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Assessment of Hydrogen Generation Potential from Biomass and its Application for Power Generation in Andaman and Nicobar Islands: A Review

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Abstract: The Andaman and Nicobar Islands located southeast of Bay of Bengal in the Indian Ocean comprises of several small islands separated by sea over large distances which makes it impractical for electrifying all the islands by a single grid. A population of 380,581 (Census, 2011) living in these group of islands get their electricity demand catered through Diesel Generator Sets from 34 power houses with an aggregate capacity of 67.8 MW. Unavailability of any form of conventional fossil fuel reserves in the islands makes the diesel supplied in barges from southeastern coast of India as a sole lifeline for its power generation. Hence there is an urgent need for the development of a self sustainable model from non conventional energy resources to not only cater for the power demands but also to reduce the GHG emissions related with diesel powered generator sets.

This paper discusses a self sustainable model for Andaman and Nicobar Islands that would cater the electrical demand through hydrogen produced from waste biomass resource which has a potential of replacing 86.65% of the diesel utilized in the diesel generator sets. The reduction in both the GHG emission and the cost of power generation would be evaluated to understand the impact of the self sustainable model on the environment and the livelihood of the local population of Andaman and Nicobar Islands.

Keywords: Bio-Hydrogen, Biomass Gasifcation, Power Generation, Dual Fuel, CO2 emission

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1 Introduction: The Andaman and Nicobar Islands is a Union Territory of the Republic of India which are located in the Bay of Bengal between 100°N - 140°N (Latitudes) and 920°E - 950°E (Longitudes). The two island group has a population of 380,581 as per the census of India [1] and has a total land area 7,950 km^2 spread over 572 small islands. Most part of the islands is covered under tropical rainforest with 48,675 hectares under agricultural cultivation. The geographical location of island is shown in Figure (1) below.

2. Power generation scenario in Andaman and Nicobar Islands: In the pre independence era of 1926, A 100 kW DG generator set was installed at the Ross Island by the British Empire. Further in the year 1929, A 100 kW Direct Current DG set was installed. The installation of Alternating Current DG sets for the rest of the islands got a pace in the post-independence era after the installation of two steam turbine based generator sets of 550 kW each which was run from the boilers fuelled from the waste products of saw mill at the Chatham Island in 1951. Later on, many diesel based AC generator sets were installed until now through the island which are listed in the Table (1) below [2].

