Strategy plan for 100% RET utilization in Lakshadweep Island

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1 Introduction

Introduction

The Lakshadweep island group in the Arabian Sea is one of the two major groups of islands in India. It consists of an archipelago of 36 small sized coral islands and reefs scattered about 200-400 kilometers from the western coast of south India. Of these, 11 islands are inhabited. The main source of electricity is diesel generators, the diesel being transported from the mainland. Considering the remoteness of the islands and the polluting nature of the existing plants, it is desirable to adopt a strategy to utilize available potential of non-polluting, renewable energy sources in these ecologically sensitive islands.

An assessment study had earlier been carried out under an OPET (Organizations for the Promotion of Energy Technologies) international action during 2000-2001, in association with OPET-ADEME (Agency for Environment and Energy Management) and Island OPET. This is a step forward for propagation of European best practices and technologies in the context of energizing islands.

Fig.1: Location of Lakshadweep in India

Aim and objectives

The main aim of the study was to prepare an action plan (or road map) for 100% electrification through renewable energy technologies in the island communities of Lakshadweep.

The objectives of the study were:

- To establish the current status of electricity supply, consumption and demand in Lakshadweep islands;
- To evaluate the potential of utilizing RETs in the islands;
- To identify European best practices and renewable energy systems;
- To study all possible technical solutions for providing the total energy requirements from RETs, including simulation and optimization;
- To assess the feasibility of utilizing European RET products taking into account financial, institutional and other aspects;
- To prepare a broad strategy plan for electrification of the islands utilizing RETs.

Methodology

The general methodology adopted for the study was as follows:

- Data collection from secondary sources – Census of India, National Informatics Centre, Lakshadweep administration, Central Electricity Authority, Regional Meteorological Centre, etc.;
- Visit to Lakshadweep islands and interaction with officials of Lakshadweep islands;
- Exchange of ideas between partner organizations[?] ;
- Preparation of Action Plan;

? The partner organizations for this project are TERI, ADEME and INSULA. ADEME, of France, has been working in the field of renewables including hybrid energy systems through GENEC laboratory at Cadarache. INSULA is active in Canary islands and other island communities and has experience in integrated island development. As an overall co-ordinator, TERI has prepared the framework for developing the Action Plan. ADEME and GENEC professionals have contributed in giving the technical input required for developing the action plan. ADEME has also identified technology suppliers for materializing the action plan for 100% electrification through renewables in island communities.

2 Profile of Lakshadweep Islands

Location and setting

The Lakshadweep island group lies in the Arabian Sea and consists of an archipelago of 36 small sized coral islands and reefs scattered about 200-400 kilometers from the western coast of south India between latitude $8^0$15'N & $11^0$45'N and longitude $72^0$00'E & $74^0$00'E. Of these, 11 islands are inhabited. These islands form the smallest of the Union Territories of India and are the country's only coral islands.

Figure 2.1: Lakshadweep Islands

Brief history

It is generally believed that the first settlement on these islands was made by a king of Kerala. Historical records show that around the 7th century, a shipwrecked Muslim saint converted the inhabitants here to Islam. The sovereignty remained in the hands of the royal family of Kerala and eventually passed on to Tipu Sultan in the 18th Century. Following the defeat of Tipu Sultan by the British at Srirangapatna, the islands were annexed by the East India Company and remained with the British until India gained independence. Lakshadweep islands were made a Union Territory of India in 1956.

Administrative boundaries

Lakshadweep islands have a total lagoon area of 4,200 sq km and territorial waters of 20,000 sq km. These islands account for 4,00,000 sq km of total Exclusive Economic Zone of the country. The entire group of islands is considered as one District and divided into four Tahsils and each put in charge of a Tahsildar. The administrative centre is Kavaratti island.

Physical Environment

Climate

Lakshadweep has a tropical climate, with summers ranging from 35^{0}C to 22^{0}C and winter temperatures between 32^{0}C and 20^{0}C. Humidity levels are high throughout the year and range from 70-80%. March, April and May are the hottest months of the year. The islands experience moderately high rainfall of 1600mm a year with the major share from the southwest monsoons. The climate of these islands may be classified as warm humid. The climatological normals for two stations at the islands of Amini and Minicoy are given below:

Table 2.1 Climatological normals for stations at Amini and Minicoy

Months	*Amini*					*Minicoy*				
	Temperature (^{0}C)		*RH (%)*		*Rainfall (mm)*	*Temperature (^{0}C)*		*RH (%)*		*Rainfall (mm)*
	Max.	*Min.*	*0830*	*1730*		*Max*	*Min.*	*0830*	*1730*	
January	31.3	23.5	78	66	3.0	30.2	22.7	80	69	27.4
February	31.8	24.4	78	68	6.5	30.4	23.1	79	69	25.4

Months	Amini					Minicoy				
	Temperature (°C)		RH (%)		Rainfall (mm)	Temperature (°C)		RH (%)		Rainfall (mm)
	Max.	Min.	0830	1730		Max	Min.	0830	1730	
March	32.6	25.3	76	68	0.9	31.1	24.3	76	69	19.8
April	33.3	26.6	76	70	22.3	31.8	25.5	76	71	72.5
May	32.8	27.0	79	75	175.0	31.3	25.8	78	74	212.8
June	30.3	25.7	85	83	366.6	30.4	25.0	81	78	261.3
July	29.4	25.2	87	86	325.2	29.8	24.6	81	78	250.9
August	29.6	25.3	86	85	201.8	29.7	24.7	81	78	202.2
September	30.1	25.3	84	81	151.8	29.8	24.6	80	77	181.9
October	30.6	25.2	83	78	139.2	30.0	24.3	80	77	183.1
November	31.2	24.4	81	74	108.1	30.3	23.6	80	75	133.0
December	31.3	23.6	79	70	37.0	30.3	23.2	80	72	94.8

Source: Regional Meteorological Centre, Chennai

Geology

There are no conclusive theories about the formation of these coral atolls. The most accepted theory is that the subsidence of a volcanic island resulted in the formation of a fringing reef and the continual subsidence allowed this to grow upwards. When the volcanic island became completely submerged the atoll was formed encircling the lagoon where, with the action of the wind, waves, currents and temperature, the islands were formed. The fringing reefs are quickly built, repaired, and strengthened by a micro-organism called polyps. These are the architects and engineers of these atolls. The corals are the hard calcareous skeletons of these polyps.

Soil

The Lakshadweep islands are identical in structure and formation and their tops are built up of coral reefs. The soil has been derived from coral limestone. It is essentially coral sandy soil underlined by limestone and gravel of different shapes and size. The land has 85 to 98 per cent calcium carbonate, which is totally unfavourable for any type of cultivation. Thus the natural eco-structure of these islands is not conducive to agricultural development. However, it is suited for coconut plantation, which is done here to a great extent.

Landuse

A large part of the islands' areas are used for cultivation of coconut trees and is indicated in the landuse pattern given below:

Table 2.2 Landuse pattern of Lakshadweep islands

	Area (Ha)	*% of total area*
Total geographical area	3200	100
Total reporting area	3200	100
Area not available for cultivation	446	13.9
Net area sown	2755	86.1
Area sown more than once	1504	43.8
Total cropped area	4259	133.0

Source: Basic Statistics 1995-1996, Dept. of Planning & Statistics, Secretariat, Lakshadweep, Kavaratti

Surface water & ground water resources

An open well in Kavaratti

There are no surface water bodies on the islands. Groundwater is the only freshwater resource available for drinking purposes and is limited in all the islands. The non-availability of drinking water is the reason for most islands to remain uninhabited. There are areas even in the inhabited areas where groundwater is brackish. Groundwater is available very close to the surface at a depth ranging from 5-10 feet.

Biological Environment

Forest cover

Coconut tree plantations in Kavaratti

The territory is devoid of any natural forests and there is no recorded forest area. However, social/agro forestry programmes were undertaken on a small scale since 1988-89 and was restricted to distribution of seedlings to the people. Most of the plantations are of coconut trees. The high density of coconut trees forms a blanket of vegetative cover on all the islands.

Habitats

There are four natural ecosystems of the islands – the land, the lagoon, the coral reef and the ocean. Many species listed in the Wildlife Protection Act (1972) are present in the waters of the fragile ecosystem of the islands.

Aquifauna generally found in Lakshadweep are Tharathasi (*Sterna fuscata*) and Karifetu (*Anous solidus*) and are generally found in one of the uninhabited islands known as Pitti Island, which has been declared as a bird sanctuary.

Flora & Fauna

The marine life around the islands is quite elaborate and sensitive to ecological imbalances. The money cowrie (C*ypraea monita*) is also found in abundance in the shallow lagoons and reefs of the islands. Other cypraeds found here are C*ypraca talpa* and C*yprea maculiferra*. Among crabs, the hermit crab is the most common. Colorful coral fish such as Parrot fish (*Callyedon sordidus*), Butterfly fish (*Chaetodon auriga*), Surgeon fish (*Acanthurus lineotus*) are also found in plenty. Molluscan forms are also important from the economic point of view.

The islands support only certain vegetation species that include Banana - Vazha (*Musaparadisiaca*), Colocassia - Chambu (*Colocassia antiquarum*), Drumstick - Moringakkai (*Moringa Oleifera*), Bread Fruit - Chakka (*Artocarpus incisa*), Wild almond (*Terminalia Catappa*), etc. Some of the shrub jungles plant like Kanni (*Scaevolakeeningil*), Punna (*Calaphylluminophyllum*), Chavok (*Casurina equisetifolia*), Cheerani (*Thespesia Populnea*) are unevenly grown throughout the islands. Coconut, Thenga (*Cacos nucifera*) is the only crop of economic importance in Lakshadweep. These are found in different varieties such as Laccadive micro, Laccadive ordinary, green dwarf, etc. Two different varieties of sea grass are seen adjacent to the beaches. They are known as *Thalassia hemprichin* and *Cymodocea isoetifolia*. They prevent sea erosion and movement of the beach sediments. The function performed by this grass in binding the soil together and preventing erosion does not appear to be given the importance it deserves by the Administration. No policy of protecting the seashore with this grass exists and at present concrete breakers are used that are incongruous in the beautiful setting of Lakshadweep.

The commonly seen vertebrates are cattle and poultry with no important (protected or endangered) fauna found on the islands.

Socio-economic & cultural environment

Demography

The demographic characteristics of each of the inhabited islands of Lakshadweep are depicted in Table 2.3.

Table 2.3 Demographic profile of Lakshadweep islands, 2001

	Area	*Population*			*Literates****			*Growth*	*Density*	*Sex Ratio*
	(Sq. km.)	*Total*	*Male*	*Female*	*Total*	*Male*	*Female*	*Rate** (%)*	*per sq. km.*	
Lakshadweep	*32.00**	*60595*	*31118*	*29477*	*45281*	*24806*	*20475*	*17.19*	*1894*	*947*
Chetlat	1.14	2553	1341	1212	1837	1011	826	12.17	2239	904
Kiltan	1.63	3664	1847	1817	2518	1337	1181	19.54	2248	984
Kadmat	3.12	5319	2685	2634	4042	2143	1899	33.48	1705	981
Amini	2.59	7340	3727	3613	5239	2892	2347	13.85	2834	969
Agatti	3.88	7072	3688	3384	5170	2898	2272	23.4	1842	918
Kavaratti	4.22	10113	5579	4534	7889	4645	3244	16.55	2396	813
Androth	4.84	10720	5356	5364	7617	4162	3455	17.52	2215	1001
Kalpeni	2.79	4319	2279	2040	3188	1863	1325	5.75	1548	895
Minicoy	4.39	9495	4616	4879	7781	3855	3926	14.12	2163	1057
Bangaram	0.58	Na	Na	Na	Na	Na	Na	Na	Na	Na
Bitra	0.10	Na	Na	Na	Na	Na	Na	Na	Na	Na

Source: Census of India 2001, Provisional population data sheet

* Geographical ** Decade 1991-2001 ***Excluding 0-6 age group

The populations of Kavaratti and Androth islands have crossed 10,000 persons only in the 2001 census. The populations of Bangaram and Bitra are not available in the Provisional 2001 Census. Their populations in the 1991 census were 61 and 225 respectively. The decadal growth rate of the islands is not uniform and varies from 5.75% in Kalpeni to 33.48% in Kadmat. The average growth rate of the islands (17.19%) is however lower than the growth rate of India (21.34%). The average literacy level of 87.6% is high (male and female) compared to the average literacy of 65.4% in India. Male and female literacy levels are comparable indicating good social development.

Considering the rural nature of the settlements, the population densities of the islands are extremely high and indicate considerable strain on per capita land availability, the average population density of India being 296 persons/sq km. This coupled with the fragile eco-structure of the islands, imposes limits to developmental activities.

Economy and employment

Land being a limited resource, the economy of the islands is mainly dependent on fishing and coconut cultivation. The thrust given to tourism development by the Administration is likely to lead to a specialisation of the economy. The immense potential for development in fisheries has resulted in the setting up of small boat building yards, canning and processing industries. The islands stand first in the country in per capita availability of fish and the annual fish landing crossed the level of 10000 MT in 1996. Tuna and shark are the main catch. Tuna is processed in the canning factory at Minicoy. A large part of the tuna catch is also dried in the sun after cooking and smoking, the resultant product known as 'Mas', which can be kept for two years, and is exported along with salt dried shark to the mainland.

Around 28.0 million coconuts (1998-99) are produced annually. Fibre extraction, copra (dried kernel of coconut used for oil extraction or food), coir spinning, rope making, mat making, etc., are the other manufacturing activities of small scale that have been established in these islands.

The following table shows the distribution of main workers in Lakshadweep and indicates that males dominate the main work force. Activities of the primary and secondary sectors involve about a quarter of the main workers each and the tertiary sector accounts for a major part.

Table 2.4 Work Participation Rate in Lakshadweep Islands, 1991

	Total main Workers ('000)	Total marginal workers ('000)	Total non-worker ('000)	% Main workers engaged in Cultivation	Agri labour	Livestock, forestry	Mining, quarrying	Household industries	Non house-hold industries	Construc-tion	Trade / commerce	Trans-port	Other services
Persons	12	1	38	0.0	0.0	25.0	0.0	5.1	4.8	15.5	5.7	11.4	32.7
Male	11	1	15	0.0	0.0	26.6	0.0	3.8	3.7	17.0	5.9	12.8	30.2
Female	1	-	23	0.0	0.0	13.2	0.0	14.2	12.6	4.0	4.0	0.6	51.4

Source: Census of India, 1991

Land holdings

The feudal character of land tenure that existed in the islands earlier was abolished in 1965 and ownership was transferred to the tenants of the land. A majority of land holdings (almost 90%) at present are thus less than 1.0 Ha in size. Limited land and the ownership of these small holdings, which mostly belongs to the local population, is a major constraint for the Administration for utilizing the land for other purposes.

Table 2.5 Land holdings in Lakshadweep, 1990-91

	Area operated (Ha)	*Operational holdings (Nos.)*	*Operational holdings (%)*	*Wholly owned & self operated (Ha)*
<0.5 Ha	810.1	4475	72.0	800
0.5 – 1.0	646.6	1197	19.3	773
1.0 – 2.0	602.4	369	5.9	489
2.0 – 3.0	201.2	94	1.5	216
3.0 – 4.0	122.8	39	0.6	128
4.0 – 5.0	61.5	24	0.4	101
5.0 – 10.0	102.8	16	0.3	98
> 10.0	145.2	2	0.0	45
	2692.6	6216	100.0	2650

Source: Basic Statistics 1995-1996, Dept. of Planning & Statistics, Secretariat, Lakshadweep, Kavaratti

Tourism

Though the potential for tourism is immense, tourism has been controlled and restricted in the islands to preserve the ecological balance and to prevent overcrowding and consequent uncontrolled development. Only two islands are open to foreign tourists and five islands to Indian tourists. However, the Administration intends to promote low volume high value eco-tourism and has initiated action in this regard. It has been proposed by the Administration to increase the share of tourism from 3% to 10% during the next five years so that at least 10,000 tourists visit the islands annually. A few of the inhabited islands are proposed to be open to tourists in a phased manner. At present, about 3500 tourists, including about 1000 foreign tourists, visit the islands annually. The existing infrastructure in terms of boarding, lodging and transportation is felt to be insufficient to take care of this growth that the Union Territory proposes to achieve.

Livestock

Intensive poultry development and cattle development programmes have been undertaken in the islands to provide for eggs, meat and milk. Considering the fragile ecology and scarcity of water, forage and grazing land, organized dairy farming has not been promoted. The objective of the programmes has been to improve the productivity of cattle and produce more milk from fewer numbers of animals. Goat rearing for milk and back yard poultry rearing to reduce the import of eggs and meat has also been promoted by the Administration.

The livestock density (cattle and goats) of Lakshadweep is very high at about 900 per sq km. However, per capita milk availability is just a fourth of the national average indicating the very low productivity of livestock.

Table 2.6 Livestock in Lakshadweep, 1997

Sl. No.	Livestock & Poultry	*Number*
1.	Cattle	3339
2.	Goats	25521
3.	Poultry	76191

Source: Basic Statistics 1995-1996, Dept. of Planning & Statistics, Secretariat, Lakshadweep, Kavaratti

Infrastructure

Physical infrastructure

Water supply

The water supply scheme mainly consists of ground water extracted through collector wells. This is a system of radial perforated pipes located at specific shallow depth through which groundwater flows and collects in a collector well. These wells are located in sites with good water availability and the extraction is carried out at brief intervals to allow for recharge. Four to six collector wells are planned for each island. Water from these wells is pumped to a collection sump and after chlorination, is pumped to overhead water tanks and then to the distribution system. The water is supplied through standpipes on the streets for a brief duration daily. The water supplied through this system accounts for just 5% of the demand according to officials. The hydrogeological nature of these islands does not allow a single system or approach to provide water supply in the islands. A major part of the demand is met through surface wells in each plot. Rooftop rainwater harvesting is also being promoted and has been adopted by a number of households, public buildings and in government buildings. The high annual rainfall of about 1400mm is spread over 8 months of the year and can meet a significant portion of the demand. Reverse Osmosis Desalination Plants have also been tried unsuccessfully in the islands due to difficulties in maintenance of the high technology equipment.

