ENERGY PLANNING FOR AN ISLAND

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree

of

MASTER OF TECHNOLOGY

in

ALTERNATE HYDRO ENERGY SYSTEMS

By

RAVINDRA PAL SINGH

ALTERNATE HYDRO ENERGY CENTRE
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
ROORKEE - 247 667 (INDIA)

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CANDIDATE'S DECLARATION

I hereby certify that the work being presented in the dissertation, entitled **"ENERGY PLANNING FOR AN ISLAND"**, in partial fulfillment of the requirement for the award of the degree of Master of Technology in "Alternate Hydro Energy Systems", submitted in Alternate Hydro-Energy Centre, Indian Institute of Technology, Roorkee is an authentic record of my own work carried out during the period from July 2005 to June 2006 under the supervision of Shri S.K.Singal, Senior Scientific Officer, Alternate Hydro Energy Centre, Indian Institute of Technology, Roorkee.

I have not submitted the matter embodied in this dissertation for award of any other degree.

Date: 29th June 2006
Place: Roorkee

(RAVINDRA PAL SINGH)

This is certified that the above statement made by the candidate is correct to the best of my knowledge and belief.

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ABSTRACT

Energy planning for an isolated remote island using abundantly available solar, biomass, wind hydro and ocean energy resources has been found to be the ideal solution for meeting energy demands of the people of that island not only in cost effective manner but also ensuring self sustained energy availability. The main objectives of the present study is to plan a self sustained energy system as a source of guaranteed supply of power to a remotely located island with the point of view of an impetus to growth, and to ensure that there should not be any adverse impact on the socio-economic life of the people of the island as well as on the environment. To achieve the desired goal, models for integrated renewable energy systems have been studied and financial analysis carried out to select the best option considering all the factors like environment issues and self sustainability etc. for an off grid isolated remote island.

Many islands of the country are so isolated that extension of power grid to such areas neither economical nor technically feasible. Providing electricity to these islands is important not only for meeting the energy demand of the inhabitants but also for improving the quality of life and reducing migration to mainland. The diminishing fuel resources like coal and petroleum products make it necessary to search for and harness new and renewable sources of energy in order to ensure self sustained energy supply to isolated islands.

In the present work, it was proposed to take up the energy planning for Neil Island situated in Bay of Bengal and is the part of the Andaman and Nicobar Group of Islands. This island is 37 km. away from Capital city Port Blair. The area of this island is 18 sq km and consists five villages with total 581 households and 2806 persons. There is no grid power supply to this island and it is being fed presently from dedicated diesel powerhouse of 400 kW capacity and a 50 kWp solar power plant running in parallel.

Based upon the survey conducted during January- February 2006, the analysis to compute the energy potential assessment from available resources, energy demand and the cost of energy for each useable resource is carried out. The cheapest energy resource is utilized first to meet the demand and for remaining energy requirements the other resources are used in order of their cost of energy to provide optimum solution to meet energy requirements.

The demand and the potential of resources shows that the demand is less than resources and due to fluctuation in the resources availability, the entire demand can be fulfilled by at least two resources assuming the constant availability of the resource throughout the year. In order to consider the fluctuations in the discharge and power generation from biomass and biogas, the solar battery stored power can be feed into the bus bar to meet the peak demand. Though the resource of solar energy is enormous but due to high capital cost of system, it cannot be harnessed beyond certain limits due to economic reasons. This situation may change in future when the technology for harnessing solar energy would be cheaper than present. The existing Transmission and Distribution network with required strengthening is proposed to be utilized for supplying power from common bus bar to the consumers.

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INTRODUCTION

1.1. GENERAL

As widely acknowledged, energy consumption is one of the most reliable indicators of the development and quality of life and the necessity of satisfying a forecasted energy demand, over a certain time period, is the basis of energy planning. In particular, energy planning builds and verifies strategies in energy economy, which is, using the definition of World Energy Council, "That part of economics applied to energy problems, taking into account the analysis of energy supply and demand, as well as implementation of the means for ensuring coverage of energy needs in a national or international context"[1].

The energy planning discipline must take into account locally available resources for sustainable development, political aspects, social and environmental considerations. Energy planning methods are generally classified in three categories [2] viz. planning by models, by analogy and by inquiry. The accuracy of these methods depends on the time interval under investigation: short-term (up to 5 years), medium-term (up to 10 and 20 years) and long-term (beyond 20 years).

The planning by models methodology includes the econometric model and optimization model. The econometric model relies on mathematical and statistical methods such as regression analysis to study economic systems. In particular, its aim is the empirical testing or validation of theoretical models. All the econometric models are based on the use and implementation of statistical data. They deal with problems implying one or several energy forms, different energy sectors and energy uses.

The optimization model, when the approach of the best possible solution according to a goal function is required, makes the step from a description by a model to a prescription by a model. This is the most important and broadest category of tools for energy planning. In particular, great relevance goes to the family of the multi-period linear programming models.

The planning by analogy methodology [3] allows the simulation of the same quantity, with a time lag, in a less developed country, through the use of a leading case as reference and the knowledge of the time behaviour of a quantity in a more developed country. The 'analogue' approach is often used to check and compare outputs produced by other methods.

Independently of the method, the energy planning requires a detailed preliminary study of the energy system. This important step assumes that a careful observation of all the phenomena involved in the evolution of energy demand and supply has to be carried out keeping following aspects in view: -[4,5]

⇒ The privatization of the most important energy sectors (electricity and natural gas), turning the previous monopolies into free competition among different companies; in particular, the unbundling of vertically integrated energy companies occurred in the electricity sector, by splitting the generation, transmission and distribution activities;

⇒ The community growing awareness about the environmental impact caused by large conventional power plants, joined with a greater interest towards distributed generation technologies based upon renewable resources and cogeneration;

⇒ The energy planning activities as regional concerned instead of national.

In such a scenario, the energy planner has to shift the border of the system under study towards a smaller observation area where, invariably, several new constraints of different nature are involved.

Energy is a major input for socio-economic development. Fossil fuels are expected to fuel economic development for a majority of the world population during the next two decades. However, during the period 2020–50, fossil fuels are likely to reach their maximum potential, and their price will become higher than other renewable energy options on account of increasingly constrained production and availability. Therefore, renewable energy options are expected to play a key role in accelerating development and sustainable growth in the next century. India is implementing one of the world's largest programmes on renewable energy, covering the entire gamut of technologies, including improved chulhas, biogas plants, short rotation fuel wood tree species, biomass gasifiers, solar thermal and solar photovoltaic systems and wind farms. Since the use of renewable energy options would be extensive by the year 2020–21, there is a need to develop a model for the effective use of renewable energy in India.

In a developing nation like India, the rural segment is predominant and accounts for a major say in dictating the overall economic prosperity of the nation. To ensure a uniform and sustainable economic growth, attention must be paid as to how adequate energy can be supplied for such segments. However, as it presently stands, a severe energy crisis exists in most parts of the Indian rural segment. This situation has forced the energy planner to evolve optimal planning strategies for sustainable development in rural segment in general and islands in particular.

The existing centralized planning strategy lays emphasis on industrial growth and development in the urban segment. It is assumed that the benefits of the urban growth would gradually diffuse into the rural segments in close proximity and that the rural segment would eventually reap the extended benefits of the urbanized growth. However, the short sightedness of this policy became apparent only after several years, when it was realized that the rural segment was receiving a mere trickle of the benefits that urban segment was enjoying. The condition of the islands is more pathetic as far as industrial growth and development is concerned.

1.2. LITRATURE REVIEW

Several models have been developed previously to examine different aspects of renewable energy. Damyant and David [6] developed a model, which involved the use of linear programming, to calculate the least cost configuration of the energy system in the province of Ontario in Canada for the year 2021. Both non-renewable and renewable sources were considered to meet the energy demands of residential, commercial, industrial and transportation sectors. Sinha and Kandpal [7] developed a linear programming model for three important end-uses, namely cooking, irrigation pumping and lighting, in rural areas of India. The objective function of this model was to minimize the annual cost and the constraints of the model were availability of the resource and demand. A linear cost function was the objective of the model developed by Joshi et al. [8] while supply and efficiency were the constraints. The model was applied to three villages from three different physiographic zones of Nepal. Ashenayi and Ramakumar [9] presented a model, which minimized the annual operating cost, based on resource constraint. Ellis et al. [10] presented a deterministic linear programming model for the development of acid rain abatement strategies in eastern North America. The model also maximized the marginal cost based on environmental constraints. Strategies for reducing carbon dioxide emissions (CO_2) were evaluated by Groscurth and Kummel [11] with an optimization model for the Federal Republic of Germany (FRG). It was originally designed to optimize the use of primary energy and the costs of the energy system. Nfaoui et al. [12] described a computer model, which investigated the feasibility of using a wind/diesel system to provide electricity for an isolated village. Ashenayi et al. [13], Joshi et al. [14] and Sinha et al. [15-17] used linear programming in which a number of resources were optimised with respect to supply and demand constraints for minimum overall system cost.

Various schemes for rural electrification model based on integration of renewable energy systems have been reported in the literature. Rama Kumar [18] proposed two schemes for integration. In one schemes of integration the various resources resulted in the producing electrical energy. In another schemes, each energy resource was utilized by itself in the most appropriate way for supplying the given energy.

Rama Kumar et al. [19] proposed some of the technical, economic and socio-economic aspects for the application of renewable energy sources for rural development in resource poor-population-rich developing countries. Rama Kumar [20] suggested an integrated energy system consisting of various devices like wind driven electric generation, biogas operated engines, micro hydel plants and solar water heaters and stills.

Sharma and Prasad [21] examined the possibility of using renewable energy for energizing rural areas in developing countries. Energy consumption pattern, resource reliability, integration and economics pertaining to renewable energy system were discussed and it was concluded that the cost of power generation using renewable is lesser than energy obtained from conventional fuels.

Rama Kumar et al. [22] considered Integrated Renewable Energy System, which utilizing different manifestations of solar energy to satisfy various energy needs of the remote rural areas of developing countries. The authors employed a linear programming approach and developed a methodology for the design of Integrated Renewable Energy System. The method is quite general and it minimizes an objective function of total annual cost, subject to a set of energy and power constraints

Nayar et al. [23] proposed a hybrid system consisting of diesel generators, photovoltaic systems and wind powered generation integrated to supply power to remote areas. Nayar [24] also highlighted the advantages of using hybrid energy systems involving the integrated renewable technologies with diesel generators and developed a stand-alone wind-diesel hybrid energy system for remote electrification in some Australian Communities.

Kishore et al. [25, 26] dealt the problems related to the implementation of biogas technology in rural areas. The economics of wood, gasifier system for irrigation pumping was discussed by the author. It was found that the gasifier systems do not turn out to be viable, when the size is small. This is mainly due to the relatively higher capital cost of equipment and the cost of wood in comparison to other options such as diesel systems.

Alam et al. [27] made use of a concept involving interaction of various energy subsystems using the principles of system dynamics. The exercise was conducted for a village in Bangladesh and energy estimates for the period (1999-2000) were estimated. Zhen [28] applied system dynamic for assessing the energy supply and demand at the village level. Chetty et al. [29] made use of multiple objective analysis for designing rural energy system on the basis of empirical data.

Ram Kumar et al. [30], have concluded that a solar energy based system can play a significant role in finding out solution to the worldwide energy dilemma. It is especially true in developing countries where cost of imported fuel is crippling their economics and retarding real growth. The authors have presented two continuous duty solar energy systems- one for the long-term future and one for the immediate future. Based upon the economic analysis, the generation costs of solar energy systems were compared with those conventional systems for a variety of operating conditions. The results indicates that solar energy conversion can generate energy at costs competitive with conventional systems in the near future as fuel costs will further rise in future.

1.3. SCOPE OF PRESENT STUDY

The present study aimed to provide a methodology for energy planning for an island over a time interval of few years and the proposed optimization method aims at the determination of an optimal mix of technologies for the energy system, subject to a number of conditions such as economical and environmental constraints. The energy system is represented as a network of energy chains, starting from the primary energy supply and ending in the end-use sectors. The model is driven by the demand for useful or final energy. The rapid depletion of the fossil fuel and growth of world population, demanding industrial development to raise the economy and standard of living, the emphasis of energy came upon or Renewable Energy Sources. In remote islands, the off-grid power distribution system is only option available. As there are sufficient local renewable resources available in remote islands, it is possible to realize large-scale energy using latest technology in the field of renewable energy systems.

RURAL ENERGY SCENARIO

2.1. PRIMARY ENERGY SUPPLY SECTOR

Fuel stores energy in its chemical structure. When the chemical structure of the fuel changes, this chemical energy is converted into other forms and released. The primary energy supply sector includes fossil fuels (coal, oil, natural gas, etc.) and local renewable sources such as (biomass, wind, hydro and solar etc.) and the unit is expressed in terms of tons of oil equivalent (toe). When harnessing energy from primary energy sources and converting them into ever more convenient secondary energy forms, such as electrical energy and cleaner fuels, both quantity (harnessing more energy) and quality (more efficient use) are important. This sector provides electricity and heat production, deriving from large-scale as well as small-scale technologies and for other needs directly in the end-use sector.

2.2. INTERMEDIATE CONVERSION OF PRIMARY ENERGY

The large-scale technologies are adopted for centralized electricity generation and small-scale technologies largely dominate distributed electricity production by local renewable exploitation. The net electricity production delivered to the power grid comes from power plants and distributed generation.

Various technologies, such as conventional diesel plants, photovoltaic panels, micro-turbine systems and wind farms etc., are in use for intermediate conversion of primary energy. The choice and the adoption of these technologies depends on the availability and objective of the optimization process: if a greater importance is given to economical requirements, cheapest options will be considered and on the other hand, when the goal is to reduce pollutant emissions, the environmentally friendly technologies would be preferred.

2.3. END-USE SECTOR

The end-use subsystem defines a set of energy demand disaggregated in electric power, fuel and gas for cooking systems, petrol and diesel oil for means of transportation, etc. In particular, domestic, non-domestic and industrial users can satisfy their electricity needs both by drawing energy from the local grid and self-producing energy through alternative means. The excess electric energy produced by them can be delivered to the local grid except in case of remote islands.

2.4. ENVIRONMENTAL IMPACT ASSESSMENT

Environmental impact assessment is, in its simplest form, a planning tool that is now generally regarded as an integral component of sound decision-making. As a planning tool it has both an information gathering and decision making component which provides the decision maker with an objective basis for granting or denying approval for a proposed development.

The purpose of the environmental assessment process is: (a) to support the goals of environmental protection and sustainable development. (b) to integrate environmental protection and economic decisions at the earliest stages of planning an activity. (c) to predict environmental, social, economic, and cultural consequences of a proposed activity and to assess plans to mitigate any adverse impacts resulting from the proposed activity, and (d) to provide for the involvement of the public, department of the Government and Government agencies in the review of the proposed activities. Balanced assessment of effects on the environment should encompass a number of considerations. Depending on the nature, scope and significance of the project or proposal the assessment may include consideration of ecological, economic, cultural, aesthetic, health and safety, social and amenity impacts in relation to decisions on the sustainable management of natural and physical resources.

2.5. WORLD ENERGY SCENARIO

If governments stick with the policies in force as of mid-2004, the world's energy needs will be almost 60% higher in 2030 than they are now. Fossil fuels will continue to dominate the global energy mix, meeting most of the increase in overall energy use. The shares of nuclear power and renewable energy sources will remain limited.

The Earth's energy resources are more than adequate to meet demand until 2030 and well beyond. Less certain is how much it will cost to extract them and deliver them to consumers. Fossil-fuel resources are, of course, finite, but we are far from exhausting them. The world is not running out of oil just yet. Most estimates of proven oil reserves are high enough to meet the cumulative world demand we project over the next three decades.

2.6. ENERGY SCENARIO IN INDIA

Energy is the prime mover of economic growth and is vital to the sustenance of a modern economy. Future economic growth crucially depends on the long-term availability of energy from sources that are affordable, accessible and environmentally friendly.

The energy production is a symbol of growth and instrument for development. The per capita consumption of electricity in India during the year 2004-05 was 606 kWh/ year [31]. The Ministry of Power, Govt. of India has set on objective of providing "Power for all by the year 2012". This will entail electrification of all villages by 2007 and of all households by 2012. The infrastructure would need the availability of assured and reliable power at affordable price through reliable and adequate generation, transmission and distribution facilities [32].

Table 2.1 and 2.2 give the present installed generating capacity of the country as 124287 MW. The share of hydro with 32326 MW capacity is about 26%. Thermal accounts for maximum share of 66.4 % with 82410 MW followed by nuclear as 2.7 % with 3360 MW and renewable accounts for 4.9% with 6191 MW. The small units in hydro, diesel and wind modes of power generation are excluded in the tables below. Table 2.3 and 2.4 give the H.V. transmission capacity and rural electrification status as on 31st March 2006. Table 2.5 shows that for the year 2005-2006, there is shortfall of power. The energy shortage is 8.35% where as peak demand is 12.5%. The energy deficit can be met by renewable energy sources as in India, there are plenty of renewable energy sources available and country has all the resources to exploit the same [31].

Table 2.1: Sector- wise installed capacity in India as on 31st March 2006 [31]

Sl. No.	Sector	Installed Capacity (MW)	Percentage
1.	State Sector	70,224	56.5
2.	Central Sector	39,924	32.1
3.	Private Sector	14,139	11.4
	Total	**1,24,287**	**100**

Table 2.2: Fuel- wise installed capacity in India as on 31st March 2006 [31]

Sl. No.	Fuel	Installed Capacity (MW)	Percentage
1.	Coal	68,519	55.1
2.	Gas	12,690	10.2
3.	Oil	1,201	1.1
3.	Hydro	32,326	26.0
4.	Nuclear	3,360	2.7
5.	Renewable	6,191	4.9
	Total	**1,24,287**	**100**

Table 2.3: High voltage transmission capacity in India as on 31st March 2006 [31]

Sl. No.	Type	Capacity (MVA)	Circuit (KM)
1.	765/800 KV	--	1,323
2.	400 KV	76,010	63,129
3.	220 KV	1,42,242	1,07,625
4.	HVDC	3,000	5,876

Table 2.4: Rural electrification in India as on 31st March 2004 [31]

Sl. No.	Description	Quantity (Nos.)
1.	No. of Villages (Census 1991)	593,732
2.	Villages Electrified (31st March 2004)	474,982
3.	Electrification %age	80%
4.	Rural Households (Census 2001)	138,271,559
5.	Having access	60,180,685
6.	Electrification %age	44%

Table 2.5: Power situation in India: (April 2005-February 2006) [31]

Sl.No.	Description	Demand	Met	Surplus/ Deficit
1.	Energy	575,616 MU	527,803 MU	-8.3 %
2.	Peak Demand	92,968 MW	81,421 MW	-12.5 %

2.7. RENEWABLE ENERGY SCENARIO IN INDIA

Various types of renewable energy sources are available within the country, some of which are site-specific while the others are available universally. The potential of all these energy sources are given in Table 2.6, which indicates that biomass, solar, small hydro and wind may play significant role in improving the energy availability situation in the country.

Table 2.6: Potential and Current Achievement of Renewable Energy India [32]

Source/Technologies		Cumulative Physical Achievements Up to 31.3.2006 (MW)	Total Potential (MW)
1.	Wind Power	5340.60	45000
2.	Small Hydro Power	1826.43	15000
3.	Biomass based Power	912.53	19500
4.	Biomass Gasifiers	69.87	
5.	Solar Photovoltaic Power	2.74	20MW/ Sq Km

Despite a trend towards urbanization, more than 70% of India's population still living in rural areas [33]. As the economy develops, one of the greatest challenges the Indian government faces, is providing people in rural areas with access to energy. Renewable energy projects - in the form of solar, wind, and hydropower-generated electricity - are the key to providing rural areas with energy where power is in short supply. In addition, replacing coal- and other fossil fuel-generated electricity supplied to India's cities with energy from renewable energy sources could aid in reducing air pollution and help to meet the growing energy needs of the country's large metropolises as well.

2.8. ROLE OF RENEWABLE ENERGY FOR SUSTAINABLE GROWTH OF ISLANDS

The development model followed so far to meet the energy requirement of the human population with excessive dependence on the fossil fuel resources such as coal, oil and natural gas is not only unsustainable in the long-run, but also has its adverse impact on the environment and ecology with disastrous consequences. The increase in land, water and air pollution levels during the energy conversion process in this model has become an area of serious concern. The depleting nature of these fossil fuel resources raises the question of the sustainability of this approach in the long run and thereby compels the humanity to go in search of other alternatives. It is in this backdrop that non-conventional or renewable sources of energy have attracted global attention and evoked interest among planners, policy makers, economists and environmental activists as a viable option to achieve the goal of sustainable development. As of today the total power generation installed capacity of about 4500 MW of power from renewables, which is over 2.5% of the total power generation capacity in the country. This has largely come through private investment. The Prime Minister has already announced a goal of 10% share, or 10,000 MW, for renewables in the power generating capacity to be added up to 2012 [31].

The renewable energy sources will not only provide a viable option to the fossil fuels based conventional resources but also ensure a self sustained energy supply system which would be unaffected even when there is no link between main and islands due to war like situations. Renewable energy sources are cheap, their exploitation have low gestation period, ensures a cleaner environment i.e.

environment friendly, requires no transportation from mainland and are less capital intensive, these can be utilised in islands providing impetus to the remote population for their social upliftment.

2.9. CONCEPT OF INTEGRATED RURAL ENERGY PLANNING (IREP)

The concept of integrated renewable energy systems is to integrate renewable energy sources viz. solar, biomass, wind, small hydro etc. depending upon the availability in a given rural area for the purpose of meeting the various types of energy needs of the people of the area in appropriate & cost effective manner. The IREP is more reliable for the development of rural areas because of the following considerations;

- ⇒ Increase in agriculture output due to availability of energy and fertilizer.
- ⇒ Timely availability of critical inputs to villages in terms of energy.
- ⇒ Generate more employment in villages.
- ⇒ Improving the life style and checking the migration of masses to cities.

Supplying energy to a variety of loads by harnessing two or more renewable energy resources in tandem can be accomplished in two basic ways:

- ⇒ Convert all the resources into one form (typically electrical because of its versatility) for supply and storage. The term hybrid is often used in this context.
- ⇒ Match the resources, needs, and technologies to maximize end-use efficiency and minimize cost. In this case, integration of benefits at the user end is the ultimate goal.

The first approach, though convenient, is not always economical and does not result in the most efficient use of the resources. The second approach invariably results in an economically viable option.

2.9.1. Significance of IREP for Remote Islands

In most of the islands of our country, there is large potential of small hydro energy, solar energy, considerable scope for undertaking extensive biomass programmes depending upon the availability of cattle and agricultural wastes. Rural electrification programmes should not cater only to domestic/light requirements, but also cover irrigation pumping, service connections for commercial purposes, agro-based and small scale village industries. This approach will not only improve the viability of the rural electrification but also contribute in improving the economic fate of backward people of remote islands.

2.9.2. Technology Options for Remote Islands

Choice of technology depends on various factors, such as available resources, type and magnitude of electrical demand, growth potential and above all progress and prospects of other infrastructure development. Another factor, often overlooked, is the adoption technology by the local users. This factor is influenced by the dependability, maintainability, social acceptability and cost of technology. The means of supplying electricity to rural areas are through either of the mode. (a) Extension of national or area grids/centralized supply and (b) Isolated generation/decentralized power supply.

In centralized supply, the main objective of utilities is to connect all areas under a national grid as far as practicable. But generally in case of islands, extending grid supply to end-users is difficult and a very costly affair. Isolated generation may prove to be very economical in such circumstances. However the choice of technology to be adopted should be made after considering different criteria, keeping in mind that planning has the objective of supplying electricity at optimum costs.

Decentralized or isolated generation has some advantages. It can serve areas more economically, which are thinly populated, remote from the grid, separated by sea, have a small number of commercial activities and low average incomes. Supplying electricity through this alternative is particularly attractive to those areas that have abundant renewable energy resources. The issue in this case is therefore the selection of an appropriate level of decentralization and type of technology, i.e. the choice is between electricity generation for a village or a group of villages (local-grid) or energy supplied directly to end users. Where capital costs predominate over energy costs, as in grid extension or some of the renewable such as hydro, solar, biomass, small hydro, or wind, lower load factors favour the low capital costs alternatives such as diesel, steam, biogas, or gasifier system.

2.10. INTEGRATED RURAL ENERGY PLANNING AT MICRO LEVEL

In India, application of science and technology at micro level, which started, in a small way with the advent of the planning era, has found an increasing role since late 1960s. Application of improved technologies led to changes in cropping pattern through induction of improved varieties, use of inorganic fertilizers, intensive irrigation, and concomitant changes in the pattern of energy inputs to a large extent. These changes led to not only improvement of the economy but also increase the disparities within the rural system.

The state of the economic development of any country can be assessed from the pattern and quantity of its energy consumption. The Per Capita Consumption of Electricity in India during the year 2004-05 was 606 kWh/Year. Energy demand in India also is increasing with the pace of development and population growth. However, the quantitative energy consumption and its pattern reveal a stark contrast between the rural system and the urban system. The urban system largely depends on commercial energy sources, while the rural system is primarily dependent on non-commercial energy sources like fuel wood, animal dung, and crop residues. But these energy resources are becoming increasingly scarce over the years, and if this trend continues, the shortage of fuel wood alone would be around 190 Million m^3 by 2007 A.D., and the estimated deficit in fodder availability would be about 160 million tons [34].

These deficits can be met either through import of energy, or by developing new energy sources within the country. However, like most of the developing countries, the policy objectives for India are also severely constrained due to high energy prices and an adverse balance of payment. Moreover, factors like the adverse environmental impacts of deforestation, and denudation because of twin pressures of increasing population and dwindling resources also make micro level energy planning an area of critical importance.

This study aims to identify the more significant parameters for rural energy planning through a two-pronged approach. They are:

- A careful perusal of the relevant literature; and
- Site-specific field study.

Several aspects covering major features of energy scenarios in Rural may be broadly classified into several categories. They are:

- Household energy consumption;
- Energy consumption in agriculture;
- Energy interactions in the rural systems;
- Assessing economic feasibility of technologies in the rural systems;
- Impact of technology on rural systems; and
- Rural energy planning at the micro level.

2.10.1. Household Energy Consumption

To assess the rural household commercial as well as non-commercial energy consumption for cooking, space heating and lighting, field studies have been conducted [35-40]. Energy consumption also varies widely with occupation, income level, and size of land holding [34-37, 39, 41-50]. Energy consumption is also found to increase with increase in size of farms [34, 36, 37, 39, 41, 42, 44, 45, 47-50]. Furthermore, large farmers consumed a larger quantity of energy compared to those in non-farm categories like landless labourers, small businessmen, and government and non-government employees [34,50]. It has been observed that for rural communities, commercial energy meets only 5–10% of the total domestic needs, the rest being met through non-commercial energy sources [35, 36, 37, 39, 41, 43, 44, 48-52]. Higher income households consume larger quantity of commercial energy, whereas, low-income households consume a larger quantity of non-commercial energy [34, 35, 43 and 48] also larger farms consume a larger quantity of commercial energy, whereas, the marginal farms consume a larger quantity of non-commercial energy [37, 39, 41,44, 48, 50,51].

Fuel wood collection is a predominant feature of the rural energy scene. Lower income households have little area under homestead lands, and have to perforce engage in fuel wood collection for meeting their cooking energy needs [35, 48, 50]. The average distance covered for fuel wood collection depends on its availability and varies from 1 km in the northern region to 3 km in the southern region

[34]. Bonded and landless labourers spent considerable time and effort in fuel wood collection, but may also sell surplus fuel wood to others [34].

Commercial energy in the form of kerosene, and electricity is mainly used for lighting in the villages. Higher income households consumed a larger quantity of electricity for lighting, whereas, lower income households consumed a larger quantity of kerosene for lighting [34, 35, 43]. It is interesting to note that in some areas of Northern India, fuel wood is also used for lighting accounting for 2% of the total fuel wood consumption in the year 1987 [35]. Labour requirement for household activities like cooking, fetching water, fuel wood collection, dung cake preparation, and cleaning utensils has been estimated to vary from 5.5 to 16.50 man-hours per day per household [36, 39, 53] with the female members of the households contributing nearly 80% of the requirement [35, 43].

2.10.2. Energy Consumption in Agriculture

Energy consumption in agriculture depends on the type of crop and the agro-climatic conditions. In fact, the choice of crops for cultivation in an area is guided by the agro-climatic conditions, irrigation resources of the region, and the availability of different commercial and non-commercial energy sources. A number of studies have been conducted for assessing agricultural energy consumption for different geographical situations and agro-climatic conditions.

RENEWABLE ENERGY TECHNOLOGIES

3.1 GENERAL

India has developed one of the world's largest programs for renewable energy, covering the entire scope of technologies including biogas, biomass, solar energy, wind energy, small hydro power, ocean energy, geothermal energy and other emerging technologies. A variety of renewable energy systems and products are now commercially available which are also economically viable.

The new and renewable energy technologies are making a great revolution mainly in isolated areas, where it is difficult to provide electrical energy through the national grid. The biogas technology, improved biomass stoves, biomass gasifiers etc. have provided a new life style to villagers. Street lights and domestic lighting systems energized by Solar Photo Voltaic (SPV), pump sets powered by solar power, and biomass gasifiers for power generation have given new hope to those living in isolated areas and remote islands. The wind farms are feeding thousands of units of power everyday into the grid. A total power generating capacity of over 4500 MW has so far been added from renewable energy sources energy sources, which constitutes 4% of the total installed capacity in the country.

The main renewable energy sources are

- ⇒ Small hydro power
- ⇒ Wind energy
- ⇒ Biomass energy
- ⇒ Solar energy
- ⇒ Ocean energy

3.2. SMALL HYDRO POWER

Hydroelectric power is the technology of generating electric power from the movement of water through rivers, streams, and tides. Water is fed via a channel to a turbine where it strikes the turbine blades and causes the shaft to rotate. To generate electricity the rotating shaft is connected to a generator which converts the motion of the shaft into electrical energy. Small hydro is often developed using existing dams or through development of new dams whose primary purpose is river and lake water-level control, or irrigation. A small-scale hydroelectric facility requires a sizeable flow of water and a reasonable height of fall of water, called the head. Basic equation for power estimation is as:

$$P = 9.81\ Q\ H\ \eta_s$$

Where,

η_s is System efficiency including efficiency of turbine, generator and gear- box

P is Power in kW.

Q is Discharge in m^3/s.

H is Head available at site in m.

The head is relatively constant in run-off-river schemes except for variation in friction losses with the varying discharge. In irrigation canal or dam toe based scheme head also vary depending water releases and season of release. Weighted average is found out to design the head of turbine. The design head is so selected that turbine is operated to the maximum time giving optimum energy generation. Energy per year is calculated as below;

$$E = P \times \text{time (in hours 8760 per year) in kWh}$$

For the run off river hydropower scheme, it is useful to know the variation of flow over the year to select the most appropriate turbine configuration and estimated power generation. Flow variation presented in the form of a flow duration curve is the most useful form. The firm power and secondary power could be easily estimated from the flow duration curve.

3.2.1. Small Hydropower Schemes

The Central Electricity Authority has classified the small hydro schemes as shown in Table 3.1 and 3.2[31].

Table-3.1: Classifications of small hydro depending on the capacity [31]

Sl. No	Size	Unit size	Installation
1	Micro	Up to 100 kW	100 kW
2	Mini	101–1000 kW	2000 kW
3	Small	1001–5000 kW	25 000 kW

Table-3.2: Classifications of small hydro depending on the head [31]

Sl. No.	Type of Head	Range
1.	Ultra low head	Below 3 m
2.	Low head	From 3-30 m
3.	Medium head	From 30–75 m
4.	High head	Above 75 m

Small Hydro Power Projects in India can be broadly categorized in two categories as; small hydropower projects in the hills, where small streams are available. These are mostly of medium/high head utilizing small discharges. The water is diverted by the weir and intake, is conveyed to the fore bay, at the entrance to the penstock. The penstock conveys the water to the turbines in the powerhouse to generate electricity. The quantum of energy generation depends on the availability of water in the river or stream and there is no provision to store water for future use. These types of schemes are beneficial if connected to grid and not suitable for isolated loads. Since there is no dam construction involved, the cost of execution of these types of projects is very less and there is no threats to environment and no social and human problems involved. These projects are categorized as run-of-river schemes. The layout of a typical run-of-river scheme is shown in Fig.3.1.

Small hydropower projects in the plains and other region of the country, which utilize water regulated for other purposes like irrigation/drinking water canals, small dams etc. are categorized as canal based schemes. This is planned to generate power by utilizing the fall and flow in the canal. The generation of power depends on the flow of water in canal thus, cannot be used for base load demand [54].

Dam based schemes are those in which water is stored in the river by constructing a dam across the river and power is generated by controlled flow from the storage. Dam toe powerhouses are common in India. The typical layout of dam toe scheme is shown in Fig. 3.2.

A plant that usually generates electric energy during peak-load periods by using water previously pumped from lower reservoir to an elevated storage reservoir (upper reservoir) during off-peak periods when excess generating capacity is available to do so. When additional generating capacity is needed, the water can be released from the reservoir through a conduit to turbine generators located in a power plant at a lower level. The major components of pump storage scheme are shown in Fig. 3.3.

