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Community based Micro Off-Grid Power System using Renewable Energy Technology (Ret): Investment Analysis, Cost Benefit and Main Factors

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Abstract

Bangladesh is the eighth populous country in the world with the highest population density and a vast majority of its population, who are living in villages and small towns, are deprived of power. Recently some steps are being taken by the Government of Bangladesh (GoB) to bring those people under electrification who are in remote inaccessible unelectrified area where grid expansion is expensive and it is being done by encouraging them to use renewable energy such as: Solar photovoltaic, Solar thermal power, Wind power, Biogas, Mini- Hydro etc for electricity generation in stand-alone system. But the high installation and maintenance cost of these renewable energy based power generation in standalone system are becoming the main hindrances to the village people to afford it. Though some financial helps are provided from government and some NGOs, but those are not enough and only a few people get these privileges. That?s why the potentiality of renewable energy couldn?t be used in an effective way. The objective of this paper is to present an alternative and - from our point of view â??" more realistic aspect of using renewable energy effectively in the reliable energy supply. This paper will discuss about an idea of cost effective community based micro off-grid power system which will emphasize on using Renewable Energy Technologies (RETs) like utilizing Biogas for power generation. Furthermore, this paper will also visualize as to how this micro off-grid system can be implemented in those villages and small towns which are currently detached from electricity and it can be done by dividing each village or town into small communities and bringing them under electrification. Many factors, such as technology costs and investment analysis, benefit-cost ratio, payback period and available potentials have been incorporated in order to fulfill this task.

Index terms— renewable energy technology; developing country; community; off-grid; biogas.

1 Introduction

ower stands as a judging criterion for indicating a strong socio-economic development of any country. Industrial growth is solely dependent on power. Without power, the development efforts of a country cease to exist. The growing need for power is intensifying day by day. With the limited resources available, developed countries have been satisfying their Authors ? ?: Department of Electrical and Electronic Engineering, Islamic University of Technology, Board Bazar, Gaziur-1704, Bangladesh. e-mails: sinjon_eee@yahoo.com, imtiazz52@yahoo.com ongoing demand for power by applying proper technologies and hence maximizing their industrial growth. But developing country like Bangladesh is far away from this race due to its weak administrative structure, poor human resource management, high population density and lack of knowledge regarding application of proper

scientific methods to utilize their available resources. Power crisis has become so acute that the gap between total generation and total demand is getting larger and larger. The Government of Bangladesh (GoB) has been failed to mitigate this power crisis in many aspects due to their imprudence in policy making regarding power crisis. The pervasive corruption and irregularities in power sector have made this problem more acute. In Bangladesh, about less than 10% of the rural people are connected with the national grid of electricity supply and about two-third of the country's 86000 villages are still outside the reach of the national grid [1]. The main reason for that is, the GoB has failed to give them full access to electricity leaving them detached from the national grid. In this situation, they can be given access to electricity by building community based micro power plants which will not be connected to the national grid rather they will be operated only those areas which are not electrified yet. Those micro power plants may be designated as offgrid power plants whose generating fuel will be renewable energy such as: Biogas. In this community based micro off-grid power system, a village or small town will be segmented into several communities where each community will consist of a certain number of consumers and they will be supplied electricity from one common micro off-grid power plant. Here total installation and maintenance cost will be shared by the consumers of each community which will result in less financial burden for a single family as compared to stand-alone RETs based power generation system.