A collector well in KavarattiStandpipes for water supply in Kavaratti

Sanitation

There is no system of sewage collection or disposal in any of the islands. Houses with toilets and community toilets are provided with individual soak pits. The porous sand of Lakshadweep presents a serious environmental problem in the discharge of wastewater through these soak pits and poses a threat to groundwater in terms of contamination. According to officials of the Administration, the incidence of waterborne diseases like gastroenteritis has risen sharply over the last few years. Various agencies of the Administration like the Department of Environment & Forests and Department of Science & Technology recognizes this as a serious problem and is active in addressing the issue.

Community toilets in some government housing Waste from coconut shells & leaves in at Kavaratti Kavaratti

Coconut shells and leaves contribute significantly to the quantum of solid waste generated in the islands and its disposal is a problem faced by the authorities.

Electricity

Electricity is generated through diesel generators and distributed in all the islands. All households have access to electricity and the electricity needs of the islands are currently being met with satisfactorily. However, the diesel required for the generators is being transported from the mainland and is associated with various problems of handling and storage, which has prompted the Department of Electricity to consider renewable energy technologies to reduce the dependence on diesel.

Housing

The traditional housing forms in Lakshadweep were made with thatch roofs and coral shingles and responded to the warm-humid climate. In view of the environmental problems associated with indiscriminate exploitation of corals, the Building Materials Development Board of the Administration has been procuring building material like cement, river sand, reinforcement steel, etc., from the mainland. Recent trends in housing therefore indicate a change towards use of heavy construction, which is inappropriate for the climate. This could create uncomfortable indoor conditions and increase the use of mechanical cooling and thereby electricity.

Traditional housing forms in Kavaratti New housing trends

As per the Census 1991, a majority of the houses are permanent structures and in good condition.

Table 2.7 Housing and Utilities in Lakshadweep, 1991

		Permanent	*Semi permanent*	*% having electricity*	*% having drinking water*	*% having toilets*
House types: (1991)	Total	88.8	9.0	98.5	11.9	71.0
	Rural	83.9	13.5	97.7	3.4	78.9
	Urban	92.8	5.4	99.1	18.8	64.7

Source: Census 1991

Transportation & communication

At present, the islands are connected to the mainland by high-speed catamaran type ferry vessels and larger mechanized cargo vessels. These vessels carry copra & coir from the islands and return with rice, sugar, provisions, etc. However, the rough sea during the monsoons is a limitation. Although great improvements have been made in surface transport, loading and unloading facilities from ship to shore is very much lacking. These activities take place in the open sea and involve a lot of risk. Only Androth has jetties for loading and unloading. In the other islands, the ships stop by reefs and cargo is unloaded onto barges and small boats. This poses a severe limitation, as material beyond 2 tonnes cannot be brought to the islands at present.

The only airport is at Agatti with facilities sufficient only for a small aircraft. There are proposals for airports at other islands as well. A helicopter service between the mainland and inter island is also available.

The total length of roads in the islands is 253 km including bicycle tracks of which 124 km has been converted into cement concrete roads. The roads appear to be in good condition. The sizes of the islands being small, the need for transportation is not very high. The vehicles are mainly composed of privately owned 2 wheelers and 3 wheelers for commercial use and are very few in number. Fuel for vehicles is procured by a cooperative society and distributed in each island.

Jetty at Kavaratti

Cement concrete roads

in Kavaratti

Low-power TV transmitters are working in all inhabited islands except Bitra. Satellite earth stations are being operaed in Kavaratti, Minicoy, Agatti, Kiltan, Kalpeni and Androth islands, which provide long distance communication circuits to all the islands via terrestrial microwave links. Kavaratti and Minicoy stations have FM FDM systems providing sufficient trunk circuits for Kavaratti, Minicoy, Kadmath, Agatti and Amini islands. Other satellite stations have SCPC systems, which are proposed to be replaced with the latest digital IDR equipment.

Social infrastructure

Health & education

Health facilities have improved significantly over the last few decades and consequently indicators such as the birth rate, death rate, infant mortality rate and maternal mortality rate show tremendous progress in improving the level of health in the islands. The present facilities provide one hospital bed for 300 persons and are equipped with X-ray, ECG, Ultrasound and laboratory facilities. A helicopter ambulance to airlift serious patients from peripheral islands to Kavaratti and also to the mainland is also available if conditions so warrant.

During the last 40 years, significant development in education has taken place in the islands. Educational institutions were established in stages in all the islands. Every island except Bitra has a high school. Senior secondary schools are at Kavaratti & Minicoy and Junior colleges are functioning in Kadmath & Androth. Vocational education providing training in fishing and coir technology is also given importance in Lakshadweep. Owing to the various incentives offered by the Administration towards education such as free education, free mid day meals, etc., the literacy levels have risen considerably over the last few decades.

3 Electricity in Lakshadweep

Energy use sectors

Electricity is the principal form of energy mainly used in the islands for domestic, small industrial, commercial and street lighting purposes. Coconut leaves, coconut shells and other non-commercial fuels are mainly used for cooking in most islands except in Kavaratti and Minicoy where commercial fuels like LPG are primarily used. There are plans to promote the use of LPG in other islands also. Petrol is the main fuel used by the transport sector.

Electricity generation

The electrification of the islands was first taken up during the early 1960's and Minicoy was the first island to be electrified by installing two DG sets of total capacity of 91 kW. Power supply, which was limited to six hours a day earlier, is now supplied round the clock (since 1983) in all the islands and the Union Territory has achieved 100% electrification. The electricity is supplied by the Lakshadweep Electricity Department and no other agency is involved in this sector. Voltage and frequency fluctuations are within limits. According to officials of the Department, the power factor ranges between 0.82 and 0.86 in all the islands. The power factor in Agatti has recently increased to 0.99 with the commissioning of the 100 kW grid interactive SPV system. The quality of supply being very good, no privately owned generators operate in the islands.

There is no inter island connection in the supply grid and stand-alone systems operate for each island. Electricity is generated through diesel-operated engines and an average of 7.0 million litres of HSD oil per annum is used. Diesel is loaded in barrels at Calicut (a mainland city) and transported on barges to off-shores at the islands' reefs. The barrels are again loaded on to barges for transportation to the jetties and transported to island stockyards by small trucks. The whole process is tedious, expensive and poses a serious threat to the fragile environment of the islands due to the problems associated with such cumbersome handling. Due to the rough sea during the monsoon season, diesel required for about five months is stored in the islands before the monsoon sets in. Diesel spillage and barrels with leaks are very evident at the stockyards.

Noise pollution and air pollution due to emissions at the generating stations are other environmental problems posed by the diesel generators.

Diesel spillages at the storage yards in Kavaratti

The average cost of generation is Rs.7.77/kWh but is provided at an average of Rs. 4.00/kWh to consumers. The tariff structure effective from April, 2000 is given below:

Table 3.1 Electricity tariff in Lakshadweep

	Tariff (Rs./kWh)
Domestic	
0-50 kWh	1.50
0-100 kWh	2.50
0-200 kWh	3.50
> 200 kWh	4.00
Commercial	6.50
Industrial	4.50
Street lighting	6.50

Source: Electricity Department, Kavaratti

Renewable energy technologies have been adopted in a big way recently, though tremendous efforts in this direction have been made by the Lakshadweep Electricity Department during the last two decades. The officials of the Department hav e keenly expressed their commitment to shift to renewable energy for electricity generation and to reduce the dependence on diesel as is very evident in the process of commissioning of 1.05 MW of Solar Photovoltaics (SPV) and 0.25 MW of biomass gasifier in the islands.

Installed capacity

The diesel sets in the islands range from 24 to 400 kW capacities. Grid interactive SPV systems have been tried successfully and commissioning of 1.05 MW of SPV is expected to be completed by June 2002. The 250 kW biomass gasifier proposed at Kavaratti is also being installed and is expected to be operational at the same time. The island wise installed DG set capacity and the proposed and installed RETs are given in **Table 3.2** below.

Table 3.2 Installed DG set capacities and RETs in each island, 2001

	DG set capacity (kW)	*SPV (kW)*		*Wind (kW)*		*Gasifier (kW)*	
		Existing	*Proposed*	*Existing*	*Proposed*	*Existing*	*Proposed*
Lakshadweep	***9368***	***685***	***365***	-	-	-	***850***
Chetlat	**430**	-	**100**	-	-	-	-
Kiltan	**510**	**100**	-	-	-	-	-
Kadmath	**750**	**50+100**	-	-	-	-	-
Amini	**1034**	-	**100**	-	-	-	**200**
Agatti	**1020**	**100**	-	-	-	-	-
Kavaratti	**1800**	**100**	-	-	-	-	**250**
Androth	**1250**	**100**	-	-	-	-	**200**
Kalpeni	**750**	-	**100**	-	-	-	**200**
Minicoy	**1800**	**100**	-	-	-	-	-
Bangaram	**74**	**10**	**40**	-	-	-	-
Bitra	**24**	**25**	**25**	-	-	-	-

Source: Lakshadweep Electricity Department, Kavaratti

Power house with DG sets in Kavaratti **100kW SPV installation in Kavaratti**

A visit to the power plant at Kavaratti revealed that the generators at that time (about 1500 hours in February) were under loaded by about 50% of its generating capacity. This, according to the officials, was due to the heat build up in the powerhouse, which under optimum loading conditions would cause the generators to trip. The heat generated combined with the hot humid conditions is thus a factor that affects the efficiency and cost of power generation in the islands. The Electricity Department however, has initiated action to house the generators in a well-ventilated building. The efficiency of the generators and its management warrants a more detailed study for optimizing the use of diesel generators in the islands.

Electricity generation

The total energy generated in all the islands was 19.8 million kWh in 2000-01. The energy generated in all the islands show an increasing trend at an average of 4.3% per year, though a few islands like Kavaratti and Kiltan show slight decreasing generation.

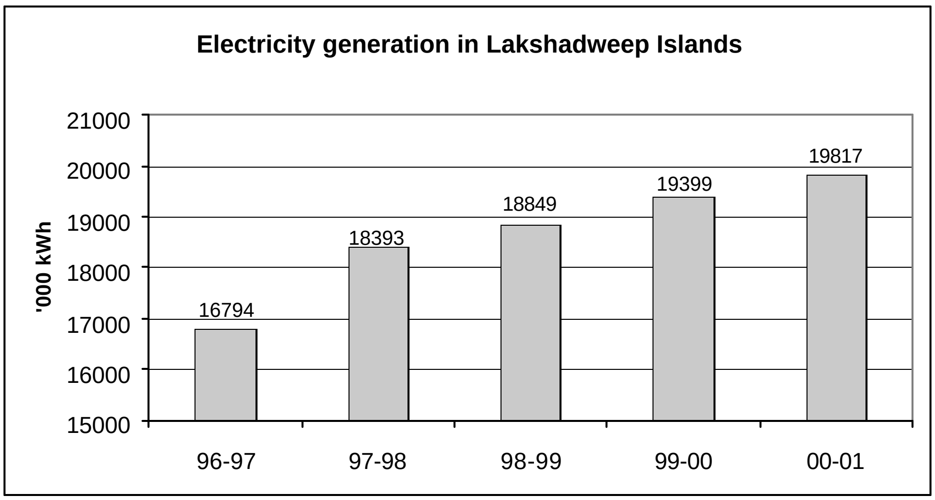


Figure 3.1: Electricity generation in Lakshadweep islands, 1996 - 2001

The island-wise electricity generated during the last five years between 1996 & 2001 is provided in **Annexure 1**. The energy generated in Minicoy is the highest and accounts for 22.3% of the total energy generated (4.5 million kWh in 2000-01). Bitra generates the lowest energy among all islands (0.07 million kWh in 2000-01).

Transmission & distribution

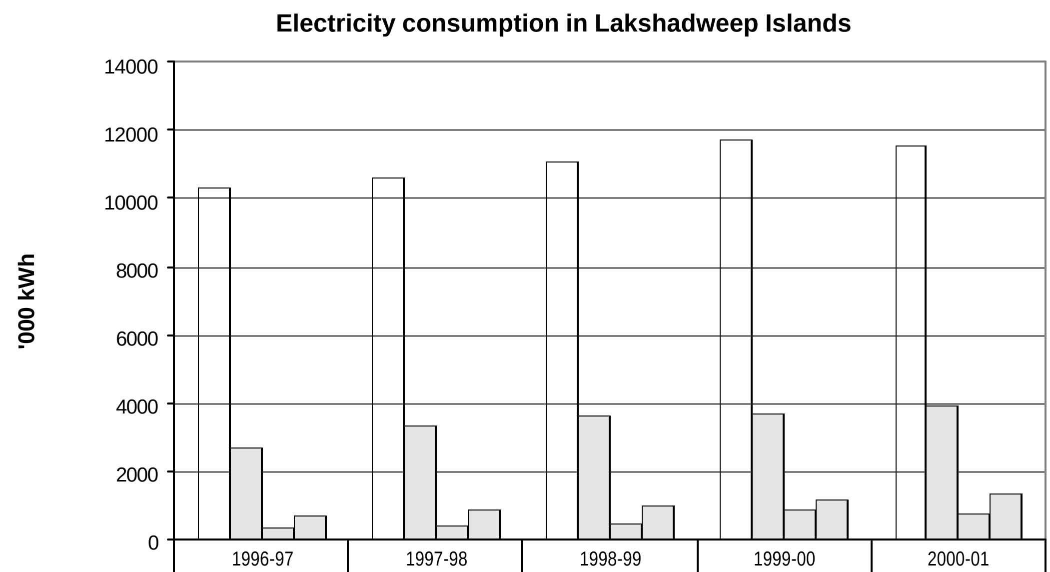
The distribution is through 11kV and 415V systems. High Tension (HT) cables of 95 sq mm are used in Kavaratti, Androth and Minicoy whereas 25 sq mm cables are used in the other islands. The grid maps of the islands are provided in **Annexure 2**. Transmission and distribution losses were earlier a major problem for the Electricity Department. However, due to efforts made over the last few years, the losses have now been reduced to 10.18%, which is the lowest in India; this has been made possible by replacing overhead lines with underground cables, adoption of electronic energy meters and modernization of power systems. The T&D losses are expected to be brought down to 8% with further efforts.

Transformers for distribution in Kavaratti

Electricity consumption

The total energy consumption in Lakshadweep islands in 2000-01 was 17.7 million kWh, the trend indicating an average increase of 5.87% annually. The domestic sector is the largest consumer of energy at 65.4% in 2000-01. Commercial consumption accounts for 22.3% and streetlights 7.8%. The industries in Lakshadweep are of small scale and do not consume much electricity accounting for a very small percentage.

Small industries in Kavaratti



	1996-97	1997-98	1998-99	1999-00	2000-01
Domestic	10302.2	10633.2	11075.2	11717.2	11561.2
Commercial	2669	3322	3632	3673	3946
Industry	341	442	459	860	794
Street light	730.2	874.1	994	1171.8	1379.9

Figure 3.2: Electricity consumption in Lakshadweep Islands, 1996-2001

The annual per capita domestic consumption of electricity is very high at 191 kWh for 2000-01, whereas the average annual per capita domestic consumption for India is just 67 kWh (from Central Electricity Authority figures of 1998-99). This is due to the domestic sector being the largest consumer (at about 65%) in Lakshadweep while this sector accounts for just 21.5% (about a third of Lakshadweep) for India.

The energy consumption per square kilometer is very high at 5,39,333 kWh/sq km and almost 6 times the all India average of 94,223 kWh/sq km. This is because of the very high density of population in the islands compared to the average population density of India (refer to Chapter 2).

The annual domestic electricity consumption per consumer is about 840 kWh / connection / year on an average during the last five years. This is only slightly higher than the all India average of 810 kWh / connection / year. This however, varies considerably from island to island, the highest average annual domestic consumption being 1788 kWh / connection / year in Minicoy, this exceptionally high value in Minicoy due to a more affluent population – a large number of the island's male population is employed as seamen on merchant ships. Bangaram being promoted as an eco-tourism spot with a very low population has the lowest consumption per connection at 200 kWh/connection /year. The other islands have a more moderate consumption per connection ranging from about 450 to 850 kWh / connection / year. The average annual electricity consumption per consumer for all sectors in Lakshadweep is just about a third of the average all India value, which is again due to the large proportion of domestic consumers in the islands.

Table 3.3 Average connected load & electricity consumption per consumer in Lakshadweep

	Total	*Domestic*	*Commercial*	*Industrial (LV & MV)*	*Industrial (HV)*	*Public lighting*	*Traction*	*Agriculture*	*Public water works*	*Misc*
Connected load in 1999 (kW)	18521	13222	Na	Na	0	195	0	0	0	0
No. of consumers in 1999	16495	13066	Na	Na	0	778	0	0	0	0
Average connected load per consumer in 1999 (kW)	**1.12**	**1.01**	**1.38**	**8.42**	**0.00**	**0.25**	**0.00**	**0.00**	**0.00**	**0.00**
India	*1.93*	*0.85*	*1.46*	*6.35*	*444.86*	*2.24*	*9941.02*	*4.06*	*13.4*	*4.83*
Average electricity consumption per consumer – 1997-98 ('000 kW)	**0.95**	**0.84**	**1.34**	**2.23**	**0.00**	**1.31**	**0.00**	**0.00**	**0.00**	**0.00**
India	*2.96*	*0.81*	*1.81*	*9.03*	*1643.25*	*8.21*	*29055.56*	*7.93*	*29.38*	*11.33*

Source: Central Electricity Authority

The connected loads, electricity consumption for each sector and number of connections in each island is provided in **Annexure 3**.