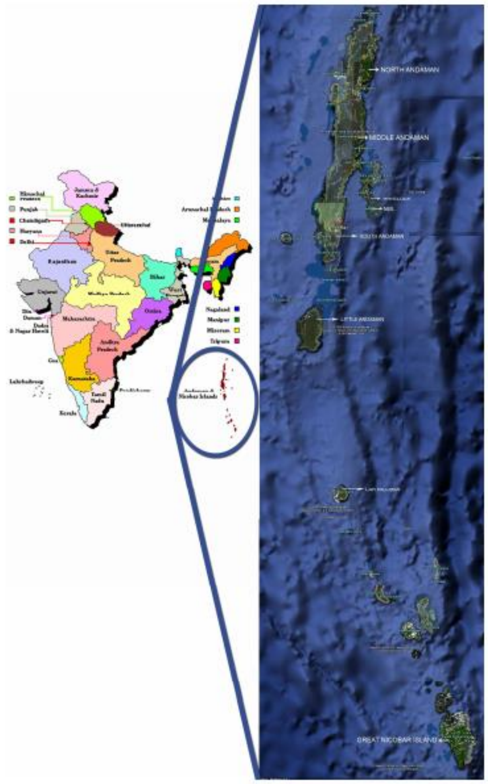

Figure (1): Andaman and Nicobar Islands

The geographical and topographical peculiarities of the islands create a barrier for development of a unified power grid for the group of islands. As these islands are separated by sea over great distances separate power houses are installed in the individual islands to cater their needs of power requirements. At present Andaman and Nicobar Islands have a total of 34 power houses with DG sets of capacities ranging from 6 – 12500 kW. A total capacity of 63.21 MW is installed throughout the Andaman and Nicobar Islands to cater the electricity demand of 241 MU annually and produce only 180 MU with peak demand of 37 MW with a deficit of 60 MU **[3]**. Most of these power houses operate round the clock for supplying power in South, Middle, North Andaman Islands, Neil Island, Havelock Island, Long Island, Little Andaman Island, Car Nicobar Islands, Katchal Islands, Kamorta Islands, Campbell Bay. 16 Hrs power supply is provided in Chowra, Campion and Teressa Islands. M/s Suryachakra is operating a 20 MW DG Power House at south Andaman on PPA basis. The detailed sector-wise consumption of electricity in Andaman and Nicobar Islands is given in figure (2) below. As per the annual electric power survey by central electric authority the peak demand in Andaman and Nicobar Islands would rise up to 323 MW by 2026-27 **[4]**.

Table (1): List of power house installed in Andaman and Nicobar Islands **[2]**.

S. No.	**Location**	**kW**	**Hours Run**
1	SMITH ISLAND	24	15-16
2	KHEP (HYDRO)	5250	24
3	SITA NAGAR	1360	24
4	JAGGANATH DERA	24	15-16
5	PACHIM SAGAR	50	15-16
6	HANSPURI	12	15-16
7	RANGAT BAY	5075	24
8	LONG ISLAND	380	24

9	STAIT ISLAND	75	15-16
10	HAVELOCK	1330	24
11	NEIL	560	24
12	BARATANG	380	24
13	IPP	20000	15-16
14	SHOL BAY	24	24
15	CHATHAM	12500	24
16	PHONEIX BAY	9018	24
17	RUT ISLAND	12	15-16
18	DUGONG CREEK	45	15-16
19	HUT BAY	4200	24
20	CAR NICOBAR	2520	24
21	CHOWRA	128	15-16
22	TERRASA	290	15-16
23	PILPILLO	24	15-16
24	KATCHAL	568	24
25	KAKANA	24	15-16
26	KAMORTA	768	24
27	CHAMPION	245	24
28	CHAMPBELL BAY	2962	24
	Total (kW)	67848	

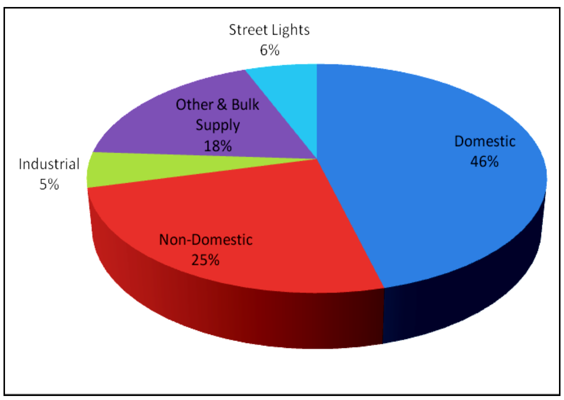

Figure (2): Sectorwise electricity consumption in Andaman and Nicobar Islands [2].

3. Fuel Demand: The power generated has been steadily increasing over the years to meet the demand of the people in the Islands. Since, the Diesel Generating sets were the only source of power, diesel has to be transported from Chennai (Tamil Nadu) in barrels. As per the requirement of 63.21 MW diesel Power Generator Sets with peak demands of 37 MW, Andaman consumes 48,000 KL annually [2] which accounts to 80% of the electricity generation cost. These barrels are transported in cargo barges to the Islands and stored for use. The transportation of diesel for power generation in these islands has results in high cost of power generation which is further provided to the customers in Andaman and Nicobar islands with a huge amount of subsidies by the government. Andaman & Nicobar Island remains third highest recipient diesel subsidy (Rs. 3,118 per capita) for the financial year 2012-13 [5].

4. Environmental Effects of Diesel Generator Sets: Diesel generator sets use about 2-3 times more energy than a large combustion plant to produce the same amount of energy in the form of electricity. Diesel as a fuel contains 82.6% of carbon which results in higher carbon based emissions in addition to various other harmful pollutants. This results in 3 times higher CO_2 emissions when compared to modern power plant. The CO_2 emissions for Andaman and Nicobar islands based on the fuel consumption is estimated as shown below.

1 liter diesel = 0.84 kg diesel.
Diesel consist for 86.2% of carbon = 0.72 kg of carbon per liter diesel.