2 II.

3 Potential of Renewable Energy

Technologies (RETs) and its Present Scenario in Bangladesh Bangladesh is heavily dependent upon conventional energy sources e.g. Coal, Gas, Diesel, ? Furnace oil etc and a large portion of total energy demand of the country is satisfied by these traditional biomass fuels. At present, Bangladesh receives energy supply both from renewable and non-renewable sources. In 2009, natural gas accounted for 50 percent of total energy supply, which declined to 46 percent in 2010. Contribution of bio-mass to total energy supply increased from 33.3 percent to 34.6 percent during this period. It may be mentioned that, use of oil as energy has increased significantly during this time. In 2009, oil represented 11.1 percent of total energy supply, which increased to 18.3 percent in 2010 [2]. Whereas Renewable energy contributes only a few percent of the total energy consumption in the country, mainly through biomass, e.g. agricultural residues contribute almost half the national total, with cow dung, bagasse and fuel wood making up the rest. The trend of annual energy consumption is presented below in the "Figure **??**I". The potential for renewable energy other than biomass is quite high, but current utilization is minimal. These sources are biomass (including biogas and solid waste), solar energy, tidal and wave. The hundred plus miles long coastal areas and hilly sections provide ample wind for wind turbines. Waterways of varied forms and speed provide ample wave and gravity driven water flow for ecologically balanced hydroelectric generators. The lush vegetation provides ample photosynthesis and biomass for fuel for a variety of purposes. Also, more than twothirds of the land area is grid free where decentralized applications of various RETs have been proven to be the most cost-effective options for generating electricity and heat [3]. The size and economic potential of the renewable energy resources (e.g., solar photovoltaic, solar thermal power, wind power, biogas, hydro etc.) in Bangladesh are yet to be determined and the capacity of renewable energy development is presently low. An estimated potential of Renewable Energy Technology (RET) in Bangladesh is shown in "Table-I" [4]. Although investment cost of renewable energy based power generation is generally higher compared to fossil fuel alternatives, this option becomes economically viable when all externalities (e.g. environmental cost, health hazards etc.) and lower operating cost are taken into consideration. In Bangladesh, currently renewable energy based power generation is being implemented using the following methodologies [5]:

? Solar power generation using solar rays ? Wind-mill power generation using wind power ? Electricity produced by Biomass Gasification Method using wood, rice husk, etc.

4 a) Solar Photovoltaic

The largest amount of sun light is available in between two broad bands encircling the earth between 15?? and 35?? latitude north and south. Fortunately, Bangladesh is located between 20 o 34? to 26 o 38? north latitude and 88 o 01? to 92 o 42? east longitude which is a good location for solar energy utilization. Daily average solar radiation varies between 4 to 6.5 KWh per square meter [6]. Maximum amount of radiation is available on the month of March-April and minimum on December-January. Despite of having large potential, utilization of solar energy has been limited to traditional uses such as crop and fish drying in the open sun. Solar photovoltaic (PV) is gaining acceptance for providing electricity to households and small businesses in rural areas. In 1988, Bangladesh Atomic Energy Commission (BAEC) installed several pilot PV systems. The first significant PV-based rural electrification programme was the Norshingdi project initiated with financial support from France. Three Battery charging stations with a total capacity of 29.4 kWp and a number of standalone solar home systems (SHS) with a total capacity of 32.586 kWp were installed [7]. Rural electrification Board (REB) owned the systems and the users paid a monthly fee for the services. Solar photovoltaic (PV) systems are in use throughout the country with over 200,000 householdlevel installations having capacity of about 50 MW (June 2011) **??** The technology involves harnessing solar radiation for generation of electricity through a number of steps finally generating mechanical energy to run a generator. This technology needs to be disseminated in the country to supplement the power supply.

5 c) Biomass

Bangladesh has strong potential for biomass gasification based electricity. More common biomass resources available in the country are rice husk, crop residue, wood, jute stick, animal waste, municipal waste, sugarcane bagasse etc. This technology can be disseminated on a larger scale for electricity generation.

