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The Transfer of Sustainable Energy Technology to Developing Countries:

Understanding the Need of Bangladesh

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Abstract: This article provides a critical review of the literature on potential Sustainable Energy Technology (SET) transfer as a means of mitigating Greenhouse Gas (GHG) emission, and preserving sustainable development within the rural community of developing countries, such as Bangladesh. A global concern about the rate of increase of GHG emission in the atmosphere makes it evident that it could be reduced through the use of SET rather than fossil fuel. Though SET is available in the global market, it is yet far from the reach of developing countries, which necessitates SET transfer from developed to the developing countries. However, there is a gap between reality and the ways and means of SET transfer suggested and discussed in earlier studies. This paper addresses that gap.

Key words: Sustainable energy technology; Greenhouse gas; Bangladesh

1. INTRODUCTION

Over the last two decades, there has been a great concern about ecological changes in the world, caused by global warming, greenhouse gas (GHG) emissions, and deforestation. There has also been a concern about poverty alleviation and sustainable development in the developing countries where energy use is a crucial issue. In fact, energy is a common factor, both at production and consumption levels, for many of the observed global environmental problems.

It is expected that energy demand will increase steadily to meet the needs of nations around the world, as industrial activities expand and the standards of living improve. If nothing is done, by the year 2025, the energy sector will have been responsible for 65% of the increase in GHG, with CO_2 emissions in the range of 12 btC/year, about double of the present volume (Ali, 2005).

This factor is of more importance because, although developing countries are currently responsible for less than 16% of CO_2 atmospheric concentration, the dimensions of future emissions are expected to change. It is expected that a higher per capita energy demand will be observed in the developing countries as their population continue to grow and they try to achieve a higher rate of economic development, they cannot possibly reduce GHG emissions by themselves alone. In other words, there is a need for transfer of sustainable energy technology

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(SET) around the globe.

The aim of this article is to analyze relevant researches in the field of SET transfer, aimed at mitigating GHG emissions and meeting energy needs, taking into account sustainable development and poverty alleviation in rural communities. The main focus of analysis is the relations among the nature of energy demands, feasibility of SET in view of specific needs to maintain sustainable development, and the people's perception of acceptability of the proposed SET in the developing countries, with special emphasis on Bangladesh.

The analysis is organised into three sections. The first section covers the studies relevant to global concerns about environmental effects of the use of fossil fuel (GHG emissions, ecological changes etc.). The second section covers researches that have examined and proposed the possibility of introducing SET as a means of providing a sustainable energy source and alleviating poverty in the developing countries. The third section covers the researches on Bangladesh energy sector.

In addition, to understand the role of SET for poverty alleviation in the developing countries, we analyze the conceptual debate on the relationship among poverty, environment, and sustainable development. Finally, based on the above-mentioned analysis, implications and conclusions are presented.

It is worth noting that issues of environmental degradation, energy use, sustainable development, poverty alleviation, and technology transfer are so inter-related that it is very difficult to differentiate them in absolute terms. Therefore, in some instances, analysis might be presented on a broader scale rather than pinpointing microscopic details.

2. STUDIES RELEVANT TO GLOBAL CONCERN ABOUT ENVIRONMENTAL EFFECTS

Although the issue of climate change has been discussed since the beginning of the 20^{th} century, the last two decades saw a universal concern about the threat of ecological change, environmental damage, and overall global warming, caused mostly by the current pattern of energy production and consumption (Ali, 2005, Fleming, 1998).

It is argued that the earth cannot withstand the constant and irrepairable damage to the ozone layer, and the effects of increasing global warming. It is also argued (Thompson, 1996) that as a result of using environmental resources in an unsustainable way, the grass root population of developing countries cannot come out of the vicious circle of poverty.

It is opined (Cavendish, 2000) that the results of development programmes financed by developed countries have not reached their target groups. The gap between the rich and the poor is becoming wider and the environment is being degraded at a rate greater than the earth can afford (Prakash, 1997). Such concerns have forced the United Nations as well as the leading countries in the world to take a serious note of climate change and take measures to address the problem. One such major international effort was the Rio Earth Summit 1992.

The major outcome of Rio Earth Summit was the recognition of global environmental threats as a common problem, irrespective of the countries' socio-economic status, by the heads of leading countries and international forums (Bebbington, 2000).

Rio Earth Summit adopted the following important resolutions: (1) signing of two legally binding conventions (Framework Convention on Climate Change (FCCC)) and Convention on Biological Diversity; (2) statement on Principles of Forest Management; and (3) Rio Declaration on Environment and Development (Bebbington, 2000, pp.8). Indeed, while Brundtland Report brought the sustainable development concept into the wider world, Rio Earth Summit has formed a platform for the policy on sustainable development (Grubb et al, 1993).