In order to combust this carbon to CO_2, 1.92 kg of oxygen is needed. The sum is then 0.720 + 1.920 = 2.640 kg of CO_2 / liter diesel.

Total CO_2 emission per year in Andaman and Nicobar Islands due to Diesel Engines is thus estimated to be 126.720 kilotons per year.

5. Utilization of Biomass for power generation: Abundant availability of biomass in Andaman and Nicobar Islands makes it the most promising renewable energy resource that could be utilized for power generation. A study conducted on one of the islands in the literature evaluates biomass gasification as the cheapest source of power generation in the island when compared to other conventional and Non-conventional sources of energy. Furthermore, Biomass is considered as a carbon neutral fuel and utilization of the waste biomass residues would help in reducing carbon based emissions in the atmosphere. Agricultural crop residue can undergo gasification to produce Syn-Gas which could be used in already available infrastructure of Diesel Generators set on dual fuel mode in Andaman and Nicobar Islands to reduce the diesel consumption and the emissions associated with it.

Many studies have been conducted to assess the replacement of diesel fuel by the gasification of biomass in the internal combustion engine. The use of coffee husk as biomass for gasification helped in achieving 31% replacement of the diesel fuel in the dual fuel mode **[6]**. The Largest biomass gasifier based power plant in India with a capacity of 500 kW was technically evaluated by Sonatan et al. **[7]** and reported 64% diesel replacement by the use of wood chips biomass. A. S. Ramadhas et al. also observed a diesel saving of 72% at 50% load on the dual fuel mode with the syn-gas obtained from gasification of Coir Pith. He also observed that the producer gas engine could run only upto 50-60% of the full load. The use of waste biomass from the agricultural residues further reduced the power generation cost as compared to conventional methods **[8]**.

6. Assessment of biomass utilization for power generation in Andaman and Nicobar Islands: Major crops under cultivation in A&N islands are coconut and arecanut with a total area under cultivation of 21689.19 and 14869 Ha respectively **[9]**. Other crops are cashewnut, cereals like paddy and maize, pulses, oil seeds, spices such as black pepper, clove, cinnamon, ginger, chilli and turmeric, fruit crops such as mango, banana, citrus fruits, papaya, pineapple, sapota etc. and root crops. Agriculture residues of coconut, arecanut and red oil palm alone are considered for the assessment. Biomass residues from other crops such as paddy, maize, oil seeds, spices and fruit crops have not been considered owing to the limited production, consumption of the residue as fodder for cattle and transportation costs.

The surplus biomass residue that would be available for the power plant was worked out after deducting the residue that is consumed for various purposes. Coconut frond, stem and leaves are used for roofing, to retain water in agricultural field, coir making and also to retain the fertility of soil. Peduncle does not have any domestic use. However, 10% of the residue is assumed to be lost in pilferage. 40% of husk and shell are assumed to be used in copra making and as domestic fuel. The Total surplus biomass residue considered for further assessment is given in table (2) below.

Table (2): Total Biomass Surplus Residue [9]

Biomass	Quantity (Kton)/Year
Coconut residue	129.614
Arecanut	14.202
Red Oil Palm	6.810
Total	**150.626**

7. Hydrogen production potential from biomass residue: Hydrogen can be produced from the gasification of the biomass residue to form syngas which is further processed to produce high-purity hydrogen to remove tars and particulates are not as much of a concern. To raise the hydrogen content, the product syngas is fed to one or more water gas shift (WGS) reactors, which convert CO to H_2 via the water gas shift reaction:

$$CO + H_2O \rightarrow H_2 + CO_2$$

The gas stream leaving the first WGS stage has CO content of about 2%; in a second stage this is reduced further to about 5000 ppm. The remaining CO can be removed by a pressure-swing adsorption (PSA) system. The CO_2 can be captured and bottled for further uses as shown in the below figure (3).

