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Achieving Energy Economy and Sustainable Development by Decentralized Energy Planning in Angkuchen Village, Sikkim: A Case Study

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Abstract

Energy is the fuel for the growth of human civilization. But what becomes of utmost importance by current trends is proper management of the energy resources. The commercial energy consumption, in current state of affairs, is about 67% of the total energy consumed in India. This includes coal with the largest share of 57%, followed by oil at 28%, natural gas at 12% and hydro energy at 3%. Non-commercial energy sources consisting of firewood, cow dung and agriculture wastes account for over 30% of the total energy consumption. Here we have a country that is rich with its share of renewable energy resources which still remain unharnessed. If these resources are harnessed judiciously and their allocation is done based on proper surveying and analysis of demography, geography and climatic conditions, a sustainable balance can be achieved between commercial and non-commercial energy sources. This in turn would be helpful in controlling the country's import bill and achieving economic stability in the country, as energy is a key component in the economic instability prevailing in the country. For this paper, the authors surveyed Angkuchen village, Pakyong, East Sikkim, India, and gathered data that helped place in context the current demography and energy trends in the village. Further, a climatic and geographic analysis was carried out. This helped us to place a great deal in the allocation of the available energy resources and optimizing them so as to increase the energy efficiency of the village. The current energy status, choice of energy options, and potential of renewable energy systems for creating sustainable livelihoods and meeting energy economy in this village has been elaborately discussed in the paper. The outline plan at decentralized level was prepared with the objective of providing energy security in villages by meeting total energy needs for cooking, lighting and motive power through various forms of available renewable energy sources.

Keywords: *Decentralized energy planning, renewable energy systems, alternative energy technology*

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INTRODUCTION

Energy is the epicenter of our civilization, it is available in abundance around us, but due to technological limitations we are unable to channelize it into useful work. The available resources suggest a need towards proper management of energy resources to cater for the ever increasing population. Until new technologies are not commercially developed that would enable us to utilize available resources more efficiently, we need to manage the available technologies along with the available resources (both commercial and non-commercial). The central point of energy management is economy. We need to find a balance between commercial and non-commercial resources so as to promote energy economy, i.e., judicious use of renewable energy resources so as to cut back on the use of non-renewable resources. This has a dual effect; firstly, this would lead to energy independence and secondly, it would promote socio-economic development of the populace.

Only a mere 30% of the total population has access to electricity. The rural population that comprises 74% of the total population does not have access to commercial energy resources. In villages, people, even today, use dung cakes, agriculture wastes and fuel wood for their energy needs [1]. The availability of LPG and electricity is limited; the shortage results in frequent power break-downs and disrupts daily life, man-power losses in offices, agriculture activities and adversely affects the industrial production and thereby the economy. When availability of these common means of commercial energy (LPG and electricity) is available with constraints, it is logical to derive an idea about their shortage in rural India. And with the current economic downturn, the scenario has reached a critical level.

The micro-level, decentralized energy planning can meet the energy need of the rural populace by making use of the locally available renewable energy sources. The government is engaged in various renewable energy programs for the promotion of biogas plants, solar thermal systems, photovoltaic devices, biomass gasifiers, as well as the integrated rural energy programs, for several years. These programs have undergone modifications in keeping with the feedback received apart from development in various technologies and operation conditions that have taken place. The 11th Five-Year Plan (2007–2012) introduced a comprehensive rural energy program, that has been started and it includes two sub-programs, namely Remote Village Renewable Energy Program (RVREP) and Grid-Interactive Village Renewable Energy Program (GVREP). The starting of such programs is a positive sign but more critical would be their implementation. Though the share of modern renewable energy is small and even under subsidy, these renewable technologies cost a sizeable amount, there has been a steady growth in the installation of different renewable energy technologies. A total grid-connected renewable power generation capacity of 14,485 MW has so far been achieved [2].

Sikkim merged with the Indian Union in 1975 and starting with its development strategies and plans, the focus was on essential infrastructure, such as roads, electrification, and water supply (Figure 1). Interventions in agricultural expansion, mineral extraction, and forest clearing were also initiated, and these, in-turn affected the landscape and the environment [3]. The complexity of the mountain terrain was not adequately considered, and development not suited to the local environment was undertaken which resulted in some unexpected delays and long-term hindrance [4]. Open grazing in the forests was not regulated, and this led to fragmentation of wildlife habitats. The development of sustainable income-generating industries such as tourism was not given adequate emphasis and consequently internal revenue generation suffered. The state has adopted a unique developmental model with a pro-environment and pro-people perspective. It is the stated policy of the government to develop rural areas on a par with towns and cities by providing all basic amenities and employment opportunities, with a vision to develop an eco-city state [5].