Rio Earth Summit recognised that the main reasons for increasing CO_2 concentration in the atmosphere are the use of fossil fuel, performing economic development activities in an unsustainable way, and the poverty of the

Third World population. In fact, Rio Earth Summit (Grubb et al, 1993) attributed the Third World poverty to its unsustainable development programmes, and the way energy is being used, emphasising that the above would pose a threat to future environmental degradation, increase GHG in the atmosphere, raising the issue of SET transfer.

Nakicenovic (1994) studied the perspectives of GHG emission on a regional basis. He stated that the developing countries are responsible for less than 16% of the CO_2 concentration due to their past consumption of fossil energy. The developed countries have a much higher share in global emissions than the developing ones.

In other words, GHG concentration is an exhaustible resource used by the industrialised countries to achieve their current levels of development. Therefore, relevant historical responsibility clearly rests with the industrialised countries. The global community is concerned that future emissions are expected to increase mostly in the developing countries, as the size of their population continues to grow, and per capita energy consumption increases due to the fast rate of economic growth.

Nakicenovic further states that the developing countries, struggling with poverty, currently have to deforest to meet their immediate energy demands, which in turn changes the land-use pattern, negatively influencing the natural environment. They are also using fossil fuel, thus following the historical development path of today's developed countries. At the same time, as they are struggling to grow more agricultural produce, they cannot reduce GHG emissions by themselves because of their economical and technical incapability. This causes a growing concern about global environmental degradation in which the current energy consumption pattern is a major contributing factor.

The findings of Nakicenovic's study are based on secondary data, and the methodology of his research is limited to literature review only. Moreover, although his study recommends the use of renewable energy technologies instead of fossil fuel for mitigating GHG emission, and advocates the need for technology transfers supported by resource flows (wherever applicable) from the North to the South, it does not elaborate on other conditions associated with the transfer of technologies to the developing countries.

In addition, his study does not address the issues of available technological options, their effectiveness in reducing GHG emissions, the costs of reducing emissions, and the requirement of adapting technical options to the users' choice, abilities, and demands.

Edmonds and Reilly (1985) carried out an assessment of the global energy for future use. Their analysis focuses on the issues of the quantity of energy to be produced and consumed in the world in the next century, impact of the energy transformation on environment, and long-run economic behavior in production and consumption sectors of the global energy market.

Their analysis recognises the global interdependence in exporting and importing energy resources (and/or services). According to them, energy problems should be viewed from two angles - energy production and energy use.

They found that the global use of energy is largely influenced by the five determinants: demographics, labour productivity, income, energy prices, and energy productivity. In other words, they recommend the use such parameters as population, economic activity, technological change, prices, and energy taxes and tariffs as inputs in determining global energy demands. Further, they have classified energy supply technologies into three generic categories: Resource-Constrained Conventional Energy, Resource-Constrained Renewable Energy, and Unconstrained Energy.

However, their assumptions are limited to the analysis of the current state of available energy technologies. Consequently, the issue of technological growth and changes has been omitted. Technological growth and its dynamics strongly influence economics of technology transfer.

Furthermore, Edmonds and Reilly's analysis of energy forecast, based on secondary information, does not account for the informal sector, though their research includes most of the variables related to the energy demand. It is a widely-known fact, though, that informal sector such as unorganised rural communities not only consumes large quantities of energy but also significantly contributes to the national gross domestic product (GDP) (Cavendish, 2000).

For example, in Bangladesh, 30% of its GDP (Ali, 2002) comes from the agricultural sector where rural sector is the main contributor, but energy sources for the rural population are unorganised and informal. Informal sector has not been accounted for in their analysis of the supply side, either. For example, rural communities derive most of their household energy requirements (cooking, heating etc.) from the abandoned forestry and livestock sources. In the developing countries such as Bangladesh, the informal sector plays a very important role (both in supply and demand).

Similarly, in forecasting global energy demand and supply, they have accounted for population size parameter, subdividing it into two categories: workforce and non-workforce. But in the developing countries, under-employment in workforce population is an important factor, and hence, while considering the productivity as a variable of energy consumption, the question of under-employment can hardly be ignored.

Furthermore, as a means of reducing CO_2 emission, the authors recommend the use of mixed energy technologies (fossil fuel and renewable sources), but it is not clearly stated whether fossil fuel would largely be replaced by renewable energy sources. In addition, the issue of natural CO_2 absorption has not been raised, hence the recommended way of CO_2 emission reduction might be far from reality.

Barfield, Clarke and Loewer (1994) conducted a study on the long-term effects of the biomass energy in reducing CO_2 emission in the atmosphere. They state that, as the use of fossil fuel is the main reason for the increase of GHG atmospheric emission, the use of biomass-derived fuel may be an alternative to its reduction. They substantiate their viewpoint with the following reasoning: a completely biomass-derived fuel system is carbon-neutral over a long period of time, thus biomass fuel production and use do not contribute to the accumulation of GHG. The quantity of gas consumed in producing the biomass is equal to the quantity generated in conversion and combustion. If such biomass system is to have an impact, it must be used on a global basis.

