables of interest in LSMS surveys, ρ ranges from 0.01 to 0.10, but it can be 0.5 or larger for infrastructure related variables.

m = Average number of households selected per PSU.

k = Factor accounting for non-response. Households are not selected using replacement.[1] Thus, the final number of household interviewed will be slightly less that the original sample size eligible for interviewing. For most developing countries, the non-response rate is typically 10% or less. So, a value of 1.1 (= 1 + 10%) for k would be conservative.

e = Margin of error, sampling errors or level of precision. It depends very much on the size of the sample, and very little on the size of the population.

2. The quality of the data (Non-sampling error)

Besides sampling errors, data from a household survey are vulnerable to other inaccuracies from causes as diverse as refusals, respondent fatigue, measurement errors, interviewer errors, or the lack of an adequate sample frame. These are collectively known as non-sampling errors. Non-sampling errors are harder to predict and quantify than sampling errors, but it is well accepted that good planning, management, and supervision of field operations are the most effective ways to keep them under control. Moreover, it is likely that management and supervision will be more difficult for larger samples than for smaller ones (Grosh, M. E., & Muñoz, J., 1996, p56). Thus, one would expect non-sampling error to increase with sample size.

3. The cost of data collection, processing, and dissemination

The sample size can affect the cost of the survey implementation dramatically. It will also affect the time in which the data can be collected, processed and made available for analysis. The availability of survey firm and cost for each country would affect the total cost of survey implementation, too. Thus, the cost of data collection, processing, and dissemination should be considered in determining the sample size for each country.

1.2. Sample size calculation

Sample surveys are appropriate for the collection of national and relatively large geographic domain level data on topics that need to be extensively explored. The main purpose of this survey is to identify and analyze the energy access tiers (tier 0 to tier 5) both at the national level and at the zonal (urban and rural) level. Equation (1) in the previous section indicates the formula to calculate the sample size. Given that the concept of the MTF has been recently introduced and the aim of this global survey is to establish the baseline of monitoring energy access globally, the indicator of interest (r) is unknown. Thus, the sample size for each selected country is calculated using the prevalence rate of 50% as the most conservative choice and to achieve the minimum margin of error (standard errors are inversely proportional to the square root of the sample size: $e=z^*\sigma/\sqrt{n}$). Since the non-response

[1] The sample size should be calculated to reflect the experience from the country in question. Hence, we will introduce the possibility of replacement of certain households in particular countries if needed. In this case, a different weight will be considered when preparing the estimates.

rate is typically under 10% in developing countries (United Nations, 2011), a value of 1.1 for k (non-response rate), therefore, would be considered a conservative choice (United Nations, 2011, p42). The number of households selected per PSU (m) is 12 (DHS normally visit 20-35 households per PSU, while socioeconomic surveys 6-16 households per PSU); however, it can be modified depending on the level of homogeneity in a given PSU and community. Due to the characteristics of infrastructure variables/indicator, we select 0.45 for intra-cluster relation coefficient (ρ), consequently, the design effect (f) will be equal to 6 ($f = 1 + \rho (m - 1)$) (Grosh, M. E., & Muñoz, J., 1996, p59).

The number of analytic domains has a large impact on the sample size and strategy, too. An analytic domain can be defined as the analytic sub-groups for which equally reliable data is required for the analysis. The sample size is increased by a factor equal to the number of domains desired, because it does not depend on the size of the population itself.

In the process of defining a strategy to calculate the sample size for the selected countries, we have considered two approaches: one calculating, at first, the national sample size as one analytic domain and, then, allocating the sample size proportional to urban and rural population; the other is calculating, at first, the sample size using the distribution between urban and rural as two analytic domains and, then, adding these two values to obtain the national sample size. Besides, these two approaches have taken into consideration data on sample size by margin of error, ranging from approximately 4% to 5.5% at national level and from nearly 5% to 11% at zonal level. Considering the results obtained, it has been chosen to keep those of the second approach, which for a margin of error of 6% at urban and rural levels gives a national sample size of roughly 3,500 households with an error of 4.2% (Table 1). However, final sample size for each country can be modified depending on the stratification strategy.

Table 1. Calculation based on two analytic domains

Sample size			Margin of Error		
National	Urban	Rural	National	Urban	Rural
3,500	***1,750***	***1,750***	***4.2%***	***6.0%***	***6.0%***
3,000	1,500	1,500	4.6%	6.5%	6.5%
2,600	1,300	1,300	5.0%	7.0%	7.0%

Within each cluster/state, PSUs are selected with probability proportional to its measure of size (PPS) and households are selected with equal probability within each PSU (the definition of this approach is reported in United Nations, 2011).