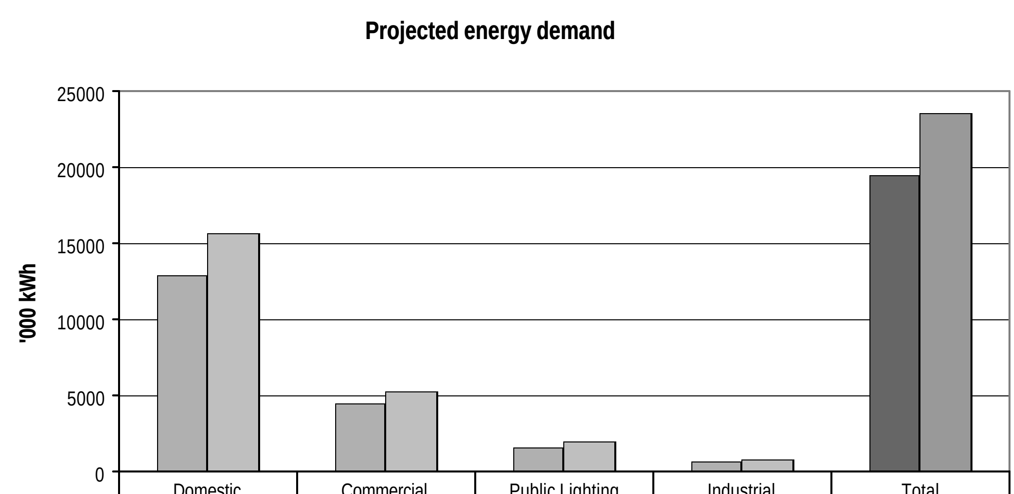
Electricity demand

The demand for electricity in the islands at present is mainly from the domestic sector since the industrial and agricultural sectors, which consume a lot of electricity, are very small. According to officials of the electricity department, the average household in Lakshadweep having 4-5 lights, 2-3 fans, a refrigerator and a television. Since most households depend upon wells to meet their water requirements, a 0.5 hp pump is also owned and operated widely. Washing machines and wet grinders are also common. There is a certain level of consciousness among the people about conserving electricity and is evident by the widespread use of energy efficient CFL fixtures. This is also due to the electricity tariff structure that discourages high consumption of electricity by making bills very high when moved to the next slab (Refer to **Table 3.1**).

As the domestic demand is the highest, the nighttime demand is much higher than the daytime demand due to lighting. The nighttime demand is typically about 1.5 times the daytime demand.

The electricity demand for the various sectors projected by the Central Electricity Authority based on surveys is shown below and the island-wise projections are given in **Annexure 4**. The growth in demand that has been projected is about 3-6% annually.

Water pumps in a household in Kavaratti



	Domestic	Commercial	Public Lighting	Industrial	Total
2006 -07	12951	4418	1569	571	19509
2010-11	15714	5215	1895	740	23564

Figure 3.3: Projected electricity demand in Lakshadweep Islands, 2006-07 and 2010-11

4 RET potential in Lakshadweep

Renewable energy sources in Lakshadweep

Renewable energy sources (RES) that can be tapped for electricity generation are mainly solar, wind and biomass energy. Other sources like Ocean Thermal Energy are also available but the technology is yet to mature to levels where it can be applied commercially. Solar, wind and biomass energy are therefore the only RES that are considered to assess the potential in Lakshadweep.

Solar energy

The monthly solar radiation levels for Agatti are provided in the following table.

Table 4.1 Solar resources in Lakshadweep

	J	F	M	A	M	J	J	A	S	O	N	D
Global Solar Radiation (kWh/m^2/day)	5.127	5.765	6.270	6.043	4.984	3.926	3.779	4.268	4.946	4.682	4.727	4.672

Source: Anna Mani and V. Rangarajan, Solar Radiation over India

The average solar radiation over the islands is 4.932 kWh/m^2/day, which indicates the vast potential offered by this source of energy.

Limitations

The main limitation of solar based RET in the islands is the large land area required for setting up the solar panels. As has been discussed in the profile of Lakshadweep, there is very limited land that belongs to the administration and whatever land is available is used for growing coconut trees. Land available for setting up solar panels is thus a major constraint.

Another limitation is the dense tree cover in the islands that shades the ground over most parts of the islands. The rooftops of buildings are also shaded as the tree cover, mainly coconut trees, extends to a height of about 10-15 metres. This necessitates clearing of trees around the installation to enable solar radiation to strike the panels. This has limited the use of solar powered streetlights, which consumes a large part of the islands' energy.

The SPV installations in the islands have been set up on land that has been leased from the local population for a fixed duration (of about 60 years). This was mainly due to the efforts of the Electricity Department in convincing the local people about the improvement in power supply and the socio-economic benefits that would accrue to the islands. About 0.4 Ha of land has been leased and cleared of the coconut trees to set up 100 kW systems.

The area of land that is available or that can be leased has to be ascertained for each island and is beyond the scope of this exercise. Considering the population growth trends and the demand for land, which is likely to increase, it is assumed that not more than 5 times the area of the existing installations in Kavaratti (2.0 Ha) will be available. This, however, is subject to a more detailed island wise study. Considering the high population densities of all the islands (Refer to Chapter 2), the same proportion has been used to determine the land available for SPV installations in the other islands.

100kW SPV installation at Agatti

100kW SPV installation at Kavaratti

Solar energy potential

The potential of this resource has been estimated island wise using the monthly solar radiation levels given in Table 4.1 and taking into account the efficiencies of current systems. The annual island wise potential is given in the table below and the monthly potential is provided in **Annexure 5**.

Table 4.2 Solar energy potential in each island

Island	*Annual electricity generation potential ('000 kWh)*
Lakshadweep	*8402.4*
Chetlat	327.1
Kiltan	467.8
Kadmath	895.3
Amini	743.2
Agatti	1113.4
Kavaratti	1211.0
Androth	1388.9
Kalpeni	800.6
Minicoy	1259.8
Bitra	28.7
Bangaram	166.4

Wind energy

The monthly average values of the wind speeds, Weibull parameters and Mean Annual Wind Power are given in the following tables. It can be seen that the wind and solar resources complement each other – June, July and August are months with the highest wind speeds and lowest solar radiation.

Table 4.3a Wind resources in Agatti Island, Lakshadweep – 20m height

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Mean Wind speed (m/s)	3.4	3.7	3.2	3.9	4.3	8.9	8.9	8.4	5.9	3.7	3.4	3.1	5.1
Weibull parameter 'k'	1.2	3.2	2.4	3.5	2.1	3.3	4.9	4.6	3.0	2.0	1.7	2.6	2.9

Source: A. Mani and S. Rangarajan, Wind Resource Survey in India-Vol. 3, Allied Publishers, New Delhi, 1994

Table 4.3b Wind resources in Minicoy Island, Lakshadweep – 20m height

	J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**Annual**
Mean Wind speed (m/s)	2.89	3.29	2.95	2.96	5.06	8.15	7.94	7.02	6.01	4.07	3.66	2.77	4.73
Prevaili	NE	N	N	NW	NW	W	W	W	W	W	NW	NE	

ng Wind direction			/NE	/NE	/NE	/NE	/E	/NE	/NE	/NE	/N	/N	
Weibull parameter ‘k’	2.0	2.3	2.4	2.1	1.8	2.9	3.0	2.8	2.8	2.0	1.9	1.8	1.6
Weibull parameter ‘c’ in m/s	2.92	3.44	2.97	3.08	5.00	8.39	8.14	7.31	6.08	4.61	3.78	2.67	4.78
Air density (g/cum)	1178	1175	1171	1165	1164	1168	1170	1171	1171	1172	1175	1176	1171

Source: A. Mani and S. Rangarajan, Wind Resource Survey in India-Vol. 4, Allied Publishers, New Delhi, 1996

Table 4.4 Island wise mean annual wind power density

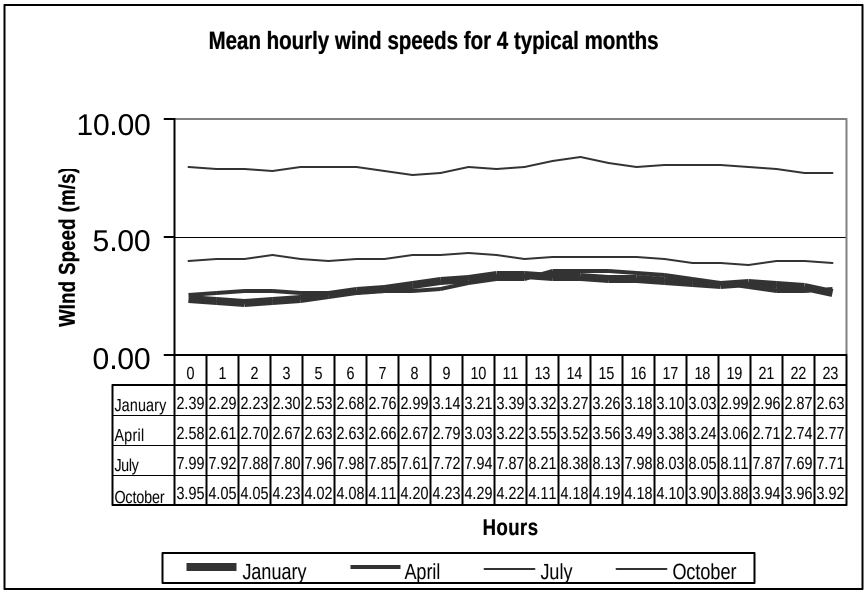
	Latitude (N)	*Longitude (E)*	*Height of mast (m)*	*Mean Annual Wind Speed (m/s)*		*Mean Annual Wind Power Density (W/m^2)*	
				At Mast	*At 30m*	*At Mast*	*At 30m*
Agatti	$10^{0}51'$	$72^{0}11'$	20	5.11	5.42	178.70	207.70
Amini	$11^{0}07'$	$72^{0}44'$	20	4.83	-	140.00	-
Bitra	$11^{0}35'$	$72^{0}12'$	20	4.58	5.36	173.00	258.00
Chetlat	$11^{0}43'$	$72^{0}43'$	20	5.28	5.57	172.00	205.00
Kadmath	$11^{0}13'$	$72^{0}47'$	20	5.00	5.39	168.60	211.40
Kalpeni	$10^{0}05'$	$73^{0}39'$	20	4.50	5.25	125.40	181.70
Kavaratti	$10^{0}33'$	$72^{0}38'$	20	5.00	5.44	160.60	205.50
Minicoy	$08^{0}17'$	$73^{0}04'$	20	4.83	>4.83	161.50	>161.50

Source: www.windpowerindia.com

The Mean Hourly Wind Speeds in Minicoy for four typical months are represented in the following chart (based on data January 1993-December 1996*). Wind speeds of less than 2.8 m/s are considered as periods of lull and occur between 0000 hours and 0700 hours in January. Similar periods of lull are evident in the months of December, February, March and April. The remaining months between May and November have hourly wind speeds greater than 2.8 m/s. There is no significant variation in the hourly wind speeds in a

* A. Mani and S. Rangarajan, *Wind Energy Resource Survey in India -IV*, Allied Publishers, 1996

typical month. Wind energy is therefore a resource that has high potential for energy generation in Lakshadweep.



	0	1	2	3	5	6	7	8	9	10	11	13	14	15	16	17	18	19	21	22	23
January	2.39	2.29	2.23	2.30	2.53	2.68	2.76	2.99	3.14	3.21	3.39	3.32	3.27	3.26	3.18	3.10	3.03	2.99	2.96	2.87	2.63
April	2.58	2.61	2.70	2.67	2.63	2.63	2.66	2.67	2.79	3.03	3.22	3.55	3.52	3.56	3.49	3.38	3.24	3.06	2.71	2.74	2.77
July	7.99	7.92	7.88	7.80	7.96	7.98	7.85	7.61	7.72	7.94	7.87	8.21	8.38	8.13	7.98	8.03	8.05	8.11	7.87	7.69	7.71
October	3.95	4.05	4.05	4.23	4.02	4.08	4.11	4.20	4.23	4.29	4.22	4.11	4.18	4.19	4.18	4.10	3.90	3.88	3.94	3.96	3.92

Figure 4.1: Mean hourly wind speeds in Minicoy

Limitations

One of the limitations of using wind energy is the lack of adequate shipping and unloading facilities in the islands, which does not permit equipment and machinery greater than 2 tonnes to be unloaded. This corresponds to about an 80kW wind generator and calls for a greater number of generators to be installed. The area required for a wind farm would be correspondingly high, which is a severe limitation as explained earlier. Another limitation is the mast height of th e generator, which needs to be higher than the coconut trees for it to catch winds of sufficient speed. The foundations required for generators of greater height could also be a limitation.

The wind generator that was installed at Kavaratti with a height of 15 m was imported and was a failure due to the lack of technical back up and the inability to procure spare parts. Officials of the Electricity Department say that the operation and maintenance of such equipment was a major problem, as the poor accessibility to the islands is a limitation for manufacturers & suppliers to provide spares and servicing.

Wind turbine installed at Kavaratti

Wind energy potential

As given in the previous section, wind generators have to be selected such that they have the following characteristics:

- Low hub weight (less than 2 tonnes)
- Hub height greater than 25m
- Light foundations
- Resistance to high wind speeds
- Low cut-in speed
- Low and easy maintenance

Though it is would seem preferable to select low speed generators, so as to have electricity generated throughout the year, the complementary nature of the monthly wind speeds and monthly solar radiation that suggests it would be a better option to have a mix of solar and wind energy for greater reliability of the installations. This indicates that wind energy would be better realized during the months with high wind speeds. The limitations listed above also support the selection of high speed and smaller capacity generators. This assumption is used for estimating the potential of wind energy in Lakshadweep. This is however an assumption based on available data and calls for a more detailed investigation that takes into account the economics of such a strategy. Offshore wind farms should also be considered in these investigations as greater generation due to lower roughness coefficients could possibly offset the capital costs and would not place any additional stress on the already scarce land resources.

It is also necessary for wind generators to be equipped with a guyed tilting tower, which would ease the installation and allow lowering and fastening the wind generator to the ground in case of storms. The main advantages of this technology are:

- Low level of maintenance
- High level of reliability
- Possibility to operate in grid-connected mode or in stand-alone mode
- High level of power quality (electronic control of the current fed into the grid).

The spacing between wind turbines is typically 5-9 rotor diameters apart in the prevailing wind direction and 3-5 rotor diameters apart in the direction perpendicular to the prevailing winds. The rotor diameters for 60-100kW turbines would be in the range of 15-20m. The coastline length on the western side of Kavaratti is approximately 8 km (the island is linear in shape with its longer axis of about 6m in the north-south direction). It is assumed that only a fourth of this length is available for locating wind turbines and limits the number of turbines (of 20m diameter) to between 20 and 30. Similarly, the numbers of turbines that can be located in the other islands have proportionately been estimated roughly.

Due to a lack of information, it has also been assumed that the wind characteristics are the same in all the islands and the low wind speeds of Minicoy given above have been used for the analysis so as to be conservative in the estimates.

The wind potential has been estimated island wise with the above assumptions and taking the example of a French turbine – Vergnet GEV 15/60, that overcomes the limitations listed above. The selection of this turbine is only for the purpose of estimating the electricity generation potential of such a turbine and is not necessarily the best suited. Further analysis of costs and electricity generation need to be carried out for other turbines and is not part of the scope of this exercise. Other European wind turbines that overcome these limitations, but with higher cut-in speeds, are provided in **Annexure 6**. The annual potential using this turbine is given in **Table 4.5** below and the monthly potential is provided island wise in **Annexure 7**. These have been estimated using a computer based simulation program and has been carried out with conservative assumptions of the effect of shadowing, roughness class, etc. (the Roughness class was taken as 3). The results too, are conservative and a more detailed study of wind characteristics is necessary for more realistic estimates.

The characteristics of the selected turbine, including the power curve, are provided in **Annexure 8**.

Table 4.5 Wind Energy potential in each island

Island	*Annual electricity generation potential ('000 kWh)*
Lakshadweep	8674.8
Chetlat	309.8
Kiltan	433.7
Kadmath	1239.3
Amini	929.5
Agatti	929.5
Kavaratti	1239.3
Androth	1239.3
Kalpeni	929.5
Minicoy	1239.5
Bitra	62.0
Bangaram	124.0

Biomass energy

Coconut is the major economic crop of the territory with the annual production reaching 283 million nuts during 2000-01. Copra is produced from the coconuts and the dried husk is used for fibre extraction. There is however, a very large portion of the dried husk, leaves or cadjins, shells and sawmill biomass that is unused and the availability of biomass in the islands is such that its disposal is a major environmental problem.

The biomass availability and the basis for proposing the 250kW gasifier at Kavaratti is given in the following table.