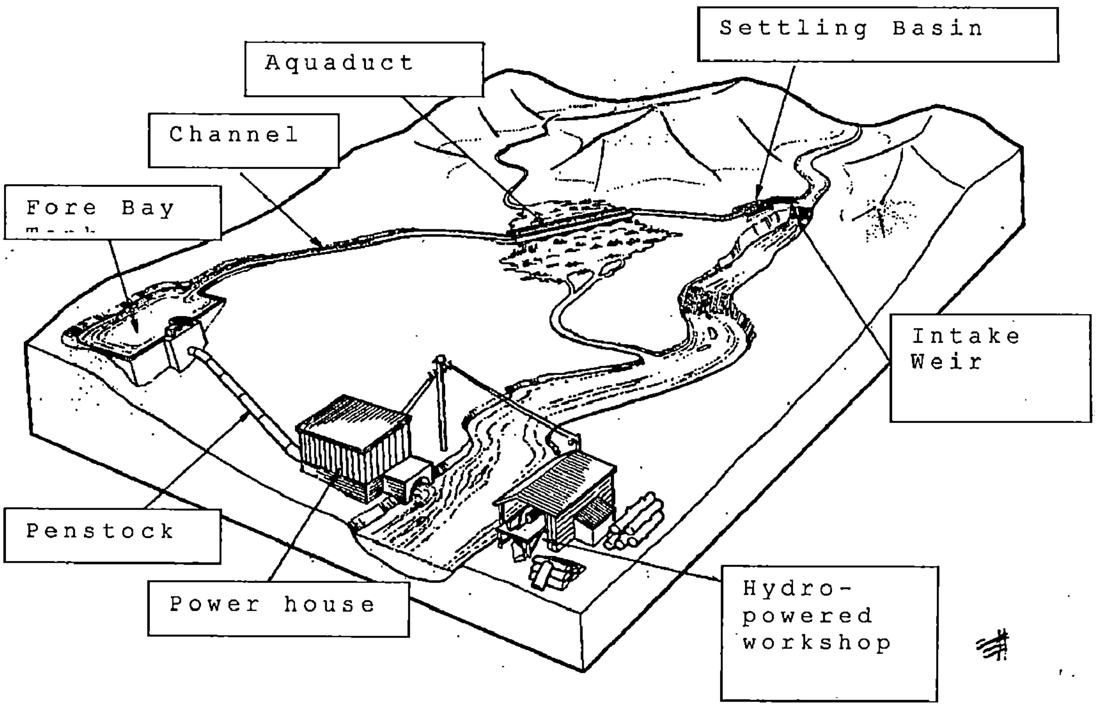


Fig. 3.1: The Major components of run of river small hydro power station

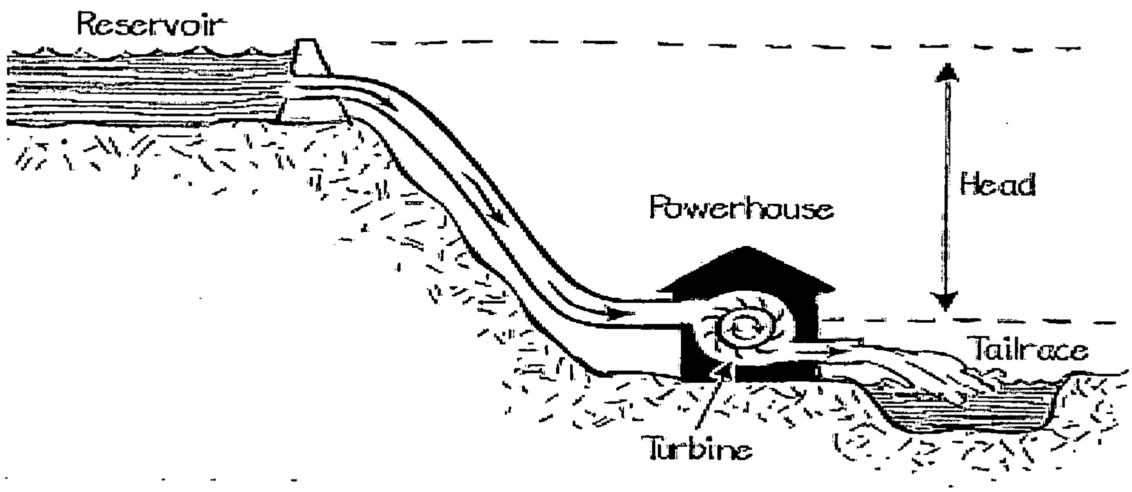


Fig. 3.2: Major components of dam toe hydropower scheme

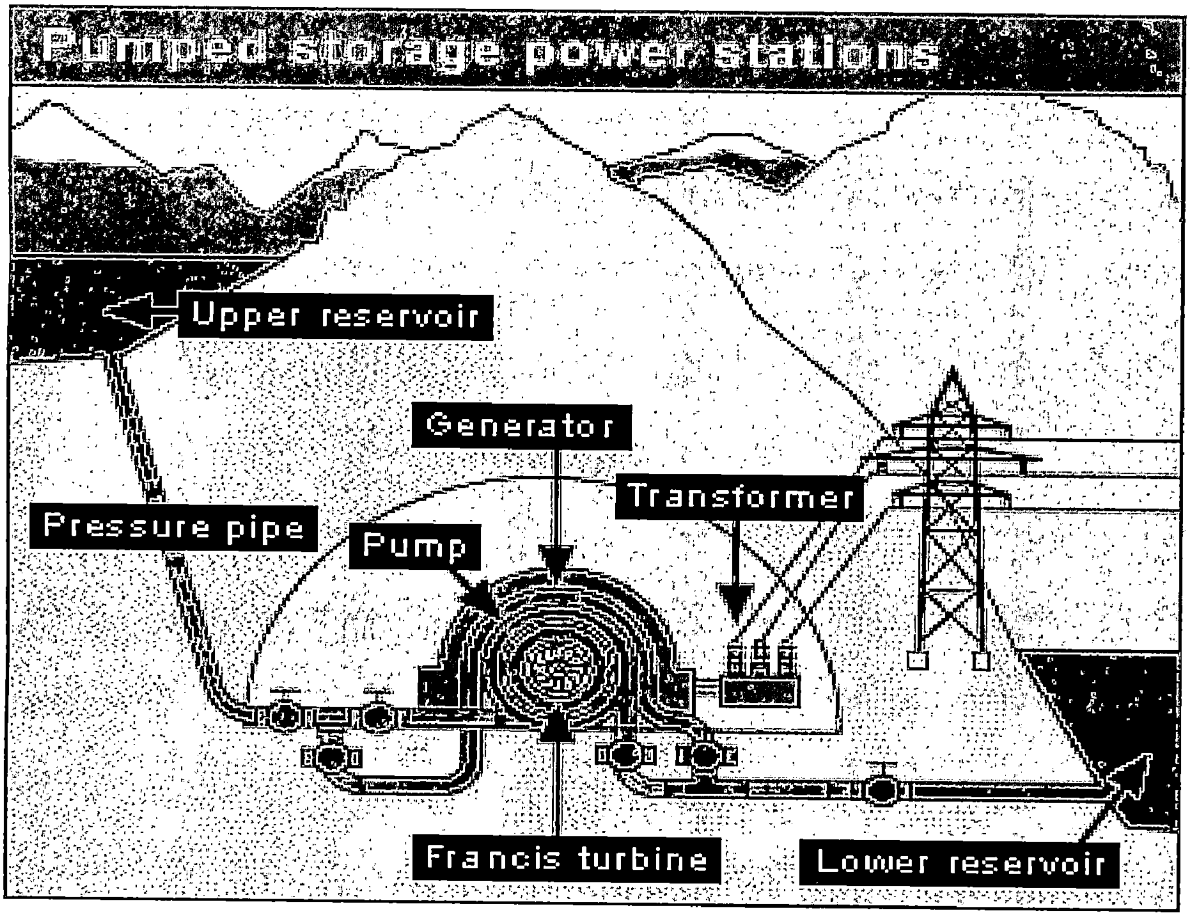


Fig. - 3.3: The Major components of Pumped Storage hydropower scheme

3.3.BIOMASS ENERGY

The term biomass is used to include wood, agricultural wastes, human & animals wastes. A wide variety of technologies are used to produce energy from biomass. The choice of a particular process depends on number of factors like location of the resource, its physical conditions, the economics of competing processes and the availability of suitable market for the product. They are basically of two types namely thermo chemical and biological (wet) process.

The thermo-chemical methods such as combustion, pyrolysis, liquefaction and gasification, convert biomass into usable fuel by using external heat. In contrast to this, the biological or biochemical method of conversion takes place at low temperatures with the help of single cell microorganisms known as microbes. For this reason, these methods are also called microbiological methods. These include mainly anaerobic digestion and fermentation processes. The microbiological reduction of carbon and water containing biomass usually takes place in the absence of air in an aqueous environment.

Biomass available in India comprises agricultural residue like rice husk, rice straw, bagasse, coconut shell, jute, coffee husk etc. forest industry wastes like saw dust, twigs, barks and lops & tops etc., animal waste like cattle dung, human excreta, slaughter house waste, industrial waste like sugar industry, distilleries etc, aquatic plants and innumerous wild plantations. Biomass may be obtained by purposeful cultivation with the help of energy farms or may be obtained as organic wastes and pollutants.

Though the use of agricultural residues is essential, the idea of growing woody biomass adjacent to agricultural production systems should gel a major fill up to meet energy needs by wide spread applications of efficient energy consumption devices. Decentralised wood production programmes & social forestry programmes may also be helpful in improving the biomass resource base by using all road sides, canal sides & rail road sides. Energy plantations using wastelands and high yielding plant species may also help provide an opportunity to provide power from wood fuel based power plants operating in decentralised mode.

Problems associated with biomass utilization for power generation are;

- Labour intensive and dispersed in large areas.
- High moisture content and low specific energy content.
- Seasonal availability and localized price sensitivity.
- Automatic feed control is required because of its non-free flow nature.
- Biomass handling, collection and storage are tedious.
- Transportation: biomass occupies a large volume due to low bulk density (30-180 kg/m^3), and therefore involves substantial cost factor.

Besides, the above problems, biomass being locally available, can meet the energy needs of rural households in variety of modes & deserves special appreciation on account of its vast availability.

3.3.1. Biomass Conversion Technologies

The technologies to convert biomass into energy fall into two general categories

(A) Biological

- (a) Anaerobic digestion
- (b) Fermentation

(B) Thermo chemical

- (a) Combustion
- (b) Pyrolysis
- (c) Gasification
- (d) Liquefaction

Among all the technologies mentioned above, only anaerobic digestion and biomass gasification shall be considered as processes for the production of electricity using biogas & producer gas as gaseous fuels respectively.

3.3.1.1. Anaerobic digestion for biogas production

The product of anaerobic digestion is a combustible gas called biogas and a value added fertilizer called sludge. The process is carried out under a set controlled condition. The biogas can be produced from cattle dung, human wastes, lignocellulosic wastes & industrial wastes. The biogas consists of about 55 to 70% methane as combustible constituents and remaining carbon dioxide. [55]. The typical gas composition of biogas is given in Table 3.3.

Table 3.3: Composition of biogas [56]

Sl. No.	Component	Composition (vol. %)
1.	Methane	50-60
2.	Carbon dioxide	30-40
3.	Hydrogen Sulphide, Nitrogen, Ammonia	Small traces
4.	Hydrogen	2-3

3.3.1.1.1. *Components of biogas plant*

A typical biogas plant has the following components:

⇒ A digester in which the slurry (dung mixed with water) is fermented
⇒ An inlet tank used to mix the feed and let it into the digester
⇒ A gas holder/dome in which the generated gas is collected
⇒ An outlet tank to remove the spent slurry
⇒ Distribution pipeline(s) to take the gas into the kitchen and
⇒ A manure pit, where the spent slurry stored

The cow dung is the main feedstock used for biogas production. However, the composition of biogas depends on the composition of the feedstock being used and on the physico-chemical equilibrium within the reactor (digester).

3.3.1.1.2. *Types of biogas plants*

There are basically two most popular designs of biogas plants. They are (i) floating dome type (KVIC model), (ii) fixed dome type (Janata model). A number of other types of biogas plants are also being developed.

A. KVIC Model (Moving Dome Type)

This model has an underground cylindrical digester with inlet and outlet connections at the bottom on either side of a masonry wall. An inverted metal drum, which serves as the gasholder, rests on a wedge type support on top of the digester and as the gas begins to accumulate, the drum starts rising in height. The weight of the drum applies pressure on the gas to make it pass through the pipeline to the point of use. As the gas flows out, the drum gradually moves down. Due to this smooth two-way motion, the gas remains at constant pressure, which ensures efficient use of gas. The gas holder can be made of metal or ferro cement. The schematic of KVIC biogas plant is shown in Fig. 3.4.

B. Janta Model (Fixed Dome Type)

Janta model is a fixed dome type with no moving parts. The dimensions and specifications of this model have been standardized to range between 2 and 6 cum. However the large and community type biogas plants are also available which are economical and useful for community use. Besides this the large digester is less affected by the fluctuations in temperature and in feedstock composition. The large biogas plant can be safely used for centralized power generation and electricity can be fed to the individual homes through the electrical lines. The line diagram of Janta model is shown in Fig. 3.5.

Advantage of a large size biogas plant over a small size plant is that there is considerable economics of scale involved in its construction. This is due to the fact that the volume-specific surface area decreases as plants become: larger. As an illustration, we may compare two plants, small one of 3-m3 volume and a very large of 300-m3 volume. If a cylindrical shape is assumed with a height equal to the diameter, we find the volume specific surface area (e.g. surface area per m^3 of volume), becomes more than 4.6 times smaller for the large plant. Also, with any other ratio of diameter and height, the difference becomes even larger. This means that for a given volume of digester, much less construction material is required if a single large plant is built instead of a number of small plants.

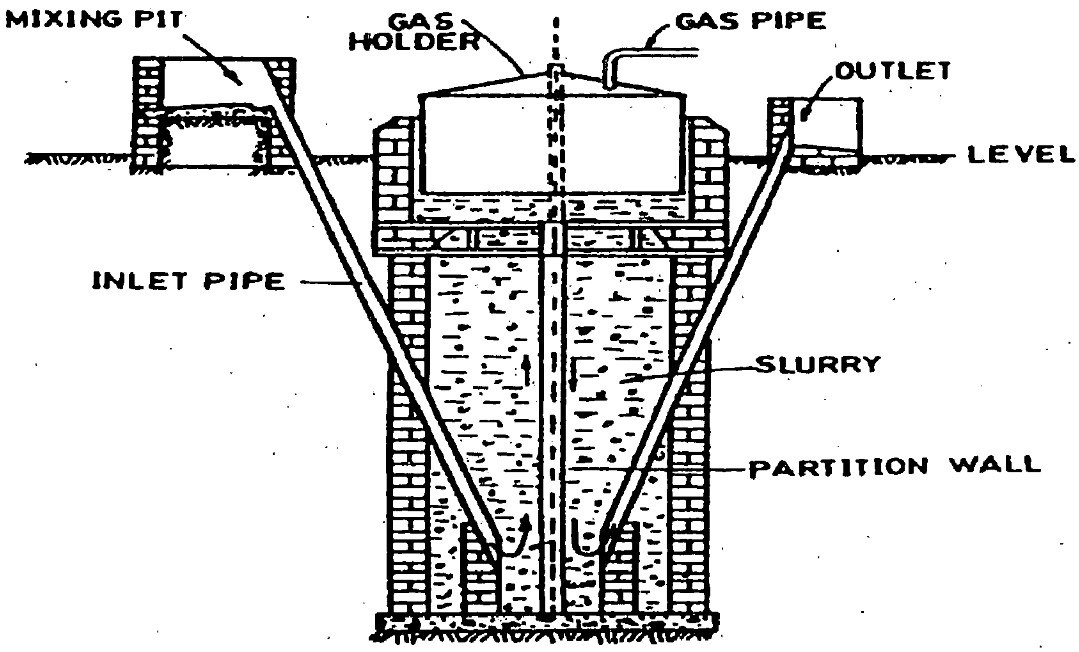


Fig. - 3.4: Schematic of KVIC biogas plant

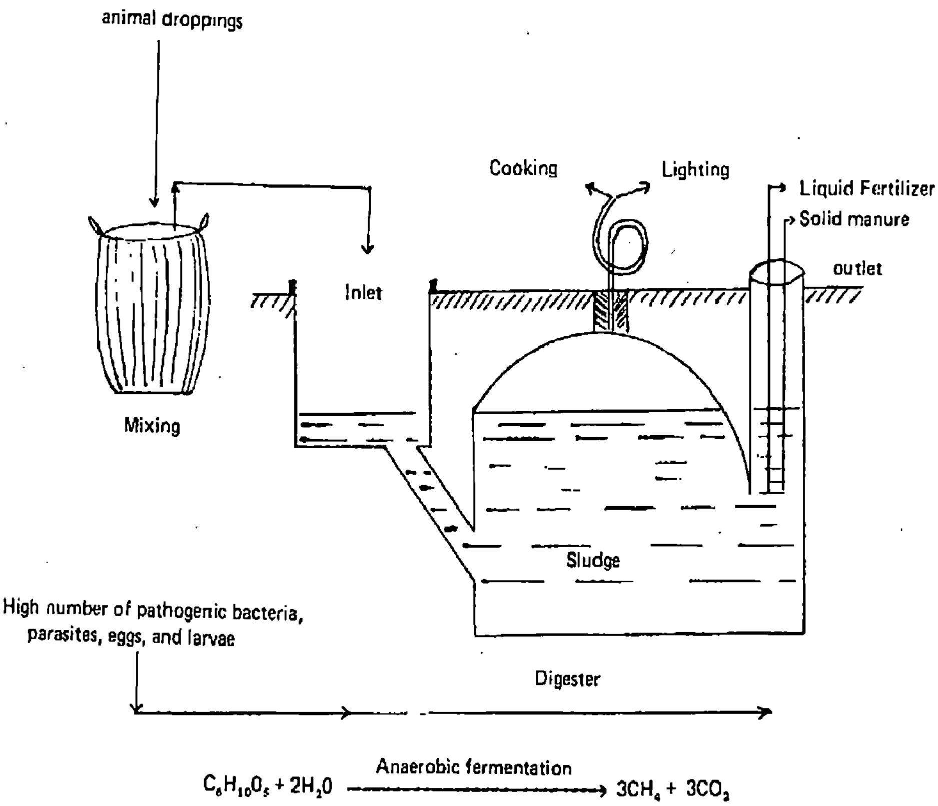


Fig. - 3.5: Schematic of Janta model biogas plant

3.3.1.1.3. *Biogas based electricity generation*

Biogas can partially replace diesel to run IC (internal combustion) engines for water pumping; small industries like floor mill, saw mill, oil mill etc. This would not only reduce dependence on diesel, but also help in reducing carbon pollutants, which adversely affect the atmosphere. Dual – fuel engines (70% biogas and 30% diesel) are now commercially manufactured in India and could use biogas to produce electricity.

In diesel (compression ignition) engines, the temperature at the end of compression, stroke becomes about 700°C, while the ignition temperature of the biogas/air mixture is 814°C. Hence, the injection of pilot diesel fuel during compression stroke is necessary to ignite the gas mixture and to ensure the normal running of the engine. Once the engine is started using pilot fuel, the biogas is simply connected to the air intake port of the diesel engine. The engine automatically substitutes diesel up to 70-75% with biogas & remaining 25- 30% diesel continues to be used by the engine. Thus, these diesel engines continue to run smoothly in dual fuel mode.

3.3.2. Biomass Gasification

3.3.2.1. Gasification technology

Biomass gasification is thermo-chemical conversion of solid biomass into a combustible gas mixture (producer gas) through a partial combustion route with air supply restricted to less than that theoretically required for full combustion. The gasification cycle of biomass gasifier is shown in Fig. 3.6.

Producer gas can be used as a fuel in place of diesel in suitable designed/adopted internal combustion (IC) engines coupled with generators for electricity generation. Producer gas can replace conventional forms of energy such as oil in many heating applications in the industry. The gasification process renders use of biomass relatively clean and acceptable in environmental terms. Large monetary savings can accrue through even partial substitution of diesel in existing diesel generator (DG) sets. Most commonly available gasifiers use would/woody biomass; some can use rice husk as well. Many other non-woody biomass materials can also be gasified, although gasifiers have to be specially designed to suit these materials and the biomass may have to be compacted in many cases.

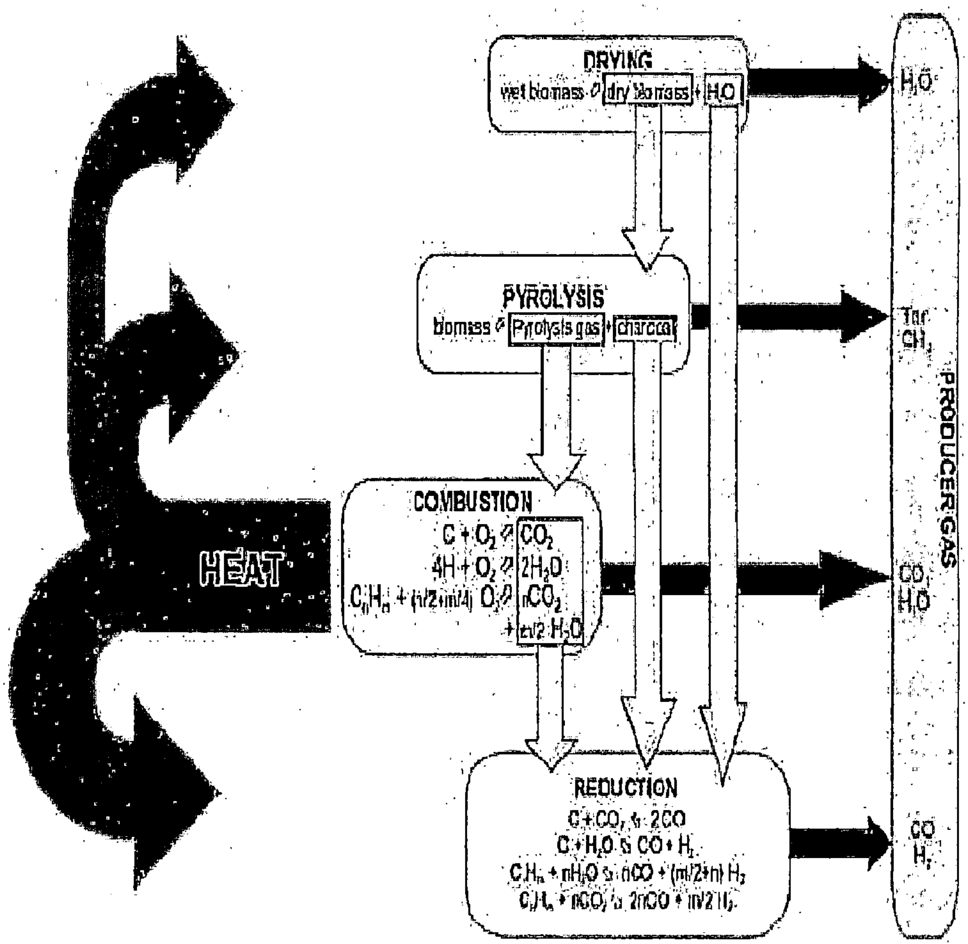


Fig. 3.6: Gasification Cycle of Biomass Gasifier

3.3.2.2.Types of gasifiers

3.3.2.2.1. *UP-draft gasifier*

It is also known as counter-current moving bed reactor having oxidation zone at the bottom and reduction zone just above it. Moving upward comes pyrolysis and drying zone. Its advantages are its simplicity of operation that no solids flow rate control is necessary & that there is internal heat exchange of the products. Its disadvantages are that large amount of tars are produced, because the gases do not pass through high oxidation zone temperature and uncracked tars & oils remain associated with outgoing gases. The schematic of up draft gasifier is shown in Fig. 3.7

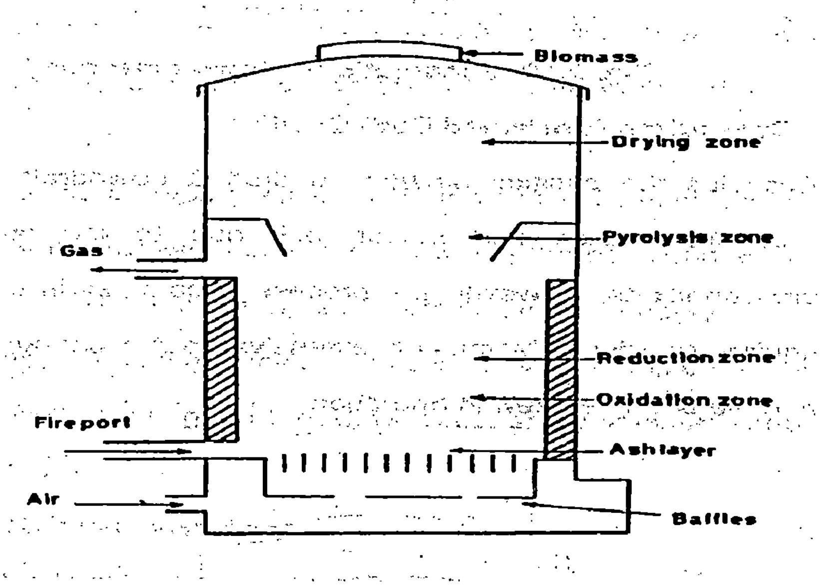


Fig. - 3.7: Schematic of up draft gasifier

3.3.2.2.2. *Down-draft (co-current moving bed) gasifier*

This type of reactor is simple to operate, produces an almost tar free product gases, because the pyrolysis gases are passed through high temperature oxidation zone where all bigger molecules of tar & oils are cracked to smaller molecules of gaseous products. It has high product gas temperature > 700°C and can also require feedstock pelletisation. The schematic of down draft gasifier is shown in fig. 3.8.

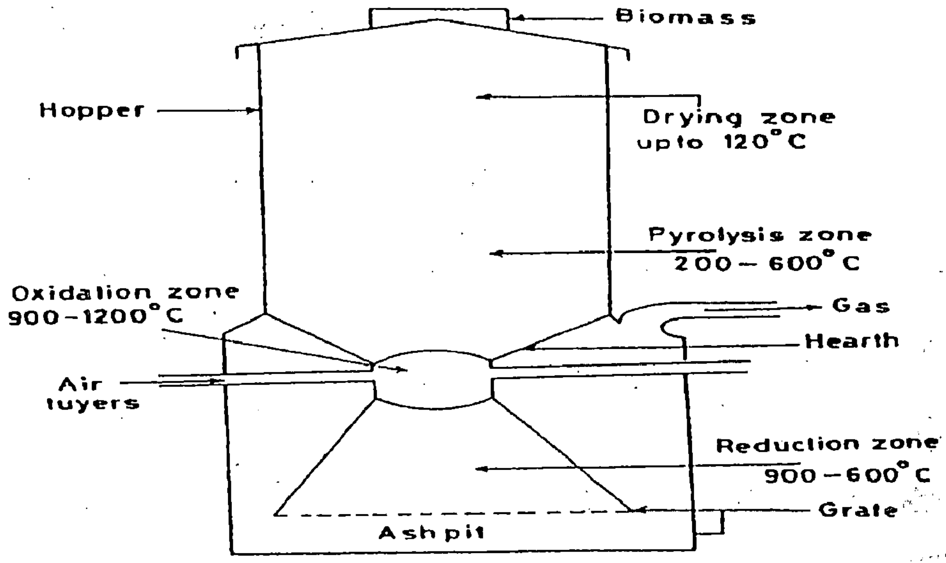


Fig. – 3.8: Schematic of down draft gasifier

3.3.2.2.3. *Cross-draft (entrained bed) gasifier*

It occupies the position between updraft & downdraft gasifiers and produces tar free gases and molten ash due to the prevailing high temperature conditions. However, the process is complex in operation. The gasifier requires powdered biomass & extensive heat exchange. Such types of gasifiers have been very few in operation. The schematic of cross draft gasifier is shown in fig. 3.9.

3.3.2.2.4. *Fluidized bed gasifiers*

These gasifiers can handle wide range of feed stocks but has a high product gas temperature (e.g. > 900°C) with minimum tar production, limited solid conversion, severe particle entrainment and is more difficult to operate (solids flow rate control etc.). This type of reactor is suitable for light materials such as chopped straw, saw dust, coffee husks, rice husks etc. having a wide range of granulometry. Because of turbulent mixing of F.B.Reactors, the capacity is usually a function of the volume of fluid bed. Traditionally, the height to diameter ratio of F .B. reactor is 10: 1 while for other gasifiers, it is usually in the range of 3:1.

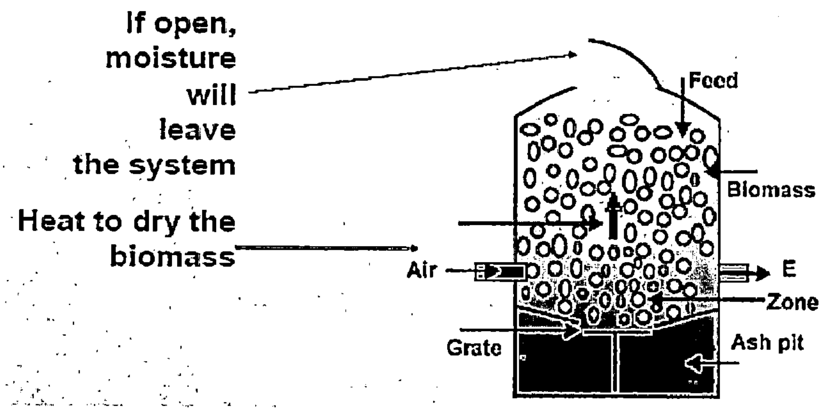


Fig. - 3.9: Schematic of cross draft gasifier

3.3.2.3. Feed stocks for gasification

The feedstocks for gasification may consist of agricultural residues, agro-industrial residues and forest waste as resources. The major agro-industrial residues include bagasse, rice husk, molasses, groundnut shells, saw dust and cotton gin waste. It is worth mention here that most of the by-products are even today used as fuel. However, in many instances, the efficiency of utilisation is indeed quite low and the typical applications are for low-grade thermal heat. In this context, the resource base is again very significant.

3.3.2.4. Chemistry of gasifier operation

The downdraft gasifier, also called the co-current moving bed gasifier, is most commonly used for engine application because of its ability to produce relatively clean gas, however, the presence of throat poses problems of fuel movement.

A complete understanding of the various complex reactions occurring in a gasifier has not been possible so far, However, the following reactions explain the process of gasification fairly well,

- ⇒ $C + O_2$ = CO_2 + 393 800 kJ/kg mole (Combustion)
- ⇒ $C + H_2O$ = $CO + H_2$ -131 400 kJ/kg mole (Water gas)
- ⇒ $C + CO_2$ = $2CO$ -172 600 kJ/kg mole (Boudouard reaction)
- ⇒ $CO + H_2O$ = $CO_2 + H_2$ + 41200 kJ/kg mole (Water shift reaction)
- ⇒ $C + 2H_2$ = CH_4 + 75 000 kJ/kg mole (Methane reaction)

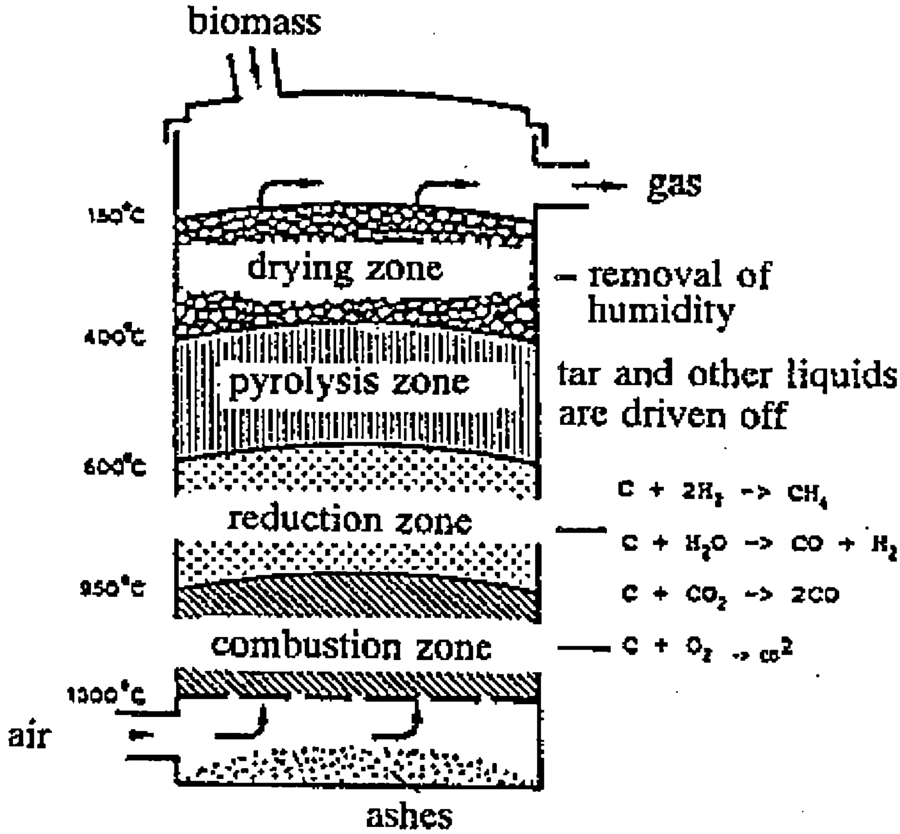


Fig. - 3.10: Biomass gasifier system

With the help of the above reaction scheme, and with a knowledge of the equilibrium constants, it is possible to predict the equilibrium composition of the gaseous products, The equilibrium composition for a given solid fuel depends upon the air supply per unit weight of the biomass, A dimensionless parameter, known as the equivalence ratio (ER), to characterize the air supply conditions, is usually defined as follows;

$$ER = \frac{Weight\ of\ oxygen / Weight\ of\ dry\ fuel}{Weight\ of\ oxygen / Weight\ of\ dry\ fuel\ stoiscimetrically}$$

The denominator in the above equation is the oxygen required for complete combustion of the fuel and it varies from fuel to fuel.