Oversampling

In some cases, it is required to oversample specific geographic sub-areas or population sub-groups for specific project or research purpose. Sample size for oversampling areas should be calculated considering the estimated impact of the project (if the purpose of oversampling is to measure the impact of the intervention), or the precision of the estimates. At the same time, we also need to consider the non-sampling error and cost into the sample size calculation for oversampling area. After the sample size for oversampling area is estimated, we need to think how we will allocate the sample for oversampling.

a. If the unit of sub-groups/areas (e.g. Region / Department / Province) is in line with the highest geographical/administrative units used in the stratification strategy: We need to allocate sample proportionally to population (estimates) of each stratum. After comparing the sample size for oversampling areas and the sample size for the area after initial allocation (PPS), we need to add more sample size to the oversampling areas to obtain the precision to meet the purpose of the oversampling.

b. If the unit of sub-groups/areas (e.g. district / village tract / commune) is lower/smaller: We need to separate these sub-groups from our core sampling frame. Since the unit of oversampling areas is smaller than our unit of geographical/regional stratification, we won't be able to predict how many of households will be sampled in the initial distribution. To be cost-efficient, we would like to treat these oversampling areas as a separate stratum in the stratification strategy and allocate the number of households to this stratum.

1.3. Stratification

Once we determine the sample size, we need to develop a stratification strategy, which is the process of dividing households into homogeneous smaller groups called strata and then sampling separately for each stratum following certain rules. Stratification often improves the representativeness of the sample by reducing sampling error. Each stratum is treated as an independent population. As explained in the final session (1.4) sampling weights need to be used to analyze the data. This section provides guidelines on stratification for the MTF Global Survey.

The guidelines provided in this section are general, and ideally, this is what we aim to achieve in the stratification of the sample for the selected countries. However, these guidelines may not apply identically to all 16 selected countries where MTF surveys are going to be implemented as these countries may well vary in their geographical structure and population distribution within and across geographical units. That is, country-specific modification of the guidelines is likely, and such modification will be covered in the country-specific data collection reports.

Before discussing the stratification strategy it is useful to go over the criteria that will guide the overall stratification strategy. Such criteria are:

1. Equal allocation between urban and rural areas. This is established during sample size calculation. This will help conduct disaggregate and in-depth analysis for urban and rural areas, which are statistically sound.
2. While the parameters of interest for the MTF study are access to grid electricity and access to non-solid fuel, the first one will be used in the stratification. However, to make the analysis representative of the underlying population, sampling weights will be used that take into account the actual distribution of both grid users and non-solid fuel users in the population.
3. Sample will have 50-50 distribution of grid users and non-users. This will help us carry out in-depth analysis of both groups. Again, sample weights will be used in the analysis to compensate oversampling of either group.
4. Twelve households will be sampled from each village or urban block (PSU).

With these criteria in place we can proceed to develop stratification strategy as follows.

1.4. Sample weighting calculation

In our survey we deal with representative samples randomly selected from the target populations. This representativeness of the sample must be considered to ensure that any statistical inferences drawn from the survey data is valid. For this purpose, we use sampling weights calculated for each interviewed household to make the sample more like the target population (ICF International, 2012; United Nations, 2011).

What exactly is a sampling weight? As explained in detail in this section, a sampling weight is an inflation factor. Weighting for household surveys involves three processes: calculation of the design (or base) weights, adjustments for non-response and adjustments for post-stratification. It is crucial that sampling weights (or probabilities) at each stage of selection are cautiously calculated, applied, and recorded in any data analysis. If the exact weights that compensate for differences between census and survey measures of size are used, the resulting survey estimates will be unbiased. Failure to adjust the weights accordingly produces biased estimates, leading to incorrect conclusions.

There are a few reasons why using sampling weights is required, even though the effect of sampling weights on survey indicators may be small: 1. to obtain valid statistical inference; 2. to correct or at least reduce bias; and 3. to keep the weighted sample distribution close to the target population distribution, particularly if oversampling is applied in certain strata or domains.

As explained in the next section, at first we have to determine the probabilities of selection of sampled units, and then construct sampling weights. The probability of selection of a sampled unit depends on the sample design used to select the unit. The calculation of sampling weights begins with the calculation of the design weight for each sampled unit, in order to reflect their unequal probabilities of selection.

Basically, the design weight of a sampling unit (household in our case, but it can be individual in other cases) is the inverse of the overall probability with which the unit was selected in the sample. That means, if a unit has probability p_i to be included in the sample, then its design weight is: $w_i = 1/p_i$.

When multi-stage designs are considered, is essential that the design weights reflect the probabilities of selection at each stage. Assuming that, for example, $w_{ij,b}$ is the design weight for the j^{th} household, $w_{ij,nr}$ is the weight attributable to compensation for non-response, and $w_{ij,nc}$ is the weight attributable to the compensation for non-coverage; consequently, then the overall weight of the household is:
$w_{ij} = w_{ij,b} * w_{ij,nr} * w_{ij,nc}$.

