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Distributed Green Power Systems to Electrify a Village – A Comparative Study

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ABSTRACT

Different systems based on various renewable energy sources have been developed as per specifications, norms and guidelines issued by Ministry of New and Renewable Energy, Government of India from time to time and other companies as per R & D carried out in their research centres. As far as local availability of resources is concerned, in general, all are some of the renewable resources like - solar, wind, cattle, perennial streams, agricultural & forest residues and waste land are available in most of the un-electrified remote villages of Madhya Pradesh being considered for electrification. Analysis of possibilities of electrifying a typical village having all the natural resources mentioned earlier with pros and cons and components associated with each option with a focus on optimization of a suitable hybrid model having combination of two or more systems dependent on locally available resources is to be highlighted. Option VI (Solar Photovoltaic + 100% biogas gen-set) is advised to be the best, green and eco-friendly alternative for electrification of remote un-electrified villages. In this option waste materials like- cow dung, de-oiled cake etc would not only be converted to valuable bio-manure but also to biogas which would be used for power production.

***Key words** - Village Electrification through Renewable Systems, Renewable Systems, Standalone Systems, Hybrid Systems,*

INTRODUCTION

Distributed power is, generally considered as small scale power generation at the places of consumption. When distributed power generation is dependent on locally available renewable energy sources, it is said to be distributed green power.

As per latest norms adopted in February 2004 by Government of India, the definition of village electrification envisages that "A village would be deemed electrified if:

(i) Basic infrastructures such as distribution transformer and distribution lines are provided in the inhabited locality as well as the hamlets where it exists. If the village is being electrified through Renewable Energy Sources a distribution transformer may not be necessary.

(ii) Electricity is provided to public places like schools, Panchayat offices, health centres, dispensaries, community centres, etc. and

(iii) The number of households electrified should be at least 10% of the total number of households in the village.[9]

In India villages which are yet to be electrified could be electrified either through grid or renewable energy systems.

The remote villages which are scattered in far flung regions and could not be electrified through grid power within a specified time span, can only be considered for electrification through distributed generation (DG) or renewable energy systems. Names of these villages are identified / verified by Rural Electrification Corporation (REC) and forwarded to the State Governments of concerned regions.

2.0 VARIOUS RENEWABLE SYSTEMS/TECHNOLOGIES

Electrification of these villages through various DG systems based on locally available renewable resources could be considered and compared. A set of renewable technologies which are being promoted and selected on the basis of locally available resources is depicted below:

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2.1.0 Solar Photovoltaic System

2.1.1 SPV Home and Street Lighting Stand-alone Systems along with SPV Water Pumping Systems and Small Power Pack for community applications,

2.1.2 SPV Power Plant for households and community application through mini grid,

2.2.0 Mini, Micro and Small Hydro Power Plants through Mini Grid Application

2.3.0 Biomass based Power Plants [Thermal (combustion)/Gasification- through Thermo-chemical / Bio-chemical route)]

2.3.1 Plant based on solid biomass (wood, briquettes etc.) combustion.

2.3.2 Plant based on agricultural residue like rice husk, ground nut shell, paddy- straw etc.

2.3.3 Plant based on liquid biomass i.e. use of non-edible straight vegetable oils (SVO)/biodiesel
2.3.4 Plant based on use of biogas produced through biochemical fermentation / bio-methanation of solid/ semi solid biomass i.e. poultry, piggery, cattle droppings, de-oiled cake of non-edible oil seeds etc.

2.4 Mini Power Plant using Muscle Power of Animals

2.5 Mini Aero-generator Systems

2.6 Engine – Generator Set (Petrol, Diesel, LPG, Bio-diesel/Bio-fuels, Biogas, Duel-fuel engines etc.)

2.7 Hybrid System (Combination of above mentioned two or more systems) [12]

3.0 SELECTION OF APPROPRIATE TECHNOLOGY/TECHNOLOGIES FOR ELECTRIFICATION OF A VILLAGE OR CLUSTER OF VILLAGES BASED ON INPUTS AVAILABLE AND COST - BENEFIT ANALYSIS

The process or route to determine the most appropriate technological solution implies always a feasibility study based on gathering field data for each specific site. Technical, economic, financial, and socio-cultural considerations must all be included in the decision making process to ensure the appropriate selection of technologies. For electrification of a village, either the application of single renewable energy technology at a time or optimum mix of two or more renewable technologies out of various technologies could be harnessed depending upon the available energy resources and the specific requirements of a village.