3.3.2.5. Composition of producer gas

In this process, a solid fuel is converted to a gaseous fuel (producer gas) by a series of thermo chemical processes such as drying, pyrolysis, oxidation, and reduction. If atmospheric air is used as the gasification agent, which is the normal practice, the producer gas will consist mainly of carbon monoxide, hydrogen and nitrogen. The typical composition of producer gas is given in Table 3.5.

Table-3.4: Composition of producer gas

Sl. No.	Description	Composition
1.	Carbon monoxide	15%-22%
2.	Hydrogen	13%-19%
3.	Methane	1%-5%
4.	Carbon dioxide	9%-12%
5.	Nitrogen	45%-55%
6.	Calorific value	900-1200 Kcal/m3

3.3.2.6. Biomass based electricity generation

Conventional dual fuel engines (e.g. biogas engine) need certain modification before its use with producer gas. This is necessary because calorific value of biogas (about 5500 k. Cal/Nm3) differs widely from producer gas (about 1100 k.cal/Nm3). Producer gas from biomass residues has higher hydrogen content than the gas produced from charcoal. Thus producer gas to be used in IC-engines needs lower compression ratio especially for operation in dual fuel mode.

Furthermore with the use of producer gas as a fuel, in general, the timing of the engine needs to be more advanced as compared to fossil fuel engines. With producer gas from charcoal, the timing of the spark need to be advanced up to 250 before Top Dead Centre (TDC), but with producer gas, it need, not be much advanced in view of its higher hydrogen and lower nitrogen contents. Producer gas needs to be mixed with air in ratio 1.1 in the intake manifold. For initial few minutes the engine needs to be run with diesel alone (throwing away the gas outside) and then switching over to dual fuel mode. This can be achieved by connecting the engine shaft to an impeller for initial few minutes and then disengaging the impeller & sucking the gas through a parallel line into the engine. A schematic of gasifier based engine generator system is shown in Fig. 3.13.

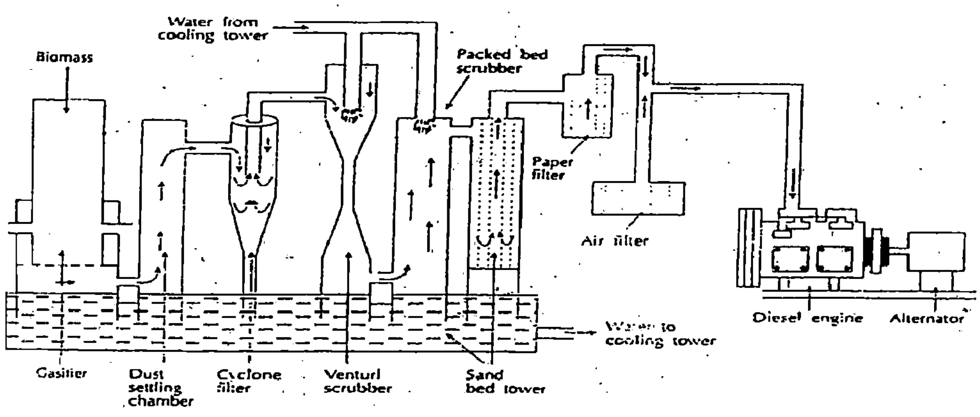


Fig. - 3.11: Biomass gasifier-energy generation system

3.4. WIND ENERGY

Winds are caused by rotation of the earth and heating of the atmosphere by the sun. Due to the heating of the air at the equatorial regions, the air becomes lighter and starts to rise, and at the poles the cold air starts sinking. The rising air at the equator moves northward and southward. Differential heating of sea causes more minor changes in the flow of air. The nature of the terrain, ranging from mountains and valleys to more local obstacles such as buildings and trees, also has an important effect on the wind [32].

In India, the wind energy averages over 3 kWh/m^2/day along the coastal line. In areas, where wind energy densities higher than 4 kWh/m^2/day is available for 5 – 7 months, two types of systems viz. wind mill pumps for irrigation and wind electric generation (aero generators) systems to generate power are used. Wind battery chargers are viable in remote areas. Wind electric systems are available with a rating of 500 – 750 kW.

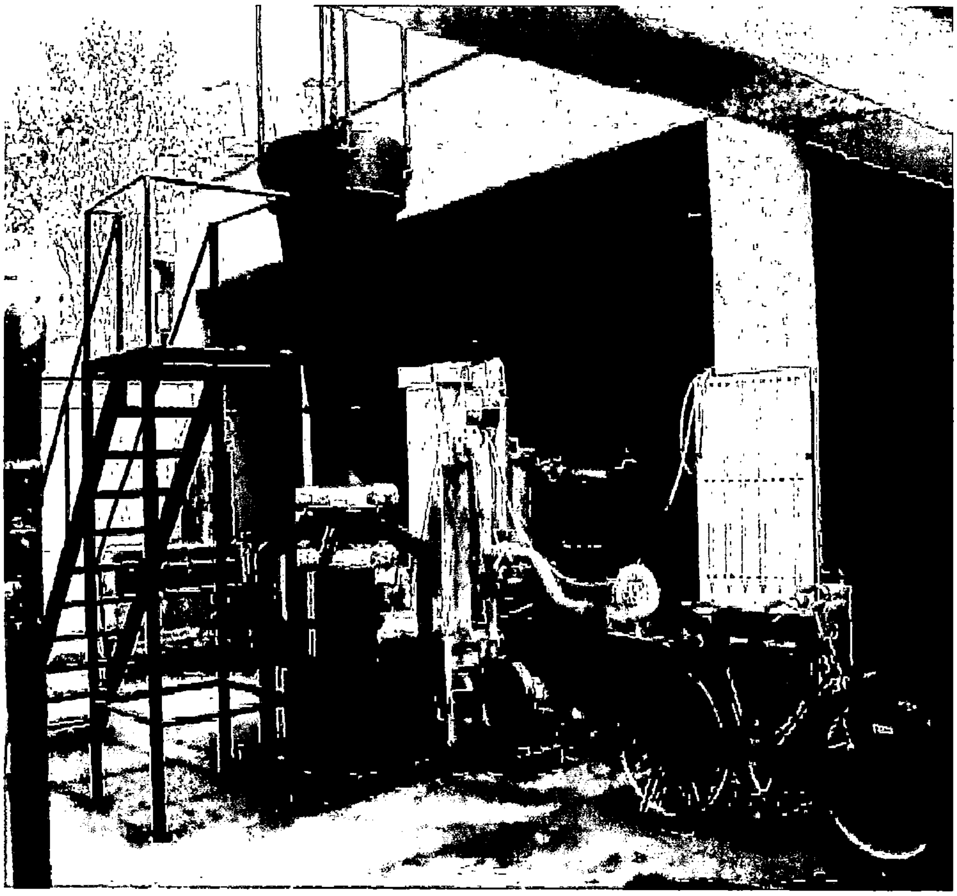


Fig. - 3.12: Biomass Gasifier at Remote Island

Wind turbines are classified in terms of the orientation of their axis of rotation in relation to the wind stream and to the surface of the earth. The development of the two principal types of the machine is namely, the horizontal – axis wind turbine generator (HAWTG) and the vertical –axis wind turbine generator (VAWTG)]. This mechanical motion can be used to pump fluids or can be converted to electricity, heat or fuel. If required, wind derived energy can be converted to other forms of energy or can be stored through the use of compressed fluid, pumped-hydro systems, water saver systems, batteries, hydrogen, flywheels, hot water etc.

3.4.1. Wind Turbine

Most turbines manufactured today are horizontal axis upwind machines that have two or three blades, which are usually made of a composite material such as fiberglass. The amount of power a turbine will produce is determined primarily by the diameter of its rotor. The diameter of the rotor defines its "swept area," or the quantity of wind intercepted by the turbine. The turbine's frame is the structure onto which the rotor, generator, and tail are attached. The tail keeps the turbine facing into the wind.

3.4.2. Tower

Because wind speeds increase with height, the turbine is mounted on a tower. In general, the higher the tower, the more power the wind system can produce. Relatively small investments in increased tower height can yield very high rates of return in power production. There are two basic types of towers: self-supporting (free standing) and guyed. Most home wind power systems use a guyed tower. Guyed towers, which are the least expensive, can consist of lattice sections, pipe, or tubing depending on the design, and supporting guy wires. They are easier to install than self-supporting towers. While tilt-down towers are more expensive they offer the consumer an easy way to perform maintenance on smaller lightweight turbines, usually 5 kW or less. Tilt down towers can also be lowered to the ground during hazardous weather such as hurricanes. Aluminum towers are prone to cracking and should be avoided. Most turbine manufacturers provide wind energy system packages that include towers. The basic parts of a wind electric system are shown in the Fig. 3.13.

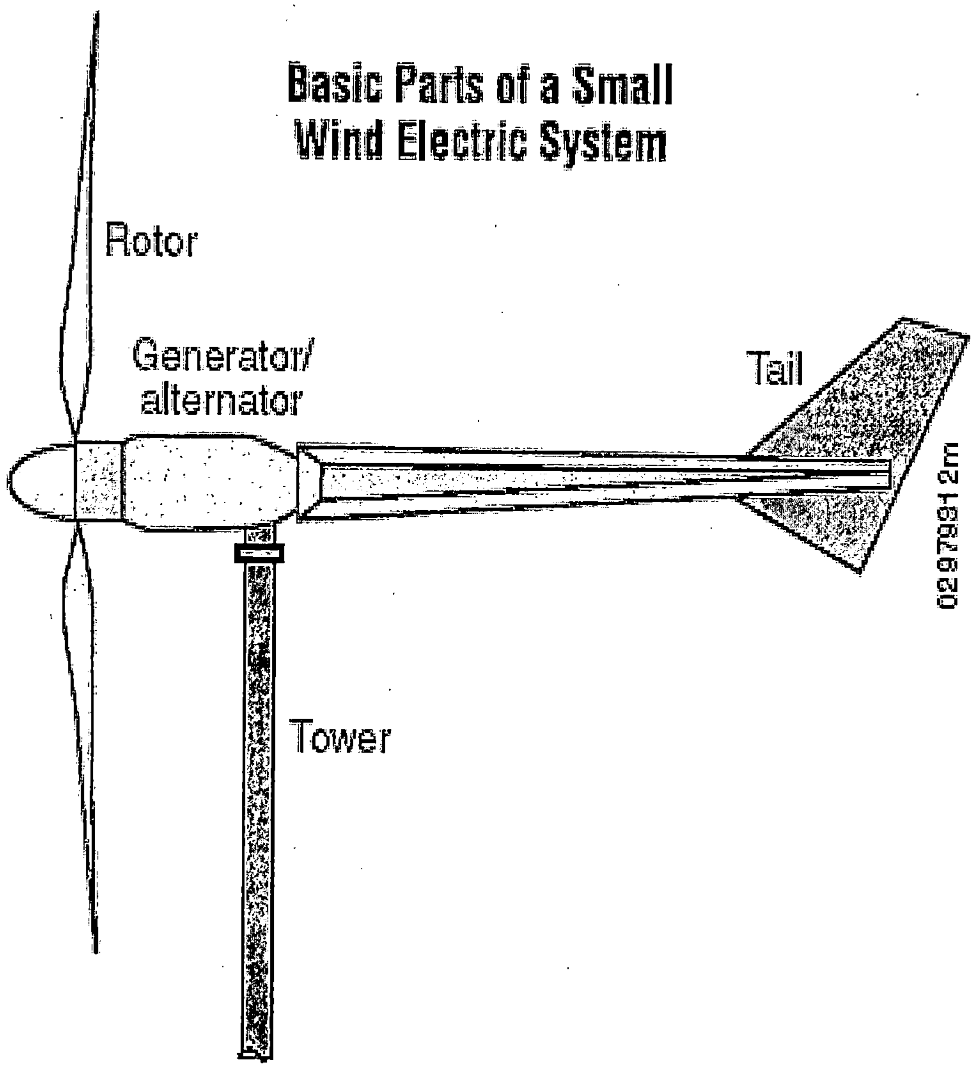


Fig. - 3.13: Basic Parts of a wind electric system

3.4.3. Design feature

Consider the wind flowing with a speed V, the Power density (i.e. the power per unit area normal to the wind) is kinetic energy flowing per unit area is given by following equation;

$$P = \frac{1}{2} C_p \rho A V^3 \text{ kW}$$

Where,

Cp = Power Coefficient

ρ = Density of air

V= wind speed

A = Swept area

P = power per unit area normal to the wind

The annual wind speed at a location is useful as an initial indicator of the value of the wind resource. The relationships between annual mean wind speed and potential value of the wind energy resource are listed in Table 3.6.

Table 3.5: Mean Annual Wind Speed and Potential

Sl.No	Annual mean wind speed at 10 m height	Indicated value of resource
1	< 4.5 m/s	Poor
2	4.5-5.4 m/s	Marginal
3	5.4-6.7 m/s	Good to very good
4	>6.7 m/s	Exceptional

Wind power density is a useful way to evaluate the wind resource available at a potential site. The wind power density, measured in watts per square meter, indicates how much energy is available at the site for conversion by a wind turbine. Classes of wind power density for two standard wind measurement heights are listed in the Table below. Wind speed generally increases with height above ground.

3.5. SOLAR ENERGY

Based on the total energy demand of the area the total number of solar photovoltaic (SPV) modules can be sized and accordingly the other components of the SPV systems can be designed.

3.5.1. Components of a Photovoltaic (PV) System [57]

The photovoltaic system consists of photovoltaic generator with mechanical support and possibly, a sun-tracking system, batteries (storage subsystem), power conditioning and control equipment (i. e. converter, charge controller, etc.), including provision for measurement and monitoring and back-up generator. A photovoltaic (PV) system has various subsystems as outlined in Fig.3.14.

3.5.1.1. PV generator

It is the main unit of SPV system, which contains cell, module, panel, and array. PV generator is the series of PV cells. The PV cells are based on the principle of photovoltaic effects. Semiconductors are used for PV cells. The input of SPV system is solar energy, which is absorbed by array cells and is converted to electricity.

The Fig. 3.15 shows that the PV cells are connected in series/ parallel connection and form a module and further the combination of these modules is known as panel and finally combination of these panels constitutes an array. A standard size PV cell of 100mm dia. or 100 mm^2 can produce about 0.5-0.8 V and 2 – 3 ampere current.

3.5.1.2. Photovoltaic cells

The fundamental power unit of a PV system is a solar cell, which is a semiconductor generally, made of silicon. The four common types of silicon photovoltaic (PV) cells are Single crystalline silicon, Polycrystalline silicon, Ribbon silicon, and amorphous silicon.

Fig. 3.16 shows a PV cell is of the single crystalline type. To produce these, silicon is purified, melted and crystallized into ingots.

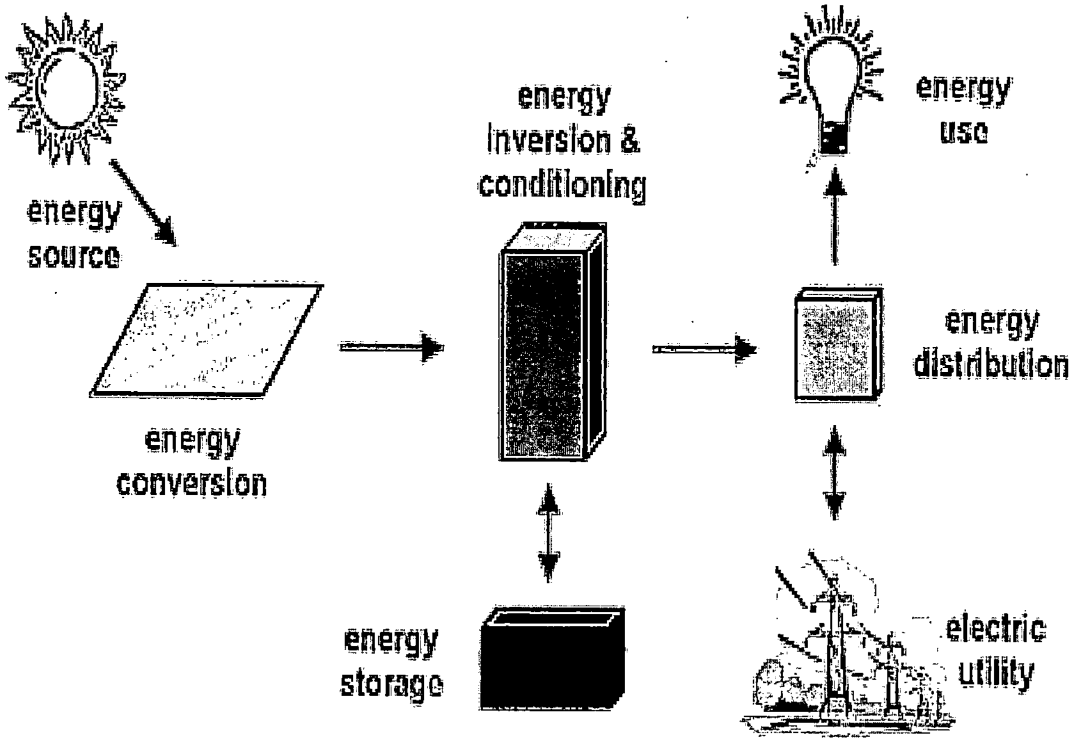


Fig. 3.14: Photovoltaic system [57]

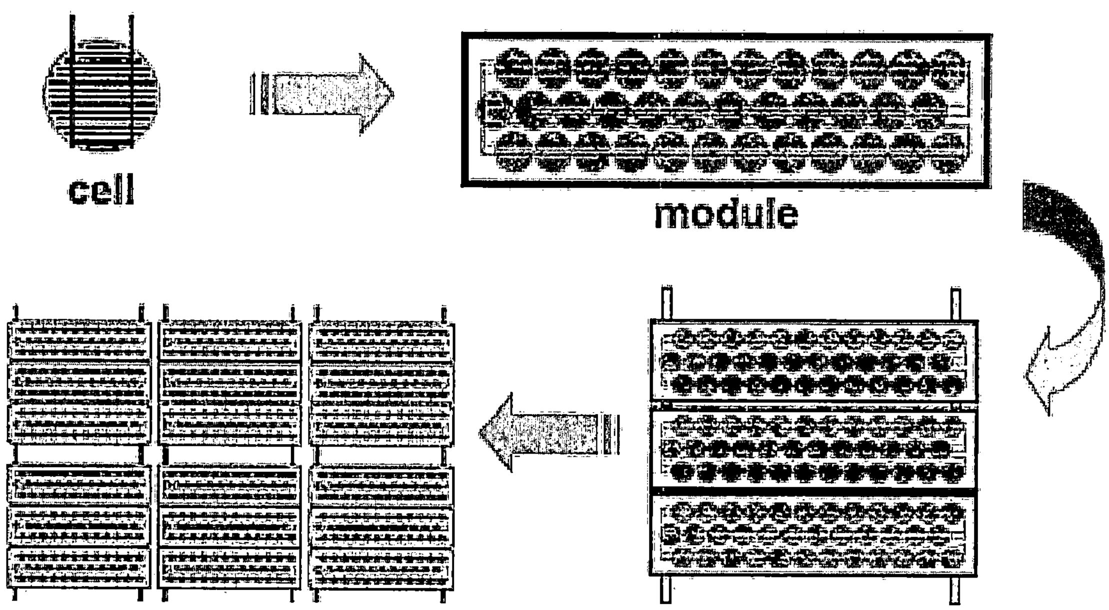


Fig. 3.15: Photovoltaic cells, modules, panels and arrays [57]

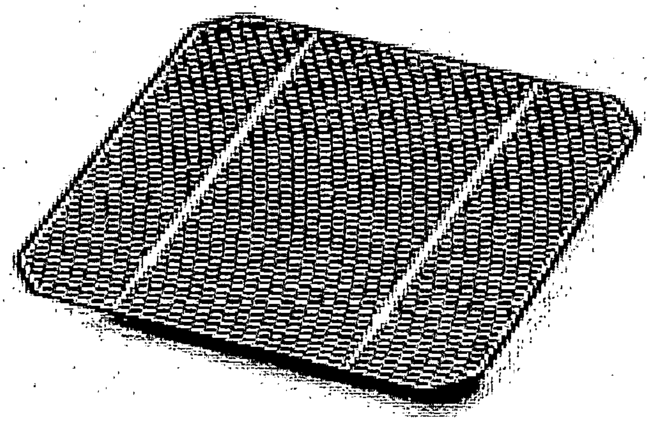


Fig. 3.16: Photovoltaic cell [58]

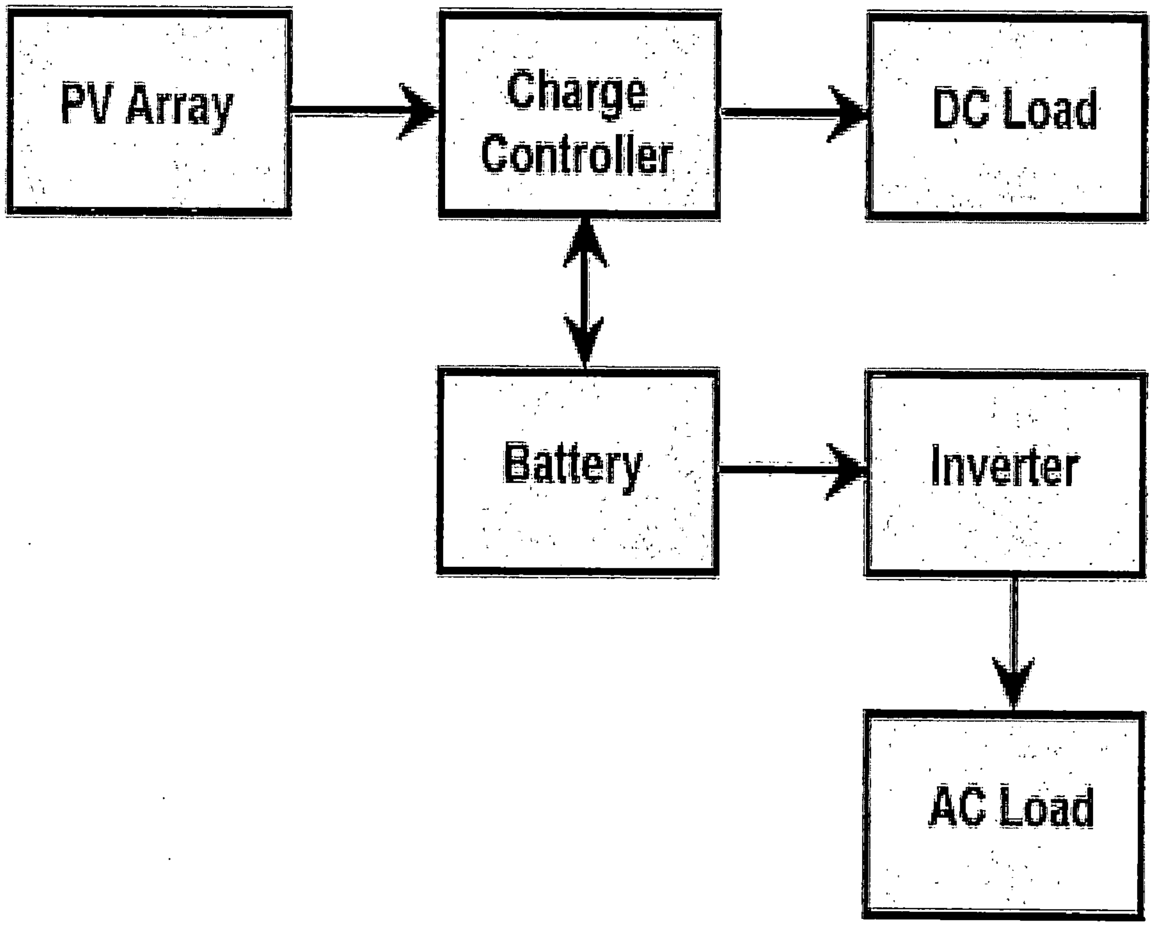


Fig. 3.17: Stand-alone PV system with battery storage powering DC and AC loads [57]

These ingots are sliced into thin wafers to make individual cells. Which are attached to a base called a 'back-plane', which is a layer of metal used to physically reinforce the cells and provide electrical contact at the bottom. All the components are connected to get stand-alone PV system according to the schematic shown in Fig. 3.17.

3.5.1.3. Storage batteries

If an off-grid PV system must provide energy on demand rather than only when the sun's shining, a battery is required as an energy storage device. The most common battery types are lead-calcium and lead-antimony. Nickel-cadmium batteries can also be used, in particular when the battery is subject to a wide range of temperatures. Because of the variable nature of solar radiation, batteries must be able to go through many cycles of charge and discharge without damage. The amount of battery capacity that can be discharged without damaging the battery depends on the battery type. Lead-calcium batteries are suitable for applications where less than 20% discharge occurs whereas Nickel-cadmium batteries and some lead-antimony batteries can be used in "deep cycle" applications where the depth of discharge can exceed 80%.

Depending on site conditions, and on the presence of a back up generator, battery banks are sized to provide a period of system autonomy ranging from a few days to a couple of weeks. Batteries are characterized by their voltage, which for most applications is a multiple of 12 V, and their capacity, expressed in Ampere-hours (Ah). For example a 50 Ah, 48 V battery will store 50 × 48 = 2,400 Wh of electricity under nominal conditions. Note that optimizing battery size is critical in obtaining good battery life, suitable system performance, and optimal system life-cycle costs. Unnecessary battery replacement is costly, particularly for remote applications.

3. 5.1.4. Power conditioning system

Several electronic devices are used to control and modify the electrical power produced by the photovoltaic array. These include:

- ⇒ Battery charge controllers - regulate the charge and discharge cycles of the battery;
- ⇒ Maximum power point trackers (MPPT) - maintain the operating voltage of the array to a value that maximizes array output;
- ⇒ Inverters - convert the direct current (DC) output of the array or the battery into alternating current (AC). Many appliances and motors require AC.
- ⇒ Rectifiers (battery chargers) - convert the AC current produced by a generator into the DC current needed to charge the batteries.

3.6. OCEAN ENERGY

The oceans have a tremendous amount of energy and are close to many if not most concentrated populations. Some believe that ocean power will provide a substantial amount of new renewable energy around the world. Ocean presents a vast quantity of renewable source of energy in the form of waves and tides. In addition, there is vast quantity of energy in the form of thermal difference which can be extracted. Several means of extracting energy from the ocean have been tried, some with limited success.[59]

- ➢ Wave power
- ➢ Ocean thermal energy conversion (OTEC)
- ➢ Tidal power
- ➢ Marine current power

3. 6.1. Wave Power

Wave power refers to the energy of ocean surface waves and the capture of that energy to do useful work - including electricity generation, desalination, and the pumping of water (into reservoirs). Wave power is a form of renewable energy. Wave power generation is not a widely employed technology, with only a few experimental sites in existence.Wave power is determined by wave height, wave speed, wavelength, and water density. Wave size is determined by wind speed and fetch (the distance over which the wind excites the waves) and by the depth and topography of the seafloor (which can focus or disperse the energy of the waves). The wave motion is highest at the surface and diminishes exponentially with depth; however, wave energy is also present as pressure waves in deeper water. The potential energy of a set of waves is proportional to wave height squared times wave period (the time between wave crests). Longer period waves have relatively longer wavelengths and move faster. The potential energy is equal to the kinetic energy, which can be expended. Wave power is expressed in kilowatts per meter at a location such as a shoreline.

The formula below shows how wave power can be calculated. Excluding waves created by major storms, the largest waves are about 15 meters high and have a period of about 15 seconds. According to the formula, such waves carry about 1700 kilowatts of potential power across each meter of wavefront. A good wave power location will have an average flux much less than this: perhaps about 50 kW/m. The formula will be

$$\text{Power (in kW/m)} = k\, H^2\, T \sim 0.5\, H^2\, T,$$

Where,

k = constant

H = wave height (crest to trough) in meters, and

T = wave period (crest to crest) in seconds.

The fundamental challenges of wave power are efficiently converting wave motion into electricity and constructing devices that can survive storm damage and saltwater corrosion. Existing wave power devices are categorized by the method used to capture the energy of the waves, by the intended location, and by the power take-off. Systems include oscillating water column, articulated pontoon, wave pump, anchored buoy, fixed buoy, and overtopping reservoir [59].

3. 6.2. Ocean Thermal Energy Conversion (OTEC)

Ocean thermal energy conversion, or OTEC, is a way to generate electricity using the temperature difference of seawater at different depths. The method involves pumping cold water from the ocean depths (as deep as 1 km) to the surface and extracting energy from the flow of heat between the cold water and warm surface water. OTEC utilizes the temperature difference that exists between deep and shallow waters heat engine. Because the oceans are continually heated by the sun and cover nearly 70% of the earth's surface, this temperature difference contains a vast amount of solar energy which could potentially be tapped for human use.

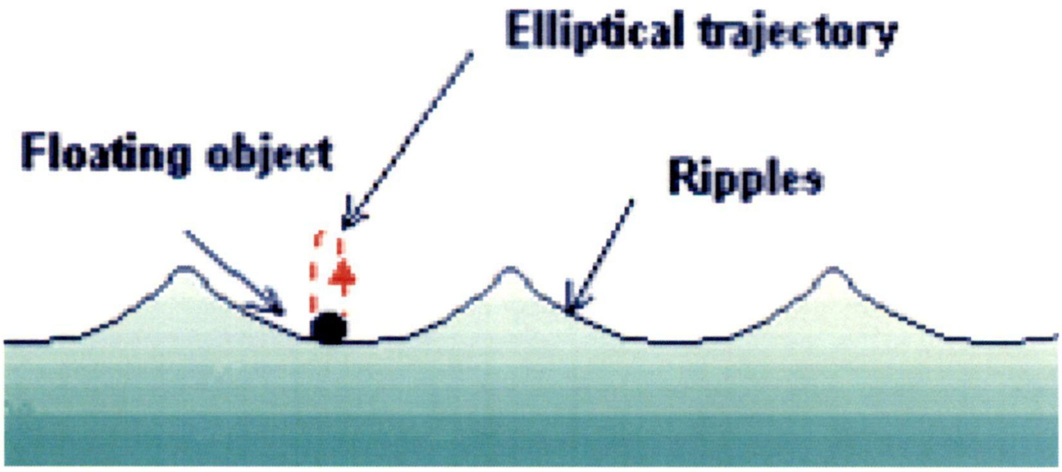


Fig. 3.18: Motion due to wave energy[59]

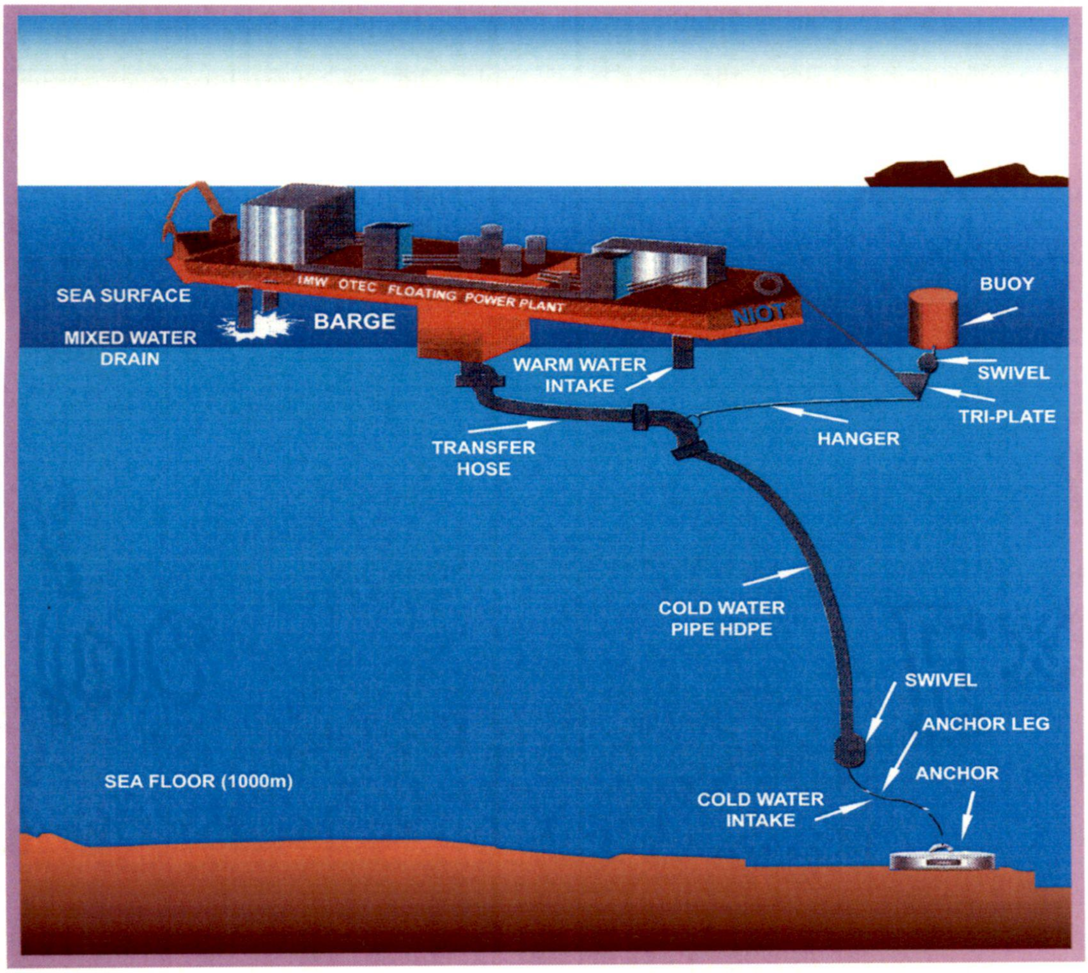


Fig. 3.19: Ocean Thermal Energy Conversion System [59]

All OTEC plants require an expensive, large diameter intake pipe, which is submerged a mile or more into the ocean's depths, to bring very cold water to the surface. Various fluids have been proposed over the past decades to be used in closed OTEC cycle. A popular choice is ammonia which has superior transport properties, easy availability, and low cost. Ammonia, however, is toxic and flammable. Fluorinated carbons such as CFCs and HCFCs would have been a better choice had it not been for their contribution to ozone layer depletion. [59]

3.6.3. Tidal Power

Tidal power is a means of electricity generation achieved by capturing the energy contained in moving water mass due to tides.The extraction of potential energy involves building a barrage and creating a tidal lagoon. The barrage traps a water level inside a basin. Head is created when the water level outside of the basin or lagoon changes relative to the water level inside. The head is used to drive turbines. In any design this leads to a decrease of tidal range inside the basin or lagoon, implying a reduced transfer of water between the basin and the sea. This reduced transfer of water accounts for the energy produced by the scheme. [59]

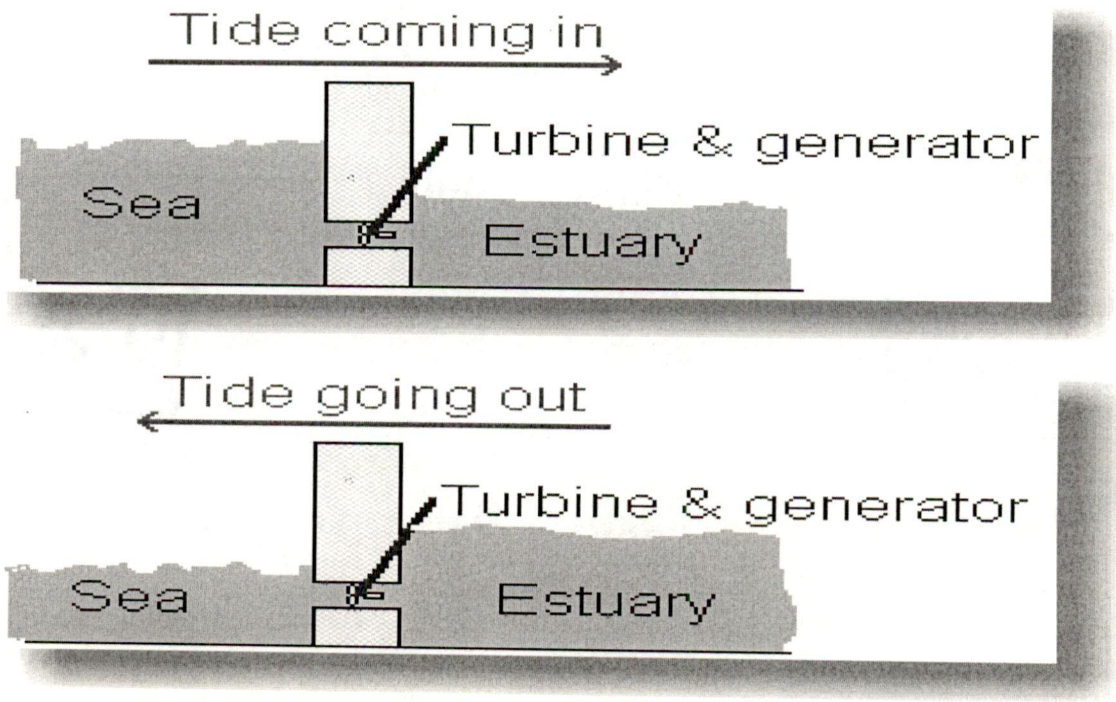


Fig. 3.20: Principle of tidal power generation [59]

The efficiency of tidal power generation in ocean dams largely depends on the amplitude of the tidal swell, which can be up to 10 m (33 ft) where the periodic tidal waves funnel into rivers and fjords. The selection of location is critical for a tidal power generator. The potential energy contained in a volume of water is;

$$E = xMg$$

Where,

x is the height of the tide

M is the mass of water and

g is the acceleration due to gravity.

