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A Model for Optimizing Site Selection for Biomass Energy Systems in the Himalayas

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Abstract

Poverty alleviation over large parts of the isolated habitations in the Himalayas has been slow as many of these areas are still beyond the reach of electricity. Taking grid based energy to these far flung places is not always possible on account of prohibitive costs of carriage, high transmission losses and provision of technical services for maintenance. The biomass based stand alone energy production and supply system, where the resource is locally available, communities are both the producer and the consumer of energy and are capable of routine maintenance tasks, is more suited to these remote parts of the Himalayas. Large quantities of sustainable production of woody biomass would be required for meeting the growing demand of energy in these localities which can not be supplied using wastelands alone as has often been proposed in national wood energy

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policies and considerable extents of new lands, not hitherto used for wood production, would have to be utilized for this purpose. This paper uses multi criteria analysis to make an objective assessment of critical physical, edaphic, climatic, demographic and floral features of production sites that balance supporting and inhibiting factors, and positive and negative externalities, for biomass energy systems and presents a model for optimizing site selection for stand-alone biomass based energy systems for remote isolated communities in the Himalayas.

Key words: *Biomass energy, Site selection, Himalayas, Multi criteria analysis*

Introduction

Human development is inextricably linked to access to energy. A developed country is one that has been able to provide access to modern forms of energy to all its citizens at their doorsteps. Often the single most important step in the direction of poverty alleviation is a significant increase in the provision of both household and commercial energy to the poor communities at affordable prices. Providing this access is difficult enough for developing countries on account of lack of human and financial resources and the technology deficit they usually face but the problem can become insurmountable in the face of geographical features of a mountainous terrain. Poverty alleviation over large parts of the isolated habitations over almost the entire Himalayan ranges spread across Afghanistan, Pakistan, China, India, Nepal, Bhutan and Myanmar has been slow as many isolated communities living in these hills are still effectively beyond the reach of electricity. Mountain villages tend to be small on account of low availability of arable lands. High cost of carriage, high transmission losses and severe difficulties in maintenance limit the extension of energy grids to remotely located communities.

Stand alone renewable energy production and supply system, where the resource is locally available, communities are both the producer and the consumer of energy and are capable of routine maintenance tasks, is more suited to these remote parts of the Himalayas. In the case of the Himalayas these renewable energy systems could be based on wind, solar, micro-hydel and biomass all of which have site specific advantages and limitations. Wind energy based systems work best during windy seasons that do not last for longer than four months in most parts of Himalayas except along the ridges which tend to be windier. But, precisely for this reason, such places are the least preferred sites for habitations since continuous high winds drains the lands of moisture leaving them desiccated. Besides, wind based systems demand relatively high expertise even for routine maintenance which is rarely available in such low population remote localities. Solar energy so far has limited use for heating water since electricity generation using solar cells has the problem of storage costs on account of the fact that it is produced during day while the demand for household energy peaks at night. Water flow based micro-hydel systems offer good opportunities in many places but has obvious limitations during the prolonged dry periods when the amount of water gets reduced sharply over most of the Himalayas.

Thus wind, solar, and micro-hydel stand-alone energy systems all have seasonal, locational, maintenance expertise and maintenance cost limitations that might not permit high levels of dependence on these systems in the Himalayas. In contrast, biomass based energy systems may prove better option since their primary requirement is land which is often available in remote areas at relatively low opportunity costs. There is plentiful human expertise available in remotest parts in tree rearing and harvesting and most small sized modern biomass gasification based electricity generation systems require a level of routine maintenance that can be undertaken by most villagers with only a few hours of training under minimal supervision by higher levels of technical expertise.

Objective

Biomass based energy systems, however, also have a number of limiting factors, and positive and negative externalities that are site specific. Large quantities of sustainable production of woody biomass would be required for meeting the growing demand of energy in these localities which can not be supplied using wastelands alone as has often been proposed in national wood energy policies and considerable extents of new lands, not hitherto used for wood production, would have to be utilized for this purpose. The production of woody biomass for this energy system has a number of associated externalities, both positive and negative. Generally, positive externalities are soil and moisture conservation on hill slopes, landslide control and energy security. Food security, water availability, biodiversity conservation and conservation of wildlife can, however, be negatively impacted by intensive cultivation of large quantities of woody biomass for energy production. For a meaningful economic development of these hill regions it is imperative that the positive externalities far outweigh the negative ones in these biomass-for-energy production sites. This paper suggests ways to balance supporting and limiting factors and positive and negative externalities for selecting suitable sites for biomass energy systems and thus develops a theoretical basis for optimizing site selection for stand-alone biomass based energy systems for remote isolated communities in the Himalayas.