Table 4.6 Biomass availability & electricity generation proposed at Kavaratti

	Biomass availability	
1.	No. of coconut trees at Kavaratti	1,20,000
2.	Average yield per tree per annum	40
3.	Total coconuts per annum	48,00,000
4.	Total husk per annum (Nos)	48,00,000
5.	*Biomass available from husk @ 0.32kg/husk (tonnes)*	*1536*
6.	Total shells per annum	48,00,000
7.	*Biomass available from shells @ 0.075kg/shell (tonnes)*	*360*
8.	Average cadjins per tree per annum	12

9.	Total cadjins per annum (Nos.)	14,40,000
10.	*Biomass available from cadjins per annum @ 2.0kg/cadjin (tonnes)*	*2880*
11.	*Sawmill ibomass available (tonnes)*	*50*
A	**Total Biomass available (tonnes)**	**4776**
	Biomass requirement for 250kW plant for 6000 hrs operation (250 days per year)	6000 x 350 kg = 2,100 tonnes (43.5% of total availability)
B	**Electricity generation per year ('000 kWh)**	**1500**
	Cost of husk	Rs 245/tonne
	Cost of cadjins	Rs 400/tonne
	Cost of shell	Rs 750/tonne
	Cost of sawmill biomass	Rs 400/tonne
	Average cost of biomass	Rs 449/tonne

Source: Lakshadweep Electricity Department, Kavaratti

The above figures show a consumption of 350 kg per hour for the 250kW gasifier, which corresponds to 1.4 kg/kW. This is a realistic consumption as the fuel is a mix of loose and dense matter.

Limitations

While the technology available for gasification has come a long way and can be termed as developed, the commercially available systems fall short of the reliability as compared to other conventional technologies. This calls for constant attention to a gasification unit while in operation by an expert technician. At present the Electricity Department is facing a lot of difficulty in installing the gasifier at Kavaratti due to technical problems. Servicing of equipment is also likely to be an impediment to making it successful in the islands. Currently available biomass gasifiers for electricity generation can typically only replace diesel consumption of the generator on an average of about 70% and not completely eliminate its use. Nevertheless, the environmental problems of solid waste disposal can be addressed to a large extent through gasification and therefore cannot be excluded altogether. The operation of the gasifier involves a lot of careful management as biomass is to be collected from the entire island, and then subjected to preliminary processing before being fed into the gasifier. The Electricity Department officials feel that these tasks cannot be undertaken by the Department and have made it the responsibility of the private agency installing the system to operate and maintain the system.

Biomass gasifier at Kavaratti to be commissioned in 2002

Biomass energy potential

The estimated biomass available in each island and the potential for electricity generation is given in **Table 4.7** and is based on the analysis for Kavaratti. However, this is only indicative and a more detailed study of the island wise biomass availability for electricity generation is essential to arrive at a true picture.

Table 4.7 Island wise Biomass availability & electricity generation potential

Island	*Coconuts harvested (1998-99)**	*Biomass available from Hus (tonnes)*	*Biomass available from shells (tonnes)*	*Biomass available from cadjins (tonnes)*	*Total Biomass available (tonnes)*	*Approximate Annual Electricity Generation potential ('000 kWh)***
Agatti	28,00,000	896	210	1680	2786	796
Androth	43,90,000	1405	329	2634	4368	1248

Amini	43,70,000	398	328	2622	4348	1242
Bitra	1,40,000	45	11	84	139	40
Chetlat	13,50,000	432	101	810	1343	384
Minicoy	26,70,000	854	200	1602	2657	759
Kalpeni	31,70,000	1014	238	1902	3154	901
Kadmat	35,40,000	1133	266	2124	3522	1006
Kavaratti***	38,00,000	1216	285	2280	3781	1080
Kiltan	17,70,000	566	133	1062	1761	503
Total	**280,00,000**	**8960**	**2100**	**16800**	**27860**	**7960**

* Source: Basic Statistics 1995-1996, Dept. of Planning & Statistics, Secretariat, Lakshadweep, Kavaratti
** Using 40% of total available biomass and 1.4 kg/kW generation.
*** The values for Kavaratti vary from those in Table 4.6, as the coconuts harvested are different in each year

Current European best practices

Many European islands have developed a wide range of demonstration projects covering all the aspects related with large-scale implementation of RES and diverse initiatives tending to a stronger integration and hybridization of all indigenous energy sources. The island initiatives of this type acquire a greater relevance if we take into account that there are more than 500 inhabited islands in the European Union, and that they occupy as a whole 5% of the territory with about 14 million European citizens. These islands are without doubt privileged laboratories of energy sustainability. A few case studies are presented below that demonstrate the use of RES in some islands of Europe.

Minorca Island

An example of an island of the Canary Islands located in the Atlantic Ocean facing the African coasts is given in this section.

The island of Minorca with a population of 65000 inhabitants and 720 square km of territory is a prototype of insularity. It is a complex territory where many economic activities converge, among which it emphasizes the tourist activity, as with what it occurs in a large part of the European islands. The protected areas from the island occupy 46% of the surface and another large proportion is represented by the singular agricultural landscape that deserves its consideration as cultural landscape according to the terminology of the World Centre of Heritage. Furthermore, the island lodges about 1500 megalithic monuments of large interest. UNESCO declared in 1993 Minorca as a World Reserve of the Biosphere. Such a nomination converts to the island into an international reference for sustainable development.

A Sustainable Development Plan established an island strategy with medium and long-term aims. Drafting of a Renewable Energy Plan, which marks the lines of energy action in the island with the perspective of the maximum penetration of renewable energies, was one of the basic elements. The need to provide to the islands of a framework for future developments in renewable energies was already highlighted in the European Commission's White Paper on Renewable Energy Sources, United Nations Conference on Islands and Small Island States (Barbados 94) and the 1st European Conference on Island Sustainable Development, which gave the general principles that inspired the present Plan. We highlight the emphasis given in the European Island Agenda on this topic: " non-renewable energy sources must be considered as provisional solutions, inadequate to solve in the long term the energy problems of the islands".

The Plan has complied with the following objectives:

- Identification of the energy economy potential and the sources of renewable resources to mobilize
- Identification of the economic and technical potential to develop
- First forecast of the degree of mobilization and the interest of the actors concerned
- Identification of political priorities for the renewables in the context of island sustainable development.

Kythnos Island

The Greek island of Kythnos is one of the lesser-known islands of the Cyclades. It can be reached from Athens in three hours by ship. Approximately 2000 inhabitants lead a calm life in villages. It is only at the peak season and on important holidays that the island comes to life when mainly Greek tourists invade it. This can also be seen in the consumption of electrical energy on the island that varies from 300 KW in winter time to peaks of 2000 KW during the high season.

The history of the Kythnos Island is unique and was the first exemplary case where an island has to be electrified by a fully stand-alone and renewable energy based energy supply system. In this island are cumulated several “premieres” in island electrification:

1980: Installation of the largest European hybrid system for decentralized application

1982: Installation of the first wind park in Europe

1983: Installation of a 100 KWp PV system with battery storage

1992: Installation of new grid -connected inverters for PV

1998: Installation of additional 500 KW wind turbine

2000: Operation of new fully automatic autonomous power supply system with 500 kW battery storage

2001: Installation of the concept of stand-alone modular hybrid system and AC-coupled PV systems

The fully automatic control system manufactured and installed by a German manufacturer (SMA) in 1998 takes over control for complete power supply of the island. A special challenge in this project was the integration of a wind energy converter with a capacity of 500 KW into an island grid where often during the winter consumption does not overcome 300 KW. This has been realized with the combination of a battery converter, a rotating phase shifter and a fast load control that takes over loads peaks from the wind turbine during gusty wind.

The specific modular hybrid energy supply system is based on a central AC grid that collects the whole energy whatever its kind. In this concept the battery bank is equipped with a bi-directional inverter that allows the charge/discharge of the batteries at optimal rates and allows a dynamical control of the load. This concept allows a simple extension of output power and exhibits the following advantages:

- Simple design of island grid due to connection of all components on the AC side
- Reliable and safe power supply with utility quality in remote areas
- Easy integration of RES plants (PV, Wind, Small hydro, diesel genset)
- Power supply for single houses or even small villages
- Expandable design (1-phase or 3-phases combination, parallel operation from 2 KW up to 30 KW)
- Load management
- Optimal battery life

This case study represents an exemplary island electrification programme, which will be generalized in Europe. It gathers most of the European state-of-the-Art in terms of power electronics and RES planning and management.

French experience in island electrification using RES

The European wind energy market is now mostly dominated by bigger wind turbines (average size up to 1 MW). Nevertheless, in the case of island electrification, some typical examples are exemplary. Another example is presented below, emphasizing the use of wind power for island electrification. Vergnet, a French turbine manufacturer, is the world leader of small wind turbines both for remote electrification and water pumping. Vergnet has accumulated over 20 years of experience in island electrification of French overseas territories.

Wind power plants in islands are typically composed of several wind turbines, whose power ranges from 10 to 60 KW. The plant is connected to the Low or Medium Voltage grid according to the local characteristics. A clever combination of wind power in addition to existing diesel generators can allow savings of up to 50 % of the genset fuel consumption and also contribute to stabilize the grid.

The following realizations cover some aspects of the worldwide programmes conducted by Vergnet and its local representatives. It is to be noticed that Vergnet has an Indian representative in Pondicherry, which could favour the operation and maintenance aspects in the context of utilizing 100% RETs for electrification of Lakshadweep.

- La Désirade (Guadeloupe): 12 wind turbines of 25 KW and 4 of 60 KW for an annual production of 2,000,000 KWh/year
- Boa Vista (Cabo Verde): 5 wind turbines of 25 KW save 30 % of the fuel costs
- Marie Galante (Guadeloupe): 25 wind turbines of 60 KW produce 1 MW of power
- Tromelin Island (Indian Ocean): 3 wind turbines of 10 KW provide 100 KWh/day connected to a diesel AC system.
- Les Glénans Solar-Wind-Diesel installation

Island electrification is of a major concern for French companies, mainly in overseas territories in which a lot of small islands need electrification (Polynesian islands, Fiji islands, etc.). In this case the design of the system includes a wind generator, to take the opportunity of the Aeolian potential of the island situation, a PV system for which the resources is less stochastic and a Genset to provide a continuous service. A local grid delivers electricity to a limited number of houses.

Several systems have been installed since the last 10 years with sizes ranging from 1 to 20 KWp PV modules, 1 to 20 KW wind generator, and 5 to 40 KVA Genset and a storage tank according to the end-user specifications. France also participates in European projects for which islands electrification is the target (mainly in the Mediterranean sea).

One typical example of an island hybrid system installed in the French Brittany (North west, Atlantic ocean), in a preserved area called “Les Glénans” island. The center serves as a training sailing and diving center in summertime, and an ornithological reserve in wintertime.

A typical system for more than 20 domestic and tourist houses is composed of:

- 11 kWp of PV modules
- 10 kWh of wind generator
- 32 kVA of Genset

5 RET solutions for Lakshadweep

Projected electricity demand and RET potential

The total RET potential has been computed for the entire island group and compared with the total projected electricity demand. This is only indicative of the RET potential and is not a true picture as the islands are not connected together through a common grid. This however, helps in arriving at a RET potential versus demand scenario for the group of islands. The chart below shows the monthly electricity generation potential of all three RETs in Lakshadweep and the projected electricity demand for 2010-11.

It needs to be understood that the RET potentials indicated in these charts are conservative in their estimates. This is especially so of the wind potentials, which could vary with the choice of turbines, location, etc. The wind potential does not also consider offshore wind farms.

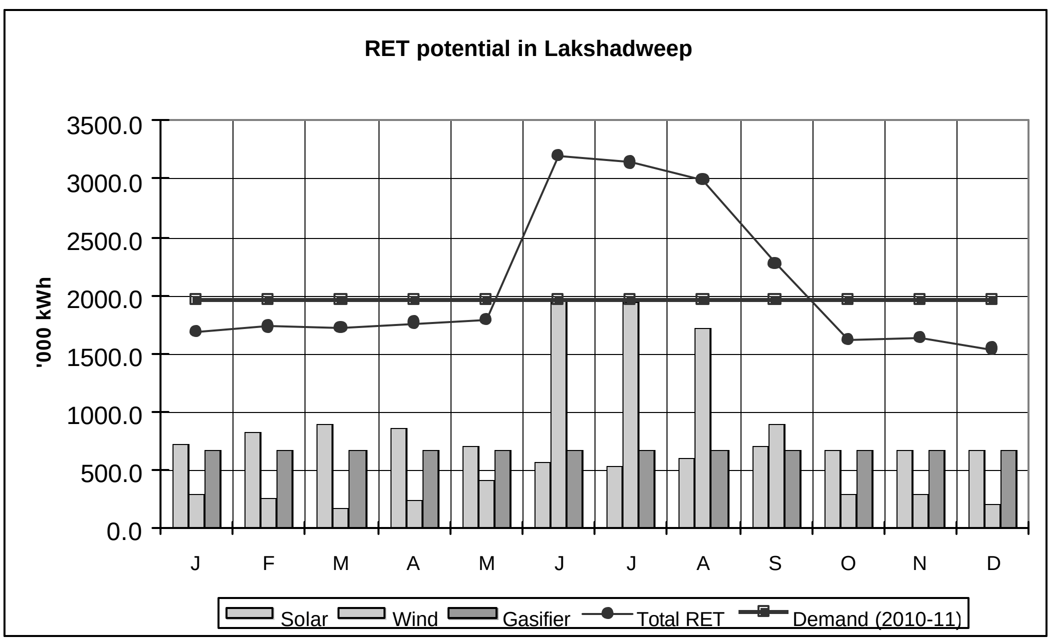


Figure 5.1: RET potential in Lakshadweep Islands

It can be seen from the above chart that the combined RET potential can during the monsoon months exceed the demand in 2010-11 but falls short during the other months. The choice of better turbines for wind, the coastline length available for wind installation and the potential of offshore wind farms can ensure that the RET potential matches or exceeds the demand. The solar potential could also be realistically estimated by a proper study that indicates the area available for the panels.

Strategies for providing total energy requirements utilizing RETs

As mentioned earlier, the RET potential needs to be reviewed for each individual island. For the purpose of this study, however, the islands have been grouped together based on characteristics of their estimated RET potentials and electricity demands. The electricity demands and potentials for the individual islands are provided in **Annexure 9**. Three categories have been formed and strategies for each have been broadly outlined as under:

Category 1: Demand is higher than RET potential

Kavaratti, Minicoy islands

The average projected demand for electricity in these islands is the highest at about 400,000 kWh per month. As a result of the large population and limited land available, the combined RET potential can only meet about 50-60% of the monthly demand for most months of the year. Even during the monsoon season when the wind potential is very high, the combined RET potential only just manages to meet the monthly demand. Androth, with its large population, would appear to fall under this category, but the chart for Androth in Annexure 9 indicates that the island exhibits characteristics of Category 3 explained later. This is because of Androth's lower electricity demand compared with Kavaratti and Minicoy. The strategies that are proposed for this category of islands are as follows:

- Conventional power generation cannot be completely eliminated
- Solar and gasifier systems together can meet about 50% of the demand, the gasifier producing a Constant Energy Output and the solar system with Variable Energy Output reducing the load of the gasifier.

- Wind can contribute significantly, especially during the monsoon when, along with solar and gasifier, it can almost match the demand. It is therefore suggested that wind potential should essentially be tapped in these two islands as the dependence on conventional generation during normal seasons can be reduced and the storage of diesel (for conventional generation) during monsoons can be substantially reduced.
- Offshore wind generation can be explored in this case. However, the choice would greatly depend upon relative economics vis-à-vis other RETs

Category 2: RET potential higher than demand

Amini, Kadmat, Kiltan, Kalpeni, Chetlat islands

The combined monthly RET potential of this category of islands exceeds the projected demand throughout the year and is almost twice the demand during the monsoon season. This makes it possible to utilize only RETs for electricity generation in these islands with conventional generation limited to serving as a back up. The strategies that are proposed for this category of islands are as follows:

- It is possible to eliminate conventional generation altogether
- The base load could be substituted with a Constant Energy Output gasifier and solar-based systems wherein the relative contribution from the gasifier system would be low during the day and more during the night. Variable Energy Output from solar generation would work in a grid interactive mode during the day and store electricity for peak loads in the nights.
- Wind generation should be looked at as supplying additional power during the normal months and contribute to its maximum potential during the monsoon. This will help in reducing the usage of solar and gasifier systems both of which will be limited because of overcast skies and higher moisture content of biomass. Investment in wind need not be a priority unless low wind speed generators are used.
- Low wind speed generators may be used to reduce capacities of other RETs
- Offshore wind generation is not required, as the demand is not as high as in Category 1.

Category 3: RET potential matches demand and is higher during monsoon season

Agatti, Androth, Bitra, Bangaram islands

The islands of Agatti and Androth, both large in terms of extent and population, do not have the high projected electricity demand as Kavaratti and Minicoy (Category 1). This is because Kavaratti being the administrative headquarters and Minicoy having a very affluent population have very high consumption patterns compared to Agatti and Androth. The RET potential of these two islands matches the electricity demand for most months and exceeds the demand during the monsoon months. The small islands of Bangaram and Bitra on the other hand have limited RET potential because of their limited extent. However, the low populations of these islands correspond to low demand and these islands too exhibit the same characteristics of this Category. The strategies therefore for this category are as follows:

- Conventional generation is required as a back up in case RETs are unable to meet the demand
- As in Category 2, the base load could be substituted with gasifier and solar based systems wherein the relative contribution from the gasifier would be low during the day and more during the night. Solar generation would work in a grid interactive mode during the day and store electricity for peak loads in the nights.
- Wind, unlike in Category 2, is essential not just for additional generation but to contribute to meet the normal demand as the potential of all RETs together more or less match the demand. This will also reduce the usage of solar and gasifiers both of which will be limited because of overcast skies and higher moisture content of biomass during the monsoon. Wind to a large extent can substitute solar and gasifier generation but needs to be integrated with a synchronous control system.
- Low speed generators could be more suited for these islands.
- Offshore wind generation is not required as the demand is not as high as in Category 1.