6 d) Biogas

Biogas mainly from animal and municipal wastes may be one of the promising renewable energy resources for Bangladesh. Presently there are tens of thousands of households and village-level biogas plants in place throughout the country. It is a potential source to harness basic biogas technology for cooking, and rural and peri-urban electrification to provide electricity during periods of power shortfalls. According to an estimate "29.7 billion cubic meter of biogas can be obtained from the livestock of the country which is equivalent to 1.5 million tons of kerosene (which is the principal fuel in the rural areas) [7]. Apart from this, it is also possible to get biogas from human excreta, poultry dropping, waste, marine plants etc. If each family of Bangladesh can be associated with a biogas plant, then only human excreta will give about 10 billion cubic meter biogas". According to Institute of Fuel Research & Development (IFRD) -there is potential of about four million biogas plants in our country [8].

7 e) Hydro

Micro-hydro and mini-hydro have limited potential in Bangladesh, with the exception of Chittagong and the Chittagong Hill tracts. Hydropower assessments have identified some possible sites from 10 kW to 5 MW but no appreciable capacity has yet been installed. There is one hydro power plant at Kaptai established in the 1960s with installed capacity of 230 MW.

8 f) Wind Energy

Wind Energy has also made some inroads but its potential is mainly limited to coastal areas, and offshore islands with strong wind regimes. These coastal settings afford good opportunities for windpowered pumping and electricity generation. The long term wind flow in Bangladesh, especially in islands and in southern coastal belt of the country indicate that the average wind speed remains between 3 to 4.5 m/s for the month of march to September and 1.7 to 2.3 m/s for the remaining period of the year [9]. There is a good opportunity in island and coastal areas for the application of windmills for pumping and electricity generation. Presently there are 2 MW of installed wind turbines at Feni and Kutubdia. A number of small wind generators have been recently installed by Grameen Shakti at its Chakaria shrimps farm, BRAC and GTZ (a German NGO). BRAC alone has installed 11 wind turbines at various coastal areas. These are small low cutting, DC operation type systems, supplying power to the target group to improve their quality of life.

9 g) Others

Other renewable energy sources include biofuels, gasohol, geothermal, river current, wave and tidal energy. Potentialities of these sources are yet to be explored. Year 2014 At present it is estimated that renewable sources of power generation is about 55 MW. As per approved renewable energy policy 5% of the total generation (500 MW) would be added by 2015 and 10% of the total generation (1600 MW) would be added by 2020 from renewable sources [14]. IDCOL has supported NGOs in installation of SHSs in more than 380,000 households. Under the new initiative, BPDB is in process of installation of 100 MW Wind Power and 9-14 MW Grid connected Solar Power through PPP. Targets of power generation from renewable energy sources as fixed by the GoB are presented in the "Table-II" [2].

10 Barriers for Sustainability of Renewable Energy Technologies (RETs) in Bangladesh

There are plenty of barriers hindering widespread deployment of potential Renewable Energy Technology (RET) in Bangladesh [10].

? Rural people have lack of idea about renewable energy resources, technical/economic information about RETs, equipment suppliers, and potential financiers.

? High initial capital costs and higher perceived risks of the renewable energy technology.

? Availability and access to existing renewable energy resource information is limited. A central information point does not exist, instead information is scattered among various sectors.

? There is not much campaign or awareness programs for the renewable energy consumption.

? The decision makers, who are urban dwellers, don't feel the necessity of renewable energy.

? GoB budgets for subsidizing RETs projects are limited as the demand for financing the various national priority areas (health, education, disaster management etc.) is great.

? The currently small and dispersed size of the renewable energy market in Bangladesh does not facilitate benefits such as economies of scale.

? NGOs working in Bangladesh are not sufficient or they do not have enough financial backup to promote the use of sustainable energy in the extreme rural areas

? NGOs have lack of technical know how people related to renewable energy technology.

? There are not much training materials and trained persons for technical backup support.

? Natural disasters are one of the barriers for promotion of sustainable energy.

? In our country financing sources are not interested in sustainable energy technology.

? Installation and maintenance cost of SHS are high due to bad communication and scattered localities. ? Lack of expertise and services in resource assessment, system design, installation, operation and maintenance of renewable energy technologies.

IV.

