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Identifying Methodology for Assessing Sustainable Energy Technology for Rural Bangladesh

Abstract: The paper aims to identify methodology appropriate for assessing Sustainable Energy Technology (SET) for rural population in a way so that the technology fits with rural people's need, aspiration, and economic and technical ability. Available literature suggests good number of methods but their main focus is either on specific energy technology or on environmental impact. This paper aims to fill that gap. Based on secondary data, the study found that appropriate method should address the socio economic and technical variables while assessing technologies for rural community. The study suggests that methodology should use more than one technique to collect data from primary source. Findings of the study might be useful for researchers, development practitioners and energy policy makers.

Key words: Sustainable Energy Technology; Methodology; Rural Bangladesh

1. INTRODUCTION

The main thrust of studying Sustainable Energy Technology (SET) for rural communities is to assess the SET in a way so that the rural population can achieve their desired development goals with minimal environmental damage. Generally this type of study is heavily dependent on both primary and secondary data, and particularly data from the energy users. Therefore the basis of using any particular methodology to assess SET is associated with the perceived needs and problems associated with meeting their energy needs.

The way these needs and problems relate to the existence of locally available energy sources, including biomass, solar, and wind power technologies, and the way people view them, forms the main purpose of information collection. The methodology should be developed and, as much as possible, used in a manner so that rural people feel comfortable to participate with the data collection team, so that their social attitudes, economic circumstances, technical skills, and cultural behaviour are taken into account during the data collection.

It is a fact that the methods appropriate for collecting information from primary sources are largely dependent on the socio-economic and cultural background of the respondents. In other words, before applying any particular method, it is very important to consider who the respondents are, what their cultural background is, and what their economic circumstances are. For instance, data gathered by using a structured questionnaire through door-to-door interviewing methods in a developed country would be different from that of data collected using the same questionnaire in a developing country's society.

Let us consider an example to explain the situation more clearly. If we ask respondents in New Zealand about their annual income, they may be able to give the correct, or very close to the real figure of their annual income—

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or they would refuse to answer that question.

That means the collected data would be reliable. On the other hand, the same question in Bangladesh or any other developing country is very likely to lead to an exaggerated or biased response. This is because the socio-economic and cultural backgrounds in the two countries are different. A respondent from Bangladesh is used to seeing corrupt practices in their every-day lives, where making a biased statement is not considered to be a major issue.

Indeed, the social values, education level, cultural norms, and economic freedom of the two societies are different, which influences the respondents' choices. That is why there must be a consistency between the ontological query, epistemological environment, and the survey method (Fredrick 1998, Shiijun 2000).

For example, there are several issues relating to the country and its history that might affect the context of research in Bangladesh. First, Bangladesh was a British colony for more than 200 years, until 1947. During the period of integration in Pakistan (1947-1971), and even after independence (in 1971), the country was ruled by military governments (Ali 2011). Second, about 60% of its annual development budget comes from foreign aid. Third, people are relatively conservative due to lack of education.

In the rural Bangladesh, 35% of population live in absolute poverty (BBS 2010). As a result of these factors, it is necessary to devise research methodologies that are culturally appropriate, for example, appointing local interviewers and applying more than one method of data collection.

The fact is that the number of literature in the field of analysis methods and techniques for assessing SET for rural community is very limited. Moreover, most of them are focused either on a particular type of energy technology or the impact of energy on environment (Ali, 2011, 2006, 2005; Senwela 1997; Senwela and Hall 1993). That means the identification of appropriate methodology issues has largely been unaddressed. This paper aims to fill that gap.

The main research methodologies adoption involves several stages. In this paper, we have discussed identification of parameters in section 2; nature of demand and supply in section 3; household as a unit of measurement in section 4; energy users' background in section 5; environmental issues in section 6; data collection issues in section 7 followed by conclusion in section 8 respectively.

2. IDENTIFICATION OF PARAMETERS AND THEIR DEFINITIONS

Definitions of variables are directly related to the purpose of data analysis. In other words, objectives of the study indicate what type of data is needed and whether data would be required from secondary sources, primary sources, or from both sources (Ranjit 2005).