Annexure – 2

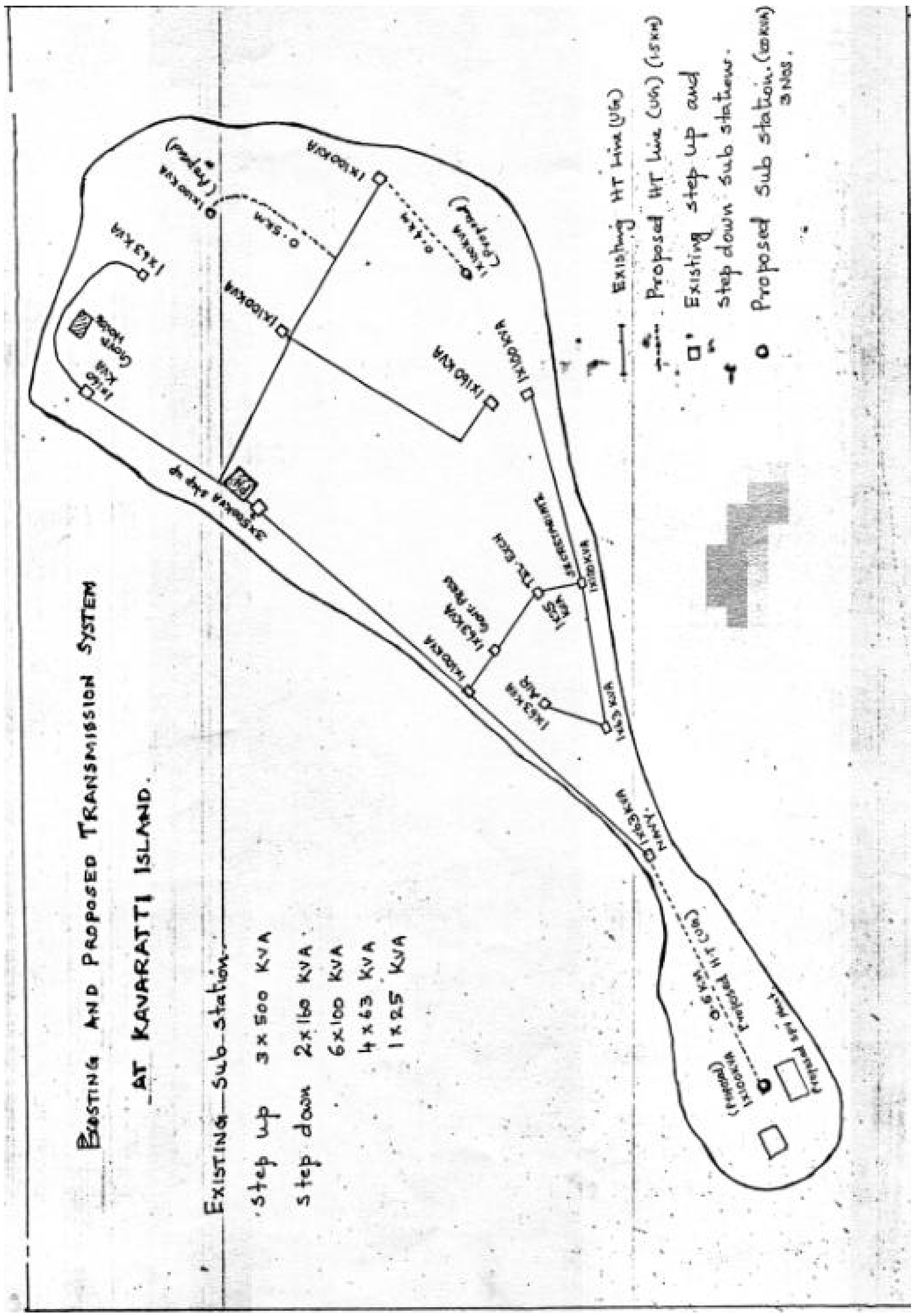
Annexure – 1

Island-wise energy generation in Lakshadweep islands ('000 kWh)

Island	96-97	97-98	98-99	99-00	00-01
Minicoy	3878	4103	4159	4395	4545
Kavaratti	3677	4068	4013	3858	3848
Amini	1438	1641	1731	1697	1750
Androth	2488	2622	2738	2875	2959
Kalpeni	1042	1295	1397	1457	1414
Agati	1352	1675	1813	1911	2021
Kadmath	1341	1332	1315	1419	1557
Kiltan	793	838	884	874	863
Chetlat	578	584	580	678	621
Bitra	46	73	66	77	74
Bangaram	161	162	153	158	165
Lakshadweep	*16794*	*18393*	*18849*	*19399*	*19817*

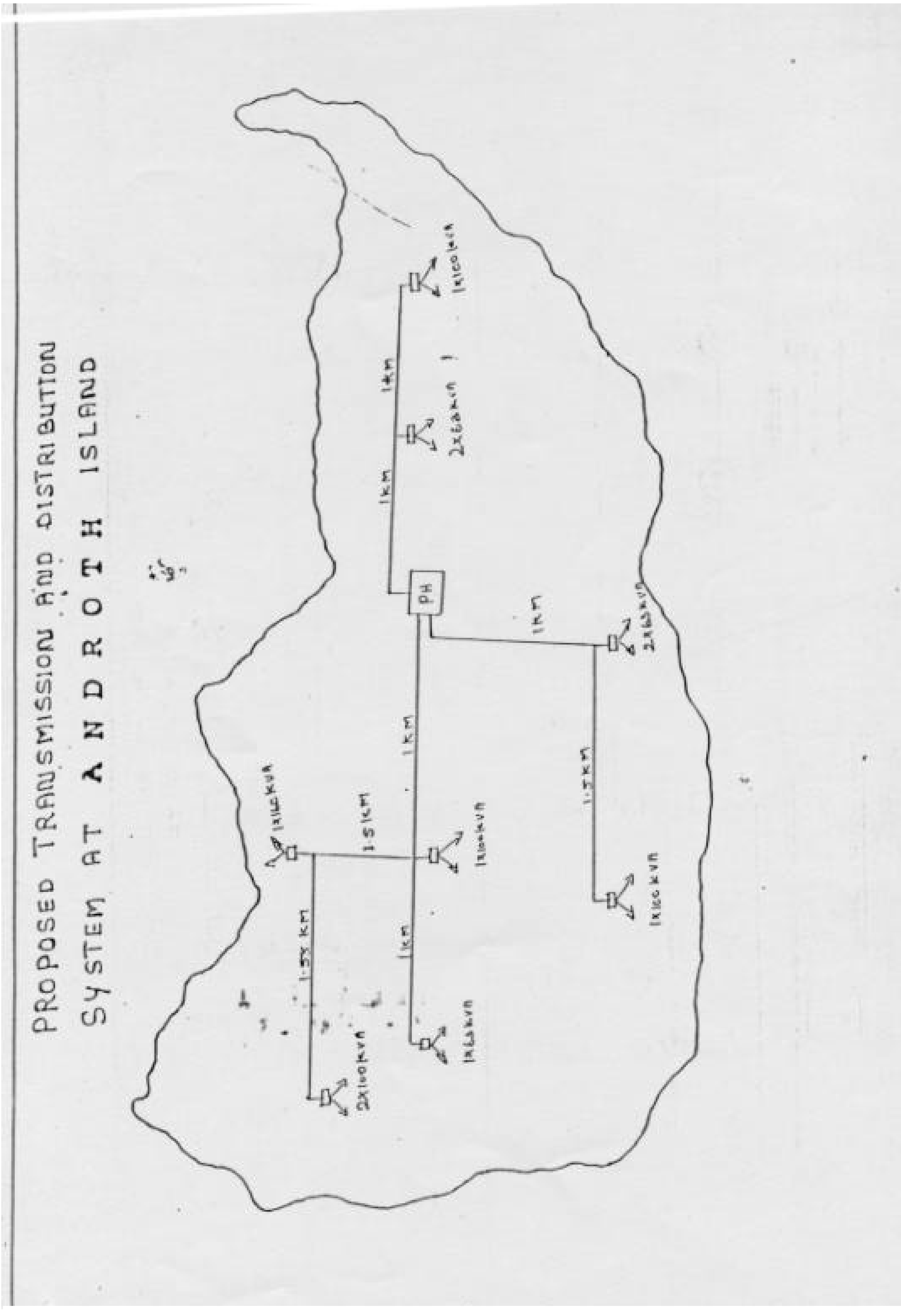
Source: Lakshadweep Electricity Department, Kavaratti