However, Clarke in his earlier studies (1991), states that the use of biomass could be the largest single source of fuel in the 21st century. He also states that, although biomass energy system is carbon-neutral, it is not necessarily totally environmentally neutral. To make it environmentally sustainable and neutral, environmental neutrality needs to be analysed (pp.383), i.e. the technologies available for energy production and supply need to be modified and renovated according to the users' demand.

They also state that environmental sustainability of the use of biomass system as an energy source should resolve the following questions: under what conditions would a global biomass production system be economically viable? What would be the demand and supply costs for the biomass-derived fuel? What would be the characteristics of such system? And could such system be environmentally sustainable in real terms? To make the biomass energy system sustainable, they advocate that it return all by-products of biomass conversion back to the land.

In another study, Ahmad et al (1999) characterises the global energy system on the basis of three elements important for determining future environmental effects. These elements are: the amount of carbon emitted per unit of consumed energy, the amount of energy used to produce a unit of GDP, and the amount of GDP per head of population (also see Jaffe et al, 1999 and 1994).

It follows that the amount of emitted carbon is the proportion indicator of fossil fuel use in the system of energy sources; the amount of energy used per unit is the indicator of the energy efficiency in the economic activities; and the GDP per capita is the measurement of public welfare. This analysis bears a strong similarity with that of Edmonds and Reilly (1985). However, the dissimilarities lie in the methodology of estimating CO_2 emission.

For example, Ahmad et al mention only fossil fuel as a source of CO_2 emission, while Edmonds and Reilly state that the use of both fossil fuel and renewable energy may result in CO_2 emission, and do not specify that renewable energy sources are free from CO_2 emission.

Johansson et al (1993) state that as the global economic aspirations increase rapidly, energy demand will also increase irrespective of the energy efficiency mechanism used. Given the necessary support, the renewable energy system can meet that growing demand with lower prices than conventional fuel (also Sims, 2001, Howarth, 1997, pp.1).

According to them, by the middle of the 21st century, renewable sources can meet 60% of the global electricity demand, and 40% of the market demand for the direct energy use system, i.e. the transition from fossil fuel to renewable sources could benefit the environment through reducing CO_2 emission.

For example, by increasing energy efficiency and using renewable energy sources it would be possible to reduce the CO_2 emission level by 25% as compared to 1985. They also argued that due to the relative novelty of renewable energy technologies, it would be possible to supply and modify SET at the lower costs (pp. 3-5), because fossil fuel energy infrastructure is older, well-founded, and faster, while the infrastructure of renewable energy technologies is still quite young. Therefore, the renewable energy system must be looked at in a global integrated context. Similar recommendations for modification of energy technologies and reducing GHG emission can be found in Hijikata (1994), Barefield, Clarke and Loewer (1994), Preece (2000), and Chakravorty et al (1997).

Read (1994) in his *Responding to Global Warming* says that, as per FCCC resolution, measures should be taken to control the possible problem of global warming due to GHG emission; and this problem can be solved at a much more affordable cost than we think, in ways that would motivate energy suppliers, and assist the process of economic growth and development in the Third World countries.

He says that the energy policy must be approached in an integrated and multidisciplinary way, through 'Tradable Absorption Obligation', to manage sustainable energy suppliers, along with the global reinvestment into advancing sustainable energy technologies, particularly biomass and wind power energy technologies. He argues that the benefits of transition to biomass fuel from fossil fuel are the certainty of undisturbed long-term energy supply, reduction of CO_2 emission, and the increase of natural CO_2 absorption.

Furthermore, according to Read, as the use of fossil fuel is one of the major contributors to the CO_2 emission in the atmosphere, an attempt to keep the former at a level of 1990 by the year 2020, as estimated by the FCCC, would not be possible unless a mechanism of natural absorption of CO_2 is introduced, through globally rebuilding forestry in an integrated way (2000 and 1997).

Read has pointed out that, although land is a major factor of tree plantation, forestry, and food production, there might be a choice to use land for tree plantations or for food—by planting trees for fuel instead of food-growing,

land owners can earn more money in exchange for fuel. In this case the real-terms return from the use of land for bio-fuel would be much higher (Read, 1997, 1998).

The above-mentioned studies can be classified into three groups, according to the time of their publication: pre-1980, 1980-1990, and post-1990. Pre-1980 studies mainly focus on managing energy supply sources in accordance with global demand (Flemming, 1998). In addition, after oil shock in the 1970's, the issue of increasing energy efficiency was gradually coming into the public focus. The environmental issue, though, was relatively less important at that time.