Therefore, a tidal energy generator must be placed in a location with very high-amplitude tides. Tidal power schemes do not produce energy 24 hours a day. A conventional design, in any mode of operation, would produce power for 6 to 12 hours in every 24 and will not produce power at other times. As the tidal cycle is based on the period of revolution of the Moon (24.8 hours) and the demand for electricity is based on the period of revolution of the Sun (24 hours), the energy production cycle will not always be in phase with the demand cycle. This causes problems for the electric power transmission grid, as capacity with short starting and stopping times (such as hydropower or gas fired power plants) will have to be available to alternate power production with the tidal power scheme. Tidal power schemes have a very high capital cost and a very low running cost. As a result, a tidal power scheme will not produce returns for decades after it is built, and investors are not likely to participate in such projects. Governments may be able to finance tidal power, but many are unwilling to do so also due to the extremely long time before returns and the huge irreversible commitment.[59]

3. 6.4. Marine Current Energy

The global marine current energy resource is mostly driven by the tides and to a lesser extent by thermal and density effects. The strength of the currents varies, depending on the proximity of the moon and sun relative to Earth. The strength of the marine currents generated by the tide varies, depending on the position of a site on the earth, the shape of the coastline and the shape of the seabed. Areas that typically experience high marine current flows are in narrow straits, between islands and around headlands. Entrances to lochs, bays and large harbours often also have high marine current flows. Generally the resource is largest where the water depth is relatively shallow and a good tidal range exists. In particular, large marine current flows exist where there is a significant phase difference between the tides that flow on either side of large islands.

Useful energy can be generated from marine currents using completely submerged turbines comprising of rotor blades and a generator. Water turbines work on the same principle as wind turbines by using the kinetic energy of moving fluid and transferring it into useful rotational and electrical energy. The velocities of the currents are lower than those of the wind, however owing to the higher density of water (835 times that of air) water turbines are smaller than their wind counterparts for the same installed capacity. The power that can be extracted from the currents is dependent on the velocity of the water flow and the area and efficiency of the water turbine, and can be calculated as follows:

$$\text{Power} = \tfrac{1}{2}\ \rho\, A\, v^3\, C_p$$

Where,

ρ is the density of sea water (1025 kg/m^3)

A is the area of the rotor blades (m^2)

v is the marine current velocity (m/s)

C_p is the power coefficient, a measure of the efficiency of the turbine

Marine current energy is at an early stage of development. There are no commercial grid-connected turbines currently operating anywhere in the world [60].

CHAPTER –4

SELECTION OF ISLAND AND CONSUMPTION PATTERN OF ENERGY

4.1. SELECTION OF ISLAND

The scope of the study was to analyze and understand the pattern of energy consumption, the requirements for future, the details of locally available energy resources and to suggest self sustained alternatives for meeting energy requirements on account of domestic, industrial and agricultural sectors of an island. India has only two union territories comprising with islands viz. Lakshdweep and Andaman and Nicobar Islands.

Lakshdweep is located 8° and 12° North latitude and 71° and 74° East longitude. It is 220 to 440 km off the Malabar Coast in Kerala. Its climate is tropical and temperatures are usually in the range of 27° C to 32° C. Its population is only 60595 as per 2001 census, of which 95% are muslims. Ethnically they are similar to the people of Kerala. It has only 36 islands having a total area of 32 sq. kilometers. It is the tiniest Union Territory of India with 12 atolls, 3 reefs and 5 submerged banks. Ten Islands are inhabited. They are Agatti, Amini, Andrott, Bitra, Chetlat, Kadmat, Kalpeni, Kavaratti, Kiltan and Minicoy. Since all the inhabited islands are tiny, the people of Lakshdweep are mostly engaged in fishing and coconut cultivation. The dispersed island situation and small size of islands were the two main constrains in choosing this union territory for the above case study [61].

The other alternative was the Andaman and Nicobar Islands, which is in the form of a chain of small and large islands, situated in southeastern region of the Bay of Bengal, mid way between peninsular India and Mayanmar. These islands are located between 6° 45" and 13° 41" North latitudes, and 92° 12" and 93° 57" East longitude. There are in all 349 islands, which can be distinguished into two groups geographically. Islands located north of 10°N latitude are known as Andaman Group of Islands while islands located south of 10° N latitude are called Nicobar Group of Islands. There are 325 islands in Andaman Group while Nicobar Group has 24 islands. Total geographic area of Andaman & Nicobar Islands is 8249 sq. km. of which Andaman Group of Islands cover 6408 sq. km. while Nicobar Group cover 1841 sq. km. Out of total 349 islands only 36 islands are inhabited by human beings – 24 in Andaman Group and 12 in Nicobar Group of Islands. Thus the Andaman Group is the main part of Andaman and Nicobar Islands sharing 88% population. The main part of this group of islands is known as Great Andaman, which comprises of 9 closely adjoining main islands, namely Little Andaman, Rutland, South Andaman, Middle Andaman, North Andaman, Baratang, Neil, Havelock and Strait Island separated by narrow channels of sea [62].

Middle Andaman Island is the biggest island of A&N Islands with an area of 1535.5 sq. km. with 98 inhabited villages and 9744 households. Similarly the area of South Andaman Island is 1347.97 sq. km with 98 inhabited villages and 1 city viz. capital city Port Blair having 29867 households. The area of North Andaman Island is 1376 sq. km with 63 villages and 6433 households and Baratang is 297.8 sq. km with 22 villages and 1135 households [62]. These four islands were not considered for above study as grid is already available connecting 20 MW private power house of Bambooflat (South Andaman), 12.5 MW diesel power house of Chatham (South Andaman), 2.26 MW power house at Phoenix Bay (South Andaman), 6.5 MW diesel power house at Rangat (Middle Andaman), 1.65 MW diesel and 5.25 MW Hydro power houses at Sita Nagar and Navagram (North Andaman).

The area of Little Andaman is 731.6 sq. km with 19 villages having 2883 households; the area of Rutland is 137.2 sq. km. with 5 villages and 158 households, the area of Havelock Island is 113.9 sq. km. with 5 villages and 769 households, the Neil Island is 18.9 sq. km. with 5 villages and 534 households and Strait Island is 6 sq. km. with 1 village and 12 households[62].

The area of Little Andaman is too big to conduct an extensive survey in a limited span of time hence the choice was with the four islands viz. Rutland, Havelock, Neil and Strait Islands. Rutland and Strait Islands have 158 and 12 households only, as such these were not considered suitable to carry out such study. Out of remaining two islands viz. Neil and Havelock, the Neil Island was selected due to its convenient size and better household concentration (area 18.9 sq. km. against 113.9 sq. km. of Havelock for same no. of villages and almost same no. of households).

4.2. ANDAMAN & NICOBAR ISLANDS - AN OVERVEIW

Andaman & Nicobar Islands is a Union Territory; centrally administrated by a Lieutenant Governor. Port Blair is the capital of these islands, which is well connected with mainland by sea routes and air services. It is located at a distance of 1190 km from Chennai, 1255 km from Calcutta and 1200 km from Visakhapatnam. In one word these islands are called 'Mini India' because people from every corner of India of different languages, caste, creed etc. are found in these islands. The total population of these islands is 356152 as per the census of 2001.The density of population is 43 persons per sq. Kms [62]. These islands are situated in the tropical zone. The climate can be described as tropical type but the sea breeze blowing in from surrounding ocean makes it pleasant. The minimum temperature varies between 19.4^0 C to 24.5^0 C and maximum temperature varies between 28.7^0 C to 32.3^0 C. The average annual rainfall in these islands is of the order of 3045 mm. The average relative humidity has a maximum value of 85% to 86% and a minimum value of 67% to 69% during August and April respectively [62].

These islands have a total forest cover of 7171 sq. km. of which an area of 2929 sq. kms. is a reserved forest. These islands do have forest wealth in abundance, but exploitation of forest wealth need to be restricted. It would be seen that forests cover is about 87% of the total land area of these islands. The details of forestland are shown as Table 4.1: [63].

Table 4.1: Details of Forest Land at A&N Islands [63]

Sl. No	Division / Zone	Geographical Area Km^2	Forest Area (Km^2) Reserved	Protected	Total Forest Area Km^2.
1.	South Andaman	11648	1208	112	1320
2.	Baratang	721	647	-	647
3.	Middle Andaman	965	53	804	857
4.	North Andaman	2325	315	1784	2099
5.	Little Andaman	789	706	-	706
6.	Nicobar Group of Islands	1841	-	1542	1542

These islands have not achieved self-sufficiency in the requirement of foodstuffs for its population. Rice, wheat, sugar, cereals, oils etc. are being brought in from the mainland. The area and production of main crops as per earlier survey are appended in Table 4.2 [62].

Table 4.2: Area and production of various crops at A&N Islands [62]

S. No	Name of Crops	Area (in Hectare)	Production (in M. Tonnes.)
1.	Rice	12,104	30,600
2.	Banana	1,572	7,850
5.	Cashewnut	876	236
7.	Rabi Pulses	2,060	1,030
8.	Coconut	24,390	85.38 (million nuts)
9.	Arecanut	2,967	5,450

4.3. DATA COLLECTION FROM SELECTED ISLAND

4.3.1 General

The Neil Island, which is selected for case study for energy planning, is 37 kms. away from Port Blair across sea and well connected with daily steamer service with Port Blair and other nearby islands. It is situated in Andaman group of islands under Port Blair tehsil. The location of island under study is shown in Fig. - 4.1. This island has an area of 18.90 sq. km. It comprises of five villages namely Bharat Pur, Laxman Pur, Ram Nagar, Sita Pur and Neil Kendra. The location of all the villages is shown in Fig.-4.2.

4.3.2 Data Collection and Analysis

The data were collected for getting different inputs from each household such as number of family members, type of house /building, land holding, irrigation facilities, average monthly income, method of cooking / lighting / water-heating and fuel / energy consumed per month, electrical domestic appliances, number of animals/birds, sources of potable domestic water, water availability for domestic use and animals, number of vehicles and food grains consumption per month.

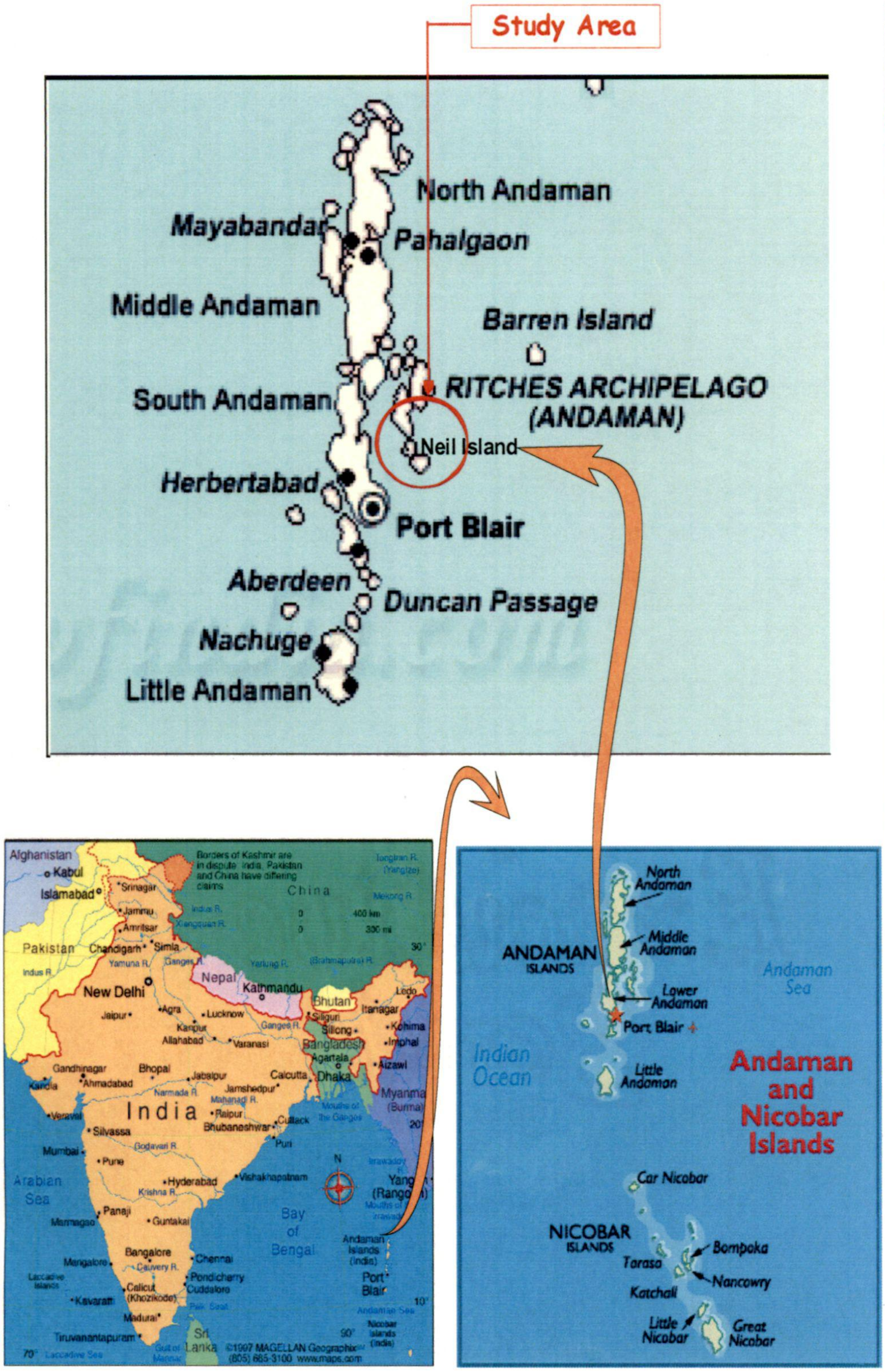


Fig. 1 : Location Map of Neil Island

Fig.-4.2: Village location map of Neil Island

In order to quantify the characteristic features of the rural energy scene, the author conducted the door-to-door survey during the month of January-February 2006 covering all the households in all the five villages at Neil Island. The respondents for household survey were heads or responsible persons in absence of head of each household. Other data concerning to the Neil Island were collected through personal contact from the different departments of Andaman and Nicobar administration and Central Government offices.

On analyzing the collected data it is found that there are 581 households with a population of 2805 and land holding of 854.88 Acres. The village wise details have been shown in the Table 4.3.

Table 4.3: Population and Households at Neil Island

Sl. No.	Name of Village	Population	No. of House Holds	Land holding in Acres
1.	Bharat Pur	605	107	186.575
2.	Laxman Pur	396	68	160.96
3.	Ram Nagar	650	131	244.003
4.	Sita Pur	294	50	116.05
5.	Neil Kendra	861	225	147.25
	Total	**2806**	**581**	**854.88**

The population density is 148.41 person / sq. km. against 43 for Andaman and Nicobar Islands. Out of 1914 adults there are 1018 (53.19%) male adults and 896 (46.81%) female adults and out of 892 children 482 (54%) male children and 410 (46%) female children. Out of 1914 adults only 44 (2.3%) persons are employed. Out of 892 children 593 (66.48%) are school going. The village wise details are shown in Table 4.4.

Table 4.4: Village wise composition of population and average family size at Neil Island

S. No	Name of Village	House Holds		Population		Average Family size	Adults-No.			Children - No.			Employed	School Going - No.		
		No.	%	Total	%		Male	Female	Total	Male	Female	Total	No.	Male	Female	Total
1	BharatPur	107	18.42	605	21.56	5.65	225	192	417	95	93	188	16	72	71	143
2	Laxman Pur	68	11.70	396	14.11	5.82	143	125	268	69	59	128	5	39	39	78
3	Ram Nagar	131	22.55	650	23.16	4.96	233	208	441	115	94	209	12	88	60	148
4	Sita Pur	50	8.61	294	10.48	5.88	113	106	219	43	32	75	7	33	32	65
5	Neil Kendra	225	38.73	861	30.68	3.83	304	265	569	160	132	292	62	118	80	198
	Total	581	100	2806	100.00	4.83	1018	896	1914	482	410	892	44	341	252	593

The climate of this island is tropical. The average rainfall is 3045 mm annually. The island is quite fertile for agricultural production and the main production is seasonal vegetables. There is a Senior Secondary School, and a P.H.C. functioning in the island since long time. For communication the police radio has established a station in the island. The P & T department has established a telephone system. There is a powerhouse having a total capacity of 404 KW of diesel generating sets being operated by the Electricity department at Neil Island to meet the full demand of all consumers. There is also a 50-kWp grid connected solar power plant functioning there and supplying solar power to the grid during daytime. The two-hour battery back up is provided to this plant to meet emergent needs of hospital and VVIP visits during failure of power generation system.

4.3.3. Family Size Land Holding and Economic Classification of Households

The classification of households in all the 5 villages of Neil Island, as per the size of the family is shown in Table 4.5. For this purpose family having up to 4 members is considered as small, consisting of 5-8 members is considered as medium and having more than 8 members is considered as large.

From the Table 4.5, it would be seen that 49.23% households are small, 43.37% households are medium and 7.4% households are large families.

The households of Neil Island have been grouped as per their monthly income and village-wise distribution is shown in Table 4.6. For the purpose of classifying the households according to the income of the family, a family earning up to Rs.2000/- per month is considered under low-income section, a family having monthly income of Rs.2001/- to Rs.5000/- is defined as medium income group and a family having a monthly income of more than Rs.5000/- is considered as the high-income group.

Table 4.5: Family size at Neil Island

Sl.No.	Village Name	Small Family <5		Medium Family 5-8		Large Family >8		Total	
		No. of House Holds	% of House Holds	No. of House Holds	% of House Holds	No. of House Holds	% of House Holds	No. of House Holds	% of House Holds
1.	Bharat Pur	37	34.58	57	53.27	13	12.15	107	18.42
2.	Laxman Pur	20	29.41	39	57.35	9	13.24	68	11.70
3.	Ram Nagar	67	51.15	56	42.75	8	6.11	131	22.55
4.	Sita Pur	11	22.00	34	68.00	5	10.00	50	8.61
5.	Neil Kendra	151	67.11	66	29.33	8	3.56	225	38.73
	Total	**286**	**49.23**	**252**	**43.37**	**43**	**7.40**	**581**	**100.00**

Table 4.6: Classification of households according to income group at Neil Island

Sl.No.	Village	House Holds	Low income group (Up to Rs. 2000/month)		Middle income group (Rs.2001-5000/month)		High income group (>Rs.5000/ month)	
			No. of Families	%	No. of Families	%	No. of Families	%
1.	Bharat Pur	107	90	84.11	15	14.02	2	1.87
2.	Laxman Pur	68	48	70.59	19	27.94	1	1.47
3.	Ram Nagar	131	86	65.65	35	26.72	10	7.63
4.	Sita Pur	50	28	56.00	20	40.00	2	4.00
5.	Neil Kendra	225	107	47.56	45	20.00	73	32.44
	Total	**581**	**359**	**61.79**	**134**	**23.06**	**88**	**15.15**

It would be seen that out of 581 households in Neil Island, 61.79% are in low-income group, 23.06% are in the middle-income group and only 15.15% are in the high-income group.

About 90% of the total area of Neil Island is forest area and the remaining 10% is available for the inhabitants for agriculture and other related purposes. The distribution of households at Neil Island has also been classified according to size of land holding and shown in Table 4.7. The land holding has been divided into 7 categories i.e. Landless, 0-1 acre, 1-2 acres, 2-3acres, 3-4 acres, 4-5 acres and more than 5 acres.

It would be seen that

- 41% of households are landless.
- 23% of households have land holding between 0-1 acres.
- 14% of households have land holding between 1-2 acres.
- 9% of households have land between 2-3 acres.
- 3% of the households have land between 3-4 acres
- 9% of households have land between 4-5 acres and
- 0.3% have land above 5 acres

4.3.4 Economical Condition of the Family according to their Occupation

As far as occupation is concerned, out of 581 families 267 (46%) are cultivators, 24 (4%) fishermen, 149 (26%) private labourers, 114 (20%) government servants and 27(5%) are businessmen. The village wise details have been shown in Table 4.8

4.3.5 Housing

Three types of houses / buildings namely temporary (thatched), wooden and concrete houses have been constructed by the people of Neil Island, the details of which are given in Table 4.9.

It would be seen that of the total of 581 houses in the island, 207 Nos. i.e., 35.63% are temporary thatched structures, 256 Nos. i.e., 44.06% are wooden structures and 118 nos. i. e. 20.31% is concrete structures.

Table-4.7: Agriculture land holdings at Neil Island

Sl. No.	Village	No. of H/H	Land less	0-1 Acre		1- 2 Acres		2- 3 Acres		3- 4 Acres		4- 5 Acres		> 5 Acres	
1.	Bharat Pur	107	40	19	18%	17	16%	11	10%	4	4%	14	13%	2	2%
2.	Laxman Pur	68	22	11	16%	14	21%	4	6%	2	3%	15	22%	0	0%
3.	Ram Nagar	131	22	43	33%	29	22%	19	15%	2	2%	16	12%	0	0%
4.	Sita Pur	50	7	12	24%	8	16%	13	26%	2	4%	8	16%	0	0%
5.	Neil Kendra	225	145	49	22%	14	6%	7	3%	7	3%	2	1%	0	0%
	Total	**581**	**236**	**134**	**23%**	**82**	**14%**	**54**	**9%**	**17**	**3%**	**55**	**9%**	**2**	**0.3%**

Table-4.8: Economical condition of family according to their occupation at Neil Island

Sl. No.	Income Group	Low Income group (Up to Rs. 2000 / month)		Medium Income group (From Rs. 2001/ month to Rs.5000 /Month)		High Income group (Above Rs. 5000/month)		Total	
1.	Occupation	Nos.	%	Nos.	%	Nos.	%	Nos.	%
2.	Cultivator	189	71%	75	28%	3	1%	267	46%
3.	Fishermen	18	75%	6	25%	0	0%	24	4%
4.	Pvt. Labourer	136	91%	11	7%	2	1%	149	26%
5.	Govt. Servant	4	4%	29	25%	81	71%	114	20%
6.	Businessmen	12	44%	13	48%	2	7%	27	5%
	Total	**359**	**62%**	**134**	**23%**	**88**	**15%**	**581**	**100%**

Table 4.9: Types of houses/building at Neil Island

Sl.No	Name of Village	No. of House Holds	Temp. Houses		Wooden Houses		RCC Houses	
			No.	**%**	**No.**	**%**	**No.**	**%**
1	Bharat Pur	107	70	65.42	35	32.71	2	1.87
2	Laxman Pur	68	21	30.88	41	60.29	6	8.82
3	Ram Nagar	131	39	29.77	69	52.67	23	17.56
4	Sita Pur	50	15	30.00	27	54.00	8	16.00
5	Neil Kendra	225	62	27.56	84	37.33	79	35.11
	Total	**581**	**207**	**35.63**	**256**	**44.06**	**118**	**20.31**

4.3.6. Electricity

All the villages of the Neil Island are electrified. At present the total capacity of the diesel generating sets at Neil Island is 400 kW. Power supply to this small isolated island is provided round the clock. The peak demand occurs during evening hours i.e. from 5.30 P.M to 11.30 P.M. when the whole population is at home after days work and almost completely comprises of lighting load. In Neil Island 109 households do not have electricity connection, which is about 19% of the total households. The per-capita consumption of electricity in this island 222 kWh. To avoid transportation of diesel and operation and maintenance of diesel generators, a 50-kWp grid connected solar power plant is functioning and supplying solar power to the grid during daytime. The two-hour battery back up is provided to this plant to meet emergent needs of hospital and VVPI visits during failure of power generation system. The typical load curve for the island is shown at Fig. 4.3. During day time when solar power plant is in operation the load on diesel generator decreases up to the extend the power is compensated by the solar power plant, thus saving the precious diesel oil.

4.3.7. Market facility

Market facility is available in the island. All consumable items, eatables, fuels etc. required for meeting the basic needs of the households are available in the market and people do not have to depend much on the main island of South Andaman for their basic needs. There are 3 fair price shops with 807 ration cards and requirement of food grains like rice, wheat and sugar is met through these shops. There are 6 cooperative societies with 596 members.

4.3.8. Education

There is only one primary school in Neil Island, located at Bharatpur village. The total strength of student is 103 Nos. and 7 Nos. teaching staffs. This island has one middle school and one senior secondary school at Sitapur village and Laxmanpur village respectively. The strength of school children at middle school is 193 and staff is 13. The total strength of school going children at senior secondary school is 297 and 26 teaching staffs are posted. The school wise details are shown in Table 4.10.

Fig. 4.3: Load Curve for Neil Island for 3.2.06(Friday)

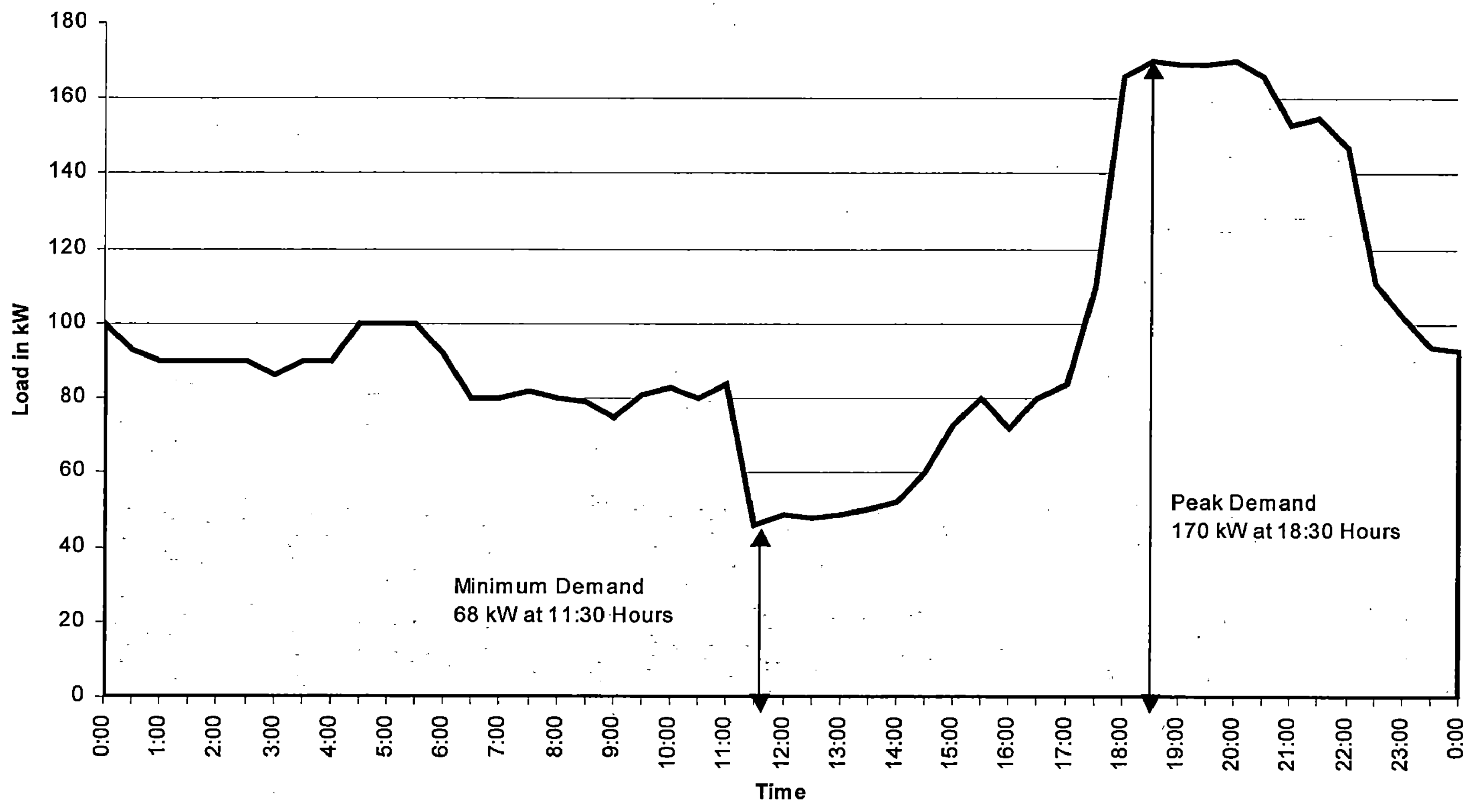


Table 4.10: Educational facilities at Neil island

Sl. No.	Category	Govt.	Private	Total	No. of school going children
1.	Primary school	1	-	1	103
2.	Middle school	1	-	1	193
3.	Higher secondary school	-	-	-	-
4.	Senior Secondary school	1	-	1	297
5.	College	-	-	-	-
6.	No. of students enrolled		-		593

4.3.9. Medical Facility

One primary health centre (PHC) and one sub center manned by a doctor, 7 staff nurses and 17 para medical staffs are functioning at Neil Kendra village. Bed strength of the primary health centre (PHC) is 10 nos. For emergency cases and special treatment, the patients are referred to other hospital in the main island of South Andaman. There is one vetenary dispensary with one doctor and 4 staffs.

4.3.10. Transport, Mass Media and Communication

Neil Island is situated in South Andaman group, which comes under Port Blair tehsil. For transportation, generally, people do not depend on vehicles and go by walk for reaching from one place to other. There are 9 Kms of pucca roads and 0.5 Kms. kutcha roads. The village wise details of vehicles at Neil Island are given in Table 4.11.