Design weights calculation

Let's now assume that the survey sample is drawn with two-stage, stratified PSU (or cluster) sampling, hence, design weights is calculated based on the separate sampling probabilities for each sampling stage and for each PSU. We have:

P_{1hi}: probability of selecting the i^{th} PSU/cluster in stratum h in stage 1

P_{2hi}: probability of selecting the household within the i^{th} PSU/cluster in stage 2

Assuming that n_h is the number of PSUs selected in stratum h; M_{hi} is the measure of size of the PSU used in the first stage's selection, which means it is the number of households residing in the PSU according to the sampling frame (or census); $\sum M_{hi}$ is the total measure of size in the stratum h. The probability P_{1hi} of selecting the i^{th} PSU in the sample is thus:[2]

[2] Since PSU and EA are considered identical and the EA is not segmented in our analysis, we do not need to multiply P_{1hi} by the factor b_{hi}, which is the proportion of households in the selected PSU compared to the total number of households in EA i in stratum h; in other words, in this case $b_{hi} = 1$. Otherwise, the probability of selecting PSU i in the sample would be: $P_{1hi} = \frac{n_h M_{hi}}{\sum M_{hi}} \times b_{hi}$

$$P_{1hi} = \frac{n_h \, M_{hi}}{\sum M_{hi}}$$

$$P_{1hi} = \frac{\text{\# PSUs selected in stratum h * \# HHs in the PSU}_i \text{ in stratum h (from census)}}{\text{total \# HHs in stratum h}}$$

Assuming that t_{hi} is the number of households selected in the PSU *i* in stratum *h*, and L_{hi} is the number of households listed in the household listing operation in PSU *i* in stratum *h*. The second stage selection probability P_{2hi} for each household in the PSU is thus:

$$P_{2hi} = \frac{t_{hi}}{L_{hi}}$$

$$P_{2hi} = \frac{\text{\# HHs selected in the PSU}_i \text{ in stratum h}}{\text{\# HHs listed in the PSU}_i \text{ in stratum h}}$$

Consequently, the overall selection probability of each household in PSU *i* of stratum *h* is the product of the selection probabilities of the two stages:

$$P_{hi} = P_{1hi} \times P_{2hi}$$

Finally, we can calculate the design weight for each household in PSU *i* of stratum *h* as the reverse of its overall selection probability:

$$d_{hi} = 1/P_{hi}$$

The calculation of the design weight is not very difficult; nonetheless, complications usually result from the fact that the design parameters involved in the above calculation are not available because they are not well documented.

Correction for non-response

Usually, non-response is common in surveys. For this reason, the design weight calculated above that is based on sample design parameters is not enough for all analyses. For example, DHS program (ICF International, 2012) confirms that rich urban households in developed regions are less likely to respond to the survey than their counterparts in poor rural and less-developed areas respectively; furthermore, individuals with higher levels of education are less likely to respond to the survey than those with lower levels of education, and men are less likely to respond to the survey than women.

In general, correcting for unit non-response is required to calculate a response rate for each homogeneous response group; subsequently, the design weight has to be divided by the response rate for each response group.

Assuming that the response groups coincide with the sampling strata, we need to calculate the sampling weight by first calculating the various response rates for unit non-response. Here we consider only PSU and household levels response rate and not the individual levels response rate, given that the survey is at household level.

- PSU/Cluster level response rate:

Assuming that n_h is the number of PSUs selected in stratum *h* and n_h^* is the number of PSUs interviewed. The PSU level response rate in stratum *h* is:

$$R_{ch} = n_h^* / n_h$$

- Household level response rate:

Assuming that m_{hi} is the number of households found in PSU *i* of stratum *h* and m_{hi}^* is the number of households interviewed in the PSU. The household response rate in stratum *h* is:

$$R_{hh} = \sum d_{hi} m_{hi}^* / \sum d_{hi} m_{hi}$$

where d_{hi} is the design weight of PSU *i* in stratum *h*. The summation is over all PSUs in the stratum *h*.

The household sampling weight of PSU *i* in stratum *h* is obtained by dividing the household design weight (previously calculated) by the product of the response rate at PSU and at household levels, for each of the sampling stratum:

$$D_{hi} = d_{hi} / (R_{ch} \times R_{hh})$$

The household sampling weight above can then be used to calculate any indicators at the household level. Given that, as previously mentioned, a sampling weight is an inflation factor, the weighted sum of households interviewed is calculated as:

$$T = \sum \sum D_{hi} m_{hi}^*$$

This is an unbiased estimate of the whole number of residential households of the country. The summation is over all PSUs and strata in the full sample.

Caveat: the increase in sampling variance caused by weighting. Weights in the analysis of survey data are introduced with the aim of reducing the bias in the estimates; however, weights could also increase the variances of such estimates.

1.5. Sampling methodology in Nepal

Through consultations with energy and survey experts, statisticians, and proper coordination with the local authorities (Central Bureau of Statistics, Ministry of Energy, Water Resources and Irrigation, Alternate Energy Promotion Center), the MTF team has devised survey tools (such as questionnaires, sampling technique, and CAPI-based programs[3]) to collect nationally representative data on access to electricity and cooking solutions in these countries. The World Bank, through a competitive bidding process, hired the Nepal-based survey firm Solutions Consultants Pvt. Ltd. to undertake the fieldwork and data collection across Nepal. The MTF household survey data collection began in July 2017 and was completed in December 2017.

3 CAPI stands for Computer Assisted Personal Interviewing. Where stand-alone full-spectrum survey cannot be implemented, the ESMAP offers governments the option of incorporating a set of MTF-related core energy questions into their existing national surveys.