The main objective of the study should be to identify a methodology by which the best option of SET might be chosen for rural community such as Bangladesh. The thrust should be to assess the long-term socio-economic and technological viability of three energy technologies (biomass, solar, and wind power). The study should be involved in analysing the following:

- a. Current state of commercial energy supply and demand in Bangladesh;
- b. Description of present energy management;
- c. Critical evaluation of current energy management;
- d. Critical evaluation of future energy supply and demand in the rural Bangladesh;
- e. Critical evaluation of energy resources of Bangladesh;
- f. Assessing the feasibility of SET in the rural Bangladesh; and
- g. Identifying the best SET for the rural Bangladesh.

Task (a) involves looking at the current supply and demand scenario of energy sector of Bangladesh. To achieve that, data should be used on the quantity of energy produced and consumed nationally, major sources of energy supply and production, the pattern of energy distribution with respect to both rural and urban sectors, deficiencies in supply, relationship of economic growth with investment in energy sector, and the historical background of energy demand and supply of the country as a whole.

To perform this task researcher should use data mainly from secondary sources. The main sources might be the published documents, research reports, annual and perspective development plan documents, energy policy of the government, statistical year book etc. The main agencies that might be consulted should be Ministry of Energy, Power Development Board, Bangladesh Council for Scientific and Industrial Research, Petrobangla, Bangladesh Bureau of Statistics, Bangladesh Institute of Development Studies, libraries, universities etc.

Tasks (b) and (c) might also be performed by using secondary data of the above-mentioned types, but special attention should be given to the contemporary energy policy, institutional arrangements, production and delivery networks, type of grid lines used, power distribution policy etc., with regards to the rural sector. The main focus of these tasks should be to identify the weaknesses and shortcomings of current energy management. In so doing the energy management data from neighbouring countries, and some global data should also be used as a basis for comparison.

Task (d) involves having an insight into potential energy demand and supply scenario in the rural Bangladesh. To achieve that, researcher should use data on the potential future sources of energy, looking for the sources that would be sustainable for long-term use, other impacts of using the resources in the future etc. Researcher should also use data regarding current and future energy-consuming activities, relevant impact on the socio-economic life etc.

Task (e) involves critical assessment of energy resources of the country. For this purpose, researcher should use data regarding the types and availability of different energy resources, their quantities, their future sustainability, the cost and benefit of using those resources, their financial and technical feasibility etc.

Tasks (f) and (g) involve assessment of appropriateness, and identifying the most viable SETs in the context of socio-economic factors of the rural Bangladesh. For doing that, data should be used resource base of producing energy, degree of technological complexity of SET, levels of technical know-how (e.g. education and training), attitude of people towards SET (e.g. willingness to participate in SET transfer), etc. In this context, data regarding the impact of SET on the environment, poverty, and future lifestyle of rural population of Bangladesh might be used.

Considering the above tasks, the major parameters for investigation of this type of study might be the sources available for energy supply, nature of energy consumption, potentiality of sustainable resources (sunlight intensity, wind speed, biomass production etc.), income, land ownership with type, education, attitudes of prospective consumers towards accepting the SET etc.

3. NATURE OF DEMAND AND SUPPLY OF ENERGY

Identifying a method for assessing the most feasible SET for the rural Bangladesh is a vital component of this paper. For achieving the study objectives, it is necessary to have a clear understanding of the concept and nature of demand and supply of energy and SET so that necessary data could be gathered accordingly.

3.1 Demand for Energy

According to economists, the Demand for Energy (DE) is the will to consume a certain amount of energy of a specific nature at a particular point of time backed by economic ability. According to this definition, the components of DE are the price, type of energy available for use, and the consumers' purchasing power used to procure that energy.

This definition is valid at a static point of time, and is bound to be misleading because the ability to use energy is a dynamic variable. Ability of energy use varies with time. For example, even if all the determinants that consume energy directly or indirectly remain unchanged, the need for energy might change because of the change in the population standard of living. It implies that the demand for energy is a function of the state of the national economy.

Economic growth of a society is directly related to the growth of population, housing, urbanisation, electrification, industrialization, climate etc. which are not static, but continuous with time. That means the need for energy is always changing with time, and hence DE is dynamic. Keeping that reality in mind, SET related study includes the factors of DE, which somehow influence the energy requirement. In Bangladesh, these factors are mainly agriculture, household, industry, production of energy, transport, commerce, service sector, and technological base of energy production, distribution, and end use.