Table-4.11: Vehicles at Neil Island

Sl. No.	Name of Village/ Department	Total No. of Vehicles			
		2-Wheelers (Scooters & Motor Cycles)	3- Wheelers (Auto Rikshas)	4- Wheelers (Trucks, Buses, Tractors, Cars & Jeeps)	Total Vehicles
1	Bharat Pur	15	1	2	18
2	Laxman Pur	7	1	3	11
3	Ram Nagar	17	4	4	25
4	Sita Pur	10	1	0	11
5	Neil Kendra	20	0	2	22
6	State Transport	0	0	2	2
7	Other Deptt.	7	0	3	10
Total		**76**	**7**	**16**	**99**

The means of transportation between Neil Island and other islands is through the inter island vessels. The island has got a jetty for the inter island vessels. For mass media and communication purposes there are 255 radio sets, 339 TV sets and 172 VCP/CD players owned by the villagers. The police department has established a police wireless station for communication purpose at Neil Island. Bharat Sanchar Nigam Ltd. (BSNL) and Reliance have established local telephone exchanges to have communication with Port Blair and mainland.

4.4 ANALYSIS FOR CONSUMPTION PATTERN OF ENERGY RESOURCES

4.4.1 Overall Consumption Pattern

The data for consumption of various energy resources such as firewood, kerosene, LPG and electricity for meeting the cooking and lighting requirement by various income groups at Neil Island were collected during survey and extract is depicted in Table 4.12, 4.13 and 4.14

It would be seen from Table 4.12, 4.13 and 4.14 that:

- Annual per capita consumption of Firewood is 455.09 Kgs, Kerosene is 17.83 Ltrs. LPG is 7.43 Kgs and Electricity is 128.27 kWh.
- The per capita annual energy consumption of firewood is 1.59 $x10^6$ kcal, Kerosene is 0.18x 10^6 kcal, LPG is 0.08 $x10^6$ Kcal and Electricity is 0.11$x10^6$ Kcal.
- Firewood meets 81.04% of the total energy requirement in the domestic sector.
- Kerosene meets only 9.07% of the total energy requirement in the domestic sector.
- LPG meets 4.28% of the total energy requirement in domestic sector
- Electricity energy meets only 5.61% of the total energy requirement in the domestic sector.

The per capita energy consumption of Low income group is2.01×10^6 Kcal, Medium income group is 1.94×10^6 Kcal and High-income group is 1.75×10^6 Kcal.

4.4.2 Methods of Cooking

A variety of methods for cooking are used at Neil Island with utilizing various energy options like fuel wood, kerosene, LPG and electricity. The village-wise details are shown in Table 4.15.

Table 4.12: Village-wise annual consumption of energy resources at Neil Island

Energy Resources		Bharat Pur	Laxman Pur	Ram Nagar	Sita Pur	Neil Kendra	Total	Annual Per Capita Consumption	Annual Per Capita Enrgy Consumption in Kcalx10^6
Firewood	Kg	297,000	200,340	321,300	151,920	306,420	1,276,980	455.09	1.59
Kerosene	Litre	7,452	6,132	13,164	4,620	18,672	50,040	17.83	0.18
LPG	Kg	1,734	0	690	672	17,748	20,844	7.43	0.08
Electricity	kWh	51,348	52,956	77,040	25,512	153,072	359,928	128.27	0.11

Table 4.13: Sector wise annual Consumption of energy resources by various income groups at Neil Island

Income Group	**LIG**			**MIG**			**HIG**			**Overall**				
Energy (Kcalx10^6)	Cooking	Lighting	Irrigation	Cooking	Lighting	Irrigation	Cooking	Lighting	Irrigation	Cooking	Lighting	Irrigation	Total	%
Firewood	2993.6			1238.16			237.72			4469.43	0	0	4469.43	81.04
Kerosene	75.12	225.36		52.75	79.13		51.03	17.01		178.90	321.5	0	500.40	9.07
LPG	48.97			72.74			114.24			235.95	0	0	235.95	4.28
Electricity		143.25	15.92		82.75	6.71		58.97	1.94	0.00	284.97	24.57	309.54	5.61
Total	**3117.6**	**368.61**	**15.92**	**1363.65**	**161.88**	**6.71**	**402.99**	**75.98**	**1.94**	**4884.28**	**606.47**	**24.57**	**5515.32**	**100**
Per Capita	**1.79**	**0.21**	**0.0091**	**1.72**	**0.20**	**0.0085**	**1.47**	**0.28**	**0.0071**	**1.74**	**0.22**	**0.0088**	**1.97**	

Table 4.14: Annual energy consumption pattern by various income groups at Neil Island

Sl.No.	Energy Source	fire wood(Cal-Value-3500kcal/kg)			Kerosene (Cal. Value-10000kcal/kg)			LPG (Cal. Value-11320 kcal/kg)			Electricity (Cal. Value- 860 kcal/KWH)			Total		Per-Capita
	Income Group	Kg	K.Cal $x10^6$	%	Lit.	K.Cal $x10^6$	%	Kg	K.Cal $x10^6$	%	KWh	K.Cal $x10^6$	%	K.Cal $x10^6$	%	K.Cal $x10^6$
1.	LIG	855300	2993.55	66.98%	30048	300.48	60.05%	4326	48.97	20.75%	185076	159.17	51.42%	3502.17	63.50%	2.01
2.	MIG	353760	1238.16	27.70%	13188	131.88	26.35%	6426	72.74	30.83%	104028	89.46	28.90%	1532.25	27.78%	1.94
3.	HIG	67920	237.72	5.32%	6804	68.04	13.60%	10092	114.24	48.42%	70824	60.91	19.68%	480.91	8.72%	1.75
	Total	**1276980**	**4469.43**	**100%**	**50040**	**500.40**	**100%**	**20844**	**235.95**	**100%**	**359928**	**309.54**	**100%**	**5515.32**	**100%**	**1.97**

Table 4.15: Methods of cooking at Neil Island

Sl. No.	Name of Village/	Chulha (Convn.)	Chulha (Improved)	Gas Stove	Kerosene Stove	Kerosene lantern	Kerosene Lamp	Total (Nos.)
1	Bharat Pur	122	1	9	25	13	258	428
2	Laxman Pur	70	0	3	22	6	201	302
3	Ram Nagar	142	2	7	74	11	396	632
4	Sita Pur	50	1	2	18	1	171	243
5	Neil Kendra	157	0	68	98	10	407	740
	Total (Nos.)	**541**	**4**	**89**	**237**	**41**	**1433**	**2345**

4.4.2.1. Fuel wood

Forest cover over Neil Island is estimated to be about 90% of its geographical area, and the fuel wood from different sources is the most preferred option of rural masses because of easy availability from either their own fields or the forest either at low-cost or free of cost. Generally, women and female children are involved in the collection and transportation of fuel wood. Fuel wood is burnt for cooking for use in low-cost, easy to construct and rugged devices like traditional *chulhas* (cookstoves), which are not energy efficient and about 95% energy is wasted. There are 545 chulhas out of which 541 are conventional and only 4 are improved.

4.4.2.2. Kerosene

Kerosene is distributed through public distribution system (PDS), and is mostly used by low and middle-income group families for cooking and lighting. Kerosene stoves are popular due to their efficient, quick, easily controllable, convenient features as compared to other rural cooking devices. There are 237 kerosene stoves in use at Neil Island. The government is providing a huge subsidy on kerosene supplied through public distribution system. The non-availability of kerosene for the households at Remote Island is a major issue, which forces islanders to adopt the inefficient devices to cook their food.

4.4.2.3. Liquefied petroleum gas (LPG)

The government is providing subsidy on LPG cylinder for domestic use since April 2002. Consumer cooperative society of Port Blair is engaged in its distribution. This cooking fuel enjoys the highest degree of popularity because of a number of advantages like cleanliness, safety, efficiency, cost effectiveness. It is much easier to use and ignite, easy to store and transport, and has the highest calorific value. But it is mostly used amongst middle- and high-income groups due to its unaffordable cost by the low income group. There are 89 households only use LPG at Neil Island. Due to the unaffordable initial cost of appliances, risk of explosion, and poor distribution network, it is not widely used in economically undeveloped and remote islands.

4.4.3. Inefficient Use of Energy Resources

As revealed from survey and shown by Fig. 4.4, the per capita consumption of energy at Neil Island is very low. Data indicates that the low-income group peoples of this island are utilizing available energy resources in most inefficient manner. As can be seen from Fig 4.5, there is not much difference in per capita consumption for cooking in low income and medium income groups but there is a vast difference between low income and high income groups, which further confirms the inefficient use of energy resources by low income group people. Adoption of improved technology is also not popular amongst the lower income households due to poverty and other social constraints, whereas, some of the medium and high-income households use devices like energy efficient stoves and liquid petroleum gas stoves for cooking.

As indicated by Fig. 4.6, the scenario for lighting is entirely different. The per capita consumption for high income group is higher than low and medium groups, which indicates the higher standard of living, whereas the consumption by medium income group is lower than the low income group this is probably due to the use of energy efficient luminaries like compact fluorescent lamps and fluorescent tube light sets by them as they can afford to purchase the energy efficient luminaries on payment of little higher cost.

By converting all the conventional chulhas into improved chulhas a sizable amount of firewood could be saved. The traditional use of fuel wood has also many drawbacks such as, indoor air pollution, health hazard to women and children, and hardship in collecting the same due to its inefficient use, which can also be reduced up to some extent.

The improved kerosene stoves are being supplied on subsidy but response of islanders is very poor. The subsidy on improved stoves and kerosene oil needs to be further enhanced with an assured supply of kerosene oil, which will help in reducing the inefficient use of firewood for cooking. For lighting 41 kerosene lanterns and 1433 ordinary kerosene lamps are being used at Neil Island, which need to be replaced with improved kerosene lanterns to prevent inefficient use of energy.

It is necessary to enhance the subsidy on LPG and appliances to popularize the use of LPG in these islands, which would reduce the use of fuel wood up to a great extent, thus relieving pressure from forest.

4.5 ANALYSIS FOR ELECTRICITY CONSUMPTION

4.5.1. Present Electricity Consumption

All the five villages are electrified through the electricity generated by the existing diesel and solar power plants. It is revealed from the survey conducted that out of total 581 house holds of the island 472 (81%) are electrified and remaining 109 (19%) do not have electricity connection. As far as population is concerned out of total 2806 persons, 2350 (84%) are enjoying the facility of electricity whereas remaining 456 (16%) do not getting this facility. The village wise details are shown in Table 4.16. On recording the load demand for 24 hours on 3.2.2006 (Friday) at Neil Island by the author, the peak load demand is found 170 kW (Fig. 4.3) against the installed capacity of 400kW. The poor economic condition of islanders is the main reason, not to avail the facility of the electricity as there is no dearth of electrical energy at Neil Island.

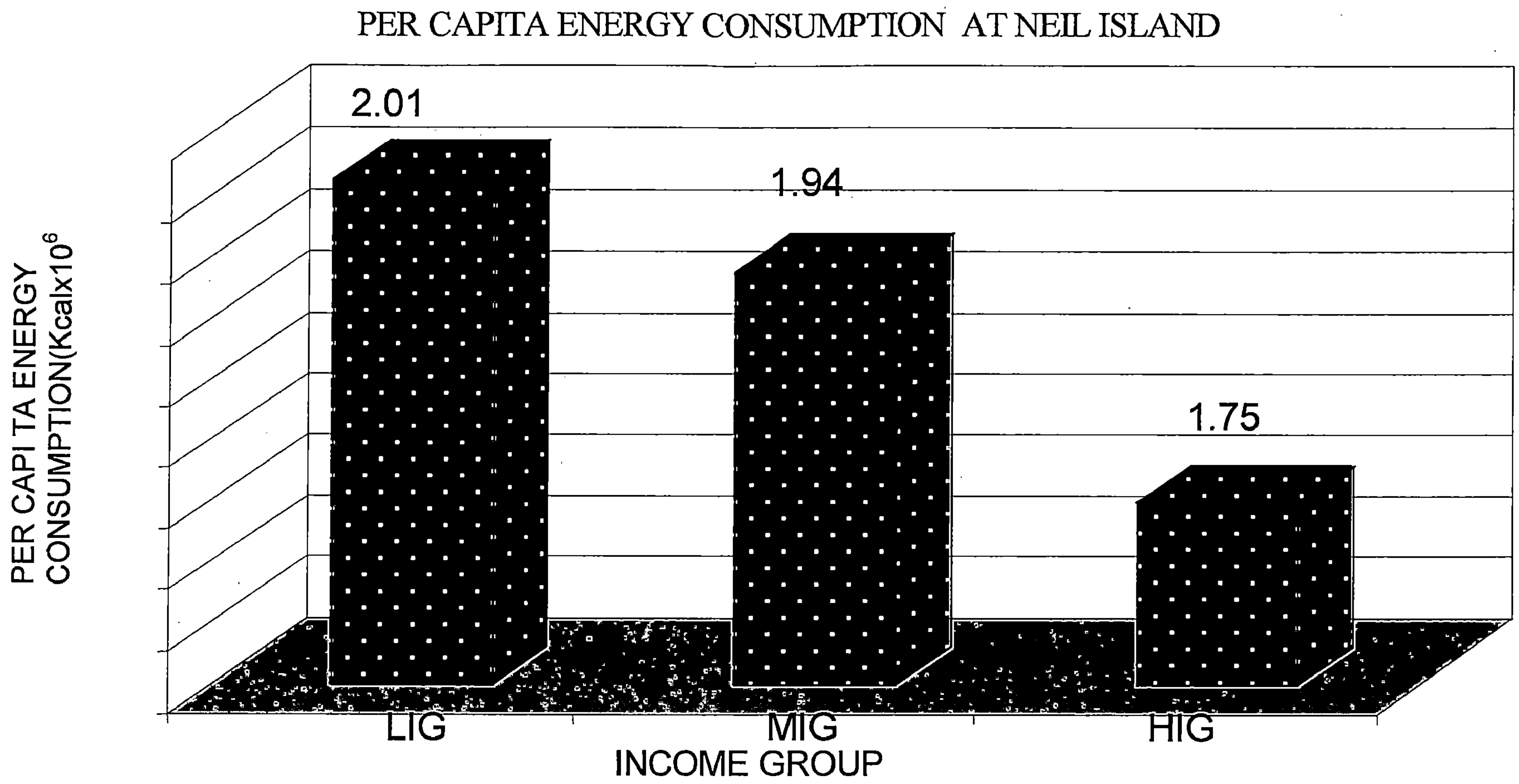


Fig. 4.4: Per capita energy consumption at Neil Island

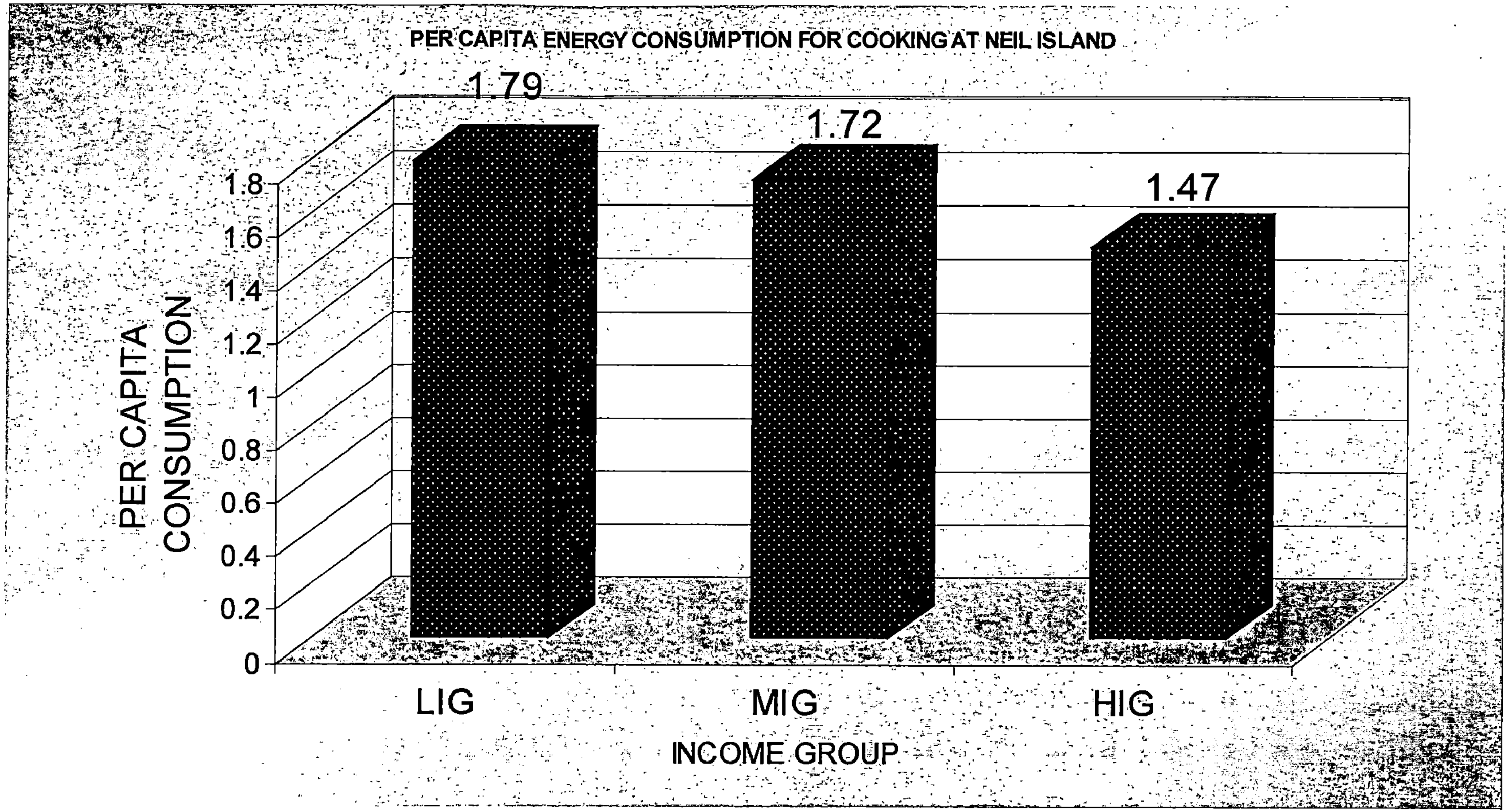


Fig. 4.5: Per capita energy consumption for cooking at Neil Island

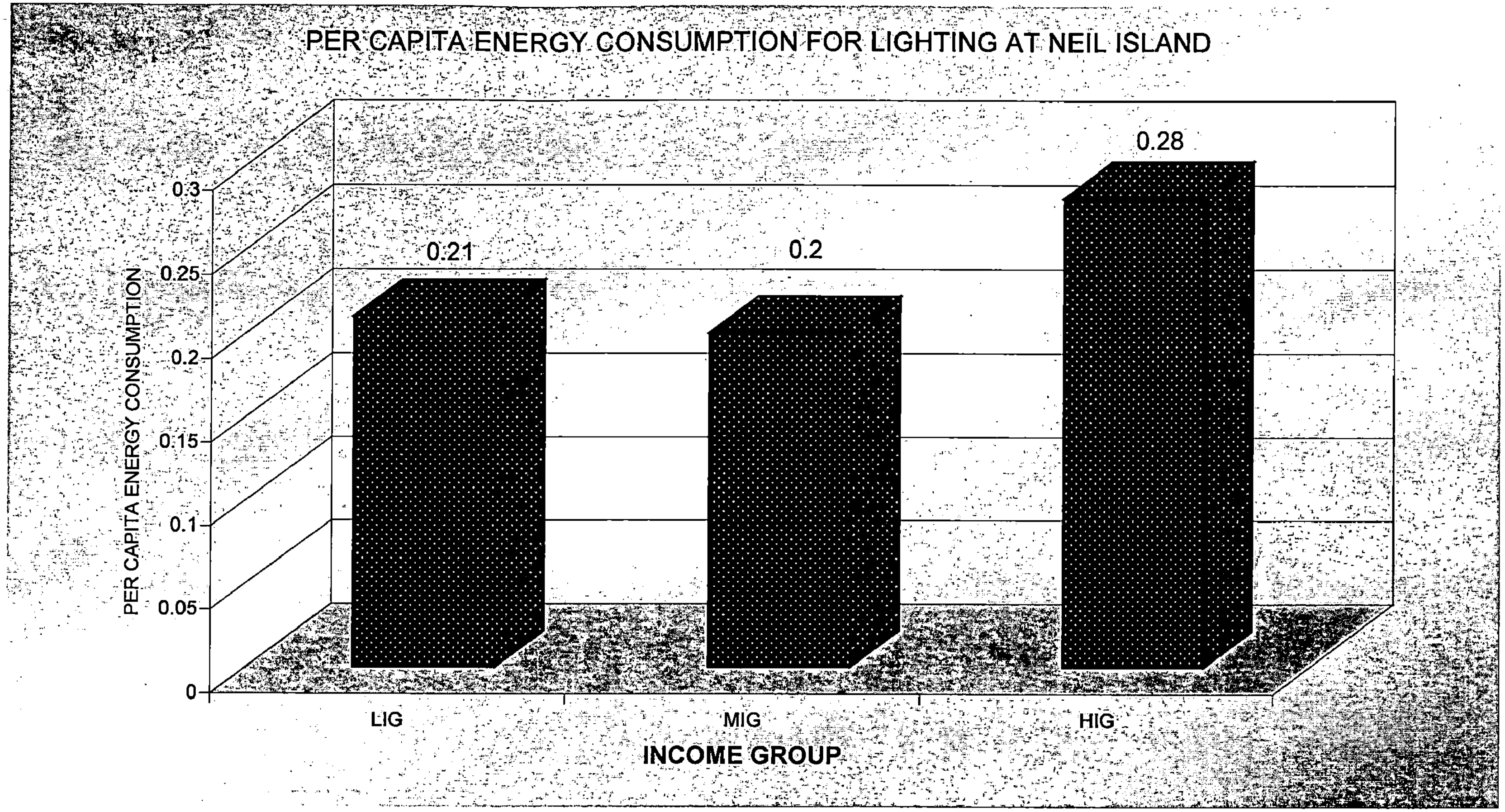


Fig. 4.6: Per capita energy consumption for lighting at Neil Island

There is 550 kW connected load out of which 1681 incandescent bulbs constitute 18.4% of total load, 348 tullu pumps (1/2 H.P.) used for irrigation constitute 25.3%, industrial and other loads constitute 20.8%, 339 television constitute 12.3% and 835 fans constitute 9.3% of total loads. Since the island is the main supplier of vegetable to capital city Port Blair, almost all the farmers have installed tullu pumps on their fields and the load demand increases during day time more than normal during vegetable session.

As seen during survey that almost all the islanders use incandescent lamps due to which the load demand during evening, peaks up rapidly as soon as sun sets. On enquiring them during survey, it is found that they are aware regarding the conservation of energy as officers and staff of local electricity department are regularly explaining them the advantages of using the energy efficient devices and luminaries, but the poor economic condition stop them to purchase these devices and luminaries and they do not have any other option except to use inefficient devices and luminaries by paying extra amount every month in the form of electric bills. Since the electric supply to the islanders is heavily subsidized, the government is also losing a huge exchequer due to inefficient use. The village wise details of use of various devices and luminaries have shown in Table 4.17 and Fig. 4.7.

4.5.2. Future Load Projections

It can be seen from the Table 4.17 that per capita connected load is 0.23 kW. If we assume that all the persons those do not have electricity supply presently, would have given electric connection the connected load would be 0.23 x 2806 i.e. 645 kW, hence we may consider the present connected load for the island as 645 kW instead of actual connected load of 550 kW. The present maximum demand at Neil Island is 170 kW and taking into consideration the demand of persons those do not have electricity the load demand would be (170x100)/84= 202 kW.

Various working groups of the steering committee on energy sector for the 10th five year plan projected an average primary commercial energy demand growth rate of 5.74%/yr for the two forthcoming five year plans. In view of the increased emphasis on energy efficiency and energy conservation, and the impact of information technology and e-commerce, the steering committee came up with a lower figure of 4.25%/yr for the demand growth rate [64].

The present consumption pattern can be taken a base and assuming a suitable load demand growth, the load projection for next five years can be done. Until and unless there is a special thrust to boost the economy of the this island, there may not be much difference in next five years as far as the economic condition of the islanders is concerned. However, we may expect some increase in standard of living of islanders in next five years and some who are below the poverty line may come up by getting benefit from the various schemes of the government of India. There is no programme to establish any big industry at this island. There is likely to increase the demand of energy due to increase in population.

Though the energy demand growth may not be higher due the reasons mentioned above, but for conservative estimates we may assume the same 4.25% yearly energy demand growth. The expected demand for next five years is shown in the Table 4.18.

Table 4.16: Status of household electrification at Neil Island

Sl.No.	Village	Bharat Pur	Laxman Pur	Ram Nagar	Sita Pur	Neil Kendra	Total
1.	Total Households (No.)	107	68	131	50	225	581
2.	Households with electricity (No.)	81	57	102	43	189	472
3.	Households without electricity (No.)	26	11	29	7	36	109
4.	% House Hold with electricity	76%	84%	78%	86%	84%	81%
5.	% House Hold without electricity	24%	16%	22%	14%	16%	19%
6.	Total Population (No.)	605	396	650	294	861	2806
7.	Population with electricity (No.)	499	348	527	256	720	2350
8.	Population without electricity (No.)	106	48	123	38	141	456
9.	% Population with electricity	82%	88%	81%	87%	84%	84%
10.	% Population without Electricity	18%	12%	19%	13%	16%	16%

Table 4.17: Details of connected load at Neil Island

Name of Village	Bharat Pur		Laxman Pur		Ram Nagar		Sita Pur		Neil Kendra		Total	
Devices	No.	Load (kW)	No.	Load (kW)	No.	Load (kW)	No.	Load (kW)	No.	Load (kW)	No.	Load (kW)
Bulb(Incandescent)	284	17.04	221	13.26	393	23.58	166	9.96	617	37.02	1681	100.86
Bulb(CFL)	14	0.14	2	0.02	1	0.01	9	0.09	12	0.12	38	0.38
Tube Light 40 W	87	3.48	36	1.44	154	6.16	69	2.76	293	11.72	639	25.56
Fan	137	8.22	108	6.48	190	11.4	93	5.58	327	19.62	855	51.3
Television	39	7.8	42	8.4	85	17	40	8	133	26.6	339	67.8
Radio/Music Sys	33	0.825	25	0.625	86	2.15	32	0.8	79	1.975	255	6.375
VCRVCP/CD Player	23	1.15	27	1.35	53	2.65	26	1.3	43	2.15	172	8.6
Computer	0	0	0	0	0	0	0	0	2	0.3	2	0.3
Inverter	0	0	0	0	0	0	0	0	0	0	0	0
Refrigerator	1	0.3	3	0.9	10	3	1	0.3	22	6.6	37	11.1
Washing Machine	0	0	0	0	0	0	0	0	2	1	2	1
Mixie/Grinder	3	1.2	2	0.8	8	3.2	3	1.2	31	12.4	47	18.8
Irrigation Pump	68	27.2	45	18	120	48	45	18	70	28	348	139.2
Industrial/other load		26.5		10		30		0		48	0	114.5
Street Light	15	0.6	11	0.44	20	0.8	15	0.6	35	1.4	96	3.84
Total	**704**	**94.455**	**522**	**61.715**	**1120**	**147.95**	**499**	**48.59**	**1666**	**196.905**	**4511**	**549.615**
Average /Household	**8.69**	**1.17**	**9.16**	**1.08**	**10.98**	**1.45**	**11.60**	**1.13**	**8.81**	**1.04**	**9.56**	**1.16**
Per Capita	**1.41**	**0.19**	**1.50**	**0.18**	**2.13**	**0.28**	**1.95**	**0.19**	**2.31**	**0.27**	**1.92**	**0.23**

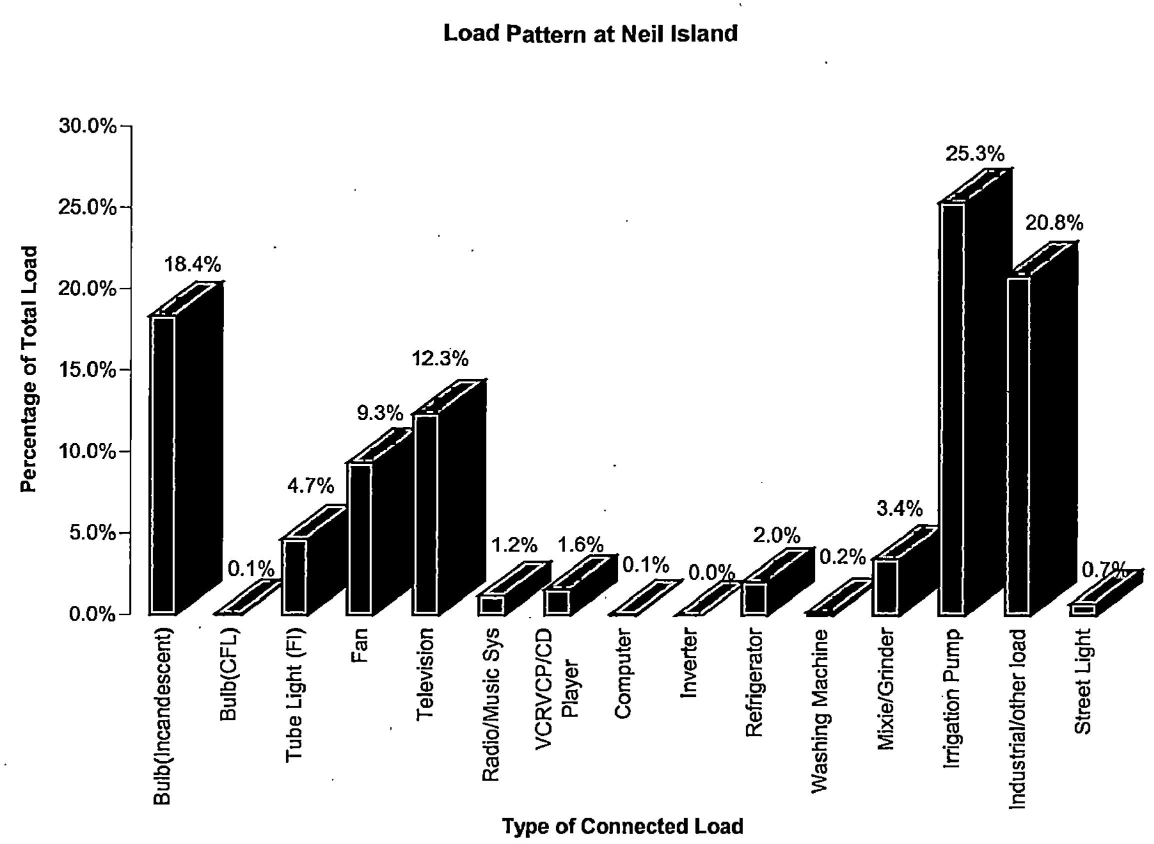


Fig. 4.7: Electrical load pattern at Neil Island

Table 4.18: Expected peak demand for next five years at Neil Island

Sl.No.	Year	Peak demand at the beginning of year (kW)	Expected peak demand at the end of the year (kW)
1	2005-06	-	202
2.	2006-07	202	210
3.	2007-08	210	219
4.	2008-09	219	228
5.	2009-10	228	238
6.	2010-11	238	248

The per capita consumption at Neil Island is 222 kWh per annum. The village wise per capita consumption is shown in Table 4.19.

Table 4.19: Per capita consumption at Neil Island

Sl. No.	Name of Village	No. of House Holds having electricity	Population having electricity (No.)	Energy Consumed per annum (kWh)	Per household annual consumption (kWh)	Per capita annual consumption (kWh)
1	Bharat Pur	81	499	92854	1146	186
2	Laxman Pur	57	348	66956	1175	192
3	Ram Nagar	102	527	97040	951	184
4	Sita Pur	43	256	46840	1089	183
5	Neil Kendra	189	720	193072	1022	268
6	Others			24000		
	Total	**472**	**2350**	**520762**	**1103**	**222**

Taking into consideration the consumption of persons those do not have electricity, the total consumption will be 222x 2806 = 622932 kWh/annum or 1707 kWh /day Assuming 4.25% yearly energy demand growth, the per day energy demand for next five years at Neil island has been shown in Table 4.20.

Table 4.20: Expected energy demand for next five years at Neil Island

Sl. No.	Year	Daily Energy demand at beginning of year (kWh)	Expected daily energy demand at the end of year (kWh)	Required energy generation to meet the demand at the end of the year (kWh)
1	2005-06	-	1707	2220
2	2006-07	1707	1780	2310
3	2007-08	1780	1855	2410
4	2008-09	1855	1934	2510
5	2009-10	1934	2016	2620
6	2010-11	2016	2102	2730

It may be seen from the Table 4.18 and 4.20 that the peak demand at the fifth year will be 248 kW and the energy demand including line losses and auxiliary consumption will be 2730. Hence the system will have to be designed for say 250 kW peak demand and 2730 kWh per day consumption which will take care of electricity need for all the islanders for another five year with 4.25% load growth. The load growth and load curves with estimated loads for next five years are shown in Fig. 4.8 & 4.9.

It may be seen from the these figures that in the fifth year, the load will never go above 150 kW except for six hours i.e. from 17:30 Hours to 11:30 hrs. The load pattern would likely to be almost constant during other months of the year as there is not much difference in sun rise and sun set timing due to its geographic location. There will be 100 kW jump during these six hours peak load periods. Hence the model is to be designed which could take care for loads of 150 kW from 00:00 Hours to 16:00 hours next day and for 250 kW from 16:00 Hrs to 24:00 hrs.