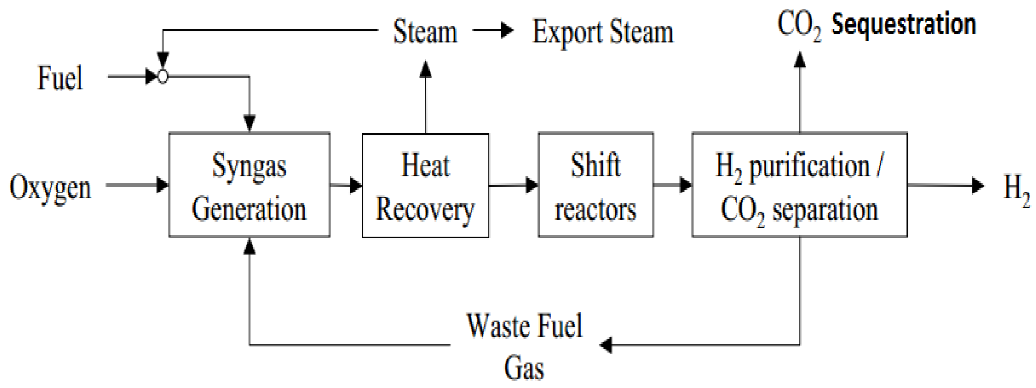

Figure (3): Hydrogen production from biomass **[3]**

As per the comprehensive industrial documents for producer gas plants and biomass gasifiers, the general composition syngas from biomass gasification process is given in below in table (3). It is also reported that biomass gasification would yield 2.5 to 3.0 NM^3 /kg of biomass feedstock **[10]**. Assuming, H_2 composition to be 20% and CO composition to be 17% in the derived syngas after the gasification of coconut, arecanut and red oil palm in the above assessment and with a yield of 2.7 NM^3/kg we would get a total of 4.06 x 10^8 NM^3/year with composition of hydrogen and carbon monoxide as shown in table (4) below.

Table (3): General composition of producer gas **[10]**

Composition	Value (% Vol.)
Carbon Monoxide (CO)	19-21
Hydrogen (H_2)	19-21
Methane (CH_4)	2-4
Carbon Dioxide (CO_2)	8-12
Nitrogen (N_2)	Balance

Table (4): Total Gas Yield

Gas Yield	Quantity (NM^3/year)
Total Gas Yield	406690200
H_2 (20%)	81338040
CO (17%)	69137334

Since by water gas shift reaction, 1 mol of Carbon Monoxide would give 1 mol of Hydrogen. And the total Carbon Monoxide can be converted to Hydrogen. Hence total hydrogen that would be generated per year would be 1.5047×10^8 NM^3.

8. Hydrogen energy potential and its application:

Energy from Hydrogen = 1.535×10^6 GJ
Energy currently utilized as Diesel Fuel = 1.77×10^6 GJ
Hence with the help of Hydrogen we can generate 86.65% of the Energy produced by Diesel. This will further help in reduction of carbon based emissions from the power generation sector in the Andaman and Nicobar Islands by 109.802 kilotons per year.

Using Hydrogen in Dual Fuel Mode in the existing infrastructure of Diesel based generator sets with 20% Energy share would reduce specific CO_2 Emission by about 40% **[11]**. Installation of dedicated Spark Ignition Gensets fuelled with hydrogen to cater to the deficit of 60 MU i.e. 2.16×10^6 GJ power requirement in Andaman and Nicobar Islands.

9. Conclusions: It is clear from the above review study that there is a significant potential in utilization of biomass residue for power generation for making a self sustainable energy model in Andaman and Nicobar Islands. As assessed in the paper, conversion of biomass to bio-hydrogen through the gasification route has the following benefits:

1. Hydrogen derived from biomass gasification is completely carbon neutral and the carbon dioxide formed in the process can be bottled for other purposes.
2. A total amount of 1.5047×10^8 NM^3 of hydrogen can be produced from the biomass gasification route.
3. With the utilization of hydrogen for power generation, 86.65% of the diesel consumption of the DG set can be relaced.
4. Tailpipe carbon based emission from the Diesel based genset can be reduced by 109.802 kilotons per year with the use of Hydrogen.
5. Hydrogen can be utilized in a dual fuel mode in the existing DG set and an energy ratio of 20% to achieve 40% reduction in tailpipe specific CO_2 emission.
6. Hydrogen can be utilized in spark ignition engine to cater for 60 MU deficits in Andaman and Nicobar islands.

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