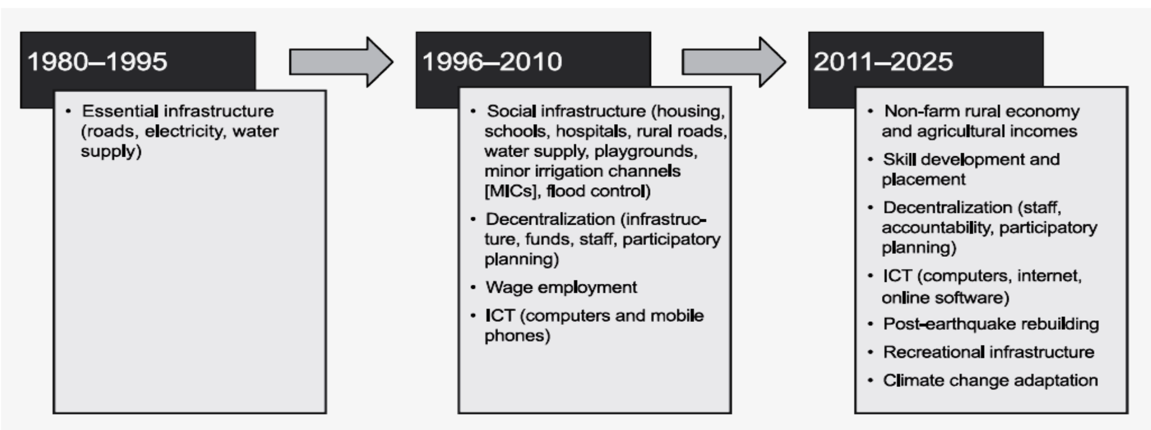

Fig. 1: *Evolution of Rural Development Priorities in Sikkim* [6].

METHODOLOGY

The methodology used for the research includes a survey based on the division of farmers on the basis of size of the farmland with each household. This led to categorizing of local populations on basis of the kind of work they had undertaken due to some percentage of carpenters in the community; these were taken as others (OTH). The categorization of farmers based on the area of cultivated land and energy requirements is:

LF – Large farmer
MF – Medium farmer
SMF – Small medium farmer
OTH – Others

The calorific values for various energy resources have been listed in Table 1. These have been used for various energy conversions in the study of the village.

Table 1: *Calorific Value of Various Fuels Used in the Analysis.*

Fuels	**Calorific Value**
Firewood	0.016093 (GJ/kg)
Dung	0.013752 (GJ/kg)
Agriculture waste	0.0156332 (GJ/kg)
Kerosene	0.0375 (GJ/L)
LPG	0.0266 (GJ/L)/11950 kcal/kg
Electricity	0.0036 (GJ/kg)

Angkuchen: A Brief Background

Angkuchen is a small village located in the East Sikkim district of the Sikkim State of India. The village is situated in a valley with steep hills surrounding it. The terrain is covered with dense vegetation as the state is located in the tropical rain forest belt. The area receives moderate to heavy rainfall. The survey details have been mentioned in Tables 2 and 3. The annual energy consumption for the village has been listed in Table 4.

Table 2: *Survey Details of the Village.*

No. of households (HH)	**Households surveyed**	**Population of village**	**Cattle holding/HH (Avg.)**	**Distance from nearest town (km)**
38	25	213	3	20

Table 3: *Land Use Pattern.*

Village	**Total land**	**Forest land**	**Waste land**	**Cultivated land**	**Land under irrigation**
Angkuchen	300 ha	80 ha	20 ha	200 ha	20 ha

Table 4: *Annual Energy Resource Consumption (in kWh).*

Angkuchen	**Firewood (kg)**	**Dung**	**Agri. waste**	**Electricity (kWh)**	**Kerosene (L)**	**LPG cylinder**	**% share**
LF	12000	-	-	8000	44	14	22.40
MF	20000	-	-	25000	118	25	50.40
SMF	4800	-	-	12000	54	10	18.84
OTH	2400	-	-	5000	84	6	8.36
Total	39200	-	-	50000	300	55	100