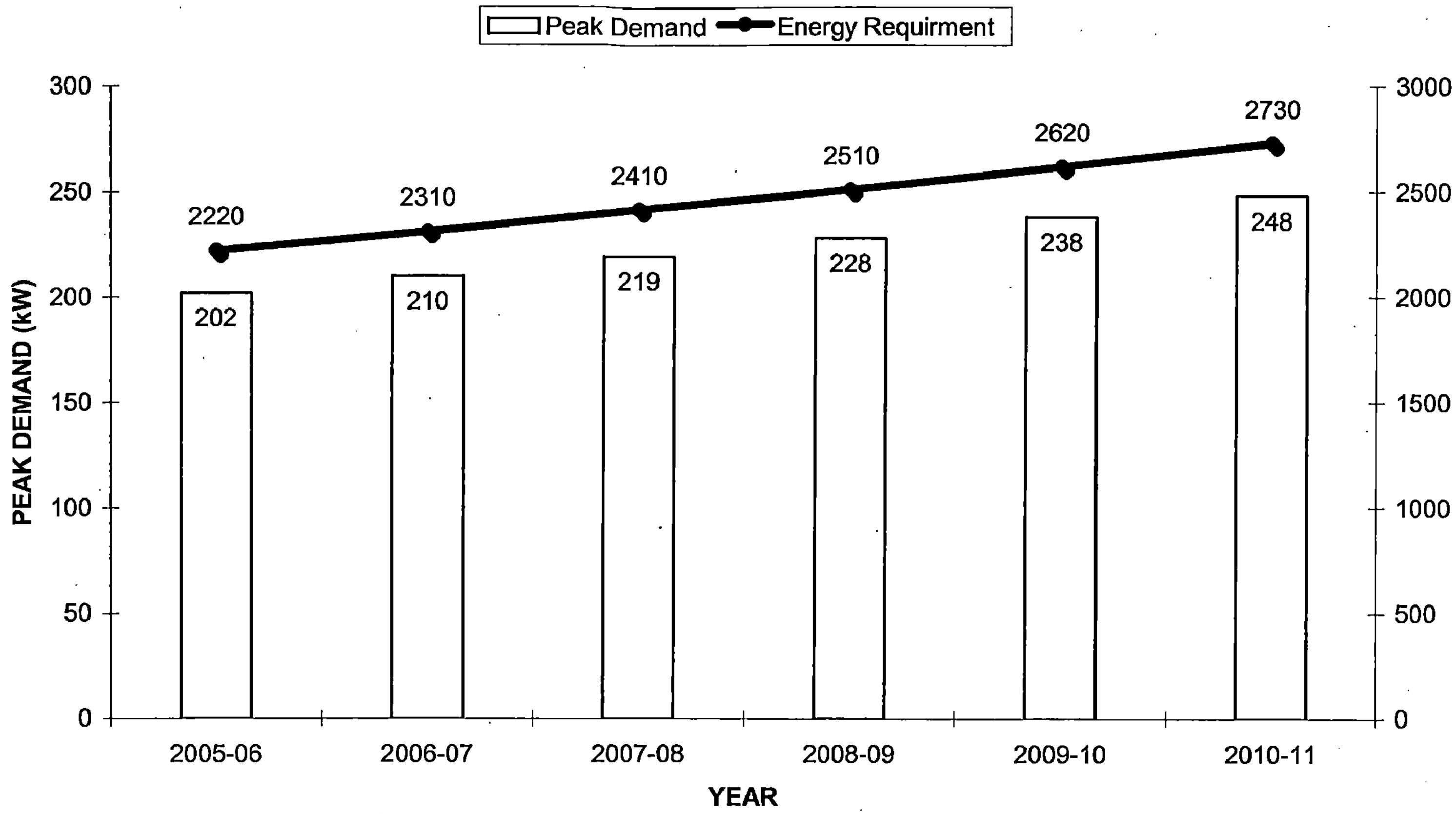


Fig. 4.8: Load growth for next five years at Neil Island

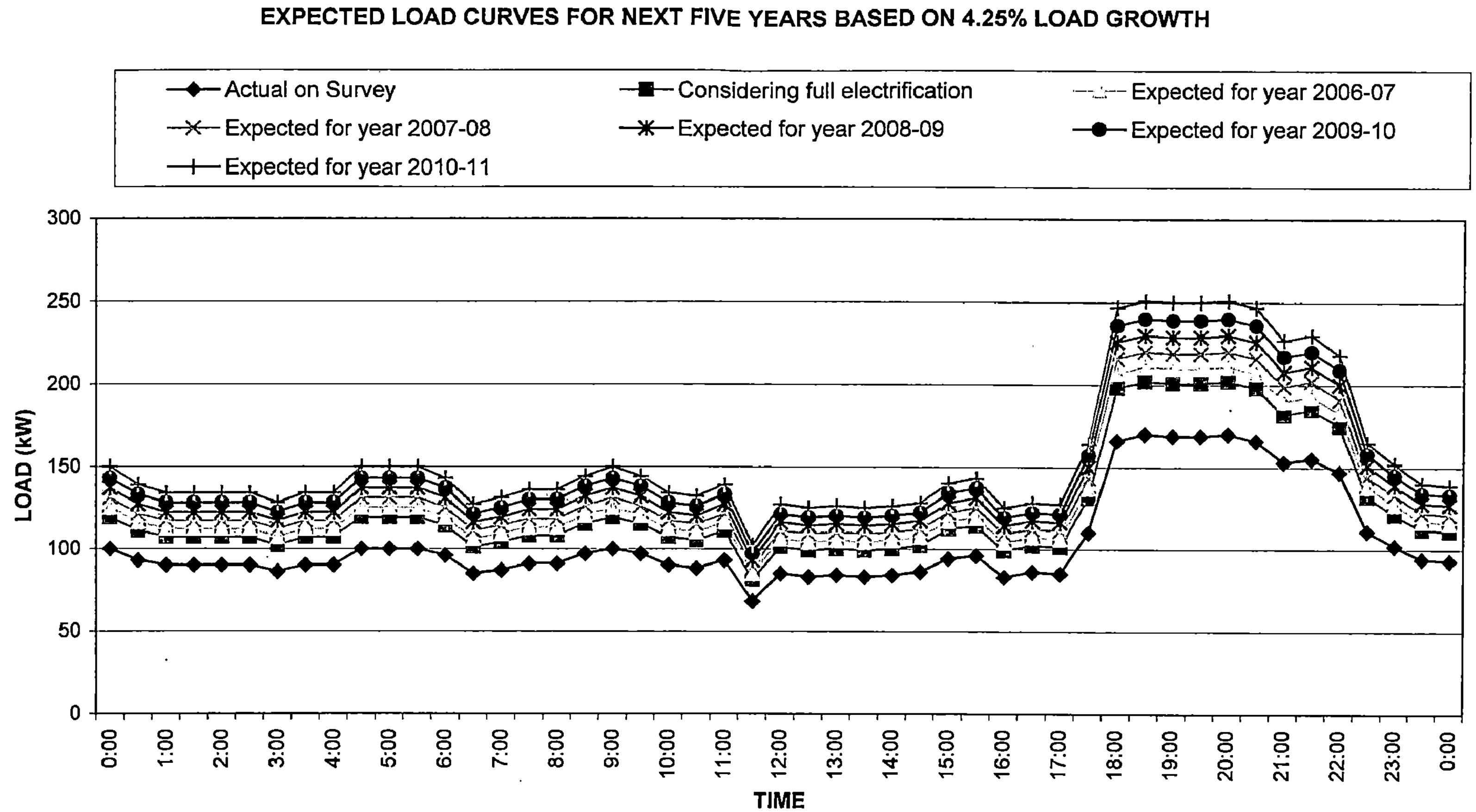


Fig. 4.9: Expected load curve for next five years based on present load demand

ANALYSIS FOR POTENTIAL ASSESSMENT OF ENERGY IN NEIL ISLAND

5.1. BIOMASS ENERGY

5.1.1. Anaerobic Digestion

5.1.1.1. Analysis for potential of biogas energy

The biomass is available in the forms of cattle dung and bird dung can be converted into biogas. On analysis of survey details it is found that there are 1180 cattle and 3633 birds' population at Neil Island. The Village wise distribution of livestocks is shown in Table 5.1 and Fig. 5.1.

Table 5.1: Details of Livestock at Neil Island

Sl. No.	Name of Village	House Holds (No.)	Goats (No.)	Cows/oxen (No.)	Buffaloes (No.)	Hens (No.)	Ducks (No.)	Total Animal (No.)	Total Bird (No.)
1.	Bharat Pur	107	104	119	6	635	219	229	854
2.	Laxman Pur	68	116	100	2	408	82	218	490
3.	Ram Nagar	131	178	153	0	845	259	331	1104
4.	Sita Nagar	50	85	113	0	428	141	198	569
5.	Neil Kendra	225	143	57	4	462	154	204	616
	Total	**581**	**483**	**542**	**12**	**2778**	**855**	**1180**	**3633**

The Biogas production from the dung has been evaluated based on the assumption that 7 Kgs. dung will be available from each cow/ox, 10 Kgs. from buffalo, 1 Kg from goat and 0.5 Kgs. per day from hen/duck. The village wise details of dung availability and energy potential have been shown in the Table 5.2.

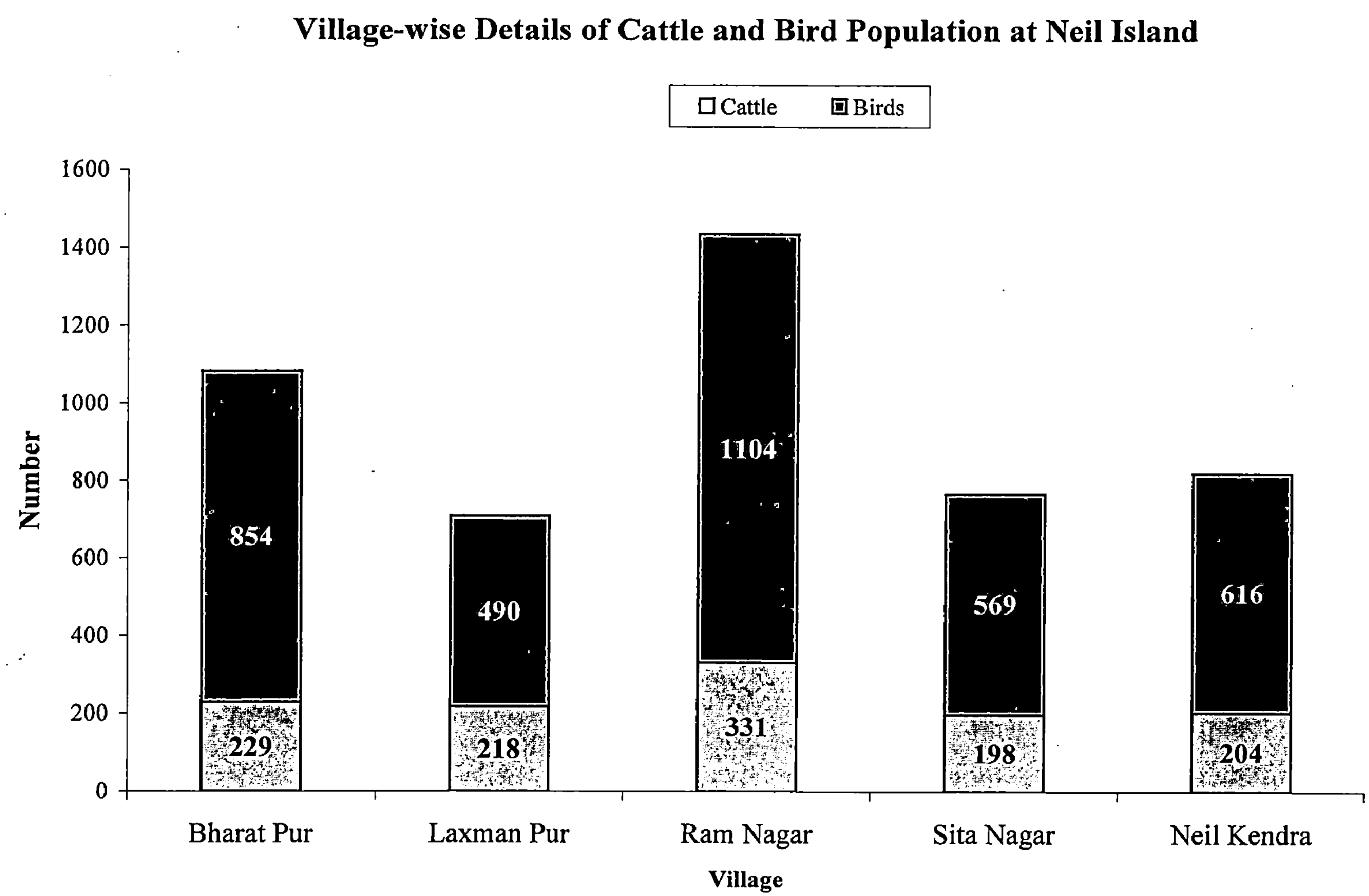


Fig. 5.1: Village-wise details of cattle and bird population at Neil Island

Table 5.2: Cattle dung availability and energy potential at Neil Island

Sl. No.	Name of Village	Animal Dung Available / day (Kg)	Bird Dung Available / day (in Kg)	Total Dung Available / day (Kg)	Net Dung Collected to convert into biogas/ day (75% collection efficiency)	Total Biogas production / ay (cu-m)	Total Energy / day (Kcal x 10^6)
1.	Bharat Pur	997	427	1424	1068	89	0.42
2.	Laxman Pur	1378	245	1623	1217	101	0.48
3.	Ram Nagar	2064	552	2616	1962	164	0.77
4.	Sita Pur	1385	285	1670	1253	104	0.49
5.	Neil Kendra	1059	308	1367	1025	85	0.40
	Total	**6883**	**1817**	**8700**	**6525**	**544**	**2.56**

The cattle dung availability in the island as shown by Table 5.2 is about 8700 Kgs. per day. Due to practical constraints it would not be possible to collect all the available dung, hence considering the dung collection efficiency as 75% the net dung available for biogas production will be as follows;

Net dung available for generation of biogas =8700x0.75= 6525 Kgs.

We know that: -

12 Kgs. of dung produces 1 m^3 of biogas and calorific value of biogas is 4700-6000 Kcal./ m^3 [65].

Total biogas produced from 6525 Kgs of dung = 6525 / 12

= 544 m^3

Assuming the calorific value of biogas as 4700 Kcal per m^3 (minimum), the energy available per day for generation of electrical power will be as follows;

Energy available from dung / day = 544x4700

=2556800 kcal

or say 2.56×10^6 Kcal.

The village wise details of energy available from dung at Neil Island have been shown in Fig. 5.2.

5.1.1.2 System sizing for anaerobic digestion

As we know that 1 kWh= 860 Kcal [65], the electricity generation from the biogas will be as given below;

$$\text{Electrical energy equivalent per day of biogas} = \frac{2.56\ x\ 10^6}{860} = 2977\ \text{kWh.}$$

Taking overall system efficiency as 33%, the net electrical energy generation per day will be 2977x0.33= 980 kWh

Assuming 8hour/day operation the total system capacity of DG set has been estimated as nearly 100 kW.

From the cattle and bird dung quantity estimated in the Neil Island, a potential of 544 m^3 of biogas/day would be available. For simplicity, 10 biogas plants would be required to produce the above amount of biogas (@ 60 m^3 /plant). This is advantageous due to the fact that in case, dung is not available in required quantity, the desired number of plants may only be operated at full capacity.

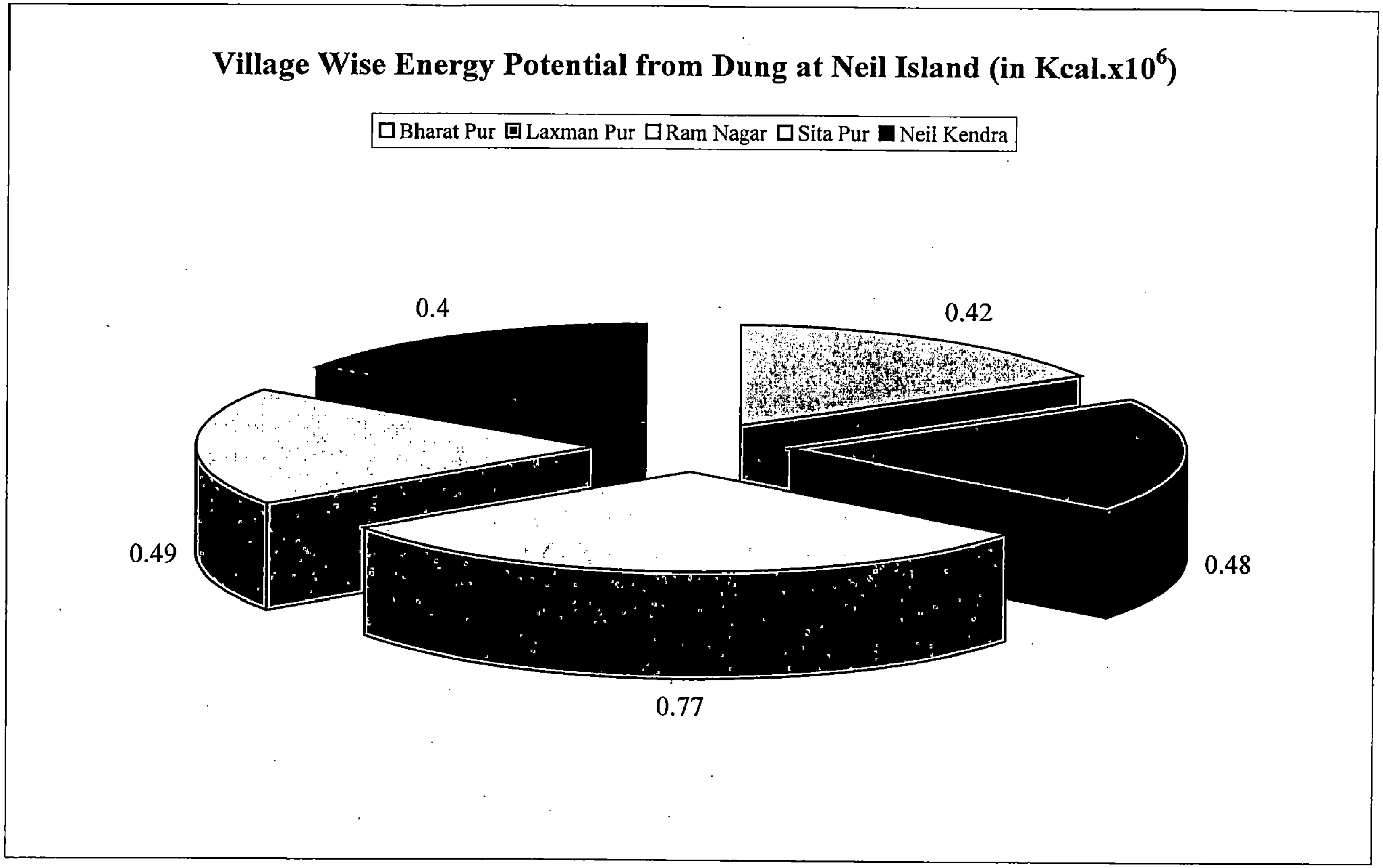


Fig. 5.2: Village-wise energy potential from cattle and bird dung at Neil Island

A biogas operated compression ignition engine-generator set of 100 kW rating shall be required to generate electric power. The engine is proposed to be operated in dual fuel mode in which case a diesel substitution up to 70% would take place. All the biogas plants will produce biogas and the same will be fed to the engine through the common inlet pipe. The electrical power so produced will be fed to the common bus bar for distribution in all the five villages.

5.1.2. Biomass Gasification

5.1.2.1. Analysis for potential of biomass energy

The quantity of agricultural wastes available annually in the area has been estimated, based on actual survey conducted. The agro wastes available in the area are crop residue (rice straw), rice husk, biomass waste (coconut shell etc.). The crop residue mainly rice straw is used by the villagers to feed their cattle. The rice husk is not used for any purpose and it is waste. Similarly the villagers do not use the coconut shells as lots of firewood easily available to them on free of cost. The details of potential of various agro wastes available for use in gasifier are given in Table 5.3, 5.4 and 5.5.

Table 5.3: Annual potential of crop residue (rice straw) at Neil Island

Sl.No.	Name of Village	Collected (Kgs.)	Used (Kgs.)	Balance (Kgs.)
1	Bharat Pur	54430	30000	24430
2	Laxman Pur	39200	24480	14720
3	Ram Nagar	62240	36000	26240
4	Sita Pur	32590	27120	5470
5	Neil Kendra	38330	14640	23690
	Total	**226790**	**132240**	**94550**

Table 5.4: Annual potential of rice husk at Neil Island

Sl.No.	Name of Village	Collected (Kgs.)	Used (Kgs.)	Balance (Kgs.)
1	Bharat Pur	13010	0	13010
2	Laxman Pur	9400	0	9400
3	Ram Nagar	15020	0	15020
4	Sita Pur	7830	0	7830
5	Neil Kendra	9430	0	9430
	Total	**54690**	**0**	**54690**

Table 5.5: Annual potential of biomass waste (coconut shell etc.) at Neil Island

Sl.No.	Name of Village	Collected (Kgs.)	Used (Kgs.)	Balance (Kgs.)
1	Bharat Pur	23136	0	23136
2	Laxman Pur	22020	0	22020
3	Ram Nagar	55464	0	55464
4	Sita Pur	2421	0	2421
5	Neil Kendra	41448	0	41448
	Total	**144489**	**0**	**144489**

On the basis of data collected from all the five villages, it is estimated that about 755.97 Tonnes of biomass is collected per annum out of which the islanders use

162.24 Tonnes to feed their live stocks and for cooking etc. The balance 593.73 Tonnes is available for generation of electricity including 300 Tonnes of wood in the form of bark and lops & tops which is available annually from the forest department on account of extraction activities of commercial wood. The details of annual potential of agro-waste and biomass energy potential are shown in Table 5.6 and Fig. 5.3.

Table 5.6 Annual potential of agro-waste and biomass energy at Neil

Sl.No.	Type of Biomass	Biomass collected per year (kgs.)	Biomass used per year (kgs.)	Biomass available for use in gasifier per year (kgs.)	Total biomass energy potential per year for power generation (in Kcalx10^{6})
1.	Crop Residue (Rice Straw)	226790	132240	94550	236
2.	Rice Husk	54690	0	54690	164
3.	Biomass Waste (Coconut shell etc.)	144489	0	144489	506
4.	Biomass waste from bark and lops & tops on forest extraction from forest department (Kgs.)	330000	30000	300000	1050
	Total	**755969**	**162240**	**593729**	**1956**

As estimated through the survey, 593.73 Tonnes of biomass is available every year for generation of electricity at Neil Island. Out of this 94.55 Tonnes will be on account of rice straw, which is surplus after consuming by the cattle, and 56.69

Tonnes would come from the rice husk, which is at present of no use for the islanders. The coconut shells would contribute about 144.49 Tonnes, which are of no use after extracting coconut pulp. About 300 tonnes biomass in the form of waste wood likely to be available from forest department to use in biomass gasifier. Further if demand of biomass is increases on account of electricity generation, the islanderss of the island would come forward to grow more trees to sell them to the electricity generation unit for very same purpose.

The calorific value of rice straw is 2500Kcal/ kg [65]. thus, the biomass energy potential from rice straw will be as follow;

$$\text{Biomass energy from rice straw/year} = \frac{95500\ x\ \ 2500}{100000} = 236\text{x}10^6\ \text{Kcal}$$

Similarly, The calorific value of rice husk is 3000Kcal/ kg [66], thus, the

$$\text{biomass energy from rice husk} = \frac{56690x\ 3000}{1000000}$$

$$= 164\text{x}10^6\ \text{Kcal / year.}$$

The calorific value of coconut shell is 3500Kcal/ kg [66], thus; the biomass

$$\text{energy from coconut shell} = \frac{144489\ x\ 3500}{1000000}$$

$$= 506\text{x}10^6\ \text{Kcal / year.}$$

The calorific value of wood is 3500Kcal/ kgs. [66], thus; the biomass energy

$$\text{from waste wood} = \frac{300000\ x\ 3500}{1000000}$$

$$= 1050\text{x}10^6\ \text{Kcal / year.}$$

Thus, the total estimated energy from biomass would be 1956 x 10^6 Kcal / year or 5.36 x 10^6 Kcal / day. The details of village wise contribution of biomass energy are shown in Fig. 5.4.

5.1.2.2. System sizing for biomass gasification

As we know that 1 kWh= 860 Kcal [65], the electricity generation from the biomass will be as given below;

$$\text{Electrical energy equivalent per day of biomass} = \frac{5.36\ x\ 10^6}{860} = 6233\ \text{kWh.}$$

Taking overall system efficiency as 33%, the net electrical energy generation per day = 6233x0.33= 2057 kWh

Thus the total electrical energy available from biomass

= 750×10^3 kWh/annum

or 2050 kWh/day.

Assuming 16 hours per day for 300 days operation/year, the capacity of biomass gasifier based diesel generator will be required as 150 kW. The down draft type gasifier will be required to convert the biomass into producer gas. This type of reactor is simple to operate, produces almost tar free producer gas, because the pyrolysis gases are passed through high temperature oxidation zone where all bigger molecules of tar & oils are cracked to smaller molecules of gaseous products. It gives producer gas of temperature more than 700°C, which will be fed to the Internal Combustion (IC) engine coupled with generator of 150 kW capacity after multi stage purification. Depending upon the quality of producer gas, it would replace 70 to 75 % diesel while running on full load. The electricity so generated will be fed to the common grid for further distribution to the consumers.

Annual Potential of Biomass Energy at Neil Island

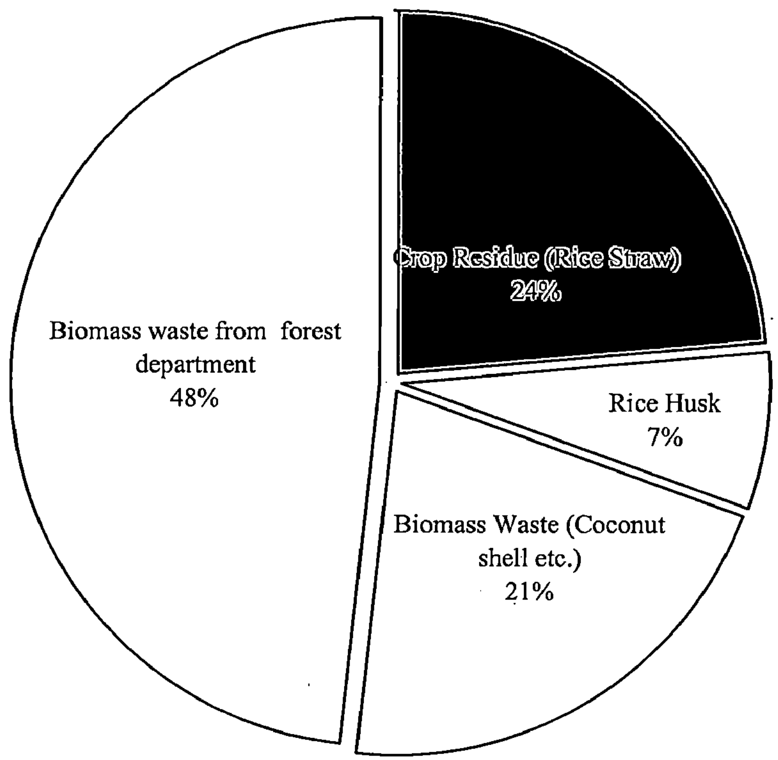


Fig. 5.3: Annual potential of biomass energy at Neil Island

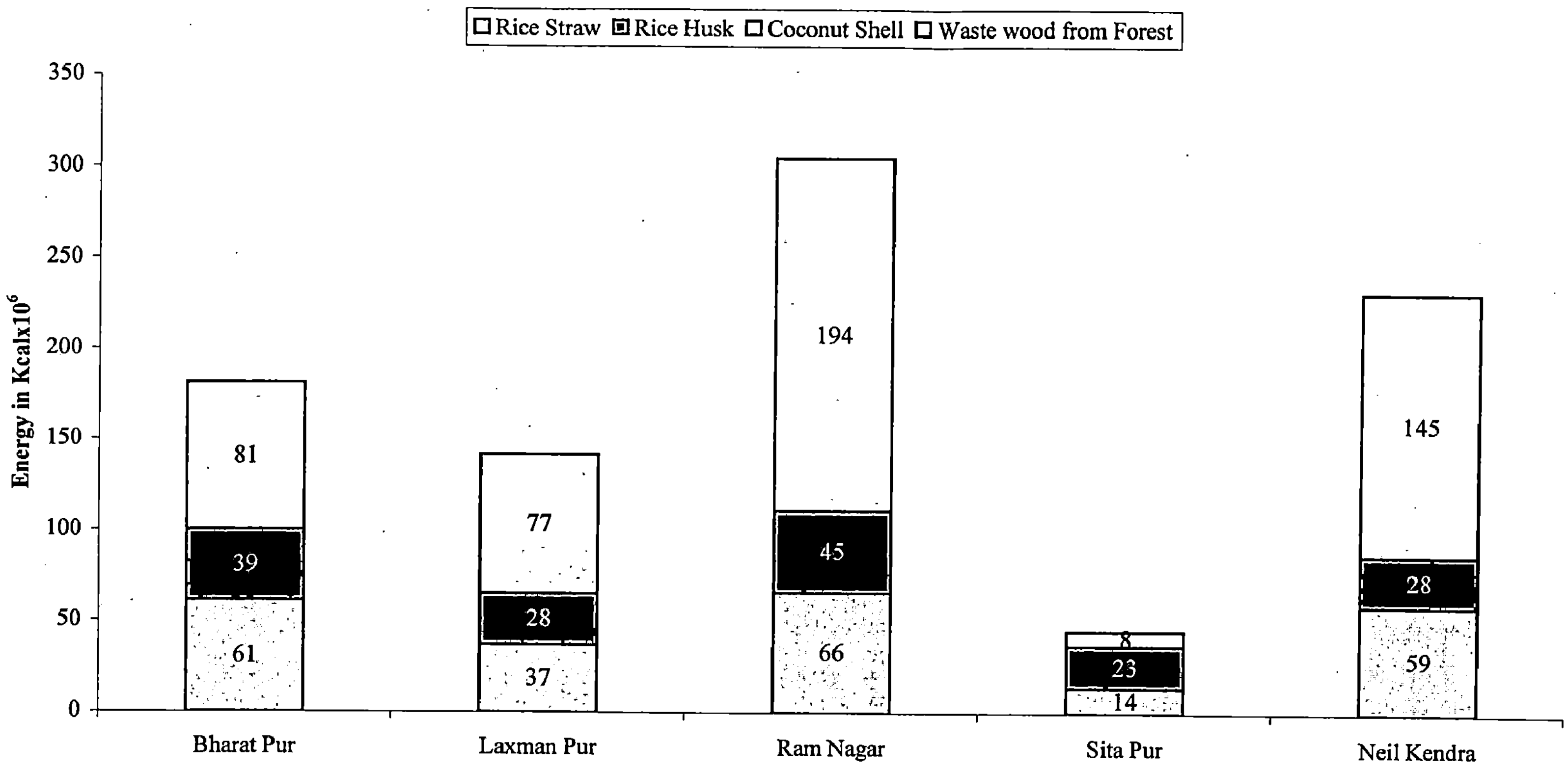


Fig. 5.4: Village-wise contribution to the biomass energy potential for electricity generation at Neil Island

5.2. HYDRO POWER

Based on the survey conducted for five villages, there is no perennial source of water in the island hence no power generation is possible from this source.

5.3 WIND ENERGY POTENTIAL

The mean wind velocity for last 10 years for Neil Island is shown in Table 5.7

Table 5.7: Wind velocity at Neil Island from 1995-2004

WIND VELOCITY (in KMPH) AT NEIL ISLAND FROM 1995-2004											
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Mean
January	5.7	5.8	4.4	5.4	5.1	5.6	4.7	6.2	5.3	6.7	5.49
February	5.2	5.3	4.3	4.1	4	3.9	3.1	4.3	5.2	4.5	4.39
March	3.4	3.6	4.9	4.2	4.2	4.5	5.3	3.7	4.7	2.8	4.13
April	3.6	4.1	4.4	4.7	6.9	4.3	3.9	3.5	3.7	4.3	4.34
May	4.4	5.4	5.8	5.8	5	5	4.1	4.9	4.2	4.9	4.95
June	6.5	7.1	6.9	7	6.9	6.9	6.5	6.7	6.5	6.3	6.73
July	7.2	7.5	7.9	7.6	7.9	7.6	6.9	7.3	6.7	7.2	7.38
August	6.6	7.8	9.1	7.1	6	7.1	6.4	6.5	7.1	7.1	7.08
September	5.1	4.8	5.3	4.1	4	4	5.5	5.1	4.9	4.9	4.77
October	6.1	6.4	4.5	3.2	4	4	5.4	4.2	4.2	5.5	4.75
November	5.2	4.8	4.5	4.9	4.9	4	5.3	5.3	5.3	5.1	4.93
December	4.2	5.1	4.5	5.3	4.2	5.6	5.3	5.6	4.7	4.6	4.91

It would be seen from the Table 5.7 that the mean wind speed at the selected island is ranging from 4.13 to 7.38 Kmph or 1.15 to 2.05 m/s as shown in Fig. 5.5.

