Renewable Energy as a means of Rural Livelihood improvement in Bangladesh -an Experience of RDA

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Abstract

Bangladesh is passing through power crises which have been continuing for several years. Day by day this situation is worsening. In irrigation period the demand of power supply increases as more as which is causing huge load shading all over the country. Rapid population growth, increases food demand that increased pressure on scarce resources in Bangladesh to support food security of ever growing population.

When there is no use of anything considered as waste, may be converted to value or in use through proper initiatives or by transform to make usable. Most of the rural people in Bangladesh face quality of life and livelihood challenges associated with sub-optimal sanitation because of existing improper waste management system.

The traditional practicing of using cow dung as fuel is deteriorating soil organic matter and environment through unmanaged wastes responsible for Green House Gas (GHG) emission. These challenges are manifested in health issues related to water-borne diseases, respiratory diseases from indoor smoke inhalation and declining agricultural livelihoods. Community based biogas technology has been identified and accepted as a socially, economically and environmentally sustainable solution for addressing these issues. Total 106 Bio-gas plants are installed over the country for better solid waste management and livelihood improvement, Tearbond village is one of them where the study was conducted. The study reveals that earlier the farm owner of Tearbond was in breakeven point along with only milk business but incorporation of Bio-gas model profit margin noticed significant (Net income $15000. Tearbond village community is managing 985 tons of waste per years. They converted waste to value and earned $9350 by selling 433 tons of organic fertilizer in addition through providing service to the community people with biogas for cooking, generating electricity, safe water supply at domestic & farm levels; thus total net benefit stood at $15000 during last year (2014). In changing of rural livelihood and waste management practice the community bio-gas is a unique model.

The viability of direct solar power irrigation study was conducted at RDA demonstration farm to make the rice base farming profitable one in multi-storied agriculture system, to ensure environment friendly energy sources and to reduce extra thrust on national electric grid and shrink electric bill. Bangladesh is the perfect location for direct solar power irrigation where sunshine hour in varies from 10 to 13 hours and solar radiation and intensity also fluctuates very little throughout the year. From the study, pump run maximum 10 hour by direct solar power where it gave full flow of water maximum 6 hour in a day. Average water discharge was 40710 liter per hour. Total water discharge per day was 310 m^3 and by this water 0.53ha. of land was irrigated per day. By the system total 4.86ha. of land was managed by irrigation. As in two storied cropping, production of rice (base crop) in experimental plot decrease up to 4.79% compare to the control plot but it produces secondary crop (127 Bottle Guard) as an extra production and also gave support for solar power for irrigation that cut the cost of electricity. Financial analysis indicated that NPV, BCR and IRR were BDT 4.675 million, 2.26 and 32% respectively. The values of NPV and BCR were > 0 and >1 so the model would be accepted and should be pursued.

The difficulty of community bio-gas was accumulation, handle and manage the degradable waste produced over the village. Overcome the difficulties and in addition to incorporate the success of using solar energy for lighting against load shedding period and using renewable energy (Bio-gas and Solar Power) for lifting and supply of water this cooperative based model house (Palli Janapad) would be a milestone for rural development. Total 288 HHs could be lived in a common tower with well facilities of rearing 500 cows and 16126 poultry birds. All degradable waste (Excreta, Cow dung, Kitchen waste and poultry drops) of 3.8512 million tons/yr could be managed by collecting them in a single point by gravity flow. Waste management becomes easier and produced bio-gas supplied to the individual flat with solar lighting facilities (50 kW) in load shedding period. Both the renewable energy (Bio-gas and Solar power) should be used for lifting water and supply. The recommended green housing model saves agricultural land of 7.81ha.; erase the construction cost of 6.15 km overhead electric line. Yearly produced 145152 m^3 of bio-gas and two tons of organic fertilizer daily which gross market value stand $0.06 million per year. 50kW of electric power will be produced using solar energy and the flat owner will be enjoyed three light and one fan facilities The piece of study is the success experience of using renewable energy in multi-dimensional sectors of rural development in efficient way.

The research findings support collaborative policy processes that include vertical and horizontal communication amongst government, NGO, private sector, and community stakeholders which might be the means of economically viable waste management system leads to livelihood improvement in an environment friendly replicable model for Bangladesh.

Key words: renewable energy, bio-gas, solar power, means of livelihood, rural housing. palli janapad.