The systems would ideally be designed on the basis of a load capability of around 1 unit (kWh)/ household/ day including supply of electricity for loads such as irrigation, drinking water pumping, village industries, health care centre, commercial establishments including shops, etc. [5]

3.1.0 Details of Villages (Cluster), Electrification of which is to be carried out by Various Systems

3.1.1 Demographic Details of Villages (Table-1)

S No.	Name of Village	Census Code as per 2001Census	No. of Households	Population
1	Khichdi	2316000401999000	48	151
2	Navatola	2316000401998800	12	48
3	Lohasur	2316000402000100	20	84
		Total	**80**	**243**

3.1.2 Connected Load & Duty Cycle (Table-2)

S No.	Electrical Appliances	Wattage x Qty. x Hrs /Day	Connected Load in Watts	Watt Hrs / Day
1	Home Lights	9 x 80 x 4 (7 PM to 11PM) 5 x 84 x 4 (any time in night)	720 420	2880 1680
2	Community Systems			

	Street Lights Water Pump Home Lights Colour T V Fans	11 x 10 x 10 (7PM to 5 AM) 746 x 1 x 3 (7 to 10 AM) 9 x 8 x 4 (7 PM to 11PM) 90 x 1 x 4 --------,,--------- 60 x 2 x 4 -------,,----------	110 746 72 90 120	1100 2238 288 360 480
3	Total	9026 Watt Hrs	**2278 Watts**	**9026 Watt Hrs.**

Daily Load W hrs = **9026 W hrs.**

3.1.3 Daily Load Pattern (Power requirements at specified timings)

Requirement of 420 watts would be taken care of SPV lanterns at any time during night independently. Water pump would operate from 7 – 10 AM at 746 Watts and Home Lights, TV, Fans and Street Lights would be operated simultaneously from 7 – 11 PM but operation of street Lights would be continued till 5 AM. Thus there would be a peak load of 1112 Watts from 7- 11 PM and from 11PM to 5 AM a load of 110 Watts.

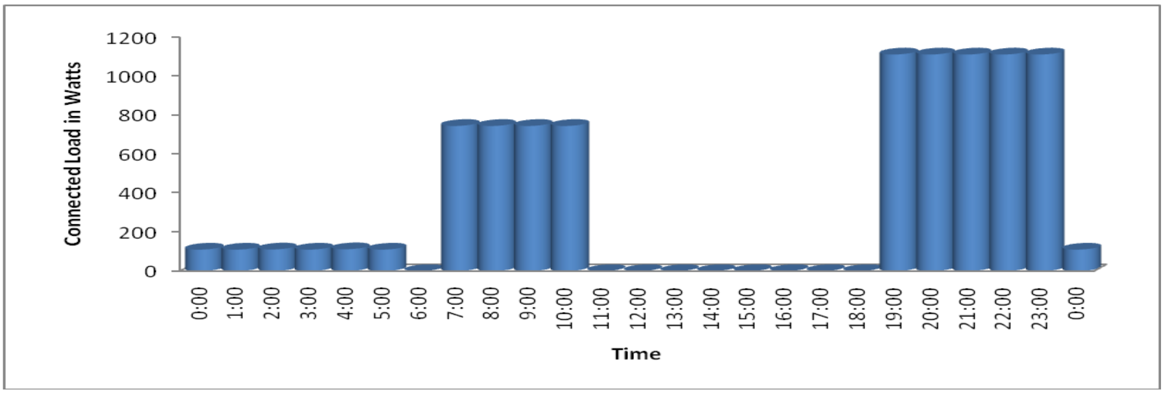

Fig. 1 Connected Load Pattern

Various options of distributed generation systems for electrification of a remote village or cluster of villages of a typical region, verified by Rural Electrification Corporation (REC - An Undertaking of Ministry of Power, Government of India) are under consideration in this presentation in which electrification of cluster of three census villages of district Shahdol, Madhya Pradesh is being considered.