ANNUAL MEAN WIND VELOCITY AT NEIL ISLAND FROM 1995-2004

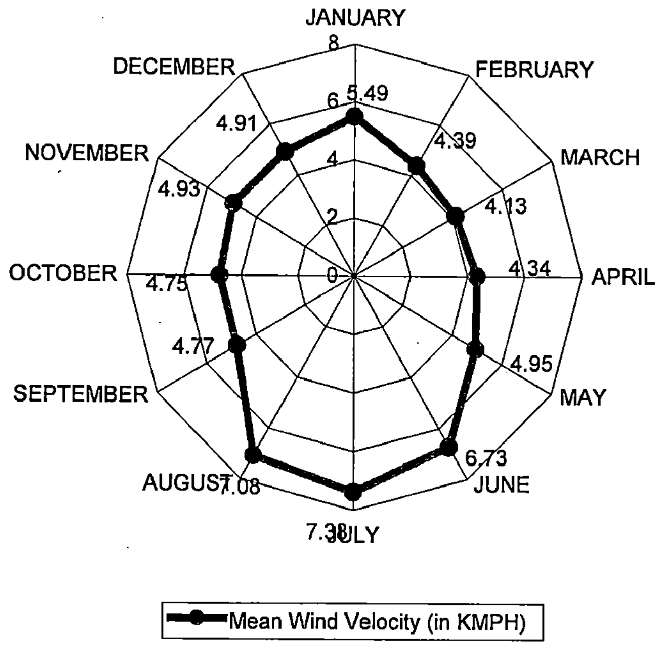


Fig. 5.5: Annual mean wind velocity at Neil Island for last 10 years

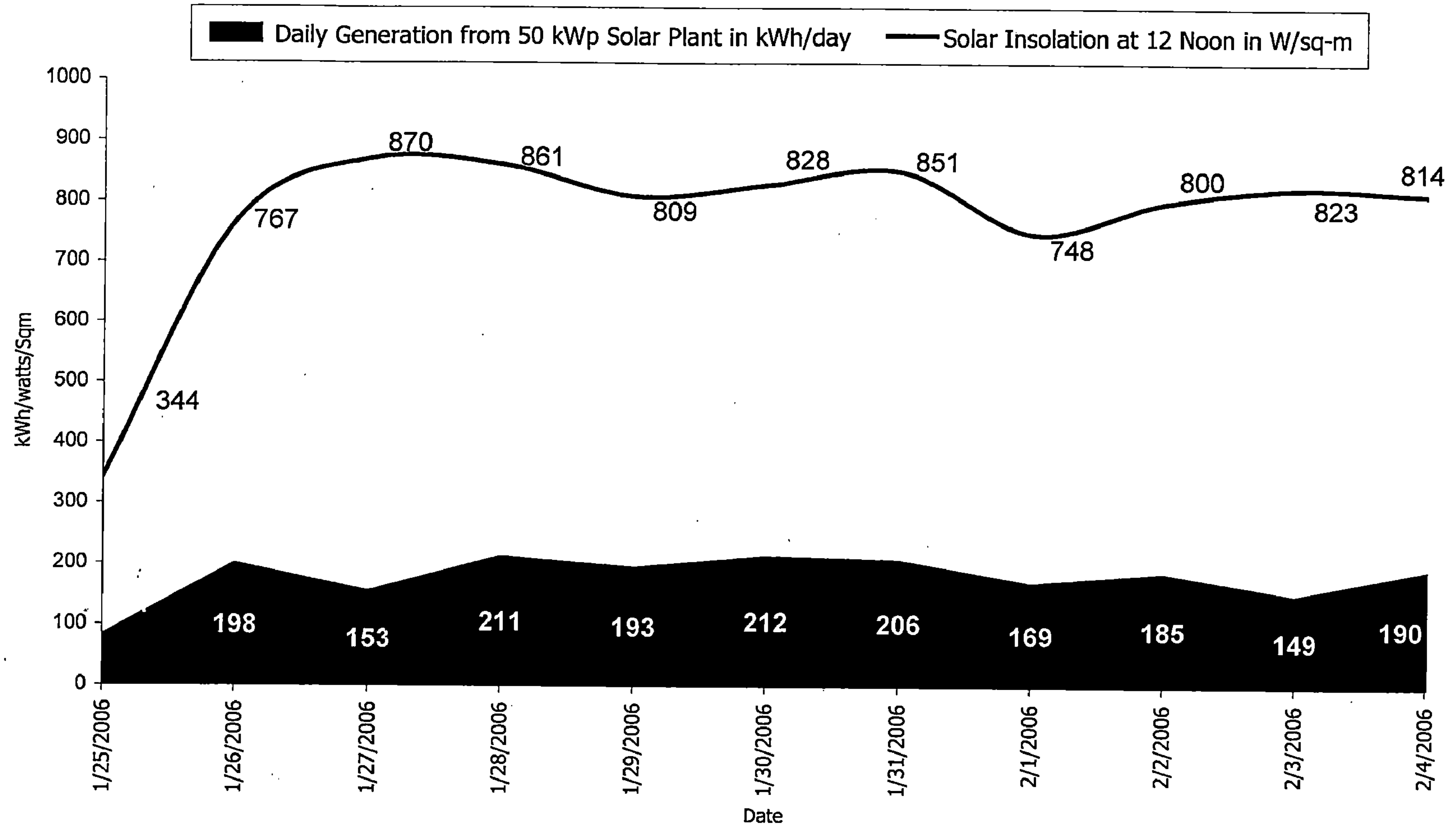
Since the wind velocity is below the limit i.e. 4.5 m/s (See Table 3.5) the indicated resource value is poor as such the power generation is not economically viable. Hence this source would not be usable at Neil Island to generate electrical energy.

5.4. SOLAR POWER

5.4.1.Estimation of Solar Insolation

First of all it is to estimate the solar radiation availability at the selected island. During the survey the readings for solar insolation at 12 noon along with electricity generation from existing 50 kWp solar power plant were recorded to estimate the solar isolation and power generation at Neil Island. The extract of the recorded data is shown in Fig. 5.6.

Solar Insolation and Generation of power at Neil Island



The raw weather data measured on a flat (horizontal) surface are converted to a tilted surface. This can be discussed with following steps:

Step-1

First, the declination, δ, is calculated for a representative day for each month of the year using following equation

$$\delta = 23.45 Sin\left[\frac{360}{365}(284+n)\right] \qquad 5.1$$

Where n is Julian day number for the representative day in each month.

The Table-5.8 shows the representative day for each month of the year i. e the Julian day (n), number for the representative day in each month. It also shows the recommended average day for each month of the year. The declination, δ, can be calculated by using n in equation 5.1

Table 5.8: Recommended average day for each month of the year

Month	n for ith Day of Month	For average Day of the Month		
		Date	day of year (n)	Declination (δ)
January	i	17	17	-20.92
February	31 + i	16	47	-12.95
March	59 + i	16	75	-2.45
April	90 + i	15	105	9.45
May	120 + i	15	135	18.79
June	151 + i	11	162	23.08
July	181 + i	17	198	21.18
August	212 + i	16	228	13.45
September	243 + i	15	258	2.22
October	273 + i	15	288	-9.59
November	304 + i	14	318	-18.91
December	334 + i	10	344	-23.05

Step-II

Calculation of the sunset hour angle, hs is determined for the representative day for each month using the following expression

$$hs = \cos^{-1}(-\tan\varphi \times \tan\delta) \quad (5.2)$$

Where,

φ is site latitude.

Step-III

The monthly average daily solar insolation on an extra terrestrial horizontal surface, Ho is then calculated using following expression

$$Ho = \frac{24}{\pi} Hsc\left[1 + 0.033\cos\left(\frac{360n}{365}\right)\right]\left[Cos\phi\cos\delta\sinh s + \left(\frac{2\pi hs}{360}\right)\sin\phi\sin\delta\right] \quad (5.3)$$

Where,

Solar constant (Hsc) is 1353 W/m^2.

Step-IV

The monthly average clearness index K_T, which is defined by the ratio of the monthly average daily insolation on a terrestrial horizontal surface (H) to the radiation on an extra terrestrial horizontal surface (Ho) is determined by using following expression,

$$K_T = \frac{H}{H_0} \quad (5.4)$$

Step-V

The diffuse solar radiation (Hd) is calculated as,

$$Hd = H\,[0.775+0.00653(hs-90)-\{0.505+0.00455(hs-90)\}\cos(115K_T - 103)] \quad (5.5)$$

Step-VI

The beam radiation (Hb) is determined by subtracting the diffuse radiation using the equation,

$$Hb = H - Hd \quad (5.6)$$

Where,

H (I) = daily sum of direct solar radiation on a horizontal surface, in kWh/m^2

Step-VII

The monthly average beam radiation tilt factor, Rb is estimated using following equation,

$$Rb = \frac{\sin(\phi - s)\sin\delta + \cos(\phi - s)\cos\delta\cos\omega}{\sin\phi\sin\delta + \cos\phi\cos\delta\cos\omega} \tag{5.7}$$

Where,

ω is hour angle and s is tilt angle of the surface with horizontal

Step-VIII

The tilt factor, Rd, for diffuse radiation is estimated using the expression given below,

$$Rd = \frac{1 + \cos s}{2} \tag{5.8}$$

Step-IX

The tilt factor for reflected radiation may be estimated by the following expression,

$$R_r = \rho_g\left(\frac{1 - \cos s}{2}\right) \tag{5.9}$$

Where,

ρ_g is ground reflectivity factor for green grass. It is taken for green islands as 0.26.

Step-X

Finally, combining the three terms, the total solar radiation intensity or flux falling on tilted surfaces is computed by using the following expression:

Total insolation on a tilted surface = Beam Insolation + Diffuse Insolation + Reflected Insolation

$$H_T \text{ or } I_T = HbRb + HdRd + HrRr \tag{5.10}$$

It can also be expressed as;

$$H_T = HbRb + Hd\left(\frac{1 + \cos s}{2}\right) + H\rho_g\left(\frac{1 - \cos s}{2}\right) \tag{5.11}$$

Monthly average hourly radiation data can be approximated from monthly average daily insolation by the following analytical expression;

$$r = \frac{\pi}{24}(a + b\cos\omega)\left[\frac{\cos\omega - \cosh_s}{\sinh_s\left(\frac{2\pi h_s}{360}\right)\cosh_s}\right] \qquad (5.12)$$

$a = 0.409 + 0.5016\sin(hs - 60)$

$b = 0.6609 - 0.4767\sin(hs - 60)$

Where,

'r' is ratio of hourly total radiation to the daily total radiation.

5.4.2. Analysis for Solar Energy Potential

At solar noon on a clear March or September day, the solar radiation at the equator is about 1000 W/m^2. Hence, the standard solar radiation has a power density of 1000 watts per square meter. The typical solar panel today achieves between 10% and 15% conversion. The theoretical maximum efficiency of a silicon cell is about 21%. Using a more costly technology 31% conversion has been achieved. Thus, assuming 13% efficiency, the solar cell having 1 m^2 of surface area in full sunlight at solar noon at the equator during either March or September will produce approximately 130 watts of peak power. Most panels, for a variety of design reasons, contain 32 to 36 individual cells. One cell has the size of 4"x4" thus the total area of a panel having 32 cell comes out to 0.32 m^2. For 100-kWp solar power plant we would need 1800 panels of 70 watt each. Thus, the total area comes to 1800x0.32= 576 m^3. As mentioned above a panel of 1 m^3 will produce 130 watts per hour as such total unit generated comes to 576x0.130= 75 kWh per hour. Assuming peak hours as 4.2 per day the total unit generation comes to 75 x 4.2= 315 kWh. Thus, for 100-kWp solar power plant, the estimated unit generation per day would be 315 kWh with silicon cell efficiency of 13% and standard power density of 1000 watts / m^3. On converting the unit generation at recorded average data (Table 5.9) the net solar energy potential will be;

$$\frac{315 \; x \; 792}{1000} = 250 \text{ kWh}$$

Thus, 100 kWp installed capacity solar power plant will generate 250 kWh per day at Neil Island. The generation of electrical energy will be more if better quality solar cells are used. To substitute the existing diesel power plant, we needs 500 kWh per day contribution from solar power plant, hence the system needs to be designed for 500 kWh solar power requirement only.

Table 5.9: Solar insolation details on horizontal surface (kWh/m²/day)

Sl. No.	Date	Solar Insolation on Horizontal Surface (Wh/m²)	Average Solar Insolation on Horizontal Surface (Wh/m²)
1.	25-Jan-06	544	792
2.	26-Jan-06	767	
3.	27-Jan-06	870	
4.	28-Jan-06	861	
5.	29-Jan-06	809	
6.	30-Jan-06	828	
7.	31-Jan-06	851	
8.	1-Feb-06	748	
9.	2-Feb-06	800	
10.	3-Feb-06	823	
11.	4-Feb-06	814	

5.4.3. SPV System Design

5.4.3.1. Array size and total number of modules

The array load and array size can be calculated, based on this average solar insolation of 4.2X 10^3 Wh/m^2 per day, and number of peak hours as 4.2 hrs, assuming mismatch factor of 0.85, battery efficiency as 0.8 and charge regulator efficiency as 0.9.

The capacity and the size of the array is calculated using the following equations:

$$Array\ Load = \frac{Total\ daily\ load(kWh/day)}{Battery\ Efficiency\ x Charge\ Regulator\ Efficiency}$$

$$= \frac{500}{0.8\ x\ 0.9} = 700$$

$$Array\ size = \frac{Array\ Load(kWh/day)}{No.of\ peak\ hours\ x\ mismatch\ factor}$$

$$= \frac{700}{4.2\ x\ 0.85} = 200\ kWp/day$$

Thus, the array, capable of delivering 200 kWp, shall be required.

Choosing standard modules of 70 Wp each with I-V characteristics having peak current 4.15 amp and short-circuit current of 4.48 amp. Peak hour of 17.43 Ah per day for average solar insolations of 4.2 x 10^3 Wh/m^2 per day, mismatch or derate factor of 0.85, battery efficiency as 0.8, charge regulator efficiency as 0.9, module nominal voltage is 12V, and the system nominal voltage is 220V.

$$No.of\ series\ modules = \frac{Nominal\ system\ voltage\ (V)}{Nominal\ module\ voltage(v)}$$

$$= \frac{220}{12} = 18.3 \quad say\ 18\ nos.$$

$$No.of\ parallel\ modules = \frac{Daily\ load\ demand(Wh)}{Module\ daily\ output(Wh)}$$

$$= \frac{Daily\ load(Ah)}{Battery\ charging\ efficiency\ x\ module\ x\ derating\ factor}$$

$$= \frac{500000/220}{0.8x0.85x17.43}$$

$$= 192$$

or say 200

Total numbers of modules = 18s x 200p

The total number of series & parallel module = 3600.

5.4.3.2. Sizing of battery

The battery capacities are selected based upon the standard ratings of batteries available in the market. However, we have considered the Tubular type & low maintenance (exide make) batteries. The capacity is decided assuming 5 days as reserve, maximum allowable DOD as 80% and temperature derating of 0.85. The battery capacity has been calculated using the following equations:

$$Battery\ capacity = \frac{Daily\ load(Ah)\ x\ reserve\ days}{Max\ allowable\ depth\ of\ discharge(DOD)x\ temperature\ derate\ x\ rate\ factor}$$

$$Rate\ factor \quad = \frac{1047Ah\ (24\ hour\ rate)}{787\ Ah\ (8\ hour\ rate} = 1.33$$

$$= \frac{(500000\ /\ 220)x5}{0.8x0.85x1.33} = 12565\ \text{Ah}$$

$$Average\ rate\ of\ Descharge\ (hours) = \frac{No.of\ days\ of\ autonomy x 24 hours\ /\ day}{Maximum\ percentage\ usable} = \frac{5x24}{0.8} = 150Hr$$

$$No.\ of\ series\ batteries = \frac{Nominal\ system\ voltage\ (V)}{Nominal\ battery\ voltage(v)} = \frac{220}{12} = 18.3 \quad say \quad 18$$

$$No.\ of\ parallel\ batteries = \frac{Capacity\ of\ Battery\ bank}{Indivisual\ battery\ capacity} = \frac{12565}{200} = 64$$

Total numbers of batteries = 18 x 64 = 1152 of 200 Ah each.

The details of batteries and modules required for 200kWp solar power plant to generate about 500kWh per day are shown in Table 5.10

Table-5.10: Modules and battery details

Sl. No	Description		Numbers
1	Batteries	Series	18
		Parallel	64
		Total	1152
2	Modules	Series	18
		Parallel	200
		Total	3600

5.5. OCEAN ENERGY

5.5.1. Ocean Thermal Energy Conversion (OTEC)

As per the state development report on Andaman and Nicobar Islands [66], a study was conducted by Indian Institute of Technology Chennai to find out suitable locations for establishment of OTEC power plant. Few sites were found suitable at South Andaman, Chinque Island and Tillangchong Island only [65]. As per their study, there is no suitable site near Neil Island to establish the OTEC power plant as such there is no possibility to harness renewable energy from this source.

5.5.2. Tidal Energy

The Central Electricity Authority (CEA) had undertaken a study about ten years back at Andaman and Nicobar Islands and found that the tide level was around two metres, which is not economically viable. However, they suggested some sites at South Andaman, Middle Andaman and Kamorta , where pilot projects can be installed[66]. At present there is no possibility to generate power from this source at Neil Island.

5.5.3. Current and Wave Energy

There are no studies undertaken by any agency to explore the possibilities for generation of power by these sources in Andaman and Nicobar Islands. The assessment of energy available from these sources can be done, when the required data will be available.

5.6. SUMMERY

The present chapter has presented an overview of various renewable energy sources viz. solar, biomass, wind, hydro and ocean energy and availability of their potential at Neil Island. In accordance with the potential available, the plant capacities have been evaluated as shown in Table 4.15. It has been found that the potential of hydro, wind and ocean energy in the area is not sufficient to yield any usable energy.

Table 5.11: Energy potential available for renewable resources at Neil Island

Sl. No	Resources	Rating of the system in kW/ kWp
1	Biomass gasifier	150
2	Biogas	100
3	Solar Photovoltaic	200
	Total	**450**

COST ESTIMATION AND FINANCIAL ANALYSIS

6.1 ESTIMATION OF COST OF ENERGY (COE)

The cost of energy of various renewable energy systems worked out for installation in the Neil Island are discussed as below:

6.1.1 Biomass Energy

6.1.1.1 Analysis for cost of energy from biomass gasifier

It is proposed to use a biomass gasification based power generating system. The cost of energy from the gasifier engine – generator system is calculated based on plant capital cost and operating cost as discussed below.

6.1.1.1.1 *Plant cost*

According to the published correlation, the plant cost has been calculated. The base cost factor is calculated by modifying it in present context on the basis of the quoted prices from the manufacturers [67].

$$\text{Plant cost (in Rs.)} = 4.73 \times 10^4(\text{kW})^{0.85} \qquad (6.1)$$

6.1.1.1.2. *Operating cost*

Since the diesel generating set works in duel fuel mode replacing 70% diesel with producer gas, the cost of fuel is calculated on the basis of the cost of diesel and the cost of feed stocks. Taking the specific fuel consumption of diesel generating set in diesel mode as 0.3 litres / kWh, the diesel consumption in duel fuel mode will be 0.09 litres / kWh.

Therefore,

$$\text{The cost of fuel} = \text{cost of diesel} + \text{cost of feed stocks} \qquad (6.2)$$

Taking the present market rate of diesel as Rs. 33.35 per litre

The cost of fuel =(0.09 x Rs 33.35 + Rs.1.25)/kWh

=Rs.4.25/ kWh

Also, the unit cost of energy is calculated by using the following expression [68]:

COE=

$$\frac{\left[4.73\,x\,10^{4}(kW)^{0.85}\right]x\left[\frac{PRF}{100}+\frac{O\,\&\,M\ \cos t}{100}\right]+\left[Unit\cos t\ of\ fuel\ x\ AnnualGeneration\right]}{Annual\ \ generation} \quad \ldots\ldots\ldots \quad (6.3)$$

Where,

PRF is the Plant recovery factor,

kW is Installed capacity of the plant

$$COE = \frac{\left[4.73x10^{4}(150)^{0.85}\right]x\left[\frac{18}{100}+\frac{3}{100}\right]+\left[4.25x150x300x16\right]}{150x300x16} = \text{Rs. } 5.23 \quad (6.4)$$

Thus, the cost of energy with gasifier plant = Rs.5.23/kWh

6.1.1.2 Analysis for cost of energy from biogas plant

6.1.1.2.1. *Capital cost*

The present cost of a biogas plant of 60 m^3capacity has been taken as Rs. 3,02,500 per plant, which also includes the cost of the diesel generating set and civil works[67].

Following cost function as reproduced below may be used for computing the cost.

Plant cost = 3,02,500 × N_B (6.5)

Where,

N_B = Number of biogas plant of capacity 60 m^3

The total plant cost of biogas system of 100 kW with accessories and civil works = 30,25,000.

6.1.1.2.2. *Operating cost*

Since the diesel generating set works in duel fuel mode replacing 70% diesel with biogas, the cost of fuel is calculated on the basis of the cost of diesel and the cost of dung. Taking the specific fuel consumption of diesel generating set in diesel mode as 0.3 litres / kWh, the diesel consumption in duel mode will be 0.09 litres / kWh.

Therefore,

The cost of fuel = cost of diesel + cost of dung (6.6)

Taking the present market rate of diesel as Rs. 33.35 per litre

The cost of fuel =(0.09 x Rs 33.35 + Rs.1.25)/kWh

=Rs.4.25/ kWh

Thus, expression used for calculating the unit cost of energy is [67];

$$COE = \frac{[302500xN_B]x\left[\frac{PRF}{100}+\frac{O\,\&\,M\ \cos t}{100}\right]+[Annual\ \ Generation\ x\ Unit\ \cos t\ of\ \ fuel]}{Total\ \ annual\ energy\ generation\ (kWh)} \qquad (6.7)$$

Where,

Nb = No. of Plants,

PRF = % Plant recovery factor,

$$\text{COE} = \frac{[302500x10]x\left[\frac{15}{100}+\frac{2}{100}\right]+[100x300x8x4.25]}{100x300x8} = \text{Rs. } 6.39 \qquad (6.8)$$

Cost of energy from biogas plant = Rs.6.39/kWh

6.1.2 Solar Energy (SPV)

The cost factor for solar panel depends upon the peak watt to be catered to the utility. Using the state-of-the art technology, the cost is about Rs. 165/Wp presently, although, it may shoot up to Rs. 3500/Wp for space application.

NASA Lewis Research Centre has analysed the cost /peak watt and found the Balance of System (BOS) cost of the installation is as follows [67];

$$\text{BOS cost} = 296 \times 35 \times (\text{kWx}1000)^{-0.412} \text{ in Rs./watt} \qquad (6.9)$$

Therefore, the total cost of PV system is equal to the cost of solar cell panel plus BOS cost. The BOS cost is inversely proportional to the PV array size, the PV capital cost may be calculated as follows:

$$\text{PV capital cost (Rs.)} = [165 + 296 \times 35\ (\text{kW} \times 1000)^{-0.412}]\ \text{kW} \times 1000 \qquad (6.10)$$

$$\text{PV capital cost} = [165+296\text{x}35(200\text{x}1000)^{-0.412}]\ \text{x}\ 200\text{x}1000 \qquad (6.11)$$

$$= \text{Rs.}4{,}65{,}63{,}300/-$$

The subsidy is provided by Ministry of Non-conventional Energy Sources (MNES) for grid connected solar power plant, which is $2/3^{rd}$ of the project cost subject to a maximum of Rs.2 crores per 100 kW [32].

Hence in this case an amount of Rs.3,10,42,200/- will be provided as subsidy by MNES as such the actual amount required for installation of 200 kWp solar power plant will be Rs. 1,55,21,100/- only

$$\text{Cost of Energy (COE)} = \frac{[Capital\ Cost]x\left[\frac{PRF}{100} + \frac{O\&M\cos t}{100}\right]}{Total\ Annual\ generation} \qquad (6.12)$$

$$\text{COE} = \frac{[15521100]x\left[\frac{14}{100} + \frac{2}{100}\right]}{500x300} = \text{Rs.}15.55 \qquad (6.13)$$

Cost of generation from solar power plant = Rs.15.55

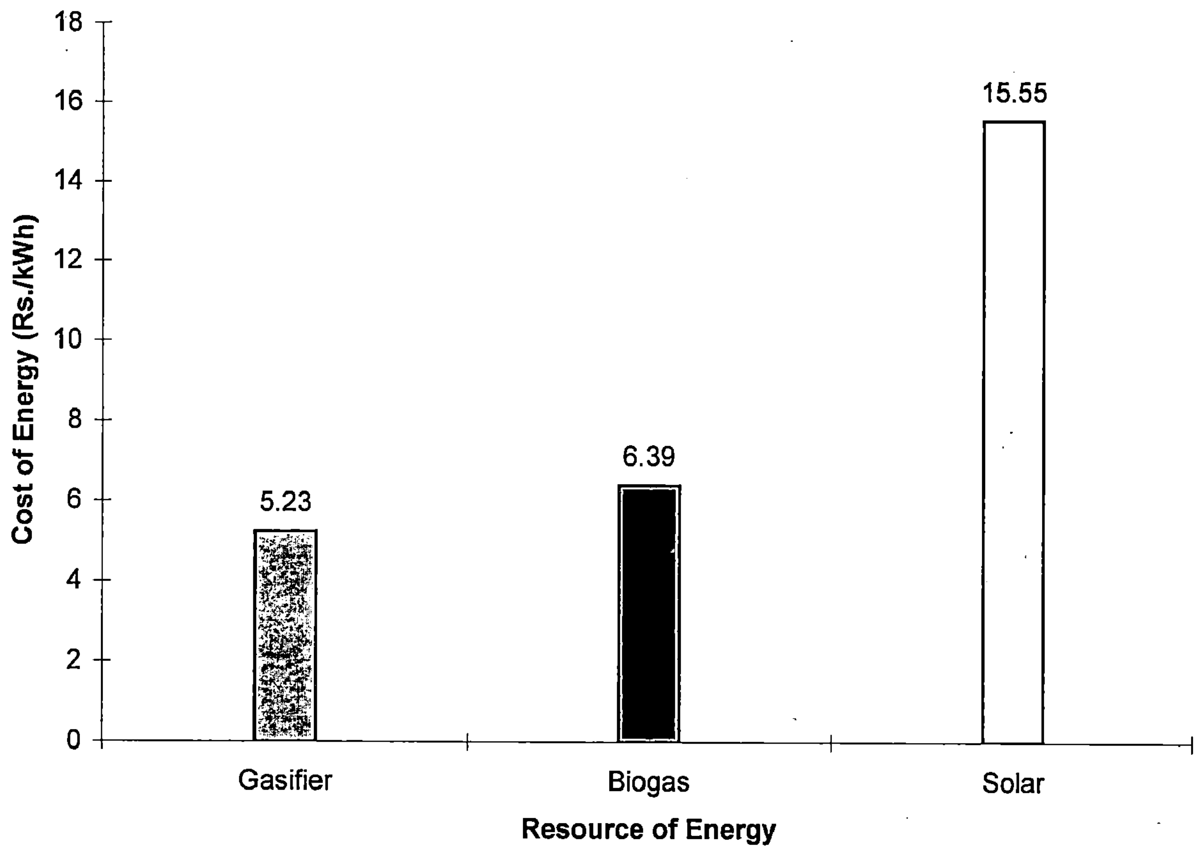


Fig. 6.1: Cost of energy for various renewable energy sources at Neil Island

6.1.3 Analysis for Cost of Energy from Existing 4x100 kW Diesel Generator

The present cost of diesel generator is Rs. 20000 /kW including the cost of auxiliaries and civil works. Assuming specific fuel consumption of 0.3 Litres /kWh and rate of diesel as Rs.33.35/litre, the unit fuel cost will be

= 33.35x0.3

= Rs.10/- per kWh

$$COE = \frac{\left[CapitalCost\ x \left[\frac{PRF}{100} + \frac{O\&M\ \cos t}{100} \right] + (AnnualGeneration\ x\ UnitCostofFuel) \right]}{AnnualGeneration} \quad (6.14)$$

Taking capital cost as 20000x400 i.e. Rs. 80,00,000/-, plant recovery factor as 15% and O&M cost as 4%, the cost of energy for diesel generator has been calculated for next five years based on load demand and shown in the Table 6.1.

Cost of generation from diesel generator will vary from Rs.12.19 in first year to Rs.11.86 in fifth year depending on the load demand.

Table 6.1: Unit cost of generation of existing D.G. set for next five years

Year	Capital Cost (Rs.)	PRF (Rs.)	O&M (Rs.)	Daily Demand (kWh)	Annual Generation (kWh)	Unit cost of fuel (Rs.)	Unit Cost of Energy (Rs.)
2006-07	80,00,000	12,00,000	3,20,000	2,310	6,93,000	10	12.19
2007-08	80,00,000	12,00,000	3,20,000	2,410	7,23,000	10	12.10
2008-09	80,00,000	12,00,000	3,20,000	2,510	7,53,000	10	12.02
2009-10	80,00,000	12,00,000	3,20,000	2,620	7,86,000	10	11.93
2010-11	80,00,000	12,00,000	3,20,000	2,730	8,19,000	10	11.86

6.2 COST ANALYSIS

The Table 6.2 represents the various parameters used for the calculation of unit cost of energy from the different resources.

Table 6.2: Parameter used for estimating Cost of Energy (COE) [67]

Sl. No.	Parameter	SPV	Gasifier	Biogas	Diesel Generator
1	System ratings (kW)	200	150	100	400
2	Total operating hours per day	8	16	8	24
3	Annual operating days	300	300	300	300
4	Annual interest rate(%)	13	13	13	13
5	Plant life period (Yrs)	20	10	15	15
6	Plant recovery factor (%)	14	18	15	15
7	O&M cost (% of capital cost)	2	3	2	4
8	Fuel cost (Rs./kWh)	---	4.25	4.25	10.00

All the plants operate for 300 days and total hours of operation per day are different for different sources e.g. 8-hours for solar, 16-hours for biomass, 8 hours for biogas and 24 hours for diesel generator. For calculation of plant recovery factor, annual interest rate is taken, as 13%, whereas plant's life is different. The fuel cost for gasifier and biogas are taken, as Rs.4.25 per kWh and for diesel generator, as Rs.10.00 per kWh.

Thus, the costs of energy for all energy resources have been determined on the basis of depreciation, interest and operation and maintenance (O&M) cost. The cost of energy (COE) and installed capacity from each major source are tabulated in Table 6.3.

Table 6.3: Capital cost, capacity and unit cost of renewable energy sources

Sl. No	Types of energy resource	Capital cost (Rs.)	Installed capacity (kW)	Unit cost (Rs./kWh)	Maximum unit generation per day (kWh)
1	Gasifier	33,46,098	150	5.23	2,050
2	Biogas	30,25,000	100	6.39	980
3	Solar	1,55,21,100	200	15.55	500
	Total	**2,18,92,198**	**450**		**3,530**

It can be seen from the Table 6.3 that the cost of power generation from gasifier (Rs.5.23 /kWh) is the lowest from biogas (Rs.6.39 /kWh), and Solar (Rs.15.55/kWh). Therefore, the cost of energy from gasifier is minimum and hence the demand can be met by this source of energy in such a way that in case of more demand, the share of the next source on the basis of COE starts taking place.

6.3 ENERGY PLANNING FOR NEIL ISLAND

The energy-planning endeavor involves finding a set of sources and conversion devices so as to meet the energy requirements/demands of all the sectors in an optimal manner. Integrated Renewable energy planning aims for optimal utilization of available energy resources, taking into consideration the future energy demand along with socio-economic and environmental aspects of energy use. Use of energy, whether renewable or non-renewable and its effect leads to different kinds of arguments in terms of its effect on environment, social cost and economic viability.

6.3.1 Model –I: (Renewable Energy Sources only)

Based on the load demand, the power requirement can be met with biomass gasifier being the cheapest source for sixteen hours a day from 00.00 (mid night) to 1600 hrs. From 1600 to 2400 hrs. the load demand will be met with biogas plant and solar power plant running in parallel . The details of energy planning for Neil Island for next five years have been shown in Table 6.4 to 6.8 below.