A key element of low carbon path of development

Biomass based modern form of energy is a key element of the low carbon path of development that is considered crucial for limiting the climate change to a level above which it can have dangerous consequences for the earth. In the G20 summit held at Italy in July 2009 it was decided that all countries, developed and developing, take steps to limit the temperature rise to 2 degree Celsius by the year 2100. Such a step would require an emission cut as high as 80% below the 1990 levels for the larger developed economies and similar departures from the business-as-usual scenarios for the big developing economies of China, India, Brazil, Indonesia and others. Such deep changes can not be achieved based on energy efficiency and other technological innovations while continuing to grow economically relying on fossil energy. The biomass based energy, even at its current stage of technological development, has a high potential to permit a significant shift from fossil energy of the past to the energy that reaches the earth today and is available to us through photosynthesis. It is for this reason that biomass based energy is a key element in the low carbon path of development that is so crucial to prevent dangerous consequences to the earth from the warming climate.

Understanding risks and uncertainties for encouraging investments

New developments in the energy sector on a scale large enough to make a significant contribution to the energy supply become possible through the willingness of the investors, developers and suppliers to enter the market which is, in turn, dependent upon the risk and reward environment of such ventures (Elghali et al, 2007). To the investors, who can not rely on ecological benefits for making gains on their investments except to the extent translated into carbon credits, the risks emanate from the complex matrix of ecological, social and economic factors that impinge on each other, sometimes compensating each other and, as often, enhancing others both in their negative and positive aspects. The complexity of a biomass based system is enhanced by the very large number of stakeholders involved not only as consumers but as producers of the biomass and as the owners of (or having stakes over) lands where the biomass is to be raised. Besides them the significant others are biomass intermediaries, plant owners and operators, regulatory authorities and the general public residing in the neighborhood and downstream all of whom can stall project consent leading to risks associated with time and cost overruns (Elghali et al, 2007).

As discussed above a large biomass based energy system in the Himalayas would attract investments if the risks and rewards are clear to the stakeholders and the uncertainties are reduced and brought within manageable limits. Since this energy system is heavily influenced by the site selection it stands to reason that the choice of sites should contain within itself a measure of risks and rewards. There are three core components of bioenergy, namely, the feed stock supply, conversion to energy and distribution of energy. All these three fundamental components are, in turn, affected by social, economic and ecological factors. These factors are almost independent of each other at their core but have large overlaps on their flanks and for best results a cohesive integration of these factors is essential. Arriving at a consensus is difficult when faced with concerns that such an array of stakeholders can bring to the negotiating table. While the national governments would be concerned about meeting their GHG reduction targets through the development of biomass based energy system the local concerns are more likely to be cheap uninterrupted energy supplies, income from their lands and employment generation and local environmental issues like the landslides and the soil and moisture conservation (Domac et al 2005, Elghalli et al 2007). These issues have been classified in three broad categories as economic viability, environmental performance and social acceptability (Elghali et al, 2007, Mitchell et al, 2004).

Multi-criteria decision analysis

In bioenergy system of the type that is under discussion here, which covers a very large area across a multitude of geographic, economic and social features constantly interacting with and influencing each other, can not be analyzed by using the normal scientific approach of reductionism. A central feature of a system approach is that a whole is greater than the sum of its part where as reductionism is examining small parts of a system and then summing them up to get a complete picture. A systems approach allows simplification of complex systems by identifying key indicators and common known principles that capture the interplay of its constituents, and thus its dynamism, without losing a holistic view. This methodology involves identification of a host of such key indicators relevant to the purpose and then using a suitable multi-criteria analysis for arriving at the desired objective.