During the 1980's research was mostly concerned with energy efficiency, GHG emission, and management of energy demand and supply. This brought into focus issues of energy export and import both nationally and internationally. Particular attention was paid to finding alternative energy sources, and the relations among energy supply and demand parameters.

After 1990, particularly after Rio Earth Summit and FCCC convention, energy professionals became concerned about CO_2 emission, and the balance between energy supply and demand in performing economic activities at a desired level. This group attached significant importance to renewable energy sources.

Above analysis indicates that there is a growing concern about the increase of GHG emission in the atmosphere, with fossil fuel use being the major contributing factor. It also appears that there is a global attempt to control CO_2 emission, for which the need for SET becomes essential.

The above analysis also argues that CO_2 emission problem needs to be, and can be controlled by (a) reducing the use of fossil fuel, (b) increasing energy use efficiency, and (c) increasing the use of renewable energy sources, i.e. replacing fossil fuel with renewable energy sources. In other words, the means of reducing CO_2 emission is the transition of energy technologies from fossil fuel to renewable energy sources. But the mechanism of technology transition is left out in the above studies. Moreover, the concept of net CO_2 emission is also unclear.

Above analysis further indicates that although the global concern about CO_2 emission and replacement of fossil fuel use by SET is well-pleaded, there is a clear gap in the research on SET in the developing countries. No study has examined whether SET will be socially accepted in rural communities of developing countries such as Bangladesh.

3. STUDIES RELEVANT TO AVAILABILITY AND TRANSFER OF SET

Various issues of SET are covered in numerous researches, but the availability and the applicability of SET are discussed only in a few of them. This is because the general availability of SET does not mean that all types (especially in view of their technological complexity) are applicable for everything (Ali 2005, 2002). This situation becomes even more critical when considering a particular SET for a particular user. For example, though biomass or solar energy technology is available in the global market, it might not be suitable for use in the rural Bangladesh communities.

Sustainability enables the programs and activities currently undertaken to meet the needs of current generation, without compromising the needs of future generations. In this context, the concept of SET refers to the energy technology that is capable of providing energy to meet consumers' needs (demands) at an affordable cost on a long-term basis without disturbing (compromising) ecological balance. That means SET is environment-friendly and cost-effective (Ali, 2005, Ali, 2006). However, the viability of SET transfer depends on the socio-economic and technical background of rural population in Bangladesh.

Jaffe et al (1999) studied the global issues and options of energy efficiency technologies and climate change policies. They stated that although GHG emissions are the product of human behavior, per capita economic

activity, and energy use per unit of economic activity, the main contributor of carbon intensity is the use of energy technology (pp. 1).

They further stated that GHG emission is growing at a rate that exceeds the metabolic capacity of this planet, and is increasingly accumulating in the atmosphere, raising the possibility of global warming and other climate changes, which—in turn—could have a devastating effect on human activities in the near future. As the CO_2 emission, mainly caused by burning fossil fuel, is the main contributor to increasing GHG in the atmosphere, it could be reduced either by increasing the energy end-use efficiency, or by moving energy technology from fossil fuel to renewable energy sources. They consider the appropriate energy efficiency a means of controlling GHG emission (pp 2-8).

This study emphasises that fossil fuel technology can gradually become substituted by renewable energy technology, with the result of improving energy end-use efficiency. As part of this programme, users, producers, and other associates might be given relevant financial incentives, such as tax credit (pp. 8).

The authors advocate transfer of energy technology as an effective instrument of reducing CO_2 in the atmosphere (energy-efficient technology), and state the importance of technological invention, innovation, diffusion, and use of transferred technology in this regard. They recommend that everybody—from manufacturers to users of the proposed technology—should intervene to protect the market failure (pp 8-13).

They have used data from the UK sampled survey of household appliances, in which the efficiency of energy consumption is measured in terms of energy units and corresponding price per unit. They argue that an appliance consuming less energy for performing a specific activity, is efficient, and hence emits less CO_2 into the atmosphere.

Howarth (1997) has countered this idea with the following argument: as a result of increased technological efficiency of energy use, the ultimate energy demand might increase and cause the supply shortage. He stated that although the technological improvement would make energy more cost-effective, unless its cost dominates the price of product or service, energy demand growth would not be dependent on the increased energy productivity.

Ogimoto (1994) researched a possibility of exporting SET from developed to developing countries. He recommends to use SET (under the condition of its global availability) instead of fossil fuel to keep CO_2 emission rate within the desirable limit. The study further suggests that more resource-based countries should participate in the SET transfer so that it becomes available to the less developed countries. His work, though, does not address such issues of technology transfer as the recipient's choice, ability, demand etc.