Sample frame

Nepal is currently divided administratively into seven provinces and geographically into three ecological regions, comprising 14 zones. At the time of the 2011 Census, as per the earlier administrative division, Nepal was divided into 75 districts, and further into 3,157 smaller Village Development Committees (VDCs) (designated as rural areas) and 217 municipalities (designated as urban areas). These VDCs and municipalities were again divided into wards (36,020 in all) which are the smallest administrative units. However, during the time of this survey, changes in the administrative divisions of Nepal replaced the earlier 14 zones and 75 districts by 7 Provinces, and the VDCs and municipalities by 744 local units. As per the current restructuring, the local units have been divided into 4 metropolitan cities, 13 sub-metropolitan, 246 municipal councils, 481 village councils and 6,679 wards. This change in the administrative structure involved merging of various wards, which increased the size of many of them. Similarly, 45 percent of the earlier rural wards have now been categorized as urban.

The sample frame of this study is the 2011 Census conducted by the Central Bureau of Statistics. The sample frame was updated to reflect the recent administrative and geographical changes. The new changes took into consideration the seven provinces of Nepal (Province 1, Province 2, Province 3, Gandaki Province, Province 5, Karnali Province, and Province 7) and the new classification of urban and rural locations officially now known as Nagarpalika and Gaonpalika.

Sample distribution and stratification

The MTF global survey has a benchmark of 3,500 households for a national level survey being implemented in different countries, with 50:50 distribution of urban and rural areas, and 50:50 distribution of grid and non-grid households if possible. Based on the needs of project teams within the World Bank, some additional areas were selected to be oversampled to better understand the use of various cooking solutions. However, the oversample did not specifically target areas with existing programs on clean or improved stove distribution, instead larger administrative regions were selected to be included. With oversampling, the Nepal MTF survey covered a total of 6,000 households. The allocation aimed at generating a sample large enough to produce estimates by province, ecological region, rural and urban areas, and grid connection status. For rural and urban areas, the sample was drawn from all the 7 provinces and the 3 geographic areas (Mountain, Hill and Terai). The Hill region was further divided into two groups—Kathmandu region and the rest of the Hill area—to highlight the findings from national capital area.

The household survey sample selection, based on two-stage stratification, aimed at being representative of the country at large. At the first stage, the enumeration areas—wards—were selected randomly from each of the newly formed provinces to be representative of urban and rural areas, and the distinct ecological regions in Nepal (the Mountains, Hills and Terai i.e. plains). The number of wards selected from each province was roughly in proportion to the province size (that is, the number of wards in a province). All in all, 400 wards were selected nationwide.[4] The field teams visited each selected ward and the enumerators compiled a list of the households in the ward to obtain an updated version of the total number of households in each ward and their grid

4 Please note that only wards with roughly 250–300 households were considered. For that, if any sampled wards (mostly urban) were found much larger, they were segmented (divided into equal-sized smaller groups) and one segment was selected as the enumeration area.

electrification status. In the second stage, 15 households were selected for interview from the list for each ward. The criterion for selection of households was that a ratio of 50:50 grid-connected and non-grid households needed to be maintained, following the standard sampling methodology for the national households' surveys on the Multi-Tier Framework for Energy Access.[5]

The rural-urban allocation will follow the recent remapping of wards. According to the recent remapping, more rural wards are included in the urban category. The planned distribution of the total sample by rural and urban category is follows.

Table 2. Nepal MTF sample: Rural – Urban Allocation

	Number of Wards/EAs	Number of households
Rural	180	2700
Urban	220	3300
Total	400	6000

At the time of the sample selection the grid connection (electrification) status of wards was not available. The distribution was estimated based on the results from recent surveys such as the 2013/14 Nepal household survey, which shows the share of households with electricity as their main source of light to be 72.9 percent in rural areas and 97.2 percent in urban areas. Because of the overwhelmingly large share of the grid households, both in urban and rural areas, it was not possible to maintain the planned 50:50 distribution of grid-connected and non-grid households in the sample. Accordingly, it was decided that the allocation of grid and non-grid households would be 10 and 5, respectively, in rural enumeration areas, and 13 and 2, respectively, in urban enumeration areas. Overall, 4,660 grid-connected and 1,340 non-grid households were sampled for the survey[6]. Table 3 shows the distribution sampled households.

Table 3: Nepal MTF sample: Distribution of Grid and Non-Grid Households

	Allocation	Total # of households	Grid # of households	Non-grid # of households	Non-grid As % of total

5 The sampling methodology and the stratification did not consider during the household selection process the share of households owning or using an improved cook stove in each ward. This decision was made during the design phase of MTF implementation because data or statistics on grid connection rate at national or sub-national level are more commonly available for most countries. Moreover, sampling based on grid-connectivity is easier to implement than doing so based on the ownership of ICS as there is a lack of consensus on the specification of ICS, not just across the countries but also within the countries in many countries. In most developing countries, ICS is disseminated by multiple vendors and agencies, and they vary in specification. Notwithstanding its dependence on grid-connectivity, the sampling methodology has so far generated fairly representative statistics on cooking solutions in all countries.