3.1.4 Availability of Renewable Resources

Renewable energy resources available in this region are mainly solar, cattle dung, agricultural residues and wasteland where non-edible oil seeds bearing trees and other trees can be grown and used for various biomass products i.e. wood, oil seeds, biodiesel, de-oiled cake, biogas etc

3.1.5 Solar Energy Availability (Table-3)

District	Latitude	Longitude	**Average Daily Insolation**
Shahdol	23:19 North	81:26 East	**5.4 kWh/Sq. M**

3.1.6 Cattle & Dung Availability in the Village/Cluster of Villages (Table-4)

S No.	Species	Adult Animals	Calves	Approx. Dung Production	Approx. Dung Collection	Size of Biogas Plant
1	Cows	169	48	1476+96= 1592Kg	1000 Kg	
2	Buffalos	49	26	343+78= 421Kg	300 Kg	
3	Goat & others	63	32	Approx. 25Kg	20 Kg	
	Total	**281**	**106**	**2038 Kg**	**1320 Kg**	**45 M^3**

A generating set developed by BHEL Hyderabad Unit is a petrol start and 100% biogas run gen-set consumes 1M^3 biogas per kW per hour on full load i. e. a 5KVA gen-set could be run for 9 hours a day by successfully running a 45M^3 biogas plant. In due course after gestation period of petro crops, cow dung can also be substituted by de-oiled cake obtained after extraction of oil from non-edible oil seeds. One thousand Kg. of cow dung is capable of producing 38 to 40$M^3$of biogas whereas same quantity of Jatropha seeds de-oiled cake could produce about 56 M^3 of biogas. [6]

3.1.7 Waste Land Availability for Cultivation of Petro-crops (Table-5) [11]

District	Available for Cultivation			Total A+B+C (Hectares)
	Immediately (A)	After Some Improvement (B)	Uneconomical Patches (C)	
Shahdol	**12056**	**8654**	**18052**	**38762**
Anuppur	5827	3431	17534	26792
Umariya	6970	4841	3628	15439
			Grand Total	**80993**

3.1.8 Estimated Cost of Cultivation per Hectare with Number of Plants (Table-6) [3&4]

S No.	Name of Tree Borne Oilseeds	Plants /ha	Cost of Cultivation/ha
1	Jatropha Curcas (Ratanjyot)	2500	25000
2	Pongamia Pinnata (Karanj)	500	13000
3	Madhuca Indica (Mahua)	200	9000

3.1.9 Gestation Period and Maintenance Cost per Hectare up to Gestation Period (Table-7)

S No.	Name of Tree Borne Oilseeds	Gestation Period (Years)	Cost of Maintenance /ha up to gestation period Rs.
1	Jatropha Curcas (Ratanjyot	2	5000/-
2	Pongamia Pinnata (Karanj)	4	11000/-
3	Madhuca Indica (Mahua)	8	23000/-

3.1.10 Average Composition of Shell, Husk and Kernel in Jatropha Fruits (Table-8)

Jatropha Fruits	1000 g	100 %
Jatropha Shell	375 g	37.5%
Jatropha Seed	625 g	62.5%
Jatropha Husk	265 g	26.5%
Jatropha Kernel	360 g	36.0%
Jatropha Oil	175 g	17.5%

Jatropha De-oiled Cake = 360 – 175 = 185 g = 18.5% [7]

Shell and Husk could be used for power production by following direct burning or gasification route. Oil extracted from the seeds could be converted into biodiesel and used for power production. De-oiled cake can be used for power and manure production through bio-methanation route i.e. through anaerobic digestion.

4.0.0 RENEWABLE ENERGY SYSTEMS PROPOSED TO BE INSTALLED

4.1.1 Solar Home Lighting Systems –I. Definition

A solar home lighting system aims at providing solar electricity for operating lights and/ or fan or energizing a DC operated portable TV set for specified hours of operation per day.