Amsalem (1983) in his work *"Technology Choice in Developing Countries"* illustrates that technology transfer in developing countries should be based on the recipient's choice. He presents the mechanism of technology transfer, but does not address the issues of the required resources flow, and technology exports, which might be essential for mitigating GHG emission.

Ali (2002) states that a country might be in an "aid trap", if the technologies are not assessed according to the recipient's choice, i.e. technology transfer backed by the resources flow is still not sufficient to reduce GHG emission unless the technologies are matched with the recipient’s demands.

For example, it is recognised that solar energy is good for environment. But if solar energy technology is transferred to Bangladesh where the population cannot operate it due to the lack of technical know-how, such technology transfer would hardly contribute to reducing GHG emission (Ali, 2006).

Similarly, if ethanol production technology used in transport sector is transferred from developed countries to the rural Bangladesh, but its population suffers shortages of energy used for cooking, and historically, cooking is

one of the most important components of their livelihoods. To iterate, this technology would not correspond to the nature of energy demand of the rural population, and would hardly be effective for reducing GHG emission.

Hijikata(1994) states that the most important factor for managing future demand and supply of energy consistently with the desired environmental quality, is energy conservation through adjusting energy technologies. According to him, energy can be saved by changing national industrial bases (from producing high-energy goods to producing low-energy goods), and by making cheaper, smaller, but higher-quality electrical equipment. That is why all energy-saving initiatives should originate from economically and technically sound countries irrespective of their location.

As a means of reducing CO_2 emission, Hijikata recommends modification of the current energy technological structure in accordance with the environment, but does not discuss the issue of costs, and its impact on the global economy. Here, it is worth noting that renovation and modification of existing energy infrastructure is much easier to perform in developing countries as compared to developed ones—energy infrastructure of the latter is mostly based on fossil fuel whereas developing countries are still on their way to building it or developing the already existing infrastructure.

Hijikata further states that solution of global environmental problems, and SET transfer (including necessary technical know-how and capital) from developed to developing countries are very important. Environmental and energy problems cannot be managed by an individual country, they should be looked at as a globally integrated issue. It implies that transfer and management of energy technology is an international issue, requiring positive cooperation among the nations involved (pp 359-70).

The above analysis suggests possible reduction of GHG through using SET instead of fossil fuel, together with the relevant global initiatives. In other words, the required environment-friendly technology, which would meet energy demands, is available in the global market but no study has yet examined socio-economic acceptance of SET by the rural population in developing countries (Ali, 2005).

4. CONCEPTUAL DEBATE

The conventional literature in the field of sustainable development, poverty, and environment claims that the poorer classes of society are more responsible for environmental degradation because they use resources in an unsustainable way. However, some recent studies have shed some doubt on this conventional view.

4.1 Sustainable Development, Poverty, and Environment

In the modern world it is almost impossible to ignore the concept of sustainable development and its various derivatives (sustainability, sustainable growth, ecological sustainability etc. (Bergh, Straaten, 1994)) It is not exactly clear, though, what these various terms mean, how they relate to each other, and to what extent they contribute to an understanding of sustainable development. And proper understanding of sustainable development is crucial when dealing with energy –a key factor of the society's production and economic development.

Bebbington (1999) states that Brundtland report is often quoted as the first to introduce the notion of sustainable development into the political arena (pp. 4). But sustainable development debate has originated much earlier than acknowledged by Brundtland commission (Lele, 1991, pp.609): the concept of 'ecodevelopment' was proposed to describe the process of ecologically-sound development with positive management of the environment for human benefit, protecting environment 'for future generations'; in the 1972 Stockholm Conference (Holdgate et al, 1982, pp 7-10, McCormick, 1986, pp.182).

Brundtland report defines sustainable development as "*development which meets the needs of the present without compromising the ability of future generations to meet their own needs*" (UNWCED, 1987, pp.8).

However, although Brundtland report recognised the concerns of sustainable development and environment, it did not facilitate understanding of poverty and environment.

Reviewing the literature on sustainable development, Lele (1991) states that, as a result of inadequacy and lack of understanding of the relations among sustainable development, poverty, and environmental degradation, the policy and programmes undertaken so far cannot really improve the welfare of the poorer classes of the society (pp.1, also Bergh and Straaten, 1994). However, Lele's findings do not specify whether it is poorer classes of the society who degrade the environmental quality because of their poverty, or it is the already degraded environment that makes them poor.

Broad (1994) carried out a research on the relationship of the poor and the environment. His case study was undertaken in the villages of Philippines. He argued that the deterministic view of the relevant conventional literature is far from reality. His study established that the rural population is poor because they do not have enough resources for their economic development, with the environment having already been degraded.

Broad's hypothesis further shows a positive correlation between the level of poverty and care for the environment, as the poorer layers of the society are aware of the direct dependence of their sustainability and survival on the environment. For example, the rural population of Philippines (pp.812) are very careful in using their limited resources such as land, forests, fish etc. (pp. 811-815).