6 The sampling strategy did not use 'districts' as a stratum for sampling. However, for an easy understanding of the geographic locations of where the survey was conducted for those familiar with Nepal, we would like to note that 71 districts we covered in this survey. The list of districts is as follows: Taplejung, Panchthar , Ilam, Jhapa, Morang, Sunsari, Dhankuta, Tehrathum, Sankhuwasabha, Bhojpur, Solukhumbu Okhaldhunga, Khotang, Udayapur, Saptari, Siraha, Dhanusha, Mahottari, Sarlahi, Sindhuli, Ramechhap, Dolakha, Sindhupalchok , Kavrepalanchok, Lalitpur, Bhaktapur, Kathmandu, Nuwakot, Dhading, Makwanpur, Rautahat, Bara, Parsa, Chitwan, Gorkha, Lamjung, Tanahun, Syangja, Kaski, Myagdi, Parbat, Baglung, Gulmi, Palpa, Nawalparasi, Rupandehi, Kapilbastu, Arghakhachi, Pyuthan, Rolpa, Rukum, Salyan, Dang, Banke, Surkhet, Dailekh, Jajarkot, Dolpa , Jumla, Kalikot, Mugu, Humla , Bajura, Bajhang, Achham,Doti, Kailali, Kanchanpur, Dadeldhura, Baitadi and Darchula.

Rural	10 Grid, 5 non-grid	2700	1800	900	33
Urban	13 Grid, 2 non-grid	3300	2860	440	13
Total		6000	4660	1340	22

Table 4 has the complete sample distribution of the 400 wards and 6000 households across provinces, ecological region and urban-rural disaggregation.

Table 4: Sample Distribution in Nepal for the Multi-Tier Framework survey

Province	Ecological Region	Total Wards (Enumeration Areas)	Total Sample	Urban Households	Rural Households	Total Households
1	Mountain	16	240	120	120	240
3	Mountain	22	330	165	165	330
6	Mountain	40	600	135	105	240
7	Mountain			165	195	360
1	Hill	39	585	285	300	585
3	Hill (excluding Kathmandu)	40	600	300	300	600
3	Hill (Kathmandu)	40	600	600		600
4	Hill	40	600	165	135	300
5	Hill			135	165	300
6	Hill	40	600	225	165	390
7	Hill			75	135	210
1	Terai	40	600	300	300	600
2	Terai	44	660	285	330	615
3	Terai			45		45
4	Terai	39	585	45	30	75
5	Terai			135	165	300
7	Terai			105	105	210
Total		400	6,000	3,285	2,715	6,000

Stage one: Selection of Wards and Sub-Wards

During the first stage of sampling a total of 400 enumeration areas (EAs) were selected based on probability proportional to size in each stratum which comprised of provincial, ecological and urban/rural divide. The first stage of sampling entailed selecting enumeration areas (EAs) or wards/sub-wards. A total of 181 EAs were selected for the rural samples and 219 EAs were selected as a part of the urban sample across the country. The urban sample included an oversample of urban EAs in Kathmandu- the capital city.

The ward selection was carried out at the central level by The World Bank team. The list of selected wards were then shared with the survey implementation firm for further planning and implementation. During fieldwork, after the enumerators reached the sampled ward, they conducted an enumeration of the entire ward from which the required number of houses were selected. However, some urban wards were too big to carry out a complete enumeration of the area. Therefore, those wards were segmented into smaller and manageable EAs (Annex 1: EA Selection process for densely populated urban areas). For this study an approximate of 300 households per EA was determined to segment the wards.

Stage two: Household Listing and Selection

In the absence of a database comprising of the list of households in all the selected EAs, household listing exercise was carried out that helped generate a sample frame for household selection in each EA. The enumerators visited and listed all the households living within the boundaries of each EA, before proceeding with household selection for the survey. However, for the listing process in big wards where the household numbers were very large, a segment was selected randomly to locate the starting point. All the houses within this segment were listed. If there were not enough number of households in the initially delineated segment/block, an additional layer was added in all directions of the segment/block from which additional houses were listed. The objective was to have a list of minimum 300 households.

For each household, the enumerators collected 3 different key information- 1) Head of household's name, 2) Size of household, and 3) Grid connectivity status.

After the household listing exercise, a systematic sampling was conducted through a random start and skip method using an interval. For all EAs, a total of 15 households were sampled from the list of all the households located within the EA. In all the EAs, the listing was carried out using two separate sheets in the form; one for grid-connected households and another for non-grid connected households. However, if there were no households connected to the grid in a particular EA, the enumerator only filled in the sheet for the non-grid connected households. The same process was followed for EAs with only grid connected households. Based on the listing information on gird connectivity status, the household selection followed the grid/non-grid allocation presented below.

For rural areas the sample allocation was determined as 10 samples from grid connected households and 5 samples from non-grid connected households. In urban areas the allocation was 13 samples from grid connected households and 2 samples from non-grid connected households. The fixed allocation was applied whenever the list was adequate to select enough number of households from both grid and non-grid categories. However, if there weren't enough households to select from one category, the remaining households were selected from the other category. This helped ensure the total number of household interviews per EA fixed at 15. In case of any confusion, particularly for the partially electrified wards, the enumerators consulted with their immediate field supervisor and the household survey field manager to determine the number of grid connected vs. non-grid connected households. As stated earlier, the household selection was carried out through a systematic random selection method. In order to reduce bias, a random start point for selecting households (for every EA) were provided to the enumerators by the central team before the start of fieldwork.