Various Models of SPV Systems with Rates & Subsidy Pattern (Table-9)

S No.	Name	System/Component Specifications	Rate Rs.	Central Subsidy	State Subsidy	Beneficiary Share
1	**Solar Street Light**	PV Module(s) 1 X 74 W under STC Lamps CFLs 11W Battery 1X 12V, 75 AH	21900	**5870**	10000	**6045**
2	**Solar Home Light M-1**	PV Module 1X 18 W under STC Lamps 1X CFL (9W /11W) Battery 1X 12V, 20 AH	6775	1620	2500	**2653**
3	**Solar Home Light M-2**	PV Module 1X 37 W under STC Lamps 2X CFLs (9W /11W) Battery 1X 12V, 40 AH	12570	3330	5000	**4241**
4	**Solar Home**	PV Module(s) 1 X 74 W under STC	16700	4473	Nil	**12226**

	Light M-3	Lamps 2X CFLs (9W /11W) Fan 1X DC Fan (with wattage less than 20 W) Battery 1X 12V, 75 AH				
5	**Solar Home Light M-4**	PV Module(s) 1 X 74 W under STC Lamps 4 X CFLs (9W /11W) Battery 1X 12V, 75 AH	21820	5871	Nil	**16047**

Notes: i) All models will have a socket to provide power for a 12V DC TV set which can be purchased separately.
ii) A small white LED may be provided as an optional feature, with an independent switch.

Ii. Duty Cycle

The system should be designed under average daily insolation of 5.5 kWh per sq. m. on a horizontal surface

Models with Average Hours of Operation / Day

Model 1 - 1 Light, (3-4 Hours)
Model 2 - 2 Lights, (3-4 Hours)
Model 3 - 2 Lights, (2-3 hours), 1 Fan (2-3 hours)
Model 4 - 4 Lights, (3-4 Hours)

[As per Ministry of New and Renewable Energy (MNRE) New Delhi Guidelines, Specifications and Subsidy Pattern & Rates circulated by M P Urja Vikas Nigam Ltd. (MPUVN Ltd.) Bhopal for 2011-12]

4.1.2 Rates of SPV Power Plants for the Year 2010-11 (Table-10)

S No.	SPV Array Capacity (Wp)	Basic Price (System cost +Warranty)	Basic Price + 3-years CMC cost	Basic Price + 5-years CMC cost
1	500	125000	140000	152466
2	1000	145000	270000	276870
3	2000	464090	481290	492755
4	3000	654280	680490	697960
5	4000	860530	894930	917860
6	5000	1060290	1106154	1136730
7	6000	1233210	1285625	1320570
8	7000	1449800	1515320	1559000
9	8000	1632620	1704690	1752740
10	9000	1859000	1940900	1995500
11	10000	2052050	2142140	2202200

[As per MNRE New Delhi Guidelines, Specifications and Subsidy Pattern & Rates circulated by MPUVN Ltd. Bhopal for 2011-12]

4.2 Remote Village Electrification through Bio-diesel/Dual Fuel Generating Set

- The Rated Capacity of the Gen-set Proposed = 5KVA
- Number of households per village = 80
- Number of 9W+ 5W connections = 80
- Connected Load = 9 kW
- Peak Load = 5.2 kW (19 to 23Hrs i.e. 4 Hr)
- Water Pump (1to 2 HP) Operation = 3 to 4 Hrs in the morning
- Number of hrs of operation of Gen-set = 4 + 3 = 7 Hours
- Amount of Diesel/Biodiesel required per BHP/hr = 175 gm
- Per day fuel requirement = 175x7x 5 = 6125 gm
- Per day fuel required in litres = 6125/1000x0.83 = 7.38 Litres
- Monthly requirement of fuel = 7.38 x 30 = 221.5 Litres
- Per year requirement = 6.125 x 365 = 2235.625 kg say, 2240 kg/year
- 1 kg of Jatropha seed oil require - 3.5 kg of seeds
- 2240 kg of oil will require - 7840 kg of seeds/year
- Taking losses into account say - 8000 kg of seeds required / year
- One Jatropha plant yields on an average - 1 kg seed / year
- Number of plants required for the project – 8000 Nos.
- Land required @ 2500 plants per hectare - 3.20 ha, say 5.0 ha

In 5 ha land 12500 plants can yield more than 12500 Kg seeds which could produce 3570 Kg oil and 2300 Kg de-oiled cake. These products could be converted into biodiesel and biogas. De-oiled cake could be substituted for replacing dung or supplementing it. [6, 10 & 14]