The above considerations imply that despite inter-relationship of sustainable development, poverty, and the environment, poorer groups of the society should not be blamed for today's environmental degradation. In other words, the developed world can hardly avoid the responsibility of alleviating poverty in developing countries.

In Bangladesh, the resources are very limited compared to population. The rate of resource exploitation is higher than what the ecology can bear. The current situation is the result of the development programmes which were undertaken in an unsustainable way, thus causing environmental degradation.

For instance, since its independence, more than 60% of Bangladesh annual development budget has come from foreign aid of which more than 80% has been invested in urban-based development programmes such as construction of urban roads and housing, flood protection dams, fuel import etc. Unfortunately, investment for the benefit of rural communities (rural development, fishery, river drainage, irrigation etc.) has been largely ignored. As a result, the gap between the resources demand and availability is gradually increasing, mostly affecting rural population.

Therefore, in Bangladesh, the SET should be able to provide energy on a long-term basis as per villagers' needs, and at affordable costs, without disturbing the ecological balance. SET should be environment-friendly and cost-effective.

4.2 Alternative, Renewable, and Sustainable Energy

Alternative energy sources with the potential for application in rural areas, are neither commercial (gas, electricity, or kerosene) nor traditional (wood, dung, and animal waste). The list includes renewable and non-renewable sources, with some sources applied commercially in urban areas (GOB, BEPP 1985 vol.1 pp. 1-29).

Renewable sources of energy have potential for long-term regeneration (in most of the cases, for an unlimited period of time). Apparently sustainable energy sources belong to this category. Sustainability, though, can be applied in a broader context, as it is related to long-term socio-economic goals and aspirations of a particular society (ibid). That is why, for a particular society, an energy resource could be renewable but might not be sustainable.

For example, hydropower electricity generation could be renewable but not sustainable in a country with different river characteristics (e.g. silted river beds due to water block). Similarly, biomass energy is renewable through replantation, but it might not be sustainable in a country with scarce land. Hence, there is a need for a clear understanding of every source and their potential applications.

4.3 Difference in Gross and Net Reduction of CO_2 Emission

Concepts of CO_2 gross emission reduction and net emission reduction are different. Most authors mentioned earlier argue in favour of gross reduction, when in the future the atmosphere will lose its capacity to absorb CO_2. On the contrary, net reduction is the only option to reduce CO_2 emission to a 1990 level as per FCCC resolution. Vakalyuk et al (1994) suggest that FCCC resolution can only be implemented if we use energy from a source allowing for the absorption of CO_2. Indirectly they recommend using renewable energy sources, particularly biomass.

Read (1994, 1996, 1997) defines net emission as gross emission minus gross natural absorption. He focuses on recycling CO_2 (emission/absorption process), through the use of the biomass fuel: "*a reduction in net emissions means lower gross emissions or increased absorption, and leads to lower level of pollution, possible after the passage of time in the case of a stock pollutant*".

As a mechanism of controlling emission, Read proposes to use market opportunities where TAO is applicable. He defines TAO as follows: "energy sellers, at the wholesale level, are required to absorb some proportion of the carbon that is emitted when their product is used by the purchaser or to contract with other firms to carry out this obligation". However, his analysis is based on a perfect competition market situation in the ideal world. A limited number of energy professionals have been working in this context (Ali, 2002).

Furthermore, energy use is an indicator of public welfare as well as one of the main production components of the development process. Developing countries are struggling to achieve their economic development and public welfare goals, meet their development targets within a specified time period. Thus, they require an energy source which would be able not only to meet their short-run energy demand, but also be sustainable in the long-run. In short, they need energy from such a source, and in such a way as to meet their development aspirations. Energy policy, planning, and production framework for the developing countries must fit these criteria.

In this context, policy definition or planning energy supplies in developing countries should be considered from the users' rather than suppliers' perspective. In other words, the analysis should evolve from the bottom up. The above-mentioned studies have approached these problems in the reverse order, from the suppliers' point of view. That implies a gap between the previous studies and the energy requirements criteria for achieving development aspirations of developing countries.

Furthermore, the pattern of energy use in developing countries differs from that of developed countries, due to the differences in the nature and type of their respective developmental activities. The nature of energy demand also varies due to the differences in technological levels, socio-economic structures, and resource bases. For example, energy demand in most developed countries is related to the industrial demand and public welfare, as their economy is mostly based on high technology, is mechanised, and capital-intensive. On the other hand, in the developing countries the economy is mainly agriculture-based, with a small share of primary products industry (Ali, 2005).

Moreover, in the Third World, economic development is mostly focused around rural areas. Hence, the criteria of assessing energy demand and supply would be quite different for the developed and developing countries. As the sustainable energy supply is a precondition for sustainable development, energy supply technology and

conditions must fit the rural development processes of the developing countries (Ali, 2005). This issue has been ignored by previous studies.