Since its independence, Bangladesh has experienced an enormous rise in energy demand because of:

- a. A process of transformation from predominantly rural to urban society,
- b. Large scale rural to urban migration,
- c. A high rate of industrialization,
- d. Infrastructural developments,
- e. Transformation of agricultural sector from manual to mechanised (limited),
- f. Growth of rural industries,

- g. Expansion of the service sector,
- h. Tremendous growth in the transport sector,
- i. Rural electrification (limited), and
- j. Use of natural gas as an input in the fertiliser and power industries.

Hence, the estimation of demand for energy in Bangladesh would refer to the demand for energy at present and potential demand from all sectors of the economy. But it is evident that as a result of huge energy demand, the present energy management is mostly concerned with the supply of energy in the urban sector where the rural sector has been neglected.

Moreover, it is also evident that in the rural economy, energy demand for household purposes and agriculture is a prime need for the rural population. Hence, SET related study must consider the present and potential demand for energy in these two sectors of the rural Bangladesh. SET related study refers to the potential demand as the expected demand for energy as a result of the changes in the state of the economy and living standards.

However, for simplicity, the demand for energy may be estimated as the sum of energy to be used for different activities by a particular consumer. For example, demand for energy of a household is the sum of energy used for cooking, plus lighting, plus heating, plus drying, plus entertainment etc.

3.2 Supply of Energy

Generally, energy supply implies the amount of energy that would be available from different energy sources for particular purposes. But issues such as energy required for energy production and energy losses from distribution channels are associated with the energy supply management. The amount of energy produced from a generator is not the same as the amount of energy available to the end-users. Therefore, the total demand for energy in a country is much higher than the net demand for energy from the end-users. It is evident that this issue is generally been ignored in energy management of developing countries such as Bangladesh (Ali 2006).

For instance, in 2001, the demand for energy in Bangladesh was 682PJ, out of which energy locally supplied by biomass and natural gas was 400PJ. Hence management would import $682-400=282$ PJ-equivalent fuel (Ali 2006). This demand was calculated as the sum of expected need of energy for different sectors (e.g. domestic, industrial etc.). In the following year it was found that a reasonable amount of energy (more than 50PJ) was spent as transmission loss, conversion loss etc. The need for energy to convert the imported fuel into local usable energy form was not shown in the total energy demand figure. This misleading calculation creates a false picture of energy supply in Bangladesh.

Further, as the urban sector is the privileged beneficiary from imported fuel, the net shortages create multiple effects on rural community. However, for the sake of simplicity the methodology should refer to energy supply as the amount of energy that would be available for end use by all consumers.

4. HOUSEHOLDS AS A UNIT

As in other societies, 'household' and 'family' are important basic economic and social units in the rural Bangladesh. They combine production, consumption, service, and social functions. Most traditional rural households in Bangladesh produce their own food, and their houses are built from naturally available materials such as wood, bamboo, and straw. Tools and utensils are usually self-produced (e.g. clay-made pots/plates, bamboo-made spoon etc.), as are sometimes clothes.

The connection of the farmers to the market is weak, and their purchasing power is limited: a small surplus of production is sold in the market, and a few items such as salt, kerosene, matches, or medicine are bought there. Sometimes, if there is an extra surplus, it is saved to meet the expenses of children's marriages, especially to give dowry to a daughter's husband. Community services and social identifications are also centred on the household.

Furthermore, rural households are the major consumers of energy. The main demand for energy in rural Bangladesh is for cooking, crop processing and lighting. But it may be true, apart from these needs, some other types of household activities such as farming, washing, entertainment are also important for rural households—to some degree at least. Interestingly, although the demand for these types of activities is low compared to cooking, the trend is increasing.

The reasons might be changing social attitudes and lifestyles. Therefore the pattern of energy demand is not static, and hence dynamic with socio-economic factors of a society. The SET programs should be based on a sound understanding of the changing nature of households in rural communities and hence the methodology should be chosen accordingly.