5.0.0 CONNECTED LOAD AND HOURS OF OPERATION IN EACH OPTION

5.1 Various Options & Connected Devices/ Systems at Different Locations (Table-11)

Various Options	Households	St. L*	Panchayat Bhawan	Health Centre	Community Centre	Drinking Water
I SPV Stand-alone Systems (Small Capacity)	80 HLS- M-1 + 80 SPV Lantern x 4hrs	10	HLS- M-4 x 4hrs + 1 Lantern	HLS- M-3 X 4 hrs + 2 Lanterns	HLS- M-4 X 4hrs + 1 Lantern	SPV Pump** 1.2 kWp
II SPV Stand-alone Systems (Higher Capacity)	80 HLS- M-2 + 80 SPV Lantern x 4hrs	10	HLS- M-4 x 4hrs + 1 Lantern	HLS- M-3 X 4hrs + 2 Lanterns	HLS- M-4 X 4hrs	SPV Pump 1.2 kWp
III SPV Stand-alone System Centralized + Mini Grid	1x9W +1x11W CFL + SPV Lanterns 80 Sets x 5hrs	10	(9x2+11x2)Wx5hr CFL+SPV Lantern	(11x2w + 60WFan + 2 lantern) X 5hrs	(9x2+11x2)W x 5hrs CFL + SPV Lantern+1TV (90Wx 5hrs)	SPV Pump 1.2 kWp
IV Dual-Fuel Generating System (Biodiesel + Diesel) + Mini Grid	1x9W +1x11W CFL + SPV Lanterns 80 Sets x 5hrs	10	(9x2+11x2)Wx5hr CFL+SPV Lantern	(11x2w + 60WFan + 2 lantern) X 5hrs	(9x2+11x2)W x 5hrs CFL + SPV Lantern+1TV (90Wx 5hrs)	2 HP Water Pump 4hrs/day
V Dual-Fuel Generating System (Biogas + Diesel) + Mini Grid	1x9W +1x11W CFL + SPV Lanterns 80 Sets x 5hrs	10	(9x2+11x2)Wx5hr CFL+SPV Lantern	(11x2w + 60WFan + 2 lantern) X 5hrs	(9x2+11x2)W x 5hrs CFL + SPV Lantern+1TV (90Wx 5hrs)	2 HP Water Pump 4hrs/day
VI Hybrid Power System (SPV + 100%Biogasor biogas + Biodiesel) + Mini Grid	1x9W +1x11W CFL + SPV Lanterns 80 Sets x 5hrs	10	(9x2+11x2)Wx5hr CFL+SPV Lantern	(11x2w + 60WFan + 2 lantern) X 5hrs	(9x2+11x2)W x 5hrs CFL + SPV Lantern+1TV (90Wx 5hrs)	2 HP Water Pump 4/hrs

*St. L – Street Lights, **1200/1800 Wp AC, 3 phase Submersible pump (Assuming Peak Sunshine at 5.5 hrs/day and 3 times manual tracking, total dynamic head {suction head + delivery + friction losses} 50 metres, water discharge per day 17625 / 35000litres)[13]

5.2 Various Options and Watt hrs of Domestic, Community & Health Centre Systems/Day (Table-12)

Op-tion	Domestic	Street Light	Panchayat Bhawan	Health Centre	Community Centre	Drinking/ Irrigation	**Total Whrs /day**
I	(9+5)x4x80 = 4480whr	**11**x10x10 =1100whr	9x4x4+5x4 = 164whr	(11x2+20+5x2)x4 = 208whr	(9x4+5)x4 = 164whr	1200x5.5 6600whr	**12716**
II	(9x2+5)x80x4 =7360whr	**11**x10x10 =1100whr	9x4x4+5x4 = 164whr	(11x2+20+5x2)x4 = 208whr	(36+5)x4 = 164whr	1200x5.5 6600whr	**15596**
III	(9x2+5)x80x4 =7360whr	**11**x10x10 =1100whr	(9x2+11x2+5) X5= 225whr	(11x2+1x60+5x2)x5 = 460whr	(40+5+90)x5 = 675whrs	1200x5.5 =6600whr	**16420**
IV	(11+9+5)x80x4 =8000whr	**11**x10x10 =1100whr	(9x2+11x2+5) X5= 225whr	(11x2+1x60+5x2)x5 = 460whr	(40+5+90)x5 = 675whrs	746x2x4 =5968whr	**16428**
V	(11+9+5)x80x4 =8000whr	**11**x10x10 =1100whr	(9x2+11x2+5) X5= 225whr	(11x2+1x60+5x2)x5 = 460whr	(40+5+90)x5 = 675whrs	746x2x4 =5968whr	**16428**
VI	(11+9+5)x80x4 =8000whr	**11**x10x10 =1100whr	(9x2+11x2+5) X5= 225whr	(11x2+1x60+5x2)x5 = 460whr	(40+5+90)x5 = 675whrs	746x2x4 =5968whr	**16428**