11 Design of our Proposed Community based Micro Off-Grid Biogas Plant

Due to several reasons mentioned earlier, RETs based power generation has not gained widespread implementation. As a result of this, a vast majority of the population living in the rural areas have limited access or in some cases, no access to electricity at all. To help ease the problem, we have come up with the idea of Community Based Micro Off-Grid Power System using Renewable Energy Technology (RET). As Bangladesh is an agricultural country and most of the villagers earn their livelihood by farming, cows/bullocks/buffalos are part and parcel of most of the farmers' households. So, the dung egested by these livestock can be used as a potential source for generating biogas which then can be used to produce electricity. According to our proposed community based micro off-grid power system, what we will do is dividing a village into small communities where each community will consist of at least five families, each family having a member of five persons. These individual communities will meet their electricity demand by installing Biogas Plant which will be independent of National Grid, that's why the term Off-grid Power System has been coined. Here we will show the design and necessary calculation of a simple biogas plant which can meet the proposed communities' electricity demand. The system design includes the estimation of total gas required, amount of feedstock (or dung) required and the number of animals required having feedstock of a given amount.

12 a) Calculation of Net Electricity Demand of a Typical Community

Biogas system design for supplying the required demand for five families each having five members is considered here. Here, we have assumed a typical electrical load profile of a single family consisting five members and it is shown in the "Table-III". Therefore, a single community of five families will have a net demand of 399W×5?2KW approximately. We have assumed that daily at most 4 hours these loads will be operated. Therefore, the total units needed will be 2KW×4Hr = 8KWh per day. b) Amount of Gas Required Per Day Here, 1KWh Electrical energy output is equivalent of 0.7 m 3 gas [11]. And 1000 liters of gas is equivalent to 1 m 3 of gas.

Therefore, 8KWh Electrical energy output 5.6 m 3 of gas ? Total gas required = 5.6 m 3 / day or 5600 Litters/ day.

13 c) Number of Livestocks Required to Fulfill Daily Gas Requirement

Amount of gas produced from 1 Kg of fresh dung = 40 Litters ? Total amount of dung As most of the people in rural villages are farmer, so it is quite possible for every family to have cows for agricultural purpose. So we will consider here cow dung to fulfill daily gas requirement. 10 Kg dung/day/cow is an approximate; it may vary with breed of the cow [11]. Thus, in order to have 140 kg of dung, total no.

14 of cows

In our case, we have considered a total of five families. Therefore, if one family possesses 3 cows on average, a total of 15 cows will be owned by five families. Thus, the total demand of dung needed per day can easily be met by these families all by themselves.

15 d) Design of Digester and Gas Holder

In order to make slurry, water should be added to equal amount of dung i.e. dung : water = 1 : 1 [11] Total mass of slurry = dung + water = 140 + 140 = 280 Kg Here, Specific gravity of slurry is about 1090 Kg/m 2 So, Volume of slurry per day

We have assumed the retention period of slurry will be 45 days. Theoretically, biogas can be converted directly into electricity using a fuel cell. However, very clean gas and an expensive fuel cell is necessary for this process. In most cases, biogas is used as fuel for combustion engines, which convert it to mechanical energy, powering an electric generator to produce electricity. Technologically far more challenging is the first stage of the generator

set: the combustion engine using the biogas as fuel. In theory, biogas can be used as fuel in nearly all types of combustion engines, such as gas engines (Otto motor), diesel engines, gas turbines and Stirling motors etc.

For using Biogas in gas or diesel engines, the Biogas must fulfill certain requirements [12]:

? The methane content should be as high as possible as this is the main combustible part of the gas;

? The water vapor and CO 2 content should be as low as possible, mainly because they lead to a low calorific value of the gas;

? The Sulphur content in particular, mainly in form of H 2 S, must be low, as it is converted to corrosioncausing acids by condensation and combustion.