4.1 Family Size

Family size is directly related to energy consumption. In general, a large family consumes more energy than a small family. However, this hypothesis might not be always true. For instance, if a four-member family consumes 20E-6PJ energy a year, a two-member family should consume 10E-6PJ in that same year (Ali 2011; 2006; 2005). But in reality, energy consumption is not as linear in relation to family size as that. A bigger family does not consume energy in direct growing proportion to a smaller one. In fact, a large family consumes less (saving) energy per capita compared to the smaller family. However, although different literature use family sizes in different ways, it is advisable to use family size as per approved government documents such as statistics department.

4.2 Joint Family

Understanding the nature of family is essential for analysing energy issue in the household sector. Generally, the number of family members in a joint family is more than the number in a single family. Moreover, members of a joint family are not limited within one relationship. For example, in a joint family, parents, children, grandparents, grandchildren or even distant relatives live in a household. Most household and commercial activities are run and managed under a common leadership in a joint family. The most important characteristics of a joint family is the sharing of resources by all family members. Therefore, it is very difficult to differentiate who uses how much resource.

For example, an adult son of a joint family is married and father of a child, lives with his wife and child in a separate house but within his parent's premises. Sometimes they cook food by themselves, and sometimes they cook their food on the parents' stove. Or even, although their child lives with them, they use light for his/her study in their grandparents' room. Indeed, joint family is a part of culture and a very common practice in rural Bangladesh, and this situation complicates the analysis of the issues of energy demand and supply in the household sector of rural Bangladesh.

5. BACKGROUND CHARACTERISTICS OF ENERGY USERS

The demand for energy, the type of sources used, and overall the acceptance of SET socio-culturally depends on the background characteristics of the energy users. The background variables are the land ownership, income, education, awareness of environment, and the attitudes towards sustainable energy sources. Reflection of these variables in methodology is essential so that data could be gathered accordingly.

5.1 Land Ownership

Land ownership refers to the quantity of land a household owns legally, irrespective of their uses. The term 'legal' refers to the relevant law of the country. The fact is that a household might own land under the ownership of different family members. Also, that family might have different categories of land such as cultivable land, fallow land, forestry etc. But as the analysis of biomass production is directly related to land, forestry, and agriculture, data should be collected on land owned by a household by legal title into different categories, then added them together to find out the total land.

5.2 Household Income

Generally, a household might have income from different sources, for example, from service, business, investment, interest etc. Also, there might be more than one income-earner in a household. Considering the physical constraints of investigating all types of income separately, methodology should define the income as the sum of annual income from different sources by different income-earners in a household. Also, as the tax deduction rate is different for different countries, it might be difficult to estimate disposable income for a particular household. Therefore, methodology should consider income as the household total annual gross income from all sources.

It is notable that some of the respondents may be reluctant to disclose their income-related information due to fear of taxation or general suspicion. In those cases, the income of a particular household should be estimated as the sum of annual expenditures for different activities plus the savings in that year.

5.3 Education

Education is another important component in analysing the background characteristics of the energy consumers in the rural Bangladesh. The overall literacy rate in Bangladesh is lower than many developing countries, where that of rural population would obviously be much less. It is better to measure the education level according to the approved academic qualifications of the country.

It is possible that a person might not have a formal academic degree or qualification but be able to read and write: will s/he be considered literate or illiterate? The answer is illiterate. This has been done for two reasons. First, for the sake of simplicity, and second, it would be difficult to justify her/his depth of academic knowledge. That is why the study should categorise education levels as illiterate, primary, secondary, higher secondary, bachelor and masters and above.

6. ENVIRONMENTAL AWARENESS

Environmental awareness is a key factor for transfer, diffusion, and sustainability of SET. This is more important in the rural Bangladesh because of the socio-economic conditions of potential SET users. The methodology should refer to environmental awareness as the knowledge of energy users (rural population) towards environmental quality, reasons for environmental degradation, effects of environmental damage on their lives, and the attitude towards protecting environment.

Respondents may be asked whether they are aware of the possible reasons for frequent flooding or drought in Bangladesh, whether they know what causes air or water pollution, and whether they know that deforestation harms the environment. If they can answer these questions correctly or reasonably correctly, they may be considered to be environmentally aware. Otherwise, they should be classified as environmentally unaware.