Household listing in sparsely populated rural areas

For the household listing in the sparsely populated rural areas (designated as VDCs as per the earlier classification), the entire ward was considered as an EA – particularly for wards whose population was around 300 households or less.Hence the enumerators were given the entire ward map in three layers (illustrated in Annex 2). This gave the enumerators a fair idea on the location of the ward and other landmarks/settlements closer to the ward. For some cases the enumerators and supervisors also relied on information from local authorities (VDC staff) for getting the exact directions to reach the ward. The enumerators then proceeded with the listing exercise of all the households residing within the ward boundary.

Respondent Selection

Once the required number of households was selected from the list, the enumerators interviewed that particular household member, who was the most knowledgeable regarding the household electricity usage (including back up sources). However, multiple household members were also interviewed for separate sections within the questionnaire (depending on who had the most knowledge and information regarding certain modules within the questionnaire).

Sample weight

Since the distribution of grid and non-grid households in the sample differs from that in the population, any findings based directly on the data are expected to be biased. To adjust for the biases, sampling weight was used in the analysis of the data so that the findings are representative of the rural and urban areas and at the national level. The calculation of sample weight required census data with rural-urban disaggregation. As mentioned, the sample frame was the 2011 census from the Central Bureau of Statistics with projections to obtain the 2017 figures.

References

Grosh, M. E., & Muñoz, J. (1996), A manual for planning and implementing the Living standards measurement study survey. Washington, D.C.: World Bank.

United Nations (2011), Designing household survey samples: Practical guidelines. New York: United Nations Publications. United Nations. (2003). Sampling strategies. New York: United Nations Publications.

ICF International (2012), *Demographic and Health Survey Sampling and Household Listing Manual*. MEASURE DHS, Calverton, Maryland, U.S.A.: ICF International

ANNEX 1: EA Selection process for densely populated urban areas

The following outlines the process of selecting an area for block enumeration within a densely populated ward. The process outlined below was carried out in the central office of the survey firm and not at field level eliminating any bias at field level.

Step 1. Selected ward - Ward no. 12 from Kathmandu Municipality is identified (outlined in blue) from the database of all wards within Nepal.

Figure 1. Identification of selected ward (outlined in blue)

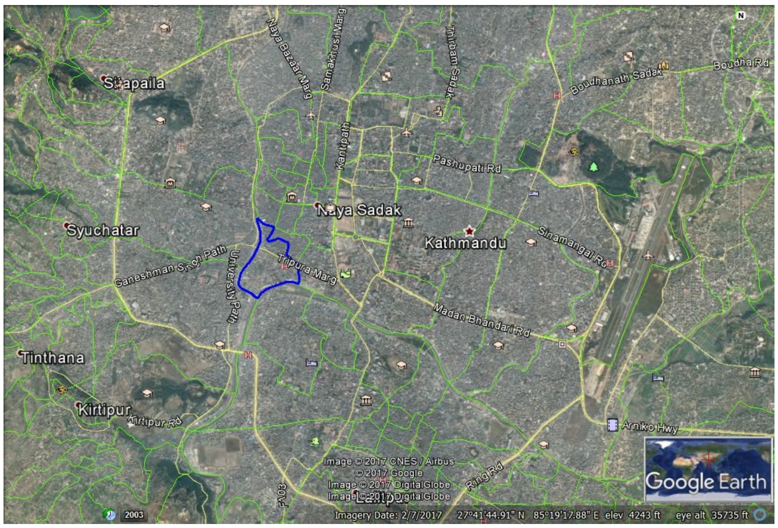
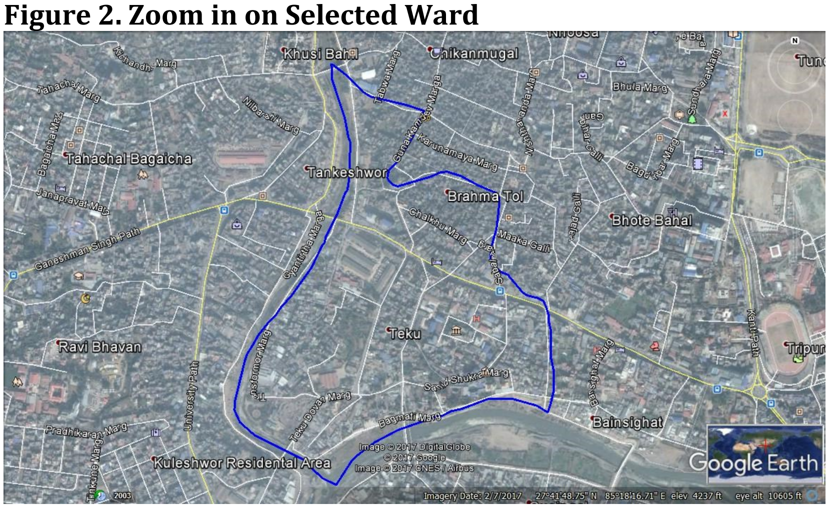