Appropriate electric generators are available in virtually all countries and in all sizes. In most commercially run biogas power plants today, internal combustion motors have become the standard technology either as gas or diesel motors. stand-alone cost. The monthly operation and maintenance costs for running this Biogas plant are estimated at BDT 2,000. To manage the Biogas power plant in the future, training modules will develop to train local community leaders in responsibilities, technical capabilities, staff and financial management, record keeping, accounting and leadership qualities.

16 b) Revenue

Here, From the Biogas plant electricity generated per day is equal to 8 KWh.

So, Electricity generated per year = 8KWh× 365 = 292020 KWh.

In Bangladesh, Rate of quick rental power is BDT 16 per KWh.

So, net revenue will be earned from electricity generated by the Biogas plant per year = 2,920×16 BDT = 46,720 BDT Again, Slurry generated per month = 1,150 Kg So, Slurry generated per year = 1,150×12 = 13,800 Kg

In Bangladesh, Rate of compost fertilizer is BDT 75 per 40 kg. Net revenue will be earned from fertilizer per year = 345×75 BDT = 25,875 BDT So, Total Revenue will be earned from the Biogas plant per year = 46,720+25,875 BDT= 72,595 BDT c) Payback (Payout) Period

The payback method, which is often called the simple payout method, mainly indicates a project's liquidity rather than its profitability [13]. The simple payback and discounted payback period methods tells us how long it takes cash inflows from our community based off-grid Biogas power plant project to accumulate to equal (or exceed) the project's cash outflows, which is an indicator of our project risk. Here calculation of the Simple Payback Period (

) and the Discounted Payback Period ( ) at MARR = 13% is given in the "Table **??** Here, B/C ratio is greater than 1. So, our proposed project is acceptable.

17 VI.

18 Conclusion

In this paper we have presented the idea of physically implementing smart micro off-grid community based power generation using RETs which can solve the existing power crisis especially faced by the vast majority of general mass who are living in the developing countries. In Bangladesh, people living in many rural areas have no access to electricity at all. Growing demand for power has already put an immense pressure on fossil fuels and with limited resources available in Bangladesh, it will be almost impossible to meet this huge increasing demand. The current reserve of fossil fuels is depleting in an alarming rate which will create an agonizing situation for the inhabitants of this country. Because, GoB has already failed to provide access to electricity in the rural areas; what is going to happen in near future when this fossil fuel reserve runs out completely can easily be imagined. Our proposed idea of smart micro off-grid community based power generation can be used as a helping tool for the solution of this problem. Detailed investment and benefit-cost ratio analysis, payback period calculation have been carried out in a realistic way to show that our proposed idea can be successfully implemented as well as keeping the poor economic condition of the general rural people in contrast. Technical assistance and economic support from GoB as well as from other NGOs should also be incorporated to implement our proposed idea thereby reducing intense pressure on national grid and conventional limited fossil fuel reserve. [1] [2]