Grid maps of island in Lakshadweep

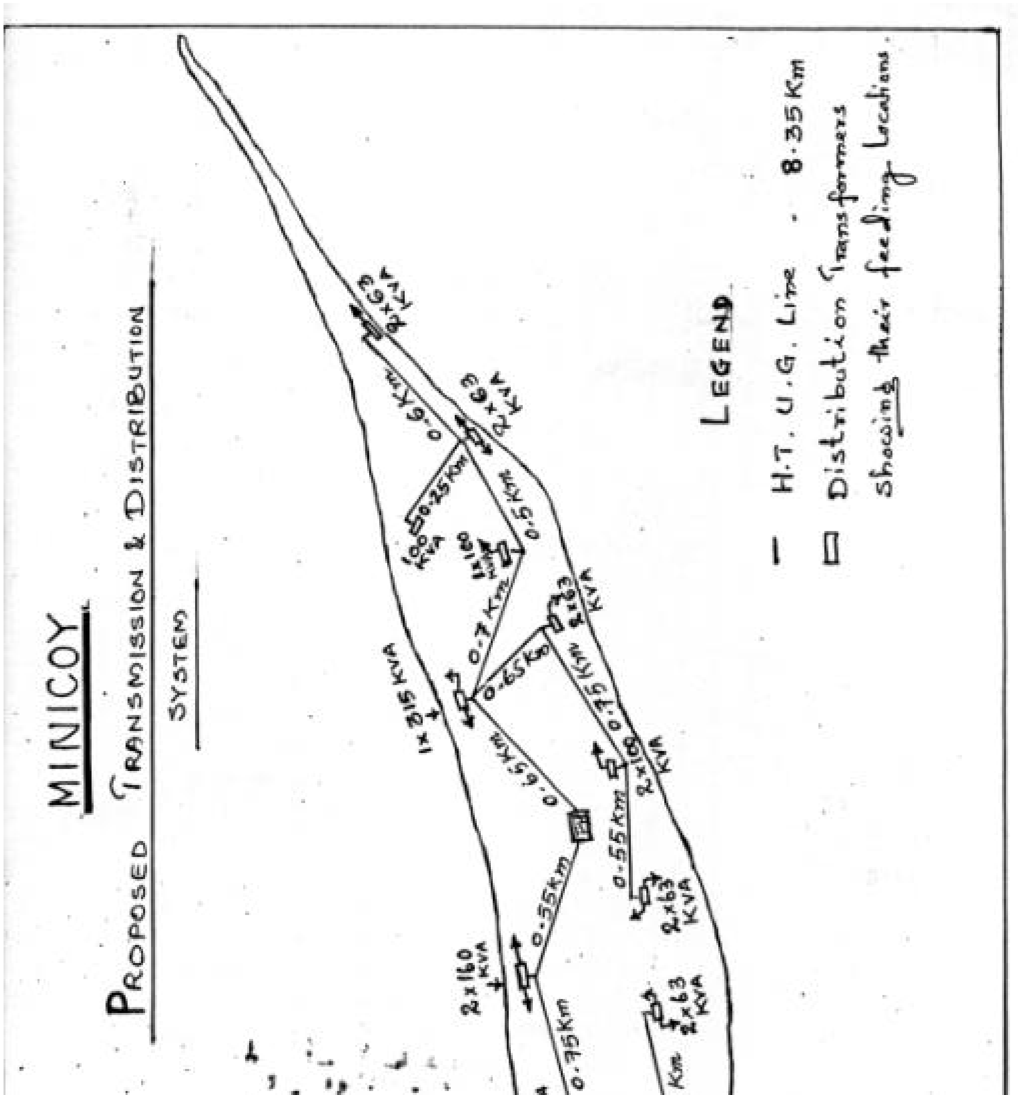


Grid map of Kavaratti Island

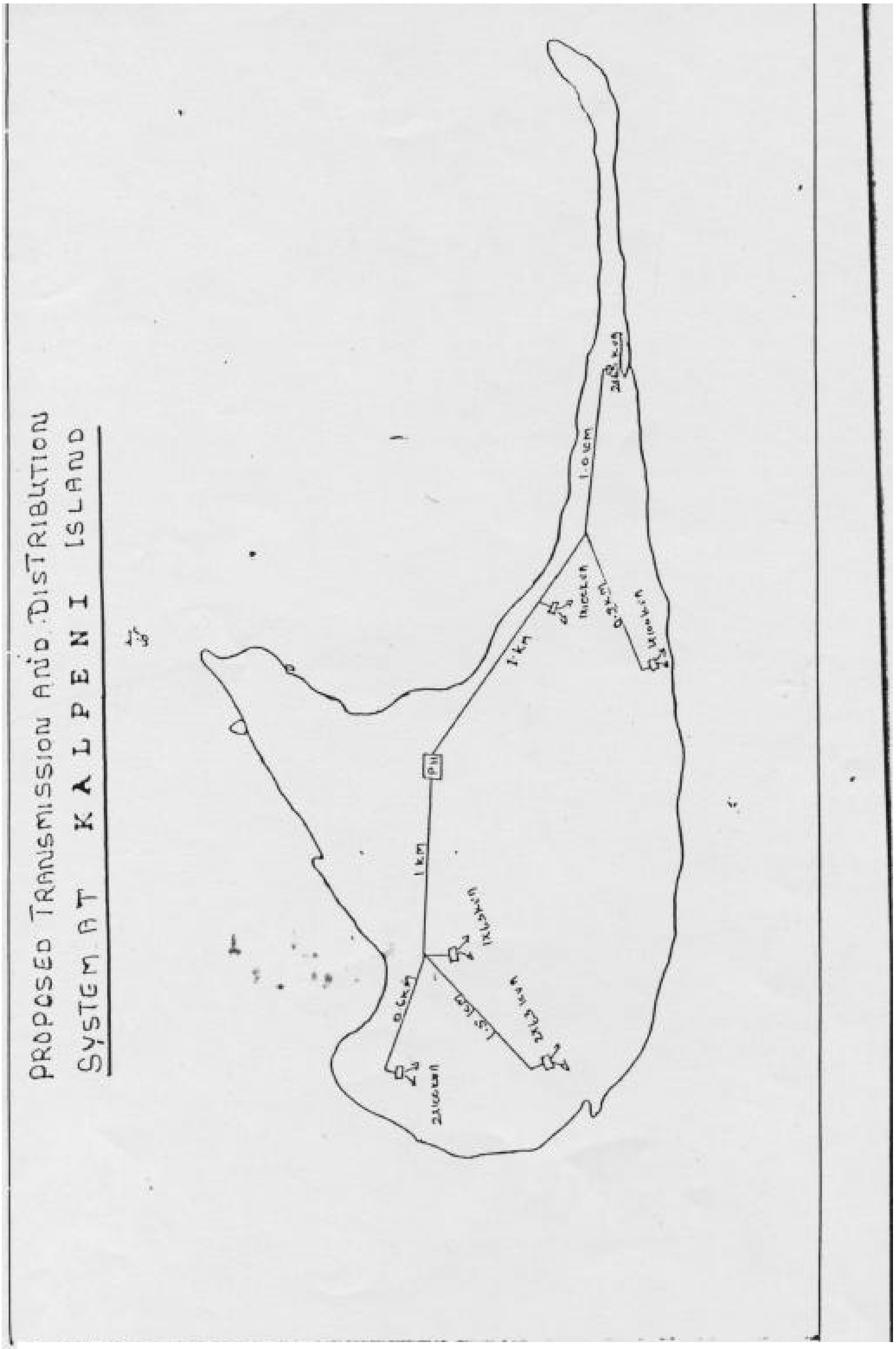
Annexure – 2



Grid map of Androth Island

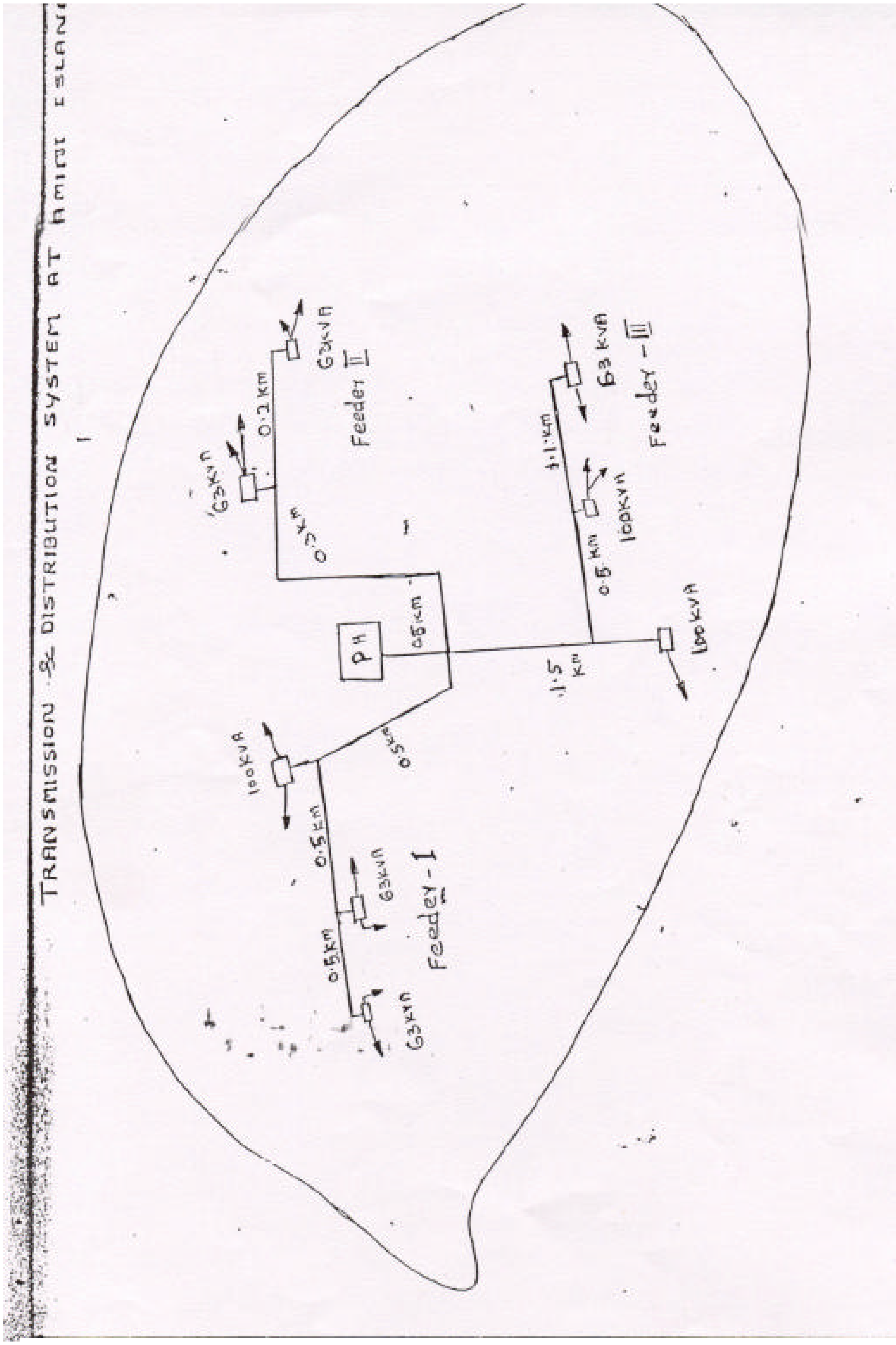


Grid map of Minicoy Island



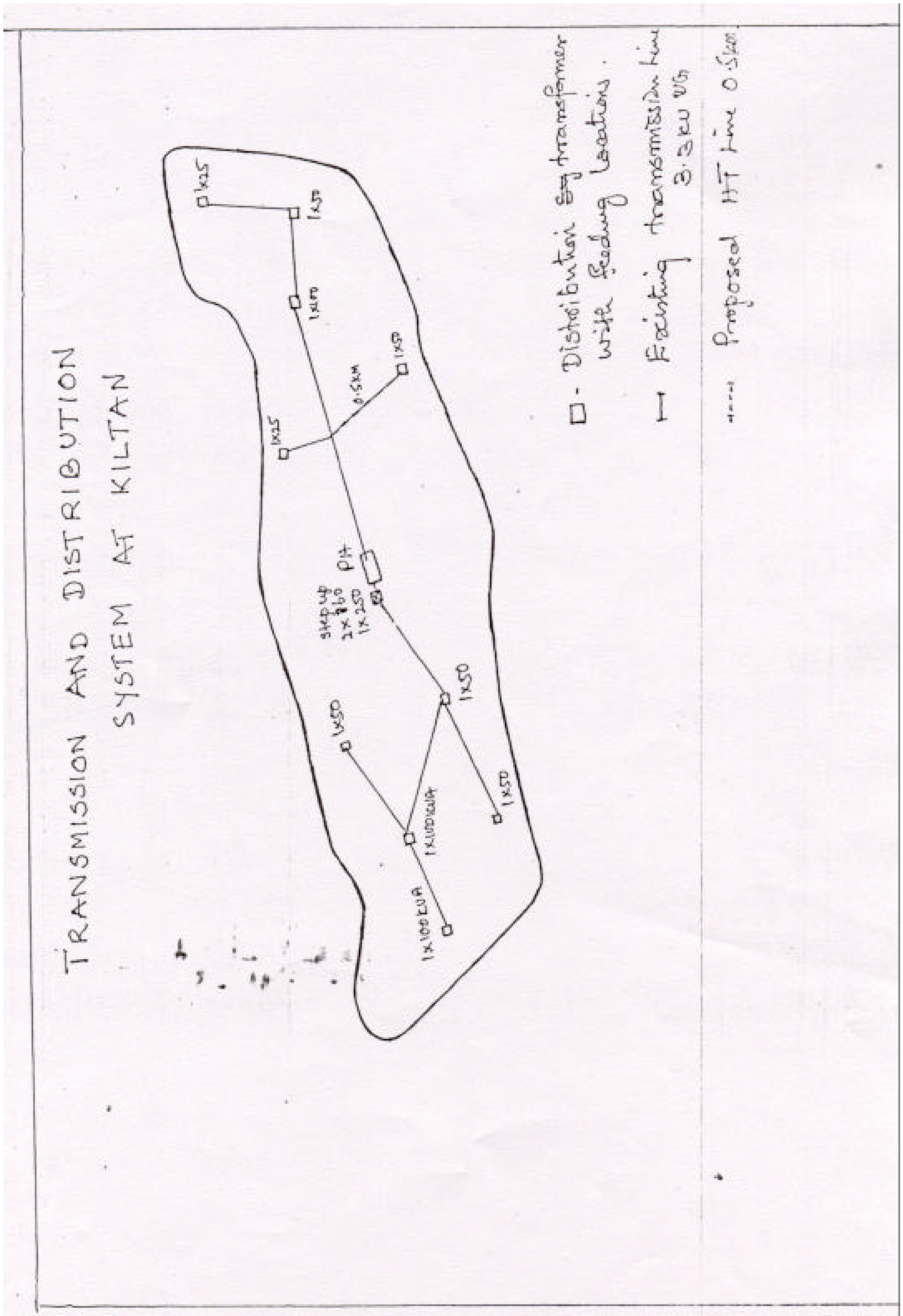
Grid map of Kalpeni Island

Annexure – 2



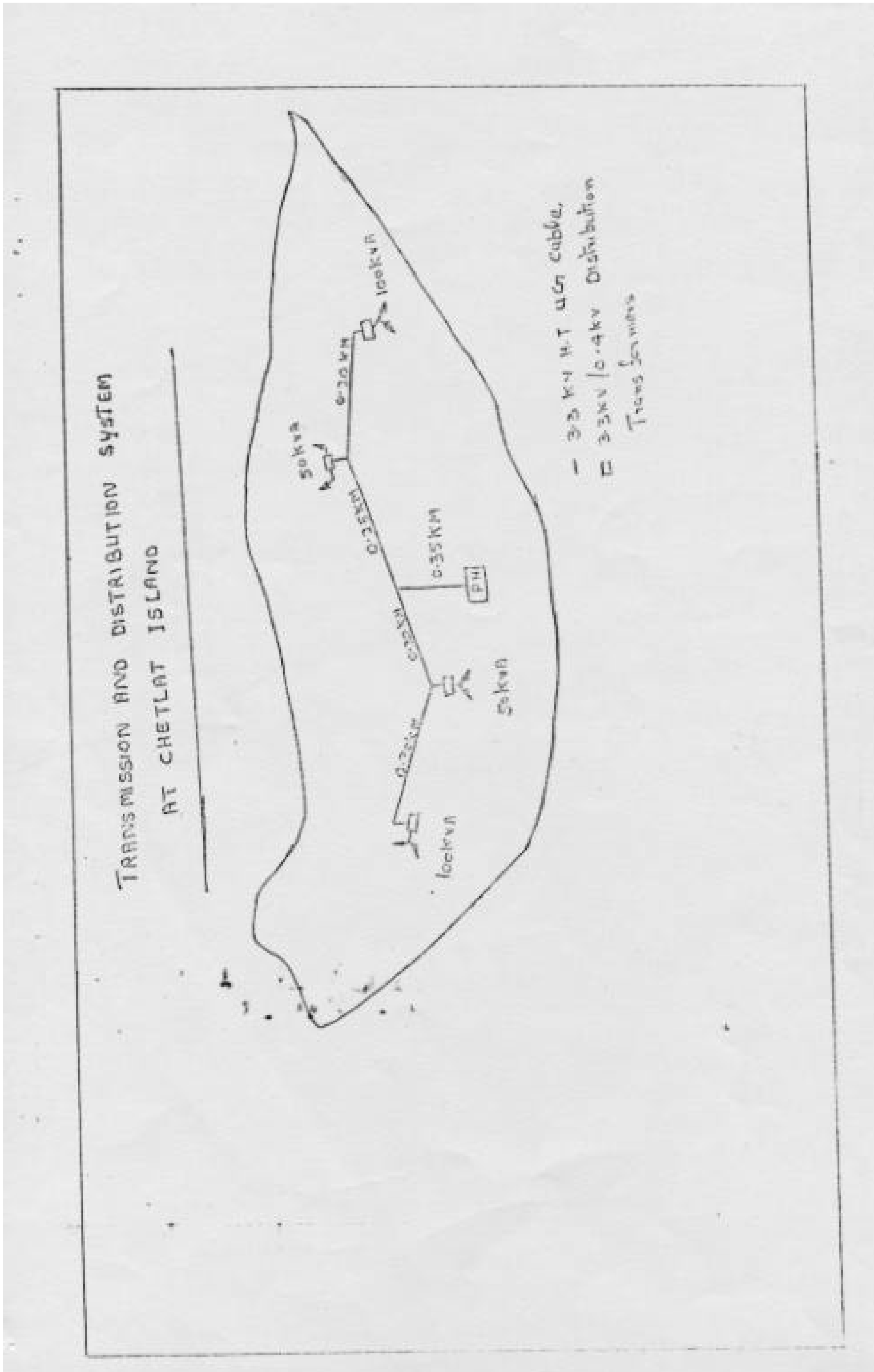
Grid map of Amini Island

Annexure – 2

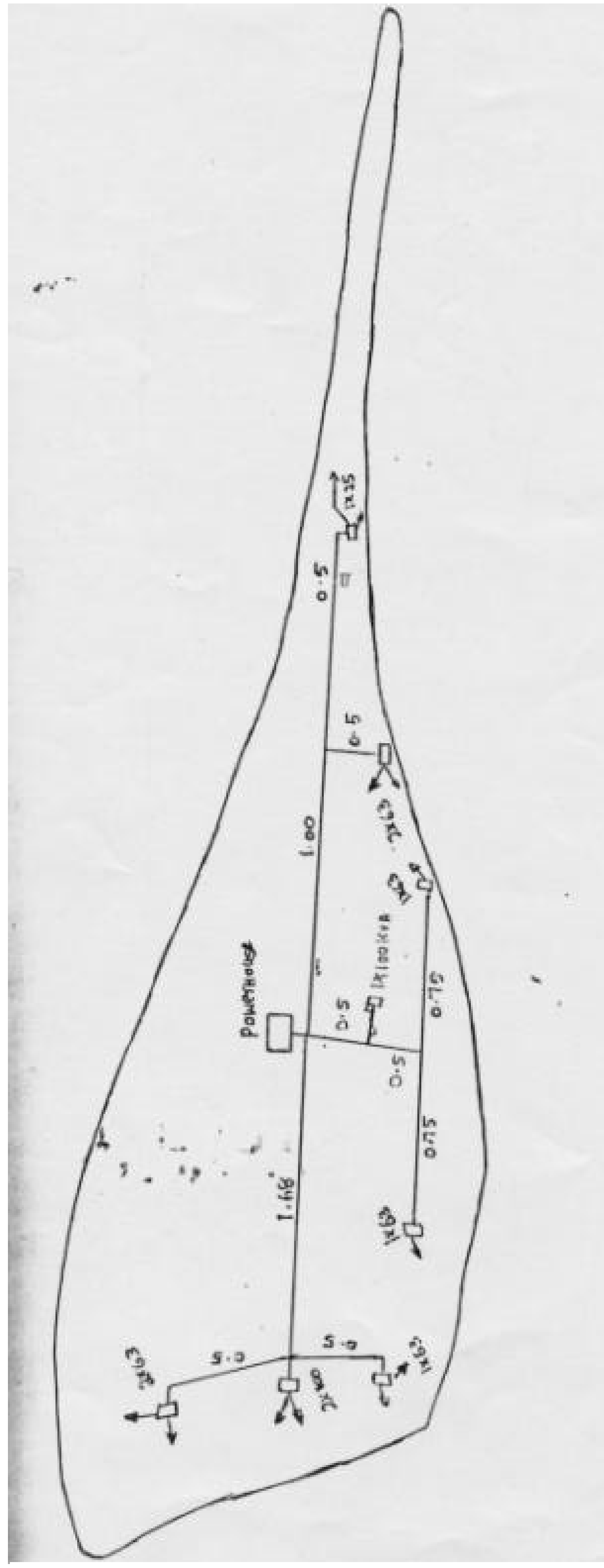


Gridmap of Kiltan Island

Annexure – 2



Grid map of Chetlat Island



Grid map of Agatti Island

Island-wise energy consumption and connected load (1996-2001)

1996-97

Island	*Installed capacity (kW)*	*Energy consumption (in '000 kWh)*				*Connected load (kW)*				*Connections*	
		Domestic	*Commercial*	*Industry*	*Street light*	*Domestic*	*Commercial*	*Industry*	*Street light*	*Domestic*	*Total*
Minicoy	1400	2534	484	47	55	2203	728	262	17	1552	1848
Kavaratti	1400	2096	866	67	126	1574	734	318	37	2285	2833
Amini	634	915	177	29	162	734	180	207	20	1515	1682
Androth	1000	1805	227	66	159	1754	202	281	35	2004	2345
Kalpeni	625	699	93	28	67	1121	256	104	22	872	1152
Agatti	703	928	185	35	27	880	252	120	16	1324	1528
Kadmat	550	608	188	47	37	578	269	194	20	1118	1425
Kiltan	310	369	179	17	85	490	130	69	10	887	1084
Chetlat	230	325	103	4	11	269	84	65	6	666	762
Bitra	62	23	11	1	1	36	16	7	3	80	145
Bangaram	74	0.2	156	-	0.2	0.3	7	-	0.5	1	7
		10302	**2669**	**341**	**73.0**	**9639**	**2868**	**1627**	**187**	**12304**	**14811**

Source: Lakshadweep Electricity Department, Kav

1997-98

Island	*Installed capacity (kW)*	*Energy consumption (in '000 kWh)*				*Connected load (kW)*				*Connections*	
		Domestic	*Commercial*	*Industry*	*Street light*	*Domestic*	*Commercial*	*Industry*	*Street light*	*Domestic*	*Total*
Minicoy	**1800**	**2599**	**475**	**66**	**69**	**2256**	**787**	**265**	**17**	**1589**	**1898**
Kavaratti	**1400**	**2020**	**1200**	**88**	**165**	**1621**	**752**	**325**	**37**	**2334**	**2900**
Amini	**634**	**1003**	**194**	**50**	**144**	**774**	**189**	**208**	**20**	**1556**	**1734**
Androth	**1000**	**1761**	**258**	**53**	**202**	**1857**	**213**	**288**	**35**	**2056**	**2409**
Kalpeni	**825**	**756**	**189**	**67**	**73**	**1161**	**386**	**104**	**22**	**915**	**1204**
Agatti	**980**	**991**	**255**	**37**	**22**	**898**	**257**	**121**	**16**	**1359**	**1565**
Kadmat	**750**	**681**	**272**	**57**	**105**	**610**	**302**	**197**	**20**	**1157**	**1480**

Kiltan	**310**	**435**	**182**	**17**	**84**	**504**	**132**	**69**	**10**	**902**	**1102**
Chetlat	**280**	**356**	**122**	**4**	**7**	**278**	**100**	**65**	**6**	**681**	**783**
Bitra	**62**	**31**	**19**	**3**	**3**	**38**	**16**	**7**	**3**	**84**	**110**
Bangaram	**74**	**0.2**	**156**	**-**	**0.1**	**300**	**7**	**-**	**3**	**1**	**7**
	8115	**10633**	**3322**	**442**	**874**	**9997**	**3141**	**1649**	**189**	**12634**	**13712**

Source: Lakshadweep Electricity Department, Kavaratti

Annexure – 3

Sheet 2 of 3

1998-99

Island	*Installed capacity (kW)*	*Energy consumption (in '000 kWh)*				*Connected load (kW)*				*Connections*	
		Domestic	*Commercial*	*Industry*	*Street light*	*Domestic*	*Commercial*	*Industry*	*Street light*	*Domestic*	*Total*
Minicoy	1800	2793	569	94	47	2765	818	265	19	1650	1963
Kavaratti	1800	2027	1248	89	168	1665	785	325	38	2386	2962
Amini	1034	1053	198	35	157	844	218	220	20	1602	1788
Androth	1280	1721	395	49	247	2021	234	305	36	2138	2507
Kalpeni	1075	797	196	78	96	1191	405	116	22	948	1257
Agatti	1152	1109	289	31	70	934	267	128	16	1411	1625
Kadmat	750	728	270	51	108	653	332	197	21	1214	1547
Kiltan	510	489	175	19	84	527	142	72	11	930	1137
Chetlat	430	326	134	10	11	287	103	103	6	699	809
Bitra	62	32	14	3	5	40	17	7	3	87	114
Bangaram	74	0.2	144	-	1	0.3	37	-	0.5	1	8
	9967	11075	3632	459	994	10927	3358	1738	193	13066	15717

Source: Lakshadweep Electricity Department, Kavaratti

1999-2000

Island	*Installed capacity (kW)*	*Energy consumption (in '000 kWh)*				*Connected load (kW)*				*Connections*	
		Domestic	*Commercial*	*Industry*	*Street light*	*Domestic*	*Commercial*	*Industry*	*Street light*	*Domestic*	*Total*