The village is a farming community with total households (HH) of 35 with only 4 HH out of the total engaged in carpentry. The families of some local farmers run two groceries and daily needs shops. The nearest town is Pakyong (21 km). This town is also coming up with the first and only airport in the state of Sikkim, although, the town is not very big, but, is well connected. The region receives heavy rainfall in the months from July to September and moderate rainfall from March-June and September to November and light showers from December to February. The maximum temperature reached here is about 27 °C in the month of July and minimum temperature of 3 °C in the month of January. The area has a lot of small streams and some small rivers, but, these are located far from the village; water scarcity is a major problem in the area due to poor planning and ill usage of the nearby streams and rivers. No micro- or mini-hydro power projects exist around the area. For electricity needs, the village is grid-dependent and this is the major cause for the frequent power cuts in the village, especially during the rainy season. In the rainy season, the power cuts can be prolonged, even by days. But, electricity is available at night time for 75% annually (approx.). The men are mainly engaged in farming-related activity and in the evening they engage in drinking and pass time by local gathering. The village has only a primary school and a preparatory school, and the nearest high school is 15 km away. This becomes the reason that most of the youth in the village get displaced to neighboring towns and cities for education or job needs. The women in the village engage in household activities including gathering of fuel wood, which is a major source for cooking and water heating needs. There is no community center present in the village to support the villagers. Only a village Gram Panchayat office is present and poor medical facilities, although a cluster level medical clinic is present at a distance of few kilometers, but, for more serious cases one has to travel all the way to the town, and due to poor road connectivity and limited transportation options, this becomes a major problem. This has also led to the people leaving the village to find better opportunities in the neighboring towns and cities. The electricity needs are met in the village, as of now, but with the industrial development in Sikkim, especially with a large number of pharmaceutical companies coming up and opening of major institutions of research and development, the future could be very dark for these villages, as has been the cases with villages that are situated around major towns in other parts of the country. Their electricity needs have been hampered and this was directly related to the industrial development in the neighboring towns and cities. The planning should be growth-intensive and should have future expansion needs integrated into it.

RENEWABLE ENERGY RESOURCES AND CURRENT ENERGY CONSUMPTION PATTERNS

The assessment of locally available energy resources is helpful in revealing the status and helps in taking conservation measures in the village. Also, it ensures a sustained supply to meet the energy demand.

Studies were made for the total energy available which can play important role in meeting the household energy needs such as cooking, lighting and in the future if need arises or to improve the socio-economic conditions of youth and women, it can be used to power and run small industries, health clinics and agriculture equipment. The most important local energy resources of the cluster available are animal excreta, and biomass energy resources basically include agriculture wastes, firewood and animal excreta, etc. These are important fuel sources in the cluster especially for domestic purposes. Solar and wind energy potential in the cluster is negligible because they are not available throughout the year and due to location of the village in a valley, these resources, economically would prove to be more waste than useful. Micro- and mini-hydro power stations can be constructed over the nearby rivers and waterfalls and prove to be of importance for future sustainable development of the village and also promote the decentralized energy model, which would give employment opportunities to the locals and provide energy independence.

Bio-mass is one of the most important and abundantly available resources in the village and also the most untapped resource in the village. Currently, no biogas plants have been installed in the village that could prove to be a clean source of energy for heating and cooking in the village. This would also help replace burning of fire wood, which is more polluting and causes respiratory problems. The already available chulas used to burn firewood, to cook food and heat water are unsafe and do not have proper ventilation and/or chimneys; this causes smoke to accumulate inside the room and can be a serious cause of respiratory problems. These can definitely be replaced by improved chulas that have high efficiency and proper chimneys for ventilation of smoke.

The hydropower available locally is enough to produce power of 5 kW through micro-hydropower station and 25 MW through mini-hydropower station and can also be diverted to the villages through proper pipelines for water needs. Grid electricity is mainly used for lighting, electric iron, television, etc. The total energy requirement percentage has been listed in Table 5.

Table 5: *Annual Energy Requirement (in kWh).*

End use type	Energy requirement (kWh)	% of total energy
Cooking	281485.6	53.47
Hot water	184931.4	35.13
Irrigation	-	-
Electricity	60,000	11.40
Total	330030	100

The area survey of the village led the authors to establish the potential of non-conventional energy system implementation in the village. This is important for minimizing dependence on the conventional resources and promoting sustainable development in the village. In Table 6, the availability of non-conventional resources is given.