The outcome of a research largely depends on its methodology. Most of the previous studies analysed secondary data while few of them analysed both secondary and primary data. Recent studies show that the findings of a research based on secondary sources might not be sufficient to represent the real demand or supply situation. Particularly in developing countries, where the large portion of the population is far from being aware of their rights and obligations, and prevailing socio-economic constraints, any policy formulation should be based on primary data (Chambers, 1997). Hence, the methodology used in previous studies is far from being ideal.

Based on the above analysis, we can present the following interpretation:

a. GHG emission is globally increasing very rapidly, with fossil fuel use being one of the main contributing factors.

b. In the next 20-30 years, energy demand increase rate in the developing countries will be much higher as compared to the current rate in the developed countries. And if the developing countries continue their fossil-fuel-based economic activities, it will threaten environmental quality. Hence, there is a need to intervene in the energy production and distribution processes in developing countries.

c. Energy availability to meet global demand, particularly for developing countries, depends on the diversity of energy resources. Hence, developing countries need adequate technological support in meeting their energy requirements.

d. The technologies required for environment-friendly energy production and distribution to meet global energy demands, are available in the market, but they are mostly contained within developed countries. This implies the necessity for SET transfer (Newell et al, 1999).

e. Developing countries cannot solve their energy problems alone, due to the lack of physical, human, and natural resources. Even though some developing countries have a higher population density than developed countries, there is still a shortage of skilled manpower, which requires assistance (capital and technical) from the developed countries (Nakicenovic, 1994).

f. In developing countries, energy shortage problems are much more severe in rural areas than that in the urban centres. The consequences of energy shortages, to name a few, are fast urbanisation rate, deforestation, natural disasters, sea level rise etc. In fact, as a consequence of energy shortage, rural population in the developing countries finds itself in a vicious circle of poverty, feeling an urgent need to make a breakthrough (ADB, 2000).

g. Methodologies used in the above-discussed studies are far from being perfect.

5. THE BANGLADESH CONTEXT

Bangladesh has been suffering multifarious problems in the area of its energy supply and demand management. The situation is aggravated by the fact that, on the one hand, the country does not have adequate energy resources, and on the other hand, its economical and technological abilities are very limited. Moreover, its geographical location makes it more vulnerable, as it is situated in the lowest part of South Asian region.

In the rural areas of Bangladesh (with 80% of the national population), agriculture is virtually the only form of employment. Large seasonal variations in demand for labour contribute to a significant level of under-employment and unemployment. There are a few middle-class farmers and even fewer large farmers, but the majority of the population is represented by small farmers, marginal farmers, and landless labourers.

Although the majority of the rural population is very poor, it does not necessarily comprise a homogeneous group (GOB, BEPP 1985, vol.1). Landless laborers, small farmers, sharecroppers, and other distinct groups all have different interests. Middle-class farmers are usually the most dynamic group, as they work on their own land, are interested in developing it, and have an access to capital subsidies, as opposed to the poor who only have a limited access to them. Large farmers are often not personally interested in agricultural progress, as they do not cultivate their land by themselves, but lease it out to other farmers (Hossain and Sen 1992; Hossain 1988). Therefore, in order to achieve positive long-term sustainable rural development, effective SET transfer should take into account the interests of all above groups.

Of a significant number of researches on sustainable energy resources and their transfer, there is only a limited amount related to Bangladesh. However, since independence, although more than a dozen of research studies have been carried out in energy sector, the scope of research and development programs is very limited in Bangladesh due to its economic and technical capacities (Ali, 2002).

6. COMMON WEAKNESSES OF PREVIOUS STUDIES

First, the scope of work and their terms and conditions were purposive as the studies were financed through foreign aid (e.g. World Bank, UNDP, ADB, OECD etc.). The studies were mainly focused on assisting in energy management planning. The recommendations were centred around the amount of deficit energy, and the amount of import energy required to cover that deficit. The recommendations were limited to the mechanism of importing liquid fuel, and coal and gas exploration. In spite of the relative insignificance of these reports' contribution to the development of energy technologies in Bangladesh, their recommendations have influenced national energy policy.

For example, in the North of Bangladesh there is no gas, and, as a consequence there is an acute energy shortage. To solve this problem, World Bank has recommended building a power generation plant on imported diesel. Accordingly, at present, country imports diesel at a cost of Taka 74 per unit, and earning Taka 54 in revenue from selling the electricity produced from that diesel (ADB, 2000). Apart from other technical, environmental, and production losses, there is a direct revenue loss of Taka 20 per unit of energy. Ironically, the feasibility study of these diesel power plants was conducted by the World Bank experts, and the plants were built with the financial assistance of the World Bank. This is the reality of the Third World politics—a country can fall into an 'aid trap' if technology transfer does not happen according to the users' choice (Ali, 2002). Unfortunately, very little attention has been paid to the needs and prospects of the rural areas' energy problems.