Minicoy	1800	3045	675	167	64	2977	851	298	19	1703	2042
Kavaratti	1800	1990	1107	94	201	1716	807	325	38	2439	3031
Amini	1034	1109	194	37	151	879	229	220	20	1643	1839
Androth	1250	1858	420	337	340	2130	267	317	40	2184	2573
Kalpeni	1060	833	205	37	126	1196	428	137	23	982	1306
Agatti	1140	1225	302	25	76	961	313	134	16	1435	1660
Kadmat	750	777	320	73	115	694	341	200	20	1157	1438
Kiltan	510	487	168	23	80	549	143	72	10	953	1163
Chetlat	430	354	122	65	9	297	114	103	6	715	829
Bitra	64	39	12	2	9	41	24	8	3	89	117
Bangaram	74	0.2	148	-	0.8	0.3	8	-	3	1	7
	9912	11717	3673	860	-	11440	3525	1814	198	13301	16005

Source: Lakshadweep Electricity Department, Kavaratti

Annexure – 3
Sheet 3 of 3

2000 – 2001

Island	*Installed capacity (kW)*	*Energy consumption (in '000 kWh)*				*Connected load (kW)*				*Connections*	
		Domestic	*Commercial*	*Industry*	*Street light*	*Domestic*	*Commercial*	*Industry*	*Street light*	*Domestic*	**Total**
Minicoy	1800	3075	656	113	69	4280	5980	307	19	1743	2102
Kavaratti	1800	1965	1244	74	227	1805	862	340	38	2585	3211
Amini	1034	1043	228	57	149	908	250	233	20	1684	1892
Androth	1250	1786	399	330	502	2214	280	345	41	2254	2665
Kalpeni	1060	809	199	35	129	1241	456	136	22	1025	1358
Agatti	1140	1223	381	20	85	998	328	140	16	1476	1715
Kadmat	750	802	364	138	118	740	365	200	20	1214	1503
Kiltan	510	465	182	13	82	575	145	73	6	966	1179
Chetlat	430	359	122	12	9	301	118	113	6	725	846

Bitra	64	34	14	2	9	42	23	8	3	91	119
Bangaram	84	0.2	157	-	0.9	0.3	37	-	0.5	1	7
	9922	**11562**	**3946**	**497**	**1380**	**13104**	**8844**	**1895**	**192**	**13764**	**16602**

Source: Lakshadweep Electricity Department, Kavaratti

Annexure – 4

Island-wise Projected Electricity demand, 2006-7 and 2010-11 (in '000 kWh)

	Domestic		*Commercial*		*Public lighting*		*Industrial*	
Island	*2006 - 07*	*2010-11*	*2006 - 07*	*2010-11*	*2006 - 07*	*2010-11*	*2006 - 07*	*2010-11*
Minicoy	3444	3950	734	825	80	97	126	170
Kavaratti	2201	2895	1394	1568	253	305	84	115
Amini	1168	1392	255	226	166	196	65	80
Androth	2001	2432	448	605	562	668	46	68
Kalpeni	905	1098	225	272	144	174	40	51
Agatti	1370	1663	427	490	95	115	25	33
Kadmat	898	1097	401	470	146	180	154	176
Kiltan	520	640	203	240	92	112	15	25
Chetlat	403	489	136	170	11	17	13	18
Bitra	40	52	20	24	10	15	3	4
Bangaram	1	6	175	225	10	16	-	-
	12951	**15714**	**4418**	**5215**	**1569**	**1895**	**571**	**740**

Source: Lakshadweep Electricity Department, Kavaratti

Annexure – 5

Monthly Island wise solar energy generation potential (kWh)*

		Lakshadwep	**Chetlat**	**Kiltan**	**Kadmat**	**Amini**	**Agatti**	***Kavaratti***	**Androth**	**Kalpeni**	**Minicoy**	**Bitra**	**Bangaram**
	Area (Ha)	3200	114	163	312	259	388	422	484	279	439	10	58
	Area assumed to be available for SPV (Ha)	13.9	0.54	0.77	1.48	1.23	1.84	2.00	2.29	1.32	2.08	0.05	0.27
	Global Solar Radiation (kWh/m²/day)												
J	5.127	*727826*.0	28337.5	40517.6	77555.2	64380.8	96446.9	104898.4	120310.0	69352.3	109124.2	2485.7	14417.3
F	5.765	818396.1	31863.8	45559.6	87206.1	72392.3	108448.7	117951.9	135281.3	77982.4	122703.5	2795.1	16211.4
M	6.270	890085.6	34655.0	49550.5	94845.2	78733.7	117948.5	128284.2	147131.6	84813.5	133452.0	3039.9	17631.5
A	6.043	857860.8	33400.3	47756.6	91411.4	75883.2	113678.3	123639.8	141804.9	81742.9	128620.5	2929.9	16993.1
M	4.984	707525.8	27547.1	39387.5	75392.1	62585.1	93756.8	101972.6	116954.4	67417.9	106080.5	2416.4	14015.2
J	3.926	557332.7	21699.4	31026.4	59387.9	49299.6	73854.2	80326.0	92127.4	53106.5	83561.8	1903.5	11040.1
J	3.779	536464.7	20886.9	29864.7	57164.3	47453.7	71088.9	77318.3	88677.9	51118.0	80433.1	1832.2	10626.7
A	4.268	605882.9	23589.7	33729.1	64561.3	53594.1	80287.8	87323.3	100152.8	57732.7	90841.0	2069.3	12001.8
S	4.946	702131.3	27337.1	39087.2	74817.3	62107.9	93042.0	101195.2	116062.7	66903.9	105271.7	2398.0	13908.3
O	4.682	664654.1	25877.9	37000.9	70823.8	58792.8	88075.7	95793.7	109867.7	63332.8	99652.7	2270.0	13166.0
N	4.727	*671042*2	26126.6	37356.5	71504.5	59357.9	88922.3	96714.4	110923.6	63941.5	100610.5	2291.8	13292.5
D	4.672	663234.5	25822.7	36921.9	70672.5	58667.3	87887.6	95589.1	109633.0	63197.5	99439.9	2265.1	13137.8
		8402436.8	327144.1	467758.6	895341.6	743248.3	1113437.7	1211006.9	1388927.4	800642.0	1259791.6	28696.8	166441.7

* The area of the solar panels is assumed to cover only 50% of the total area available for SPV installations. A solar panel efficiency of 11% has been used to calculate the power generation potential and further, a factor of 0.6 has also been used to take into account the effective number of sunshine hours, dust, cloud cover, etc.

Annexure – 6

European small wind turbine manufacturers

Name	Country	Products
Vergnet	France	From 15 KW to 200 KW Preferred 60 KW GEV 15/60
Travere	France	
Ecolab	France	
Enercon	German	80 KW (E 16/17/18) 200 KW (E30)
Ecotecnia	Spain	
Adler	Germany	165 KW
Aeroman	Germany	33 (33 KW)
AN Bonus	Danish	150 KW
Fuhrländer	Germany	AstOs 100 (100 KW)
HSW	Germany	HSW 30 (33 KW)
Kano-Rotor	Germany	KN 30 (30 KW)
Krogman	Germany	Krogman 15 (50 KW)
Lagerway	Germany	LW 15/18 (50 … 80 KW)
NEG Micon	Danish	M 3000 (55 KW) M 450 (150 KW) M 530 (200 KW)
Nordex	Danish	N 27 (150 KW)
Nordtank	Germany	NTK 150 (150 KW)
Seewind	Germany	Seewind 110/132 (110 ... 132 KW)
Südwind	Germany	Serie 1200 (30 … 45 KW)
Tacke	Germany	TW 45/60/80 (60 … 80 KW)
Ventis	Germany	Ventis 20-100 (100 KW)
Vestas	Danish	Vestas V 17/20 (75 … 100 KW)
WKA Dülmen DWA	Germany	50 KW
WTN	Germany	WTN 200 (200 KW)
Wind World	Germany	WWW 2500/2700 (200 KW)

Annexure – 7

Monthly Island wise wind energy generation potential (kWh)

	Lakshadweep	Chetlat	Kiltan	Kadmat	Amini	Agatti	Kavaratti	Androth	Kalpeni	Minicoy	Bitra	Bangaram
Coastline length on longer side: axis N-S (km)*	132	2.0	3.0	8.0	6.0	6.0	8.0	8.0	6.0	8.0	0.5	1.0
Coastline length assumed to be available for wind (km)	14.1	0.5	0.8	2.0	1.5	1.5	2.0	2.0	1.5	2.0	0.1	0.3
Number of turbines @100m spacing	140	5	7	20	15	15	20	20	15	20	1	2

Annual wind energy from one turbine (Vergnet GEV 15/60) in kWh
61963.0

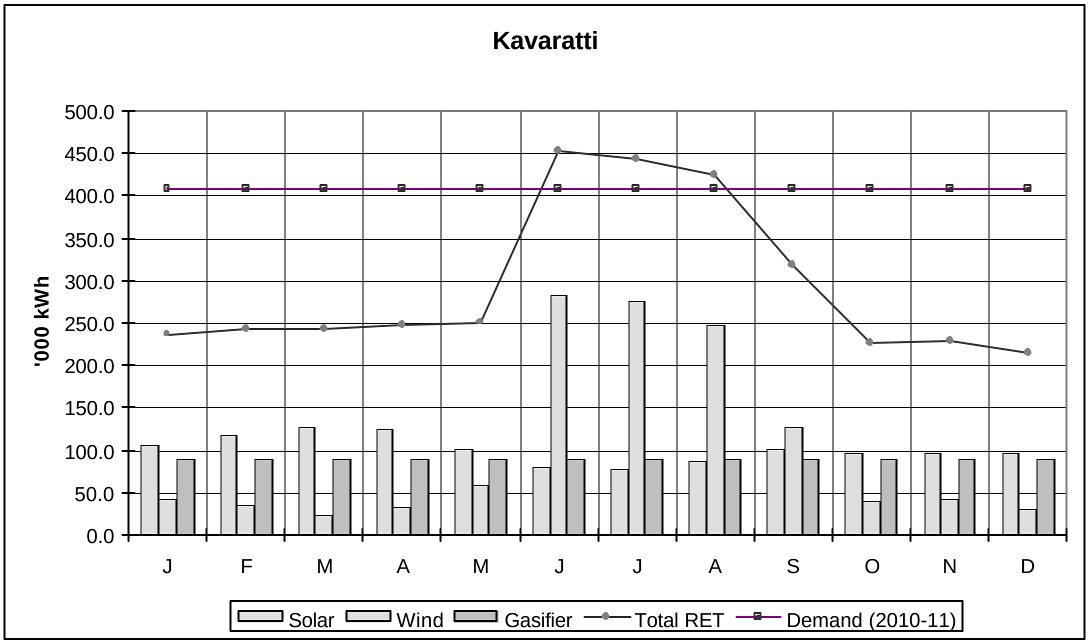
	Monthly wind energy per turbine (kWh)	Lakshadweep	Chetlat	Kiltan	Kadmat	Amini	Agatti	Kavaratti	Androth	Kalpeni	Minicoy	Bitra	Bangaram
J	2106.742	294943.9	10533.7	14747.2	42134.8	31601.1	31601.1	42134.8	42134.8	31601.1	42134.8	2106.7	4213.5
F	1765.946	247232.4	8829.7	12361.6	35318.9	26489.2	26489.2	35318.9	35318.9	26489.2	35318.9	1765.9	3531.9
M	1171.101	163954.1	5855.5	8197.7	23422.0	17566.5	17566.5	23422.0	23422.0	17566.5	23422.0	1171.1	2342.2
A	1703.983	238557.6	8519.9	11927.9	34079.7	25559.7	25559.7	34079.7	34079.7	25559.7	34079.7	1704.0	3408.0
M	2949.439	412921.4	14747.2	20646.1	58988.8	44241.6	44241.6	58988.8	58988.8	44241.6	58988.8	2949.4	5898.9
J	14084.190	1971786.6	70420.9	98589.3	281683.8	211262.8	211262.8	281683.8	281683.8	211262.8	281683.8	14084.2	28168.4
J	13842.534	1937954.8	69212.7	96897.7	276850.7	207638.0	207638.0	276850.7	276850.7	207638.0	276850.7	13842.5	27685.1
A	12324.441	1725421.7	61622.2	86271.1	246488.8	184866.6	184866.6	246488.8	246488.8	184866.6	246488.8	12324.4	24648.9

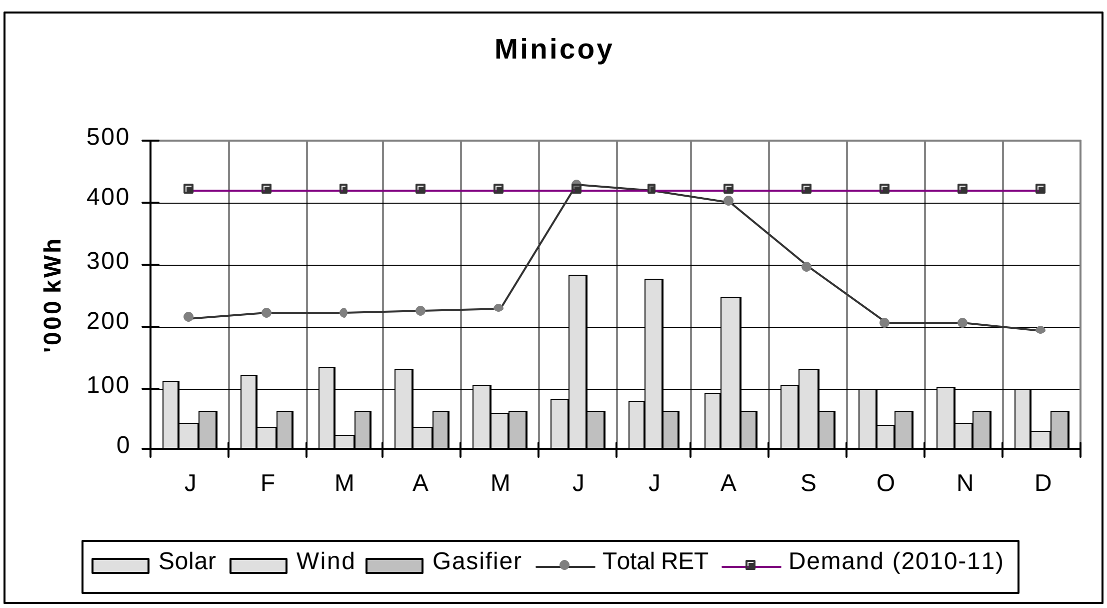
S	6406.974	896976.4	32034.9	44848.8	128139.5	96104.6	96104.6	128139.5	128139.5	96104.6	128139.5	6407.0	12813.9
O	2044.779	286269.1	10223.9	14313.5	40895.6	30671.7	30671.7	40895.6	40895.6	30671.7	40895.6	2044.8	4089.6
N	2081.957	291474.0	10409.8	14573.7	41639.1	31229.4	31229.4	41639.1	41639.1	31229.4	41639.1	2082.0	4163.9
D	1480.916	207328.2	7404.6	10366.4	29618.3	22213.7	22213.7	29618.3	29618.3	22213.7	29618.3	1480.9	2961.8
		8674820.0	309815.0	433741.0	1239260.0	929445.0	929445.0	1239260.0	1239260.0	929445.0	1239260.0	61963.0	123926.0

?? The coastline length for each island has been estimated based on the electrical grid maps provided by the Electricity Department

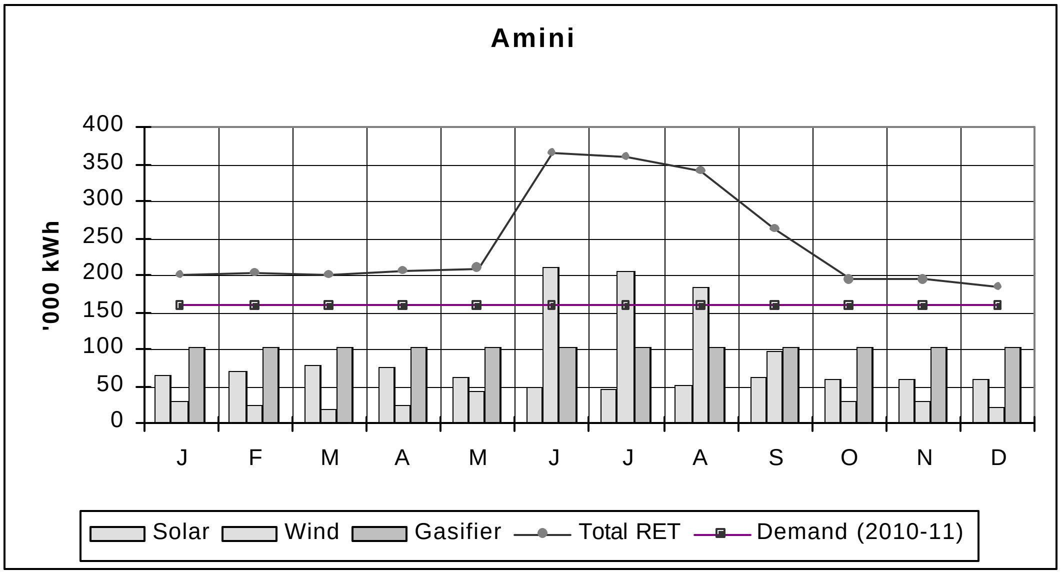
Island wise RET potential and electricity demand