6.1 Willingness to Participate in SET Transfer

Willingness to take part in the SET transfer is another major parameter in this type of study. This is simply because SET transfer would not be effective unless the potential energy users are willing to accept, learn, and use it. This type of study should measure this parameter by asking question whether and how the respondents would participate in the SET transfer, in what form they would contribute to making SET successful in their locality etc.

7. METHODS OF DATA COLLECTION

The methods of data collection for this type of study may be questionnaire survey, participant observation, and participatory rural appraisal techniques.

7.1 Questionnaire Administration

After completing sample selection, the appropriateness of the draft questionnaire should be tested by conducting a 'pre-test' survey. The questionnaire should be drafted on the basis of the objectives and theoretical frameworks set out for the study. After pre-testing, the draft questionnaire should be modified accordingly. That modification may involve the inclusion of some new ideas, as well as exclusion of some prior assumptions.

7.2 Participant Observation

The participant observation method is used to fill the gaps apparent in the interview method. There are some socio-economic and cultural issues where better results can be obtained by observing the respondents' behaviour rather than asking questions in a straightforward way. In the participant observation process interviewer observes the respondents' behaviour, and takes note of the relevant information, in addition to asking questions while interviewing. Hence, interviewing through a pre-designed questionnaire together with participatory observation produces better-quality data.

The use of two techniques together in data collection can be seen in a good number of researches. For instance, Senelwa (1997) has used the questionnaire as well as participant observation methods in his energy study. Ranjit (2005), Senelwa and Sims (1998) have also put positive comments in favour of using joint techniques in their article on the methodology of energy planning. Jurgen and Harmut (1975 cited in Hossain, 1995) state that the use of two techniques together can give a better-quality database. In fact, the use of more than one method in data collection always compensates for one another's deficiency, and provides a better scope of investigation, especially in social science researches.

7.3 Participatory Rural Appraisal

There is a wide range of methods used to engage communities to participate in development programmes. PRA is a methodical framework for understanding and assessing rural (and urban) situations, and planning development. They are based on attitudes, methods, and exchange. The knowledge of local people is taken as the starting point, and visiting planners or administrators learn from them, by using many different locally adapted methods. The ultimate goal is to identify possible concrete actions, based on shared understanding of the situation at hand (Jegillos 1997, p.5; also see Hossain and Sen 1997; Johnson et.al 1993).

The PRA philosophy is based on the principle that development should not be imposed, people's felt needs and aspirations must be focused, local people know more than we do, and rural people should be regarded as partners in the development process. They can not only provide information, but also analyse it effectively. This mechanism can ensure sustainability of the project because of the local people's involvement right from the beginning of the project until its end (Jegillos 1997, pp 2).

It is notable that the aim of the paper is to identify the appropriate methodology to assess SET for the rural Bangladesh where the recipients' attitude and reaction have a strong role to make the option viable. Data might be collected from secondary sources or by using a pre-designed questionnaire administration or participant observation technique would not be sufficient for knowing the recipients' ability, knowledge, and the reality. The issue might be more serious if the prospective users of the transferred technology are low-educated and suffer from poverty as is the case with Bangladesh.

One of the limitations of interviewing by a pre-designed questionnaire is the gap of understanding. Understanding gaps may arise either from interviewers or from respondents. To overcome this situation, the study should use the PRA technique to collect data, in addition to the questionnaire survey and participant observation method.

In fact, the use of PRA method, in addition to interviewing and participant observation methods, can overcome the shortcomings of interviewing system, and can provide an extra layer of better-quality data.

7.4 Sampling Design

Ecologically Bangladesh is divided into four regions. Although the country as a whole is flood-prone plain land, the regions differ significantly according to land type, population density, literacy, agricultural pattern, and availability of natural resources. For example, all natural gas wells identified so far are situated in the Eastern zone of Bangladesh. Similarly, agricultural cropping patterns differ in the Eastern, Western, and South-Western zones. Due to these agro-ecological differences, the pattern of energy consumption and energy sources used is also different from region to region.

Administratively, six divisions represent four regions. Therefore, primary data of the study might be collected from the six villages sampled from six divisions so that the result of the survey is representative of the country as a whole. For example, the number of sampled villages might be:

$$6 \text{ Divisions} \times 1 \text{ Upazilla} \times 1 \text{ Village} = 6 \text{ Villages}$$

The criteria of selecting six villages from six divisions are location, remoteness, population, their near-absolute dependence on traditional energy sources such as biomass, and their related needs. The procedures of selecting households for data collection along with some of their socio-economic characteristics may be as follows.