Second, these studies have made a very small contribution to exploring rural energy resources. Moreover, government has withdrawn subsidies in the form of fertilisers, diesel, and high-yielding variety seeds, which caused a major problem for small and marginal farmers in the crop production. Since 1960's diesel and fertilisers were supplied to farmers at a subsidized price, where rural farmers were being motivated to produce more food. But, as per recommendations of the above-mentioned energy reports, government has canceled that programme. As a result, small and marginal farmers have been facing numerous constraints in meeting production costs especially meeting energy demand. In mid eighty's this issue drew policy makers' attention (Ali, 2002).

Finally, these studies have made only a minimal contribution to developing energy technology of Bangladesh. Expatriate consultants, and their local counterparts limited their activities to producing a report, without arranging training programmes to build skilled manpower or efficient management. As a result, the country did not receive any technological support apart from having a collection of such reports.

Some studies also argued that, due to the Bangladesh need to develop its economy at a faster rate than the population growth, it needs rapid industrial growth, and renewable energy sources cannot meet its heavy industrial

energy demands. Hence the necessity to import liquid fuel. In fact, these studies either misunderstood the concept of renewable energy or simply ignored it. Indeed, the potential for using renewable energy in Bangladesh is very large (Ali, 2002).

The biggest study in Bangladesh energy sector carried out so far is the Bangladesh Energy Planning Project, (GOB, BEPP 1985). This report consists of nine volumes; Volume 4 deals with the rural energy sector. Although its recommendations primarily focus on estimating energy demand and the required amount of fossil fuel (especially oil and coal) to import, this study has covered a wide range of variables in the energy field. For example, this is the first study to have included environmental issues in the Bangladesh energy policy and planning.

The major limitation of this study is contained in its methodology. This study has used data both from secondary and primary sources (four major divisions), collected through a pre-designed questionnaire. The survey was conducted in urban or semi urban sampled areas. Questionnaires were filled in by the interested (identified) local leaders and get their feedback on the policy in the areas of energy demand and supply. As a result, the real beneficiary (the focused group) has not been consulted. Moreover, this study estimated energy demand on the basis of economic growth rate. It implies that the study recommendations might serve the short-term goals rather than long-term aims of sustainable energy management policy. In addition, the rural population's choice has been ignored in the data collection process.

Ali (2005) studied the potential of renewable energy technologies in Bangladesh. This study is mostly devoted to forecasting the demand and supply of natural gas. Although it contains the analysis of the potential of solar and wind power in Bangladesh, it is limited to the number of plants in Bangladesh. The major contribution of this study is the identification of failures of biogas plants in rural Bangladesh.

Further, some other studies have also discussed issues of rural energy, but only regarding biomass fuel, and leaving out other forms of sustainable energy. Their methodology could raise certain doubts as to sample and survey area selection (Ali, 2002).

ADB (2000) focuses on environmental issues, while highlighting the consequences of using fossil fuel. These studies are the first of its kind in Bangladesh—it has introduced the estimation of GHG emission (methane and carbon dioxide), due to the use of fossil fuel, paddy fields, and livestock waste. In fact, it is recognised that ADB has made a significant contribution to raising environmental awareness in Bangladesh.

7. CONCLUSIONS

On the basis of the above review, we can produce the following implications and conclusions:

a. Research and development programs in the Bangladesh energy sector are very limited, with rural energy sector being severely neglected.

b. The recommendations on the choice of energy technology for Bangladesh, particularly those for rural Bangladesh, have not been made, as they should have been.

c. Most of the rural energy sector studies discuss biomass energy, leaving outside their scope other renewable energy sources.

d. There is a gap in understanding the concept of renewable, alternative, and sustainable energy sources applicable to rural communities.

e. There is a gap between understanding SET and sustainable development.

f. The pattern of energy demand and its appropriate sources have not been addressed.

g. Methodologies used are not sufficient for analysing rural energy scenarios, and they do not reflect the real choice of rural population.

h. Energy requirements and potential demand have not been addressed properly.

On the basis of the above, this article proposes the following to fill those gaps by:

a. Critically evaluating options of using energy resources for the needs of present and future generations, through an appropriate methodology;

b. Evaluating the type and potential demand for energy use in the Bangladesh rural communities;

c. Estimating SET potential for rural Bangladesh;

d. Identifying the best energy technologies for the rural population of Bangladesh—environment-friendly, effective in reducing emission, appropriate for sustainable rural development, available in the market, and cost-effective; and

e. Identifying motivational factors to ensure the diffusion of SET in rural Bangladesh, based on the need for support from the developed countries in the SET transfer.

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