5.3 Comments on Various Options

5.3.1 In **all the options** it is advised to provide a SPV Lanterns to each household, Panchayat Bhawan, Community Centre, and 2 lanterns to Health Centre so that any emergency requirement of light of all the beneficiaries is fulfilled. In view of this advice a lantern with 5W CFL or LED module lamp would be provided with each option and to all the beneficiaries as mentioned above. .

5.3.2 In case of **centralized SPV power plant or hybrid options** home lights, community lights including street lights and fans would not be of standalone type and energized through mini grid. Power supply for households, Panchayat Bhawan and Community Centre would be for 4-5 hrs and Street Lights and health Centre's Light and Fans for 8-10 hrs. All water pumps would be of standalone type but at times or on regular basis grid supply could be provided so that drinking water and irrigation needs could be met. At times pump supply could also be given to a flour mill. With each hybrid system using a gen-set a dummy load of variable wattage would also be provided so that load balancing could be done when battery bank is in fully charged condition.

Alternatively 50% of the solar lanterns proposed with each option could be purchased without SPV Panels and substituted in place of dummy load.

5.3.3 In case of **Option-I** all systems like home lights model I, solar lanterns, street lights and SPV pump proposed are standalone type. These systems have SPV penal, battery, lamp or fan, housing to keep battery and fix lamp and circuitry of specified size. Solar pumps are generally operated in day time. The home and other community systems have 2-3 days autonomy i.e. the system could be used 2-3 days without charging during rainy days when there is no sun light due to clouds. Hence because of limited depth of discharge, provision of higher autonomy and duty cycle, it would be required to have higher capacities of batteries which lead to a very costly Battery Bank. If the system is used for more than the specified duty cycle/ hours and is within the autonomy limit the battery could be revived by normal charging through SPV panel provided with the system. But by mistake or intentionally the limit of autonomy and duty cycle is crossed the system's battery would attain the deep discharge condition and it would be difficult to recharge it by SPV panel alone. It would be possible to charge the battery by grid or gen-set or through vehicle charging system by keeping the vehicle standstill and engine under running condition. Lower is depth of discharge higher is life of the battery. Higher capacity of battery enhances the cost of the system. Therefore, it is always endeavored to keep the depth of discharge of the battery or battery bank as low as possible so that battery bank replacement cost is minimized after the expiry of the batteries. In standalone system use of the systems/devices is under the sole control of the user. Hence it could be used or misused or over used.

5.3.4 In case of **Option II** same conditions and short comings are applicable as in case of Option I. Only the capacity of home lights is on higher side.

5.3.5 In case of **Option III cost of centralized SPV Power Plant would be very high. A 5 kWp System with 5 kWp array and 2000 Ah battery bank and two days autonomy may cost Rs. 1.2 – 1.3 million as displayed in Table -10.** In the case of all the solar systems number of clear sunny days are considered to be 300 in a year. Remaining 65 days which are considered to be overcast by clouds mainly cause problems. Generally the SPV systems are designed considering 2-3 days autonomy. **If sun light is not available for more than 4 days, all systems might pose problems. This could be avoided by providing back-up through an adequate capacity, single or dual fuel gen-set or by having a Hybrid Power Plant as proposed in Options IV, V, & VI.** Generally it is the tendency of households to draw excessive power than the allocated load from the grid. They always attempt to do so. Hence in order to put a check on such activities each household's connection should be provided through **Load Limiter Switch** from the grid. Grid requirement is common to III, IV, V & VI Options. The grid should be designed to accommodate the future growth of the village and enhancement in the duty cycle of the connected systems or providing other systems like fan, radio, TV etc.