Table 6.4: Energy Planning for Neil Island for the year 2006-07

Resources of Energy	From	To	Total Hours	Daily Total Generation (kWh)	Cost of Energy (Rs./kWh)	Total cost (Rs.)
Gasifier	0:00	16:00	16	1280	5.23	6694
Biogas	16:00	0:00	8	550	6.39	3515
Solar	16:00	0:00	8	480	15.55	7464
Total	**0:00**	**24:00**	**24**	**2310**	**7.65**	**17673**

Table 6.5: Energy planning for Neil Island for the year 2007-08

Resources of Energy	From	To	Total Hours	Daily Total Generation (kWh)	Cost of Energy (Rs./kWh)	Total cost (Rs.)
Gasifier	0:00	16:00	16	1330	5.23	6956
Biogas	16:00	0:00	8	600	6.39	3834
Solar	16:00	0:00	8	480	15.55	7464
Total	**0:00**	**24:00**	**24**	**2410**	**7.57**	**18254**

Table 6.6: Energy planning for Neil Island for the year 2008-09

Resources of Energy	From	To	Total Hours	Daily Total Generation (kWh)	Cost of Energy (Rs./kWh)	Total cost (Rs.)
Gasifier	0:00	16:00	16	1420	5.23	7427
Biogas	16:00	0:00	8	600	6.39	3834
Solar	16:00	0:00	8	490	15.55	7620
Total	**0:00**	**24:00**	**24**	**2510**	**7.52**	**18881**

Table 6.7: Energy planning for Neil Island for the year 2009-10

Resources of Energy	From	To	Total Hours	Daily Total Generation (kWh)	Cost of Energy (Rs./kWh)	Total cost (Rs.)
Gasifier	0:00	16:00	16	1490	5.23	7793
Biogas	16:00	0:00	8	640	6.39	4090
Solar	16:00	0:00	8	490	15.55	7620
Total	**0:00**	**24:00**	**24**	**2620**	**7.44**	**19503**

Table – 6.8: Energy planning for Neil Island for the year 2010-11

Resources of Energy	From	To	Total Hours	Daily Total Generation (kWh)	Cost of Energy (Rs./kWh)	Total cost (Rs.)
Gasifier	0:00	16:00	16	1520	5.23	7950
Biogas	16:00	0:00	8	720	6.39	4601
Solar	16:00	0:00	8	490	15.55	7620
Total	**0:00**	**24:00**	**24**	**2730**	**7.39**	**20171**

6.3.2. Model-II: (Renewable Energy (Biogas+Gasifier)+ 50 kWp Existing Solar Power Plant+100 kW Diesel Generator)

Owing to the higher capital cost of solar power plant and thus the high unit cost of generation, 150 kWp capacity of solar power plant can be replaced with existing one unit of 100 kW diesel generating set along with gasifier and biogas plant except the existing 50 kWp solar power plant. The gasifier will meet the demand from 0:00 to 16:00 hours and demand from 16:00 hours to 24:00 hours will be met by biogas plant, solar power plant and diesel generator running in parallel.

6.3.2.1. Analysis for cost of energy from 100kw diesel generator

The cost of energy for the 100 kW diesel generator will be

$$= \frac{\left[CapitalCost\ x \left[\frac{PRF}{100} + \frac{O\,\&\,M\cos t}{100} \right] + (AnnualGeneration\ x\ UnitCostofFuel) \right]}{AnnualGeneration} \quad ....(6.15)$$

= (20000x100x0.19+400x300x10)/400x300

Cost of energy (COE) for 100 kW diesel generator= Rs.13.17

6.3.2.2. Analysis for cost of energy from 50 kwp existing solar power plant

The total cost of PV system is equal to the cost of solar cell panel plus BOS (Balance of System) cost. The BOS cost is inversely proportional to the PV array size; the PV capital cost may be calculated as follows:

PV capital cost (Rs.) $= [165 + 296 \times 35\ (kW \times 1000)^{-0.412}]\ kW \times 1000$ (6.16)

PV capital cost $=[165+296x35(50x1000)^{-0.412}]\ x\ 50x1000$

= Rs. 1,42,52,803/-

The subsidy is provided by Ministry of Non-conventional Energy Sources (MNES) for grid connected solar power plant, which is 2/3rd of the project cost subject to a maximum of Rs.2 crores per 100 kW [32].

Hence in this case an amount of Rs. 95,01,869 will be provided as subsidy by Ministry of Non–conventional Energy Sources (MNES) as such the actual amount required for installation of 50 kWp solar power plant will be Rs. 47,50,934 only

$$\text{Cost of Energy (COE)} = \frac{[Capital\ Cost]x\left[\frac{PRF}{100}+\frac{O\&M\ cost}{100}\right]}{Total\ Annual\ generation} \quad (6.17)$$

$$\text{COE} = \frac{[4750934]x\left[\frac{14}{100}+\frac{2}{100}\right]}{100x300} = \text{Rs.}25.3 \quad (6.18)$$

Cost of energy from existing 50 kWp solar power plant = Rs.25.34/kWh

The capital cost, installed capacity and cost of energy for model-II are given in Table 6.9

Table 6.9: Capital cost, installed capacity and unit cost of renewable energy sources & diesel generator

Sl No	Types of energy resource	Capital cost (Rs.)	Installed capacity (kW)	Unit cost (Rs./kWh)	Maximum unit generation per day (kWh)
1	Gasifier	33,46,098	150	5.23	2,050
2	Biogas	30,25,000	100	6.39	980
3	Diesel generator	20,00,000	100	12.53	500
4.	Solar	47,50,934	50	25.34	100
	Total	**1,31,22,032**	**400**		**3,630**

The details of energy planning for Neil Island for model –II are shown from Table 6.10 to 6.14

Table 6.10: Energy Planning for Neil Island for the year 2006-07

Resources of Energy	From	To	Total Hours	Daily Total Generation (kWh)	Cost of Generation (Rs./kWh)	Total cost (Rs.)
Gasifier	0:00	16:00	16	1280	5.23	6694
Biogas	16:00	0:00	8	550	6.39	3515
Diesel generator	16:00	0:00	8	380	13.17	5005
Solar	16:00	0:00	8	100	25.34	2534
Total	**0:00**	**24:00**	**24**	**2310**	**7.68**	**17748**

Table 6.11: Energy Planning for Neil Island for the year 2007-08

Resources of Energy	From	To	Total Hours	Daily Total Generation (kWh)	Cost of Generation (Rs./kWh)	Total cost (Rs.)
Gasifier	0:00	16:00	16	1330	5.23	6956
Biogas	16:00	0:00	8	600	6.39	3834
Diesel Generator	16:00	0:00	8	380	13.17	5005
Solar	16:00	0:00	8	100	25.34	2534
Total	**0:00**	**24:00**	**24**	**2410**	**7.61**	**18329**

Table 6.12: Energy Planning for Neil Island for the year 2008-09

Resources of Energy	From	To	Total Hours	Daily Total Generation (kWh)	Cost of Generation (Rs./kWh)	Total cost (Rs.)
Gasifier	0:00	16:00	16	1420	5.23	7427
Biogas	16:00	0:00	8	600	6.39	3834
Diesel Generator	16:00	0:00	8	390	13.17	5136
Solar	16:00	0:00	8	100	25.34	2534
Total	**0:00**	**24:00**	**24**	**2510**	**7.54**	**18931**

Table 6.13: Energy Planning for Neil Island for the year 2009-10

Resources of Energy	From	To	Total Hours	Daily Total Generation (kWh)	Cost of Generation (Rs./kWh)	Total cost (Rs.)
Gasifier	0:00	16:00	16	1490	5.23	7793
Biogas	16:00	0:00	8	640	6.39	4090
Diesel Generator	16:00	0:00	8	390	13.17	5136
Solar	16:00	0:00	8	100	25.34	2534
Total	**0:00**	**24:00**	**24**	**2620**	**7.46**	**19553**

Table 6.14: Energy Planning for Neil Island for the year 2010-11

Resources of Energy	From	To	Total Hours	Daily Total Generation (kWh)	Cost of Generation (Rs./kWh)	Total cost (Rs.)
Gasifier	0:00	16:00	16	1520	5.23	7950
Biogas	16:00	0:00	8	720	6.39	4601
Diesel Generator	16:00	0:00	8	390	13.17	5136
Solar	16:00	0:00	8	100	25.34	2534
Total	**0:00**	**24:00**	**24**	**2730**	**7.41**	**20221**

There will be a yearly saving on account of use of Renewable Energy Sources against existing 400 kW diesel generating set as shown in the Table 6.15 and 6.16 for model-I & II. The graphical representation of comparision of savings for both the models is shown in Fig. 6.2.

Table 6.15: Savings on account of use of model-I

Year	Unit Generation /Day (kWh)	Cost of Energy by Renewables (Rs./kWh)	Total cost per day with Renewables (Rs.)	Cost of Energy by Diesel Generator (Rs./kWh)	Total Cost per day with Diesel Generator (Rs.)	Saving per day due to use of Renewables (Rs.)	Yearly saving due to use of Renewables (Rs.)
2006-07	2310	7.65	17,672	12.19	28,167	10,496	3,148,650
2007-08	2410	7.57	18,244	12.1	29,167	10,923	3,276,990
2008-09	2510	7.52	18,875	12.02	30,167	11,292	3,387,540
2009-10	2620	7.44	19,493	11.93	31,267	11,774	3,532,260
2010-11	2730	7.39	20,175	11.86	32,367	12,192	3,657,690

Table 6.16: Savings on account of use of model -II

Year	Unit Generation /Day	Cost of Energy by Renewables+ Diesel Generator (Rs./kWh)	Total cost per day with Renewables +Diesel Generator (Rs.)	Cost of Energy by Existing Diesel Generator (Rs./kWh)	Total Cost per day with Existing Diesel Generator(Rs.)	Saving per day due to use of Renewables (Rs.)	Yearly saving due to use of Renewables (Rs.)
2006-07	2310	7.68	17,741	12.19	28,159	10,418	3,125,460
2007-08	2410	7.61	18,340	12.1	29,161	10,821	3,246,270
2008-09	2510	7.54	18,925	12.02	30,170	11,245	3,373,380
2009-10	2620	7.46	19,545	11.93	31,257	11,712	3,513,540
2010-11	2730	7.41	20,229	11.86	32,378	12,149	3,644,610

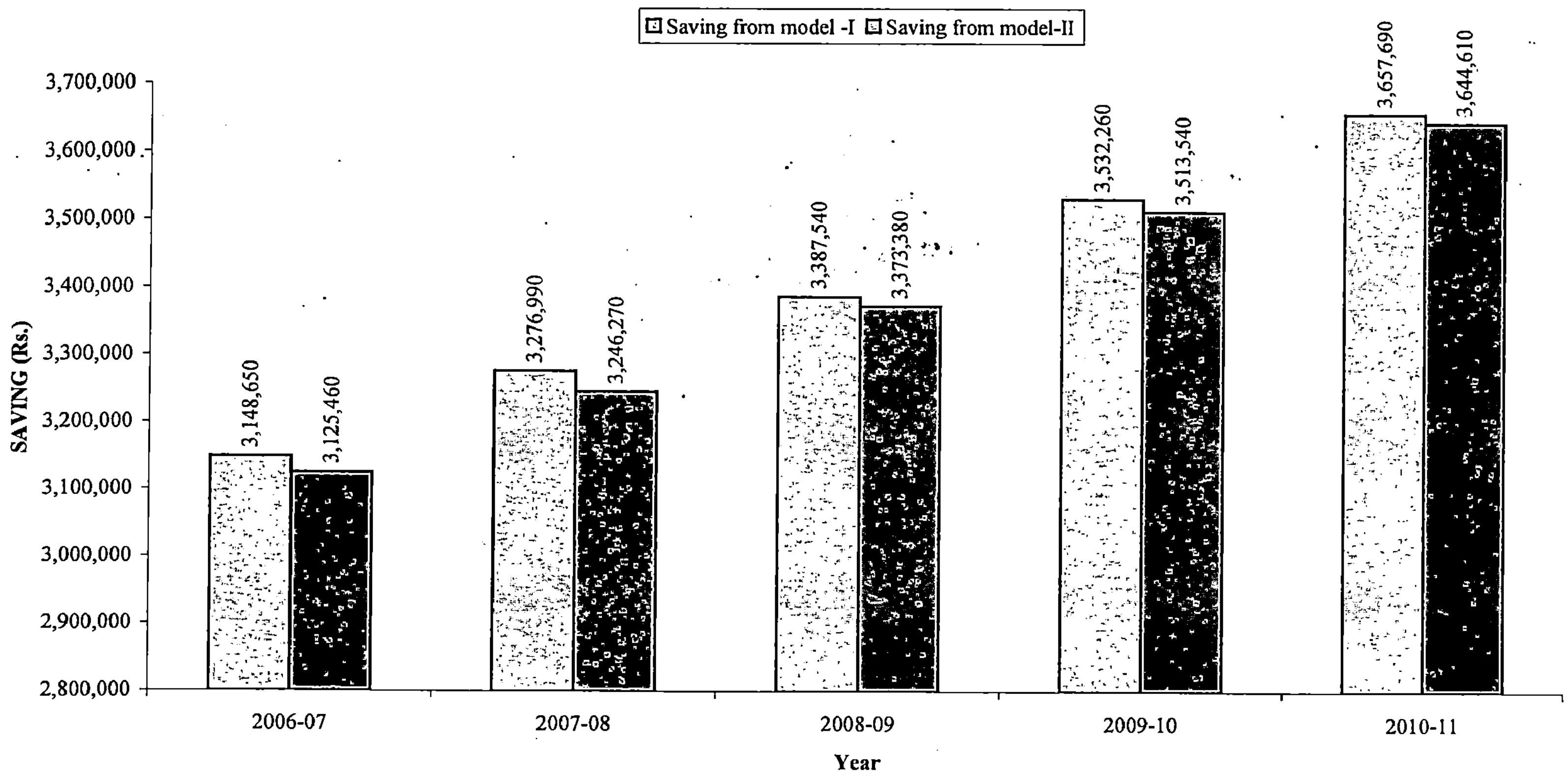


Fig. 6.2: Comparision of Savings from Model-I & II

6.4. FINANCIAL ANALYSIS

When planning any project, the costs involved are always considered and proposals are prepared to show the likely returns on any capital that is invested. In order to make a decision about the investment it is required to apprise all the cost involved in the project and determine the potential returns. To make the correct and objective assessment, numbers of accounting and financial appraisal techniques have been developed out of which net present value and internal rate of return methods are found quite effective. Thus, these two methods have been employed for financial analysis for both the proposed models viz. Model-I and II.

6.4.1 Net Present Value

Net Present Value method considers the fact that cash saving in future years will be worth less than the present value. The net present value method achieves this by quantifying the impact of time on any particular future cash flow. This is done by equating each future cash flow to its current value. The present value is determined by using an assumed interest rate usually referred as discount rate. Discount is the opposite method of compounding. The whole credibility of the net present value method depends on a realistic prediction of future interest rates, which is generally unpredictable. It is prudent therefore to set the discount rate slightly above the interest rate at which the capital for the project is borrowed. This will ensure that the overall analysis is slightly pessimistic, thus acting against the inherent uncertain ties in predicting future savings.

The plant life for gasifier is assumed as ten years; as such financial analysis is restricted to 10 years only, though the cash flow will be available for other sources thereafter. Since the actual saving have been calculated for five years only and yearly increase in saving is noted as 4%, the savings from sixth year to tenth year have been extrapolated accordingly to calculate the cash flow for these years.

6 .4.1.1 Model – I

The net present value is calculated assuming 10% rate of discount for the model–I, where only renewable resources available at Neil Island have been taken into account to replace the existing diesel generator set.

Table 6.17: Net Present Value for Model - I

Year	Net Saving	Discount Factor for10%	Present Value
0	-21892198	1	-21,892,198
1	3148650	1.1	2,862,409
2	3276990	1.21	2,708,256
3	3387540	1.331	2,545,109
4	3532260	1.4641	2,412,581
5	3657690	1.61051	2,271,138
6	3803998	1.771561	2,147,257
7	3956158	1.9487171	2,030,134
8	4114404	2.14358881	1,919,400
9	4278980	2.357947691	1,814,705
10	4450139	2.59374246	1,715,721
		Net Present Value	**534,513**

6.4.1.2 Model – II

The net present value is calculated assuming 10% rate of discount for the model–II, where renewable resources viz. gasifier system and biogas system along with existing 50 kWp solar power plant and a 100 kW diesel generator are proposed to used to meet the demand of Neil Island to replace the existing 400 kW diesel generator set.

Table 6.18: Net present value for Model-II

Year	Net Saving	Discount Factor for10%	Present Value
0	-13122032	1	-13,122,032
1	3,125,460	1.1	2,841,327
2	3,246,270	1.21	2,682,868
3	3,373,380	1.331	2,534,470
4	3,513,540	1.4641	2,399,795
5	3,644,610	1.61051	2,263,016
6	3790394	1.771561	2,139,579
7	3942010	1.9487171	2,022,875
8	4099691	2.14358881	1,912,536
9	4263678	2.357947691	1,808,216
10	4434225	2.59374246	1,709,586
		Net Present Value	**9,192,235**

6.4.2 Internal Rate of Return

The discount rate which achieves a net present value of zero is known as the Internal Rate of Return (IRR). The higher internal rate of return indicates that the proposal is more beneficial.

6.4.2.1 Model - I

The Internal Rate of Return for use of Renewable energy resources at Neil Island to replace the existing diesel generating set has been calculated. In this exercise the net present values have been calculated and by interpolation the discount rate is found out where the net present value becomes zero.

Table 6.19: Net present values for calculation of internal rate of return for Model - I

Year	Net Saving	10% Discount Rate		11% Discount rate	
		Discount Factor	Present Value	Discount Factor	Present Value
0	-21892198	1	-21,892,198	1	-21,892,198
1	3148650	1.1	2,862,409	1.11	2,836,622
2	3276990	1.21	2,708,256	1.2321	2,659,679
3	3387540	1.331	2,545,109	1.36763	2,476,940
4	3532260	1.4641	2,412,581	1.51807	2,326,809
5	3657690	1.61051	2,271,138	1.68506	2,170,661
6	3803998	1.771561	2,147,257	1.87041	2,033,772
7	3956158	1.9487171	2,030,134	2.07616	1,905,517
8	4114404	2.14358881	1,919,400	2.30454	1,785,349
9	4278980	2.357947691	1,814,705	2.55804	1,672,759
10	4450139	2.59374246	1,715,721	2.83942	1,567,270
	Total	**NPV**	**534,513**	**NPV**	**-456,821**

It can clearly be seen that the discount rate which results in the net present value being zero lies some where between 10% and 11 %.

For 10% discount rate the NPV is positive and for 11% discount rate NPV is negative. Thus for some discount rate between 10% and 11% present value benefits are equated to present value cost. To find out the value exactly, we will interpolate between the two rates as follows;

$$\text{Internal rate of return} = 0.10 + (0.11\text{-}0.10)\,\text{x}\frac{534513}{534513-(-456821)}x100 \qquad (6.19)$$

$$=0.10+(0.11\text{-}0.10)\text{x}\frac{534513}{534513+456821)}x100$$

$$= 10.54\%$$

6.4.2.2 Model-II

The Internal Rate of Return for use of Renewable energy resources viz. gasifier and biogas along with existing 50 kWp solar power plant and a 100kW diesel generator to replace the existing diesel generating set has been calculated.

Table-6.20: Net present values for calculation of internal rate of return for model-II

Year	Net Saving	20% Discount Rate		22% Discount rate		24% Discount Rate	
		Discount Factor	Present Value	Discount Factor	Present Value	Discount Factor	Present Value
0	-13122032	1	-13,122,032	1	-13,122,032	1	-13,122,032
1	3,125,460	1.2	2,604,550	1.22	2,561,852	1.24	2,520,532
2	3,246,270	1.44	2,254,354	1.4884	2,181,047	1.5376	2,111,258
3	3,373,380	1.728	1,952,188	1.81585	1,857,744	1.90662	1,769,295
4	3,513,540	2.0736	1,694,416	2.21533	1,586,009	2.36421	1,486,135
5	3,644,610	2.48832	1,464,687	2.70271	1,348,503	2.93163	1,243,205
6	3790394	2.985984	1,269,395	3.2973	1,149,544	3.63522	1,042,688
7	3942010	3.5831808	1,100,143	4.02271	979,939	4.50767	874,512
8	4099691	4.29981696	953,457	4.90771	835,358	5.58951	733,462
9	4263678	5.159780352	826,329	5.9874	712,108	6.93099	615,162
10	4434225	6.191736422	716,152	7.30463	607,043	8.59443	515,942
	Total	**NPV**	**1,713,639**	**NPV**	**697,114**	**NPV**	**-209,842**

It can clearly be seen that the discount rate which results in the net present value being zero lies some where between 22% and 24 %.

For 22% discount rate the NPV is positive and for 24% discount rate NPV is negative. Thus for some discount rate between 22% and 24% present value benefits are equated to present value cost. To find out the value exactly, we will interpolate between the two rates as follows;

$$\text{Internal rate of return} = 0.22+(0.24-0.22)\ x \frac{697114}{697114-(-209842)} x100$$

(6.20)

$$=0.22+(0.24-0.22)\ x \frac{697114}{697114+209842)} x100$$

$$= 23.54\ \%$$

The comparision of both models is shown in Table 6.21 and Fig. 6.3

Table 6.21: Comparision of both the models from financial point of view

Model	NPV @10% Discount rate (Rs.)	Internal rate of return (%)
Model-I	5,34,513	10.54
Model-II	91,92,234	23.54

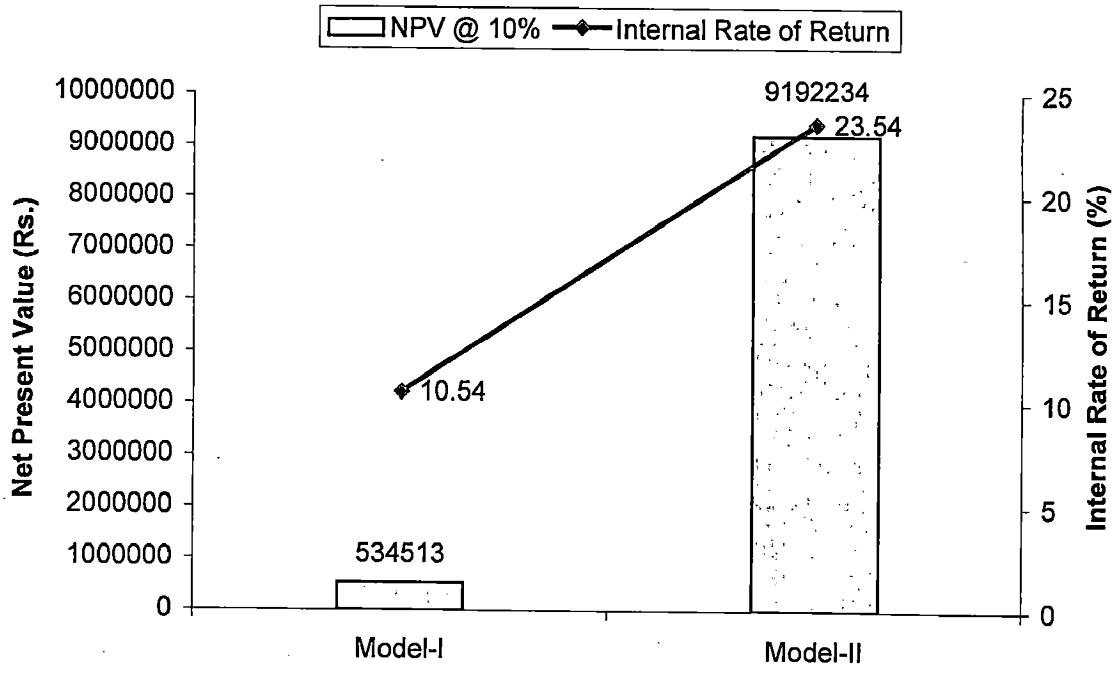


Fig.6.3: Comparision of model-I & II from financial point of view

From financial analysis for next ten years it is clear that there will be huge saving by replacing existing system either by biomass gasifier (150kW), biogas (100kW) and solar (200kWp) or biomass gasifier (150kW), biogas (100kW) solar (50kWp) and small diesel generating set(100kW). In case of first model the internal rate of return is 10.54% whereas in case of second model it comes to 23.54% due to less capital cost.

6. 5 DISTRIBUTION NETWORK

The generated power from common bus bar will be distributed to all the five villages through the existing 4 Kms. of 11kV and 14.75 Kms. of 0.4 kV distribution systems. Presently the one part of Neil Kendra is fed directly through 0.4 kV lines whereas other villages are fed through 11kV system with the help of four step-down transformers kept at Sita Pur (50 kVA), Ram Nagar (63 kVA), Bharat Pur (50 kVA) and Laxman Pur (100kVA). The existing distribution system is capable to meet the load demand for another five years and hence no investment is required in this sector.

RESULTS AND CONCLUSION

7.1. RESULTS

The Neil Island of Andaman and Nicobar Islands was selected for the study and survey was conducted during January -February, 2006, covering all the households there. The selected island is 37 Kms away from Port Blair, the capital of Andaman and Nicobar Islands. It consists five villages namely; Bharat Pur , Sita Pur, Ram Nagar, Laxman Pur and Neil Kendra.

All the five villages are electrified through the electricity generated by the existing diesel and solar power plants. The per capita consumption of electrical energy is 222 kWh per annum. As far as electrification is concerned the 81% households are electrified and 84% of population has access to electricity facility. The present installed capacity is 400kW having 4 units of 100 kW (diesel operated) each and the peak load demand is 170 kW with daily energy requirement of 1855 kWh. The estimated peak load demand in fifth year will be 248 kW and electrical energy requirement will be 2730 kWh/ day.

Total biogas potential is estimated as 544 m^3, which would generate 980 kWh with 33% efficiency by installing 100 kW biogas operated compression ignition engine-generator set. Similarly, the biomass energy potential is estimated as 1956 million kilocalories per year, which can generate 2057 kWh per day by installing 150 kW duel fuel diesel engine.

The resource for solar energy is enormous, but its extraction is quite costly and direct returns on investments are negligible as such it is proposed to generate 500 kWh only out of the solar energy resource. To get 500 kWh per day from solar power plant a solar power plant of 200 kWp capacity need to be installed with 3600 panels of 70 watts each and 1152 batteries of 12 volts and 200 Ah.

Based on the survey conducted for five villages, there is no perennial source of water in the island hence no power generation is possible from this source. The mean wind speed is ranging from 4.13 to 7.38 Kmph or 1.15 to 2.05 m/s, which indicates that the resource value is poor as such the power generation from this source, is not economically viable. There is also no possibilities for harnessing ocean energy like ocean thermal, tidal, wave and current energy as no suitable sites are available near the said island.

The capital cost of 150 kW duel fuel diesel generator with gasifier and other accessories including civil works is estimated as Rs. 33.46 lacs and present unit fuel cost for duel fuel system is Rs. 4.25. The cost of energy per unit for gasifier system is Rs.5.23. The capital cost of 100 kW diesel generator set with 10 numbers biogas plants and other accessories including civil works is estimated as Rs. 30.25 lacs and present unit fuel cost for duel fuel system is Rs. 4.25. The cost of energy per unit for biogas system is Rs.6.39. The capital cost of 200 kW solar power system with accessories including civil works is estimated as Rs. 465.63 lacs out of which Rs.310.42 lacs will be provided as subsidy by Ministry of Non-conventional Energy Sources (MNES). On the basis of net capital cost i.e. Rs. 155.21 lacs the cost of energy per unit for solar system comes to Rs.15.55.

Cost of energy for proposed Model-I (100kW Biogas system+150 kW gasifier system+200 kWp solar system) varies from Rs.7.39 to Rs.7.65 per kWh. Cost of energy for Model-II (100 kW Biogas system+150 kW gasifier system+ existing 50 kWp solar system+ existing 100kW diesel generator) varies from Rs.7.41 to Rs.7.68 per kWh. The cost of energy for 400kW existing diesel generator varies from Rs.11.86 to Rs. 12.19 depending on energy demand.

7.2. CONCLUSION AND RECOMMENDATIONS

The energy development is a socio-economic-technological process having the main objective of raising the standard of living of the people. The energy development needs to be not only economical but also sustainable and acceptable from an environmental point of view. It may be noted from this work that the supply of power produced by conventional methods to the remote island is not only uneconomical but also unsustainable and unacceptable from environmental point of view. Alternatively, the use of non-conventional renewable energies are being proved to be viable, self sustained, environmentally friendly and more efficient in the context of planning to meet the total energy needs of an island population.

The capital investment to execute the scheme of model –I will be Rs. 218.92 lacs and for model –II will be Rs.131.22 lacs. On replacing the existing diesel generator with Model – I, the average savings will be Rs. 34 lacs per year whereas with model –II it will be Rs. 33.80 lacs per year. The net present value for Model-I for 10 years is Rs. 5.34 lacs and for model–II, Rs. 91.92 lacs. The internal rate of return for Model–I is 10.54 % and for Model – II is 23.54 %.

It is clear from above that both the models studied in the present work are beneficial in comparision to existing diesel generator system. The Model-I having installed capacity of 450 kW is purely based on non conventional sources of energy and the Model –II of 400 kW is a mix of gasifier, biogas, and existing 50-kWp solar and one unit of existing 100 kW diesel generator system. Though in case of model –II the net present value and internal rate of return on investment is more than model –I but one should not remain confined, in decision making, to immediate cost considerations but take a comprehensive view of all the different aspects of the problem and indirect costs involved.

Since the main objectives of the present study is to plan a self sustained energy system as a source of guaranteed supply of power to a remotely located island with the point of view of an impetus to growth, and to ensure that there should not be any adverse impact on the socio-economic life of the people of the island as well as on the environment, the model-I seems to be better choice and thus recommended, which will completely replace the existing diesel generating system with available renewable sources of energy to achieve the energy independence as called for by Hon,ble President of India in his address on the eve of 59th Independence day on 14th August 2005.

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APPENDIX

Fig. A-1: Embarkation to ferry boat scheduled to Neil Island

Fig. A-2: View of Sita Pur Village at Neil Island

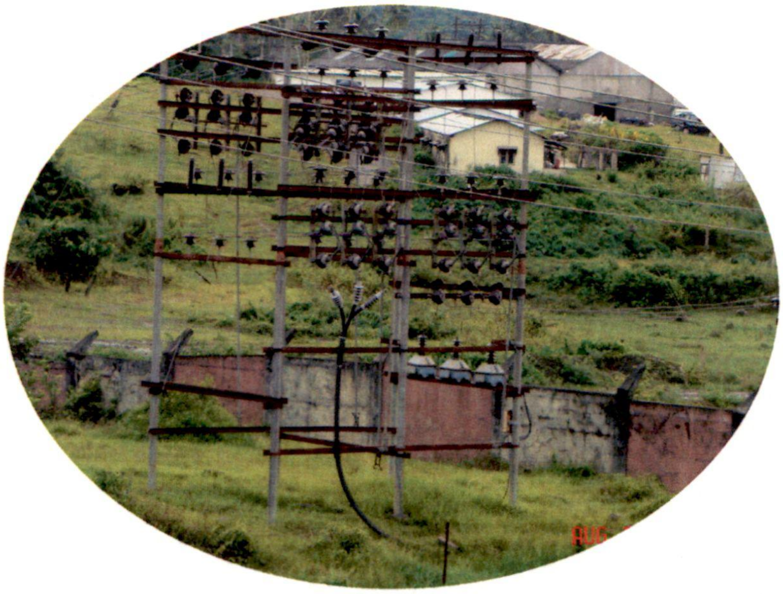

Fig. A-3: 11-kV Distribution System at Neil Island

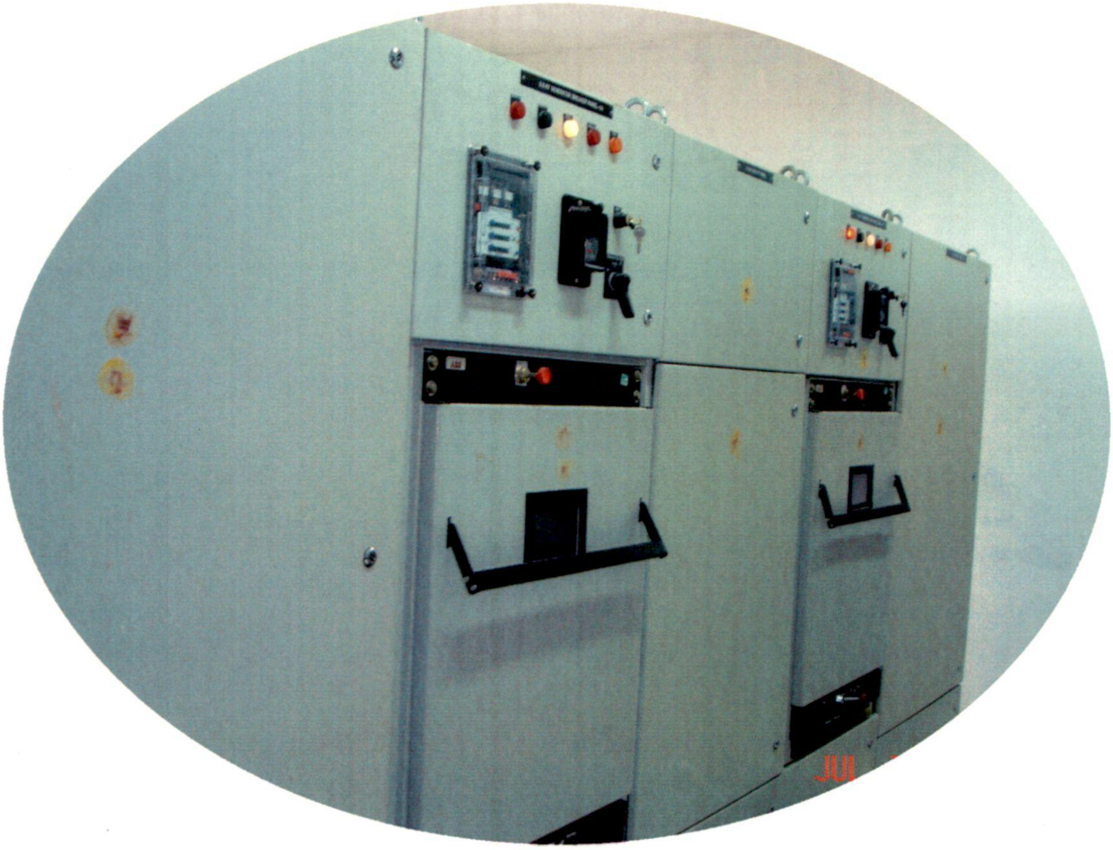

Fig. A-4: Control System of diesel power house at Neil Island

Fig. A-5: 100 kVA Transformer at Laxman Pur

Fig. A-6: 50 KWp Solar Power Plant at Neil Island