A three-fold procedure can be employed for data collection. First, a 100%-census of all households of the six villages should be conducted to collect the basic statistics of physical, social, economic, demographic, and energy resources (forestry, livestock, sunshine, wind flow etc.). Also, some other basic information about these six villages (geographical location, land areas, land types, agriculture cropping pattern, sources of energy supply, nature of energy uses, existence of energy production plants, fallow lands etc.) might be collected from the documents available in respective upazillas. The households should be categorised on the basis of this information.

7.5 The Questionnaire

As this type of study is heavily dependent on primary data, the questionnaire should be designed in a manner sufficient for gathering adequate and correct field information, to achieve the research objectives. In designing the questionnaire, the first task may be to make a list of issues relevant for our analysis. The thrust of designing the questionnaire should be directed at the types of necessary data and the reasons for their choice, and alternative ways of collecting that information.

The questionnaire may consist of five sections. The first section regards the background characteristics of respondents (name, sex, size of household, occupation, quantity of land owned and its types, number of cattle owned and their variety, income etc.) This information will be needed to identify 'who is who' in the rural society, and the respondents' basic socio-economic characteristics.

The second section regards the sources of energy supply available in the respondents' society. This may include all available types of energy sources (electricity, dung, trees, leaves, gas, kerosene, wood, gas cylinder, petrol, diesel, LPG etc.).

The question about the pattern of energy demand and the nature of energy consumption may include in the third section. Respondents might be asked what they do with energy, recording all possible types of consumption. The main variables of energy demand would be cooking, lighting, washing, entertainment, security, machine operation, heating, air conditioning, fan operation etc. For simplicity, this section may be divided into two parts: household and commercial consumption.

The next section may include the present state of energy technology of the locality. In this section main questions might be asked about the existence of solar, wind, biogas, or any other forms of energy production plants in that locality. The potential demand for energy questions may include in the following section. In this section, particular emphasis may be given to what they would do if more energy were available. Alternatively, which of their activities has been suffering from energy shortages.

Information about management of energy technology may be included in the last part of the questionnaire. Respondents may be asked whether they would prefer to use the SET individual ownership or co-operative system of management. In this section, questions may be asked about the types and nature of resources they would suggest for establishing the energy plant(s). In fact, the information on the respondents' attitudes, ability, and willingness regarding SET transfer are included in this section. Ability may be measured in terms of investment capacity of land, labour, entrepreneurship, and capital. Information regarding the respondents' environmental awareness and knowledge of sustainability might also be included. The last part of the questionnaire can be kept open for respondents' comments.

7.6 The Interview Team

Interviewers for this type of study should be recruited from either the surveyed or a nearby village. They may be either college or university students. Proper training should be given to the interviewers after recruiting them. Careful attention must be given to the use of the language and the research objectives so that they realise the importance of quality data and are committed to their job. Interviewers may be instructed to use the mother tongue, if necessary, while interviewing. This needs to do minimise misunderstanding.

There might be a number of advantages in recruiting interviewers from individual local villages. They facilitate the entry to the village, as they are known to the locality and aware of the socio-economic and cultural background of the villagers. Thus, they can provide basic information about the respondents and the locality. Without that assistance, it may be difficult for researcher to find out 'who is who' in the village, and who should be asked for co-operation.

And finally, being local, it is easier for interviewers to make researcher trustworthy to the villagers and get the responses effectively. Sometimes, interviewers correct the respondents' answers if they provide absurd information due to fear or lack of knowledge.

8. CONCLUSION

Based on the above discussion, it can be concluded that assessment of SET for rural community requires data from both primary and secondary sources. Primary data may be collected using three methods: pre-designed questionnaire administration, participant observation, and PRA.

The main parameters of investigation might be: pattern of energy consumption, potential demand, availability of energy resources, respondents' ownership of resources (e.g. land, forest, cattle etc.), their income, education, environmental awareness, attitudes towards SET, ability to contribute to SET etc. These parameters are directly related to the socio economic and technical conditions of the rural population, the energy users. Hence the methodology of collecting data requires careful attention.

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