Table 6: *Annual Energy Availability.*

Energy resources	Resource availability (in kWh)
Electricity	40,000
Wood	121591.6
LPG	5689.4
Kerosene	3125
Dung	8709

The utilization of these resources is important to create local energy systems that are important for decentralized energy planning, which in-turn is important for sustainable development. This also promotes energy independence and socio-economic development of the village. With these developments, the prospects for community development are introduced and can be a factor for promotion of ruralization.

RESULTS AND DISCUSSION: THE DECENTRALIZED ENERGY PLAN MODEL

For the village under research, the selection of non-conventional systems is entirely dependent upon the available non-conventional resources mentioned in Table 7. The energy systems suggested below are entirely based on the survey data collected. No major solar device has been suggested due to the location of the village in a valley and the fact that sun energy is not predominant in the area also the fact that the long rain spells result in little solar energy system development.

In Table 8 are mentioned the suggested energy systems to help in development of a decentralized energy system. In addition to these recommendations, it is also suggested that a mini-hydro power plant of 25 MW be installed on the nearby river stream for meeting the electricity needs of the village.

Table 7: *Recommended Systems and Devices.*

System/Devices	Number of units
Family type biogas plant	38
CFL 8 W	19
CFL 14 W	19
CFL 18 W	19
Improved chula	16–20
SPV lantern	20
Electric pump for drinking water	6
Street light	12
Biomass gasifier	1

The numbers of units have been calculated based on the available non-conventional energy resources. The costing charts of these systems have been discussed in Table 8. The cost analysis and cost benefit of the whole planning project has been listed in Table 9.

Table 8: *Cost of Energy Generating Systems.*

System/Device	Capital cost (Rs.)	Annual cost (Rs.)
Biogas plant	304,000	60,800
CFL	1,900	380
CFL	2,280	456
CFL	2,660	532
Improved chula	1,600–2,000	320–400
SPV lantern	120,000	24,000
Electric pump for drinking water	2,500,000	500,000
Street light	297,600	59,520
Biomass gasifier	174,400	34,880
Mini hydel power	225,000	45,000

Table 9: *Cost Analysis of the System Proposed and the Cost- Benefit Analysis.*

System/Device	Number of units	Capacity	Per unit cost (Rs.)	Total cost (Rs.)	Annual savings in firewood/electricity/kerosene	Annual saving in monetary terms (Rs.)
Biogas plant	38	2 cum	8,000	304,000	104.5 t/year firewood	156,750
CFL	19	8 W	100	1,900	3.22 MWh/year of electricity	12,075
CFL	19	14 W	120	2,280	3.62 MWh/year of electricity	13,570
CFL	19	18 W	140	2,660	8.24 MWh/year of electricity	70,350
Improved chula	16-20	-	100	1,600–2,000	7.43 t/year of firewood	11,115
SPV lantern	20	-	6,000	120,000	1.43 MWh/year of electricity	5,337.5
Electric pump for drinking water	6	5 kWh	500,000	2,500,000	-	-
Street light	12	20 W CFL	24,800	297,600	2.35 MWh/year of electricity	8,812.5
Biomass gasifier	1	25 kW	174,400	174,400	0.0241 MWh/year of electricity	90,375
Mini-hydel plant	1	5 MW	225,000	225,000	1 MWh/year of electricity	1,820,000

CONCLUSIONS

For cooking requirement, biogas system, stoves, kerosene stoves and improved chula were selected. Since cooking demand could not be fully met by local resources, i.e., dung and wood, kerosene and LPG were required to fill a part of the cooking fuel demand. The average variable costs were very low for cooking and hot water. Cost for electricity was low due to subsidy available in centralized electricity for rural uses. But considering future needs, the plan for mini-hydro-plant was proposed as this would empower the village and prove a milestone in the village for sustainable development in the long run.

There is abundant availability of non-conventional resources, as was seen in the survey, but proper utilization using modern energy systems and their proper planning for cost optimization is missing at every level of rural planning. This study was a means to analyze and plan implementation of the non-conventional energy resources through non-conventional energy systems to increase energy independence and allow for sustainable development.

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