5.3.6 In case of **Option IV a Hybrid System** having Dual fuel **(bio-diesel + diesel) Gen-set in addition to a SPV Power Plant of 40%** array and battery bank **capacity** than in Option III is proposed. **The cost of 2 kWp system is around Rs. 0.48 – 0.50 million (as displayed in Table-10) which is much less than the cost required for Option III plant.** But this hybrid system is feasible only when plantation of petro-crops preferably Jatropha Curcas is ensured on at least 10 ha waste land at the planning stage of this project itself so that timely availability of oil seeds could be ensured in adequate quantity for extracting oil and making biodiesel. In the beginning gen-set could be run with diesel fuel alone and gradually it could be substituted with biodiesel as soon as the production of biodiesel is taken up locally. Around 225 liters of diesel/biodiesel is monthly required for running the gen-set 5 hrs a day. In this Option conditions and short- comings of Option III are also applicable.

5.3.7 In case of **Option V a Hybrid System** having Biogas Plant of adequate size **say 45 M^3,** dual fuel **(biogas + diesel) Gen-set in addition to a SPV Power Plant of 40%** array and battery bank **capacity** than in Option III, is proposed. **Biogas plant could be run on available cow dung in the cluster.** It could also be run on mixed feed of dung and de-oiled cake of non-edible oil seeds. As the production of oil seeds increases gradually, efforts should be made to utilize the de-oiled cake as much as possible in place of dung in order to ensure the successful operation of biogas plant by eliminating social and other problems faced during door to door dung collection. In this case requirement of Bio-diesel/Diesel would be reduced to 20% i. e. about 22 liters/monthly for daily 5 hrs operation. In addition to power production about 400 Kgs of bio-manure would also be produced everyday against input of 1200 Kgs.

5.3.8 In case of **Option VI a Hybrid System** having Biogas Plant of **45 M^3 rated capacity, a 100% biogas or a** dual fuel **(biogas + bio-diesel) Gen-set in addition to a SPV Power Plant of 40%** array and battery bank **capacity** than in Option III, i.e. a 2 kWp System is proposed. At the initial stage a floating dome biogas plant could be run on available cow dung in the cluster and later on dung could be replaced by “de-oiled cake”- residue left after extraction of oil from edible or non-edible oil seeds but this could be taken care of only when fast growing, high oil content species of Jatopha Curcas seedlings are planted on all the available waste land as soon as the project is conceived. Satisfactory running of 100% biogas gen-set developed by BHEL Hyderabad would eliminate the requirement of diesel/biodiesel. For designing optimum size of various renewable systems / components of Hybrid System, software available in the market like- Homer software, LINDO software 6.1version could be utilized. [13, 14]

6.0 CONCLUSION

Thus in view of comments given above in case of Option VI complete supply of power would be dependent on locally available renewable resources which will ensure sustainability of the project and would also be able to meet future demand of irrigation, trade and industry and after some training plant could be maintained by local people. In view of limitations / short coming pointed out above and past field experience, Option VI in which Home Lights are replaced by fixed supply point CFLs in Houses, Panchayat Bhawan, Community Centre and Health Centre and energized through mini grid. Fans and community water pump could also be energized through it and for longer time depending on availability of biogas. In the opinion of the authors this option may prove to be the best and is capable of meeting domestic, community and irrigation/ industrial power demand through the supply of green energy. In this case production of per unit cost of power is cheaper than centralized SPV Power Plant. Its day to day running cost would also be less as compared to other options. As almost all the inputs are locally available and could be substituted by other by-products of petro-crops. It is capable of keeping low depth of discharge of battery bank due to low autonomy and daily charging round the year as the system is backed by 100% biogas gen-set which could be run to support higher loads and peak power demand. This will enhance the battery bank life and ultimately reduce battery bank maintenance cost per annum as the expiry span of the batteries would be extended. This system would ensure round the year supply of electricity which is to be supplied centrally as per pre-decided duty cycle so that there is no misuse or overuse of the same. Beneficiaries would also be able to make use of SPV lanterns at any time as per their need. Microprocessor based control unit could also be provided to ensure optimum use of different systems/generators but this would not only enhance the initial cost but also enhance the maintenance cost as the system is required to be maintained by skilled staff and workers.

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