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Figure 1: P © 2014

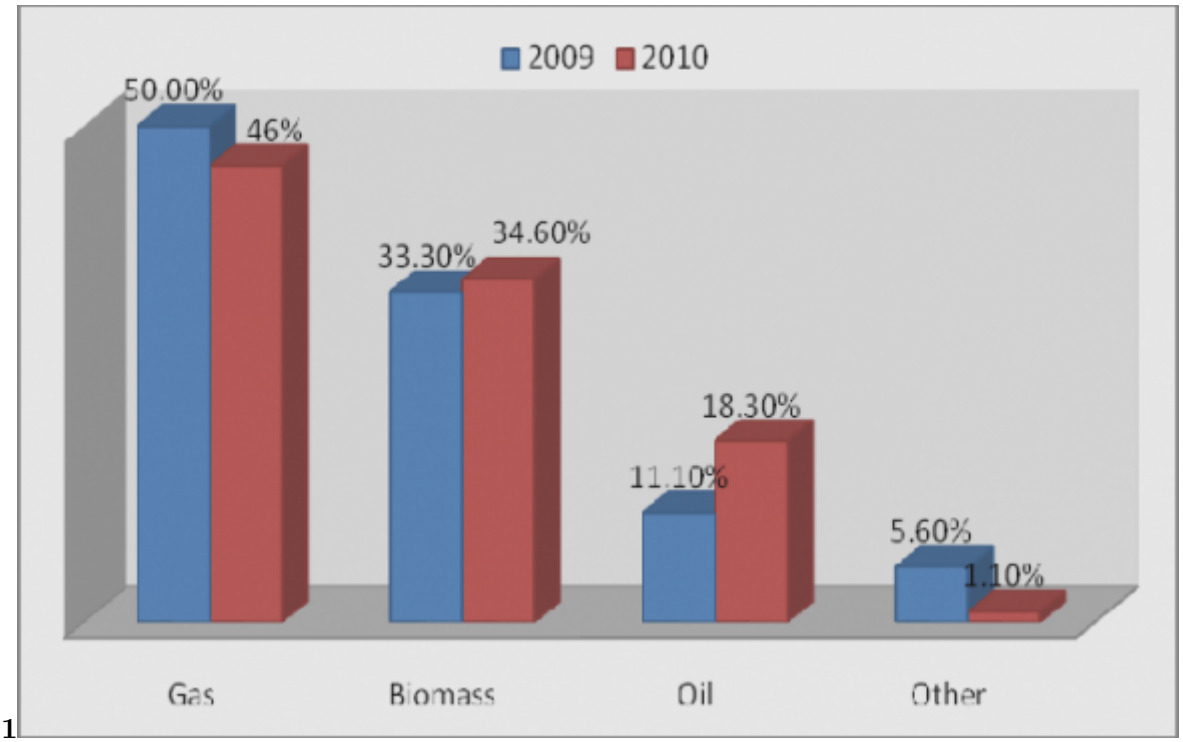

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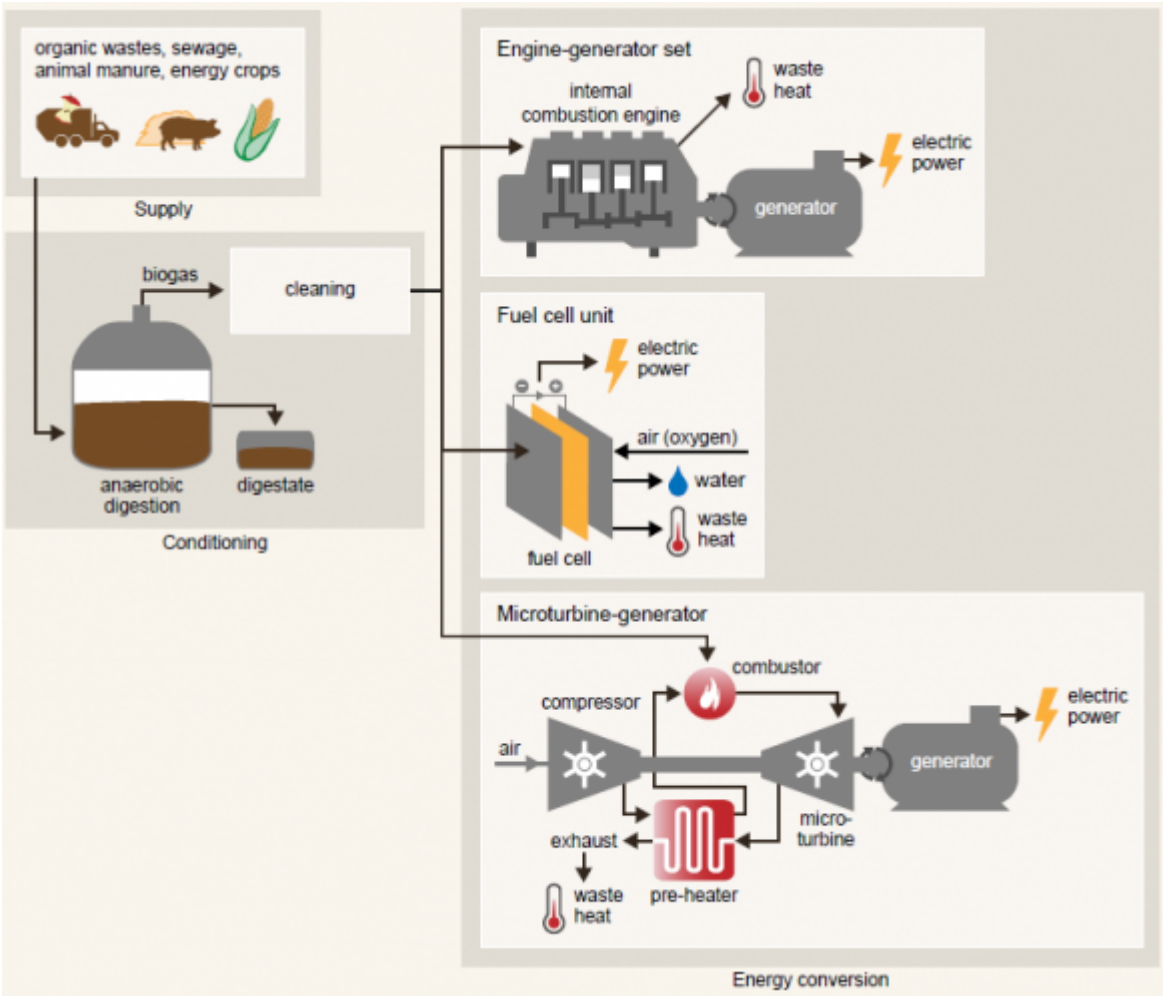
Figure 2: Figure 1 :