A number of multi-criteria approaches have been developed over the past few years that seek to integrate a host of varying indicators with different dimensions, as well as uncertainties and ignorance, using explicit value judgement by a trained body of peers and stakeholding communities (Elghalli et al, 2007). For this analysis eleven attributes including extent of isolation, population, land availability, soil, moisture, biodiversity and wildlife conservation, landslide control, energy security, food security, and NTFP production were selected as suitability attributes and attribute parameters were identified. These attributes were made dimensionless dividing them in very low, low, moderate, high and very high categories on 1 to 5 scale on the basis of their impact on the desirability of establishing biomass based energy systems. Negative externalities are awarded negative weight. Detailed explanation is given below:

The extent of isolation of the site is measured in terms of distance from an all weather road. The more remote the site more is its utility as a site for stand-alone biomass based energy since those near the roads are easily served by the grid based energy systems that can not only supply their higher requirements, since commercial activities requiring higher amount of energy are more likely to be located along roadside, but can also be maintained properly on account of ease of access.

The population is another attribute taken in consideration and the number of households is considered a suitable parameter because it is a more reliable indicator of energy consumption than the number of people and also because this data is generally available all through the Himalayan region cutting across the nations, with the possible exception of Afghanistan. The smaller the size the greater would be the utility for a stand alone system. Tiny hamlets are also more likely to be remote thus according defacto additional weight to the remoteness.

Third attribute is the land availability and the attribute parameter chosen is the sufficiency of the available land for meeting the biomass demand for energy production. If the land available at a site is much more than required for meeting the biomass demand then it is most suitable. This would mean that no land fit for agriculture would be put under bioenergy production thus reinforcing the food security requirement which is also dealt separately. Further a site with much higher extent of land availability is also likely to be remote and thus this requirement is also further likely to strengthen the remoteness requirement.

Next attribute is the landslide control with severity of the landslides taken as the attribute parameter. With an appropriate harvesting mechanism undertaken in a sustainable manner tree growing for energy would play a positive role in landslide control and hence the most landslide prone lands are considered the best choices for biomass growing for energy.

Next attribute is the moisture conservation and the amount of rainfall and number of rainy days are taken as twin parameters. The sites with the least rainfall occurring over the shortest span are considered most suitable as the trees raised for biomass generation on such lands would provide the highest positive externality in so far as moisture conservation is concerned.

Another attribute is the energy security with the amount of energy available from other sources in terms of fulfilling the requirement as the attribute parameter. The site that has the least availability of energy from other sources would score the highest on this scale since the objective is to enhance the energy security of the communities.

Yet another attribute is the food security where the attribute parameter is the extent of agriculture land that is used for raising trees for biomass generation and carries negative weight. Food security concerns have been given high weight and sites, where more than a quarter of the available agriculture lands would have to be used for meeting the tree bioenergy needs, are awarded the highest negative weight. The most preferred are the sites where no agriculture lands are diverted for raising biomass for energy.

Another attribute is the wildlife conservation having one negative and one positive attribute parameter. The negative attribute parameter operates in sites where the keystone wildlife species requires a grassland habitat as is the case in many high altitude Himalayan areas which are suitable habitats for the rare Tibetan antelope. This is because tree raising for biomass could lead to reduction of grassland habitats. Highest negative ranking is accorded to sites where raising trees for biomass would reduce more than a quarter of the community landscape suitable for such a keystone species. The positive attribute parameter becomes operational if tree raising for biomass increases the habitat of a keystone species for wildlife conservation and the highest ranking is awarded where the increase in habitat is more than 75% within the community landscape.

Yet another attribute with negative dimensions is the economic security of the local resource poor people dependent upon the NTFP for livelihood requirements. Tree planting for biomass has the potential of reducing the income of these people significantly. Just like in the case of the other two negative externalities in this case also high weight has been accorded to the loss of income from NTFP to the poor community and a 25% decrease in such income would result in the maximum negative valuation.

Soil conservation is another positive externality of tree planting for biomass. For the sake of ease only one attribute, namely, steepness of slope has been taken as attribute parameter and the higher the slope the higher is expected to be the benefits from tree planting and slope in excess of 75% is awarded the highest ranking. It is, ofcourse, presumed that bio-energy harvesting would be sustainable.

Biodiversity conservation is also an important attribute with the extent of restoration of the original habitat taken as attribute parameter. Highest rank is accorded when the biomass generation is expected to lead to restoration of more than 75% of the native fauna.