Figure 2. Zoom in on Selected Ward

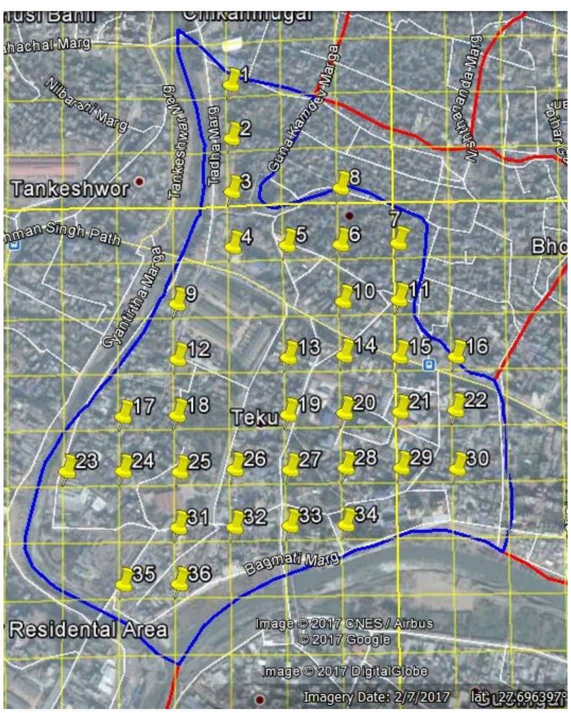


Step 2. A grid overlay (outlined in yellow) is imposed on the selected ward to generate multiple intersections within the ward.

Figure 3. Selected ward with Grid overlay (outlined in yellow)

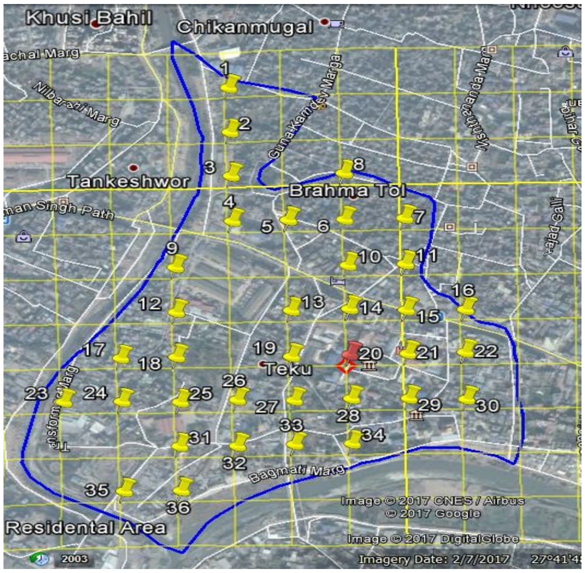
Step 3. The intersections are geocoded and numbers are allocated to each geocode. While geocoding the intersections, any empty area or parts of large commercial complex are avoided.

Figure 4. Selected ward with grid points selected for random selection.



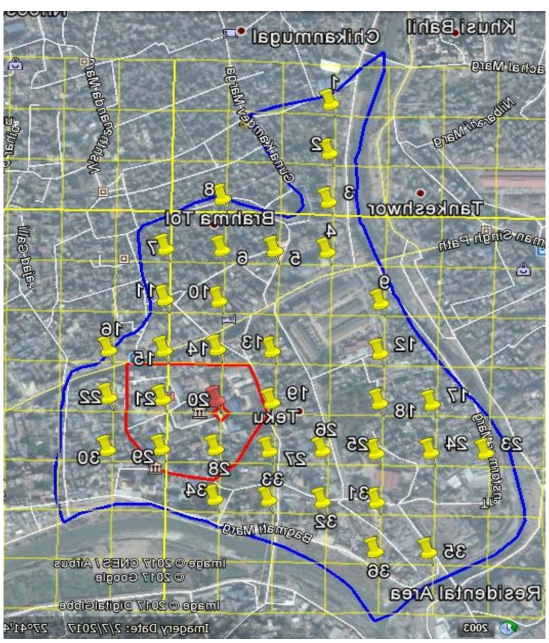
Step 4. Using a random number selection process, one of the geocode is selected as a random start point for Ward no. 12. (If multiple Enumeration Area are required within a ward then multiple random start points would be selected.) Intersection number 20 is selected for this example.