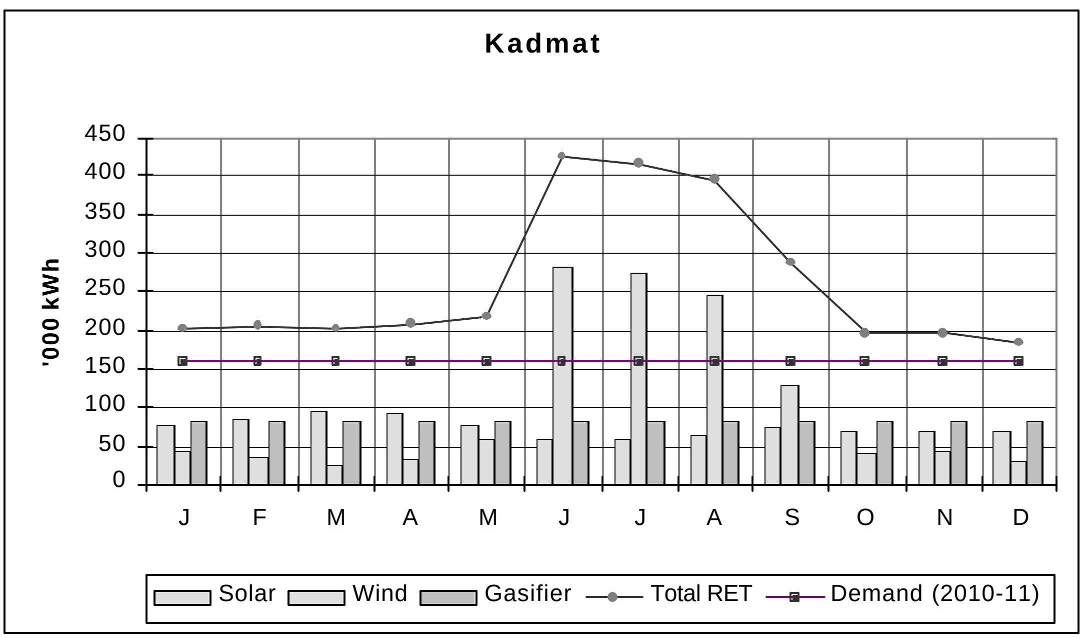
Category 1: Projected Electricity Demand is higher than RET potential

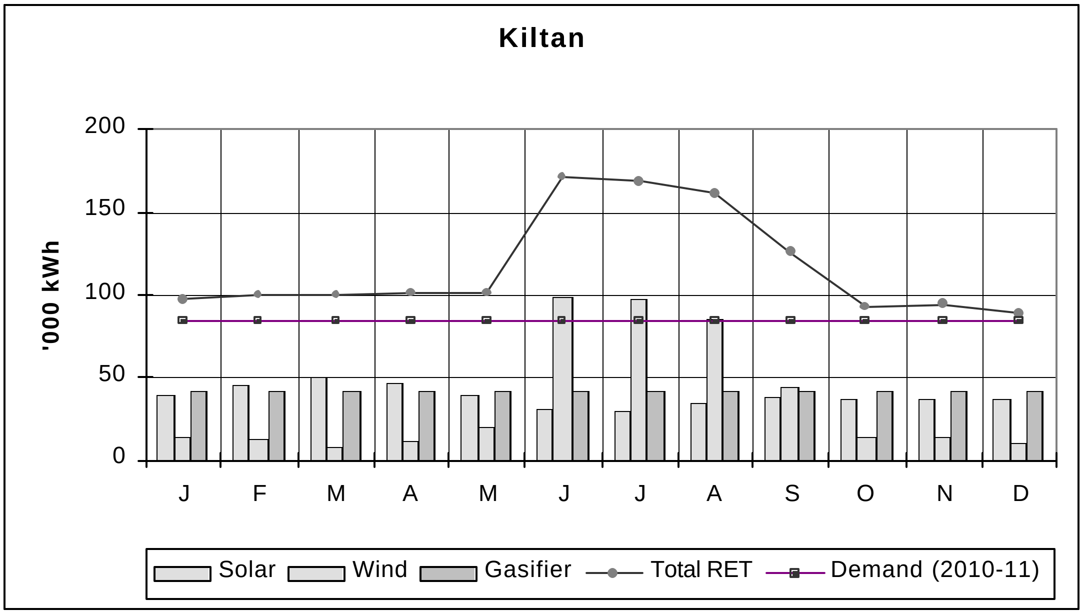


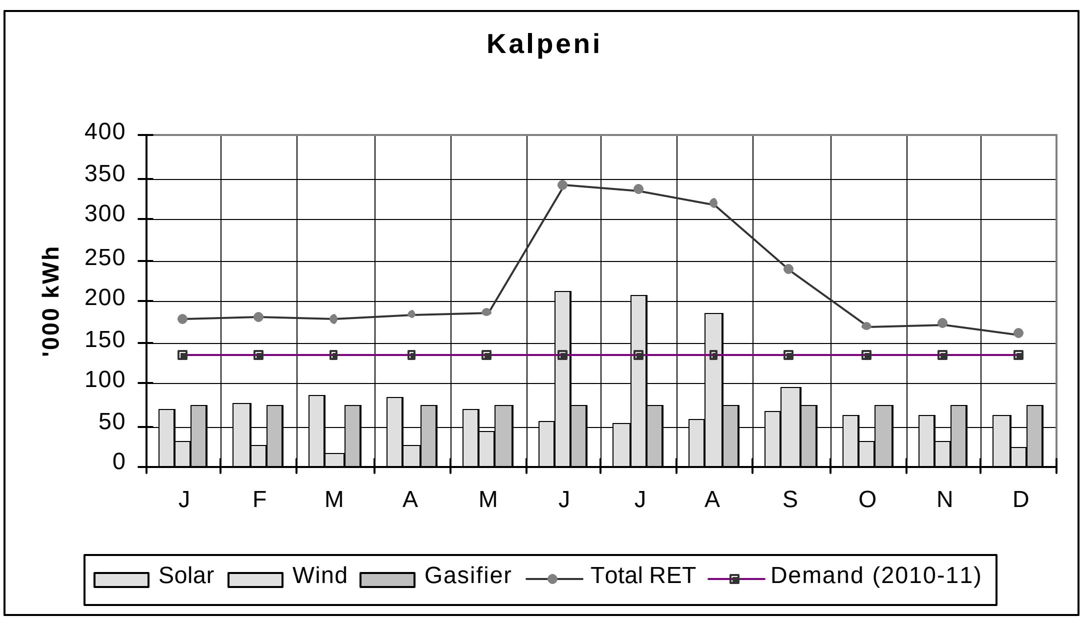


Category 2: RET potential higher than projected electricity demand






Kiltan
'000 kWh
200
150
100
50
0
J F M A M J J A S O N D
Solar
Wind
Gasifier
Total RET
Demand (2010-11)


Kalpeni
'000 kWh
400
350
300
250
200
150
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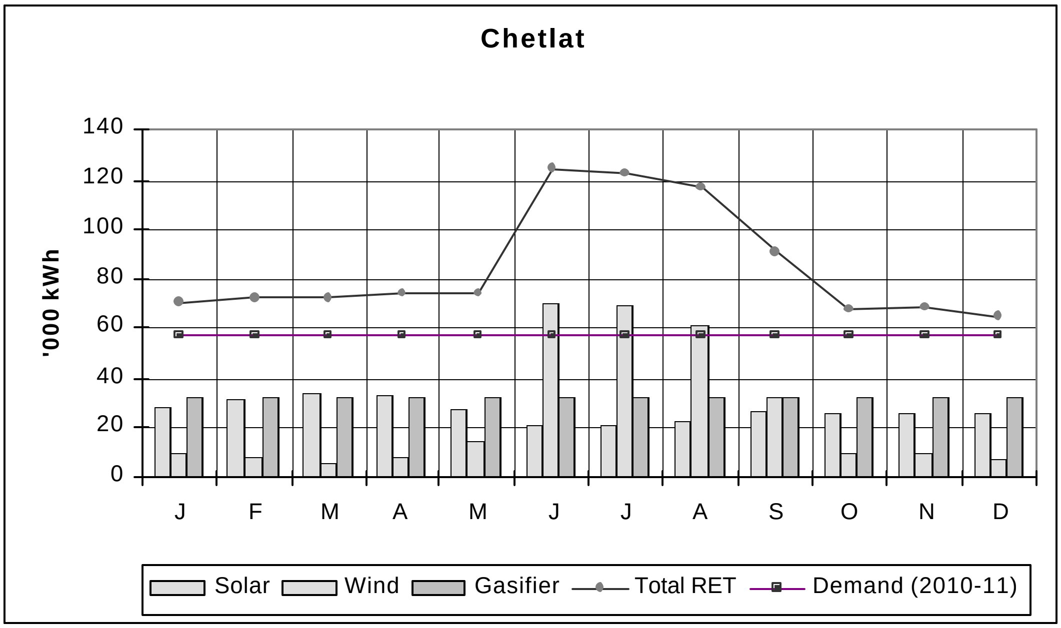
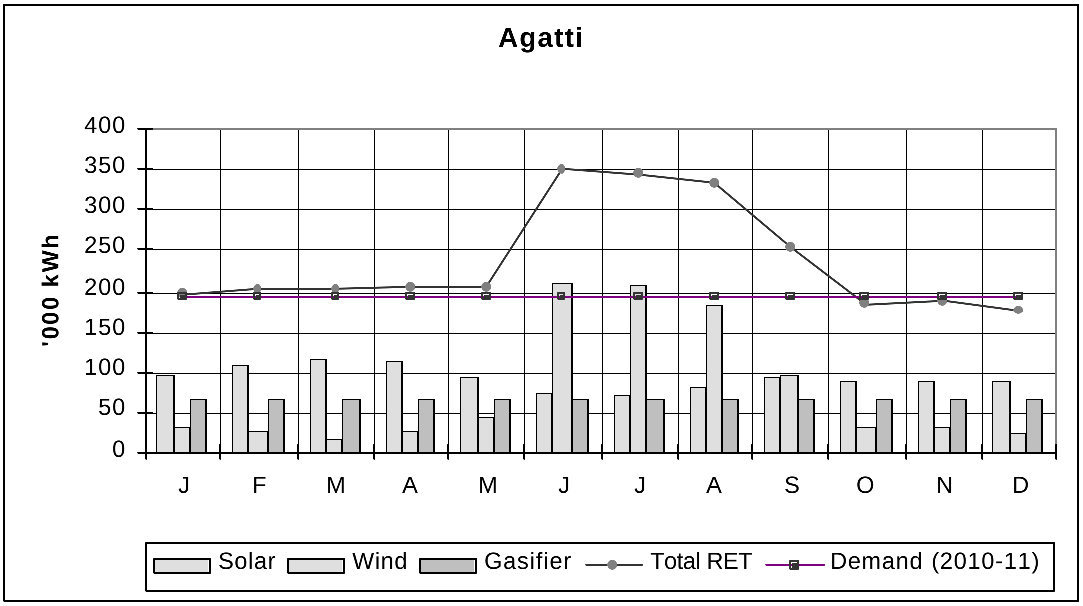
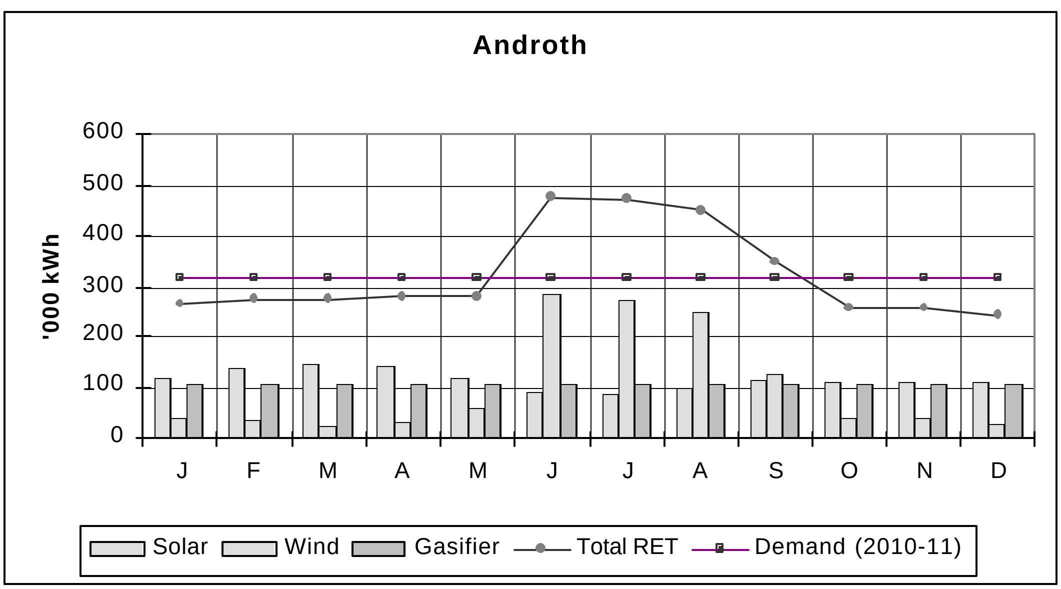
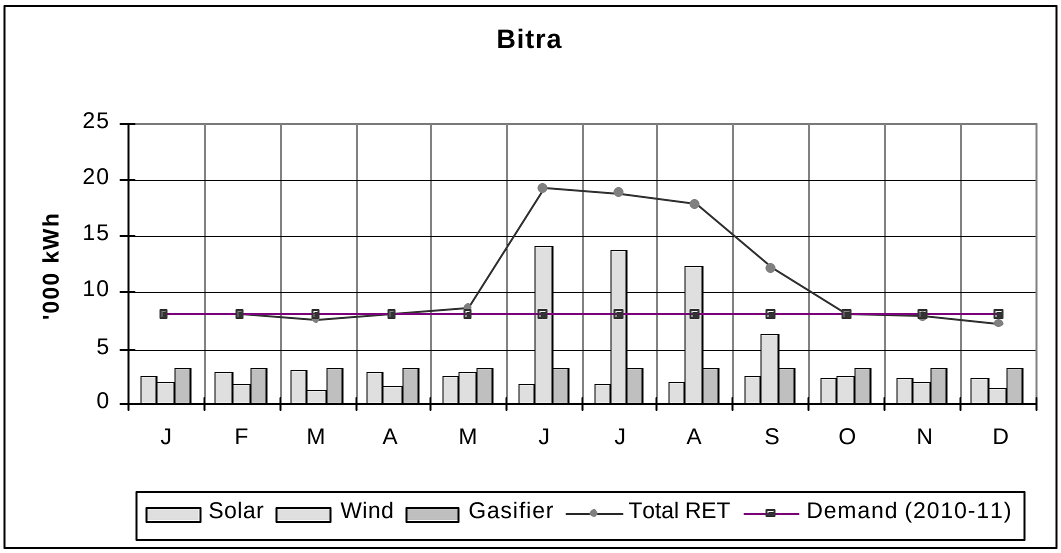
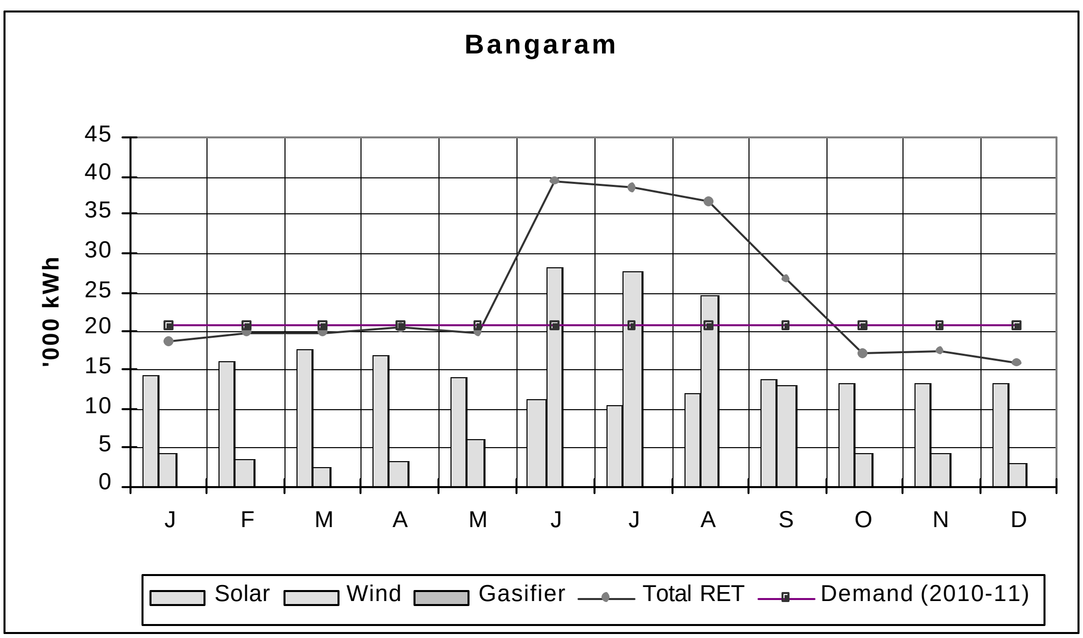
50
0
J F M A M J J A S O N D
Solar
Wind
Gasifier
Total RET
Demand (2010-11)


Chetlat
'000 kWh
140
120
100
80
60
40
20
0
J F M A M J J A S O N D
Solar
Wind
Gasifier
Total RET
Demand (2010-11)


Agatti
'000 kWh
400
350
300
250
200
150
100
50
0
J F M A M J J A S O N D
Solar
Wind
Gasifier
Total RET
Demand (2010-11)


Androth
'000 kWh
600
500
400
300
200
100
0
J F M A M J J A S O N D
Solar
Wind
Gasifier
Total RET
Demand (2010-11)


Bitra
'000 kWh
25
20
15
10
5
0
J F M A M J J A S O N D
Solar
Wind
Gasifier
Total RET
Demand (2010-11)


Bangaram
'000 kWh
45
40
35
30
25
20
15
10
5
0
J F M A M J J A S O N D
Solar
Wind
Gasifier
Total RET
Demand (2010-11)