Scoring plan for different attributes:

Attributes	Attribute Parameter	Positive Externalities / Supporting Factors					Neutral	Negative Externalities / Limiting Factors				
		Very Low	Low	Moderate	High	Very High		Very Low	Low	Moderate	High	Very High
Extent of isolation	Distance from road	Upto 5 Km	5-10 km	10-15 km	15-20 km	20-25 km	On road	—	—	—	—	—
Population	No. of households	> 100	50-100	25-50	5-25	<5	—	—	—	—	—	—
Landslide control	Severity	Very rare	rare	Sometimes	Frequent	Very frequent	—	—	—	—	—	—
Moisture conservation	Amount of rainfall	>200 cm	150-200 cm	100-150 cm	50-100 cm	Upto 50 cm	—	—	—	—	—	—
	No. of rainy days	>200	150-200	100-150	50-100	<50	—	—	—	—	—	—
Energy security	Energy from other sources	Much more than required supply available from other sources	More than required	As per requirement	Less than required	Much less than required	—	—	—	—	—	—
Food security	land used for dedicated plantation	—	—	—	—	—	Not affected	Upto 5% of agriculture land used for biomass generation	5-10% of agriculture land used for biomass generation	10-20% of agriculture land used for biomass generation	20-25% of agriculture land used for biomass generation	>25% of agriculture land used for biomass generation

Wild life conservation	**If the keystone species requires high altitude meadows**	—	—	—	—	—	Not affected	Upto 5% decrease in habitat area	5-10% decrease in habitat area	10-20% decrease in habitat area	20-25% decrease in habitat area	>25% decrease in habitat area
	Increase in habitat of Keystone species	Slight increase habitat area	Upto 25% increase in the habitat area	25-50% increase in habitat area	50-75% increase in habitat area	More than 75% increase in habitat area	Not affected	—	—	—	—	—
Economic security	**Reduction in the income from NTFP**	—	—	—	—	—	Not affected	Upto 5% reduction in the income from NTFP	5-10% reduction in the income from NTFP	10-20% reduction in the income from NTFP	20-25% reduction in the income from NTFP	>25% reduction in the income from NTFP
Land availability	**Land availability for biomass generation**	Meets only a part of the requirement	Meets most of the requirement	As required	More than required	Much more than required	—	—	—	—	—	—
Soil conservation	**Steepness**	Gentle	Upto 25%	25-50%	50-75%	>75%	—	—	—	—	—	—
Biodiversity	**Likely positive impact in bringing the native floral species back**	Slight impact	Upto 25% of native species are expected to return to their native habitat	25-50% of native species are expected to return to their native habitat	50-75 % of native species are expected to return to their native habitat	More than 75% of native species are expected to return to their native habitat	—	—	—	—	—	—

Discussion and Conclusions

All the possible sites are than ranked against each attribute parameter by a well trained peer group along with well informed local stakeholders. The total of all attribute parameters for each site would give its score and those with higher scores would constitute priority that would help optimize economic, ecological and social benefits through appropriate site locations.

Now we turn our attention to the question of sustainability. Any energy system has to be sustainable in order to attract investments of the scale required and this sustainability has to be achieved in a very dynamic moving frame of rapid advancements in technology and the equally rapid changes in the physical environment and the societal understanding of these changes and expectations of dealing with them. At this stage it is important to clarify what is meant by sustainability which has been variously defined. In natural resource management an acceptable definition would be that a sustainably managed renewable natural resource like forests enables maintenance of its ecological integrity permitting the continuance of evolutionary processes with least hindrance and leaves its capital stock of economic value intact across generations.

But this definition can not be applied satisfactorily to all components of a economic production system spread over a large area like provision of bioenergy. One interesting definition of sustainability that it is the capacity to create and maintain adaptive capabilities of a system meaning thereby that a system is sustainable when it possess now, and through its life, the necessary infrastructure and material wealth to enable adaptation. A sustainable system should thus be able to create, or at least access, technological advancements and finances in order to deal with the changes that are necessitated by the changing environment and the altered societal expectations of dealing with them both in quantitative and qualitative terms.

The balancing of attributes through multi criteria analysis should help enhance the overall sustainability of the biomass production system. But it may not able to ensure the economic sustainability of the system over any significant length of time since technological advancements, and consequential increase in financial requirements, have not been integrated in the analysis. For example, the probable technological advancement of shift to lingo-cellulosic fuels in the coming decades would render a system of bioenergy based on the current technology redundant and threaten its economic sustainability.

The model accords high importance to food security, conservation of wild life and economic security of poor people depending upon NTFP. The most suitable site for biomass based power plant selected by using this model are those with least negative externalities and high values of positive externalities.

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