Figure 5. Random start point (no. 20) selected



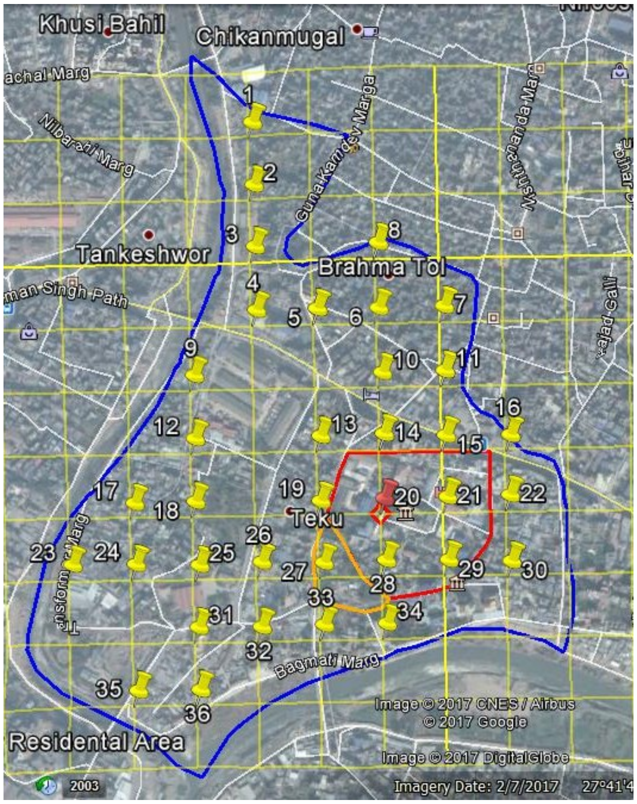
Step 5. An immediate boundary (block selection) around the random start point would be identified. The household listing exercise would be carried out for all the households that fall within this boundary.

Figure 6. Block selection around random start point



Step 6. An additional boundary (outlined in orange) would also be identified to be used in case the immediate boundary does not have the minimum number of households (275 household) required for household selection. Such additional boundaries would be pre-identified only to be used in cases where the household listing exercise does not meet the minimum required number of households.

Figure 7 1st extension (outlined in orange) added to selected block



ANNEX 2: Household Listing in sparsely populated rural areas

Figure 8. Aerial view of the selected ward (outlined in red) with the closest roadway visible (outlined in yellow).

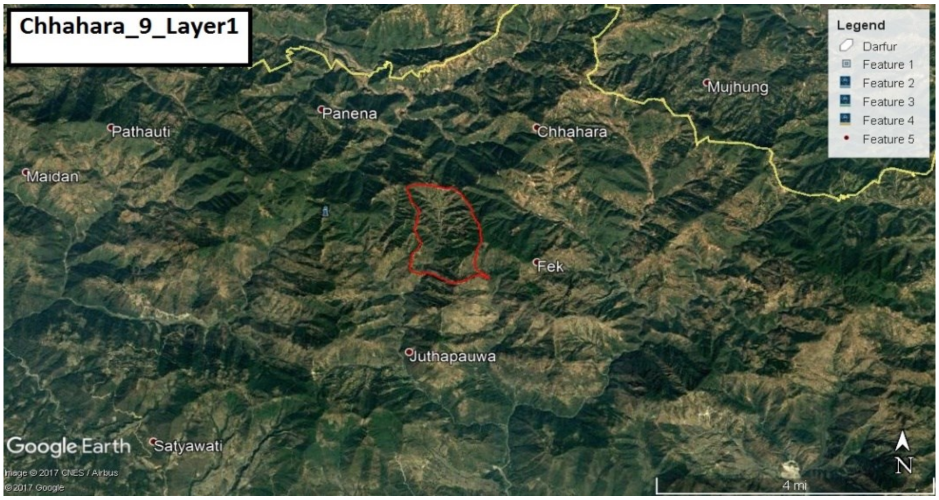
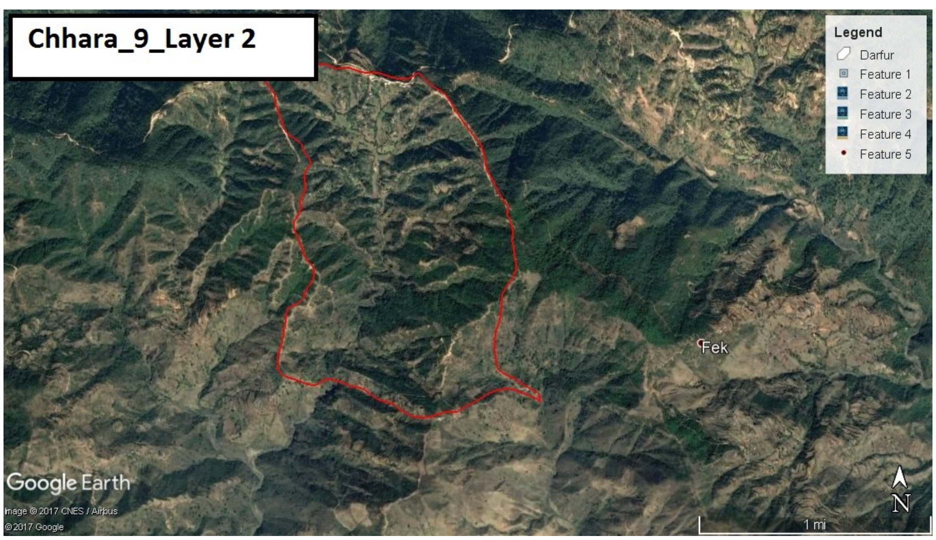


Figure 9. Zoomed in view of the ward



Chhahara_9_Layer_3

view of the wards showing the terrain and the scattered households