organic wastes, sewage,
animal manure, energy crops
Supply
biogas
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digestion
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Conditioning
Engine-generator set
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heat
electric
power
generator
Fuel cell unit
electric
power
air (oxygen)
water
waste
heat
fuel cell
Microturbine-generator
combustor
compressor
air
generator
electric
power
micro-
turbine
exhaust
waste
heat
pre-heater
Energy conversion

Figure 3:

2

Figure 4: Figure 2 :

1

(Ret) In Bangladesh

Figure 5: Table 1 :

Community based Micro Off-Grid Power System using Renewable Energy Technology (Ret):
Investment Analysis, Cost Benefit and Main Factors

	Sources	Unit size	Potential number	Total conventional unit
	Solar LED based lantern	5W	11 million line) (below poverty	55 MW
	Solar LED based lantern + 10W CFL	15W	11million (below poverty line)	165 MW
Year 2014	Solar Home System Mini grids Mini grid of moderate size	30W 12.5W	12 million 40011	360 MW 300 MW 100 MW
20	Solar water pumping		225000 (around)	1200 MW
I	Grid connected PV system			600 MW
( ) F Volume XIV Issue I Version	Solar PV System Rice husk gasifier Wind electricity Micro hydro Biogas power plants	200kW	1% area of Bangladesh with 10% efficiency 500 0.202 million (from poultry waste)	40000 M 100 MW 10 MW 1.2 M (according to BPD Potential 4 MW Possil generation 1 MW

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Figure 6: ?

[Note: b) Solar Thermal Power/Concentrating Solar Power (CSP)]

Figure 7:

2

Utilizing Renewable Energy Technologies (RETs) and Achievements Till Date
III.

Figure 8: Table 2 :

3

Family In A Village				
Load	Quantity	Wattage rating	Hours/day	Units (Wh)
1. Fan	2	80	4	640
2. Light (Energy saving/CFS bulb)	3	23	4	276
3. TV (19" color)	1	160	4	640
4. Mobile charger	1	10	4	40
		Total demand = 399 W		Total = 1.596 KWh

Figure 9: Table 3 :

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