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1.0 Introduction

Waste is a resource by its' nature of use, it may vary on the basis of location or on ownership's decision; so there is nothing waste if its transform into usable ones. The waste particularly produced in livestock farms may be converted into biogas as a source of environment friendly renewable energy. Access to energy is crucial for the development of any country (Okello, *et al.*, 2013). While access to energy did not make the list of Millennium Development Goals, it has been cited by United Nations Secretary-General Ban Ki-moon as the very foundation for all the Millennium Development Goals (United Nations, 2010, September). Bangladesh has traditionally relied on biomass wood, charcoal, cow dung as a primary source of fuel for cooking. Inefficient use of wood is associated with pollution, deforestation and related issues such as undesirable change in biodiversity, wood scarcity, and degradation of land and water resources (Okello, *et al.*, 2013; Pandey *et al.*, 2007).

Bangladesh has major problems with energy shortage, persisting poverty and environmental degradation. Per capita energy use is only 180 kW-h (***Energypedia-2014***). With only 59.60% of Bangladesh's having access to electricity connection whereas the national grid could so far cover only 42 percent of 161 million of the total population, and only 06 percent people are enjoying piped gas supply major in urban areas as well as 90 percent of Bangladeshi cook with biomass such as rice straw, dried leaves, jute sticks, cow-dung or wood (***World Bank 2014)***.

About 70 per cent people of Bangladesh live in rural areas, where the energy situation is not satisfactory. As a result, rural to urban migration is high in Bangladesh. In the rural areas, the houses are scattered. Neither grid nor piped supply is suitable for those areas. Renewable enerty systems like solar, biogas; wind, etc. have no alternative. About 90 percent of the electricity now produced in the country is based on natural gas, which has limited reserves and will be exhausted in the near future. Bangladesh has a wonderful condition for biogas production. The ideal temperature for biogas production is around 35^0C. The temperature in Bangladesh usually varies from 6^0C to 40^0C. But the inside temperature of a biogas digester remains at 22^0C-30^0C, which is very near to the optimum requirement ***(Gofran, 2007)***.

Fuel wood scarcity is an escalating economic and social problem in the case of Bangladesh almost similar to Uganda contributing to both the increased cost of fire wood and the increased time required to collect it. Pandey et al (2007) calculated that the average household in Uganda spends nearly one hour per day collecting fire wood. Studies indicate, however, that 400,000 people in Sub Saharan Africa die each year from the health impacts of smoke inhalation (Okello *et al.*, 2013). This is because a house with an open fire can have up to 75 times the maximum advised level of air pollution (Hivos, n.d). Surveys completed in Uganda indicate that 75 percent of Ugandans have reported concerns over respiratory health which is most likely related to heart cooking (Smith *et al.*, 2012, Nov 19). Moreover, the people who are connected with the national grid electricity supply system are experiencing frequent load shedding. At present, while the peak demand is about 6000 MW ***(USAID, 2011***), therefore, the supply is unreliable. Most of the supply is limited to urban areas; access to electricity in rural areas is less than 10%. Renewable Energy Technology (RET) can solve this problem by harnessing energy from country's free flowing renewable such as sunshine, wind, tidal waves, waterfalls or river current, sea waves or biomass. Use of renewable energy, increased energy efficiency and enhancement of energy security constitute a sustainable energy strategy approach (Sarkar *et.al.* 2014).

To minimize the energy problem, Rural Development Academy (RDA), Bogra, Bangladesh has been carried out experimentation since 2000. Initially two bio-gas plants having capacity of $130m^3$ each has been constructed at RDA campus under the ADP funded project. At present, a total number of 63 households (4 storied building), Guest house, DG's Bungalow have been connected under biogas facilities. Moreover a 5 KVA generator is being operated using biogas and a portion of RDA demonstration farm premises has come under gas-electricity. The slurry (fermented cow dung & Kitchen waste) produced from biogas plant are processed as organic manure and sold at market through Advanced Chemical Industries Limited (ACI) in a branded name of "Palli Joibo Sar" (Rural Organic Manure) after mitigating local demand ***(Sarkar, et.al. 2013).***

Rapid population growth, increasing food demand and urbanization are the main causes that create increasing pressure on scarce resources in Bangladesh to support food security of ever growing population. One of the lowest land-person ratios (0.12 ha) in the world (FAO, 2001) the country is loosing 1% of cultivable land every year. Horizontal increase of production is nearly impossible due to limited cultivable land area. Therefore, it is becoming imperative to go with the vertical increase of crop production. Moreover, rice cultivation alone is no more profitable enterprise for the farmers of Bangladesh. During dry season the demand of power supply increases to 40% which causes huge load shading all over the country. Evaporation is also high in dry season. Abundant sunshine in Bangladesh is a blessing of nature can be exploited to increase agricultural productivity in many fold. Combining knowledge and wisdom of agronomy and astronomy the concept of two storied cropping system has been evolved which can efficiently drive the non profitable rice cultivation to a profitable one. The present cropping intensity of Bangladesh (180%) can increase the intensity by double and even triple through the innovation **Two-Storied Agriculture with Solar Irrigation in Bangladesh.** Moreover the cropping system for lifting ground water for irrigating rice as the base crop and cucurbits vegetable as the second layer, crop even during the driest period of the year. Moreover the two storied agriculture with solar panel requires zero or no electricity as the top layer is furnished with solar panel thus minimized load shading and creates less demand on national power grid.

With the on station successful experimentation, RDA started implementing GoB funded action research project entitled “Poverty Alleviation through Livestock Management and Bio-Gas Bottling (2009-2015)” targeting 112 areas through community approach whole over the country. Under this action research project there is a provision of constructing community based biogas plant each capacity of 130-200 m^3 rather than traditional household level with a package support of skill development training and distributing cattle among the beneficiaries as on leasing out basis as a source of input of the biogas plant ***(Sarkar, et.al. 2011).***

At present RDA, Bogra has already been completed 106 community bio-gas plants (capacity 100-200 m^3) out of 112 sub-projects in almost 7 Divisions of Bangladesh. At every sub-project level 5 KVA generators is being provided for localized electricity generation and supplied to community households’ level. This paper would highlight the major impact of implementing biogas plant following community approach in the northern region of Bangladesh.

Rural Development Academy, Bogra has conducted research on two storied cropping system keeping rice as the base crop and bottle gourd (Vegetables) on the 2nd layer and solar panel for irrigation on the 3rd layer. The gross additional income was US $ 1400 from one hectare of land where rice yield was not significantly decreased compared to single layer method of rice cultivation. Deducting the cost of trellis and other operational cost, a net additional income of US $ 1250 was obtained from one hectare of land by applying multistoried cropping system of RDA. More over, the solar panel irrigation system helps in reducing huge pressure on national power grid it harvests sunshine as 3rd crop and generates power for lifting ground water using sunshine, and brings the electricity consumption and cost to zero. About 1.3 million units of small borehole used for irrigating rice each consuming 5 kW of electricity put huge load on power sector can be solved by popularizing two stored agriculture model.

The difficulty of community bio-gas was accumulation, handle and manage the degradable waste produced over the village. Overcome the difficulties and in addition to incorporate the production of solar energy for lighting the load shedding period and using renewable energy (Bio-gas and Solar Power) for lifting and supply of water. The piece of study is the success experience of using renewable energy in multi-dimensional sectors of rural development in efficient way.

2.0 Main Objectives

The main objective of the study is to explore out the impact of using renewable energy for food security and livelihood of rural Bangladesh

The specific objectives are as follows:

i. To focus the RDA-model of community based biogas, produced from all degradable waste in a village community as a model of better solid waste management;

ii. To use bio-gas in multi-dimensional livelihood activities (cooking; electricity generation for compensating load shedding and water lifting) for the safety net of rural women health and improvement of rural life style;

iii. To focus the RDA-model of direct solar power irrigation with two-layer agriculture in increasing cropping intensity for food security and reduce the extra thrust on national grid; and

iv. To explain a sustainable waste management model for accumulating all waste by constructing a cooperative based multi-storied rural housing “Palli Janapad” with modern urban amenities.

3.0 Materials and Methods

The overall methodological approach is focused on integration of quantitative and qualitative methods. Along with questionnaire, which is the main source of data, a number of qualitative tools have been used for data collection. The secondary sources data also collected from the concerned project offices. The findings from the questionnaire survey and qualitative investigation are made complementary to each other throughout data collection to analysis.

The Rural Development Academy (RDA), Bogra, Bangladesh, completed a community based action research project at 106 sub-projects areas of Bangladesh out of total targeted 112 during (2009-2015). Necessary data were collected from purposively selected site (Tearbond village of Shahjadpur upazila under Sirajgonj district), where there was no gas supply from national grid while the community biogas project started in September 2012 with direct participation of village people but with single ownership who contributed necessary land for biogas plant installation along with deep tube-well (bore-whole), biogas generator, slurry processing floor and deposited as down payment on behalf of the community $1812.5 (10% of total cost $18125). Respondents interviewed were engaged in community biogas plant management and allied energy generation and distribution activities at the community level.

The Tearbond village community is oriented in organized form by the intervention of Community Biogas Project (GoB funded action research project of RDA) since its inception in February 2013. A participatory approach was used for both qualitative and quantitative data collection during March to May 2015.

Regarding solar powered irrigation model data were recorded from 31 March 2013 to 29 June 2013 in daily basis with a time period one hour interval from 07.00 am to 06.00 pm. Static water level, total time of pump run, time of full flow by pump, pumping water level (in meter), water flow (liter per hour), voltage and ampere loaded by pump, total water discharge (in m3), total land area (in hectare) coverage by irrigation etc. data were recorded in daily basis. Two storied cropping data, rice as the base crop and cucurbits vegetable (Bottle Guard) as second crop, were also recorded. Types of crop, variety, plantation, plant height, distance of plant to plant and row to row, weeding, irrigation, use of fertilizer, use of pesticide, yield etc. data were collected from both experiment and control plot.

After collecting data were compiled, tabulated and analyzed according to the objectives of the study. The collected data were verified to eliminate errors and inconsistencies. For cost benefit analysis the collected data, the probable cost induced with year-wise project cost of establishment and the revenue (benefit/return) were incorporated in a spread sheet. Then the economic and financial analysis i.e. Net Present Value (NPV), Benefit-cost Ratio (BCR) and Internal Rate of Return (IRR) were calculated.

4.0 Result and Discussions

Biogas: Biogas is a colorless fuel gas, which is produced as a result of decomposition of cow dung and other perishable materials in absence of air. It contains 50% to 55 % of methane gas and the rest part is Carbon dioxide. In the biogas production process, high value organic manure is produced as byproduct.

4.1 Scope of Biogas production and RDA's Experiences

At present, Bangladesh has 22 million cattle in number. They produce near about 220 million kg of cow dung. About 1.3 cubic ft (0.037m^3) gas can be obtained from one kg of cow dung. Based on this calculation, it is possible to get 2.97 X 10^9 m^3 of gas which is equivalent to 1.52 X 10^6 tons of kerosene or 3.04 X 10^6 tons of coal. Besides this, a noticeable amount of biogas can be produced from the excrement of man, poultry, goat, ram etc, and other degradable waste, water-hyacinth or aquatic plant. Every year 1.2 X 109m^3 gas can be produced only from human waste, if we are able to bring every family of Bangladesh under biogas plant project. To meet up the present fuel crisis, Fuel Research and Development Institute under Bangladesh Council of Science and Industrial Research started to produce biogas from cow dung and various perishable materials. At first the Institute constructed a floating typed dome model biogas plant in1976, having capacity of 3 cubic meter gas. It costs $150 only. In 1981, it became possible to reduce the biogas plant construction cost at $39.38. The longevity of this biogas plant was 3-5 years. As the gas-holders were made of MS sheet, it started leaking within 3-5 years. In rural areas, there is no effort of welding facilities and it is difficult to renovate the gas-holders.

Rural Development Academy, Bogra has successfully carried out experimentation renewable energy. Firstly two number of bio-gas plants having capacity of 130 m^3 each have been constructed at RDA campus under the ADP funded project "Expansion, Renovation and Modernization of Physical Infrastructure of the RDA Bogra" during 2003. At present, a total number of 61 households, Guest house, DG's Banglaw have been connected under bio-gas facilities. Moreover a 4.6 KVA generator is being operated using bio-gas and electrified a small portion of RDA demonstration farm. The slurry (fermented cow dung & Kitchen waste) produced from bio-gas plant are processed as organic manure and sold at market in a brand of "Palli Joibo Sar" (Rural Organic Manure)

Community biogas technology offers a potential for boosting up rural productivity and changing livelihoods and stakeholder participation to the policy process may help to facilitate the creation and establishment of a successful biogas sector. The challenge is therefore to improve stakeholders' participation to the policy-making process and ensure successful establishment of a waste management strategy as well as enhancing biogas sector in Bangladesh.

RDA-developed Community Bio-gas Plant (CBP) offers a package system which mainly included for e.g. a demand based biogas plant (Capacity 100-200m^3) for managing all sorts of degradable wastes produced by a particular community; biogas generator for producing electricity, Deep Tube Well (DTW) to have safe water both for domestic use of the community and for running biogas digester smoothly, pipeline both for water and biogas supply to the households level and with a drying-cum processing floor to manage organic fertilizer etc. along with this to some extent financial support also provided to the community people on training match income generation activities (IGAs) towards sustainability.

This paper fills a gap in the literature by identifying methods to improve a policy making process for a national biogas framework in Bangladesh. Stakeholder collaboration was identified suitable as an approach of community participation for waste collection and benefit sharing which should result in an improved policy making process. These tools included Participatory Rural Appraisals, Power Analysis, Social Network Analyses, Stakeholder Analysis Matrices, Micro-political mapping, and Value Chain Analysis. Combined, these tools can be used to improve stakeholder collaboration, which can be used to improve the policy making process to establish a national biogas framework for increasing biogas technology, which can then be used to improve the quality of life and livelihoods of community people (Bernhard Heikoop, 2013).

4.1.1 Bioslurry as Palli Jaibo Sar in Bangladesh

Palli Jaibo Sar has highly positive impact on the agricultural production in Bangladesh. Research findings confirmed that bioslurry as an organic fertilizer has affected crops by increasing the yields. Furthermore, bio-slurry has vital role on restoring soil organic matters which are at alarmingly low levels (less than 1% to some regions) in Bangladesh.

RDA running about 200 community based biogas plants over the country which are proved as environment friendly and economically feasible model through her action research projects (2009-2015). The average production of each bio-gas plant is about 90-100 tons/day bio-slurry contents 100% organic fertilizer that has been proven as the most suitable fertilizer for supplementing chemical fertilizers in Bangladesh. As one of the marketing & extension partners, the private company ACI has vast network has engaged to promote the use of bio-slurry as organic fertilizer with the brand name as ("Palli Jaibo Sar" Reg. No. M-604, Pack: 40 Kg.).

A proper fertility management of soil as seen very critical, because, farmers are used mostly chemical fertilizers (with under/over doses of certain nutrients). To conserve and boost up the soil health farmers need motivation and convert locally available organic resources into resources through community biogas plants to capture multidimensional benefits such as- biogas for cooking & electricity generation, organic fertilizers and safe water supply with various scopes of having friendly environment, employment generation and overall economic supports etc. This organic fertilizer would certainly put a vital role to reduce the quantity of using chemical fertilizers and would help to get sustainable agricultural practice in Bangladesh.

A community bio-gas plant is a waste management unit capable to manage the total degradable waste of a village and make the village green one. The comparative identification of a community based bio-gas plant is notice in the Table below.

Table-1: Comparative analysis Between Community Biogas Plant and Household level Biogas Plant

Community Biogas Plant	Household Biogas Plant
Community based	Family based
Bigger in size (100-200 m^3)	Small unit (1.2-4.8 m^3)
Active participation in waste management	Waste management in household level
Common output sharing	Individual family use
Community investment without subsidy	Individual contribution with subsidy
Package support for sustainability	Only Bio-gas plant
Total investment $18125	Cost $437.5-$750
Family coverage: 120-200 families	One family only
Waste management capacity- 2.5-3.0 Ton/day	Waste management capacity- 30-60 kg./day
Proper decomposition	Improper decomposition
Daily gas output- 50-90 m^3	Daily gas output- 1.1-2 m^3
Manure output- 400-500 kg/day	Manure output- 6-12 kg/day
Safe water supply system	No water supply system
Biogas generator for electricity (5kVA)	No generator
Main grid pipeline for supply of water and biogas to the community households	Only biogas line connected to individual family
Average cost minimal	High cost
Maximum scope of benefit sharing	Least scope of benefit sharing

Out of 106 bio-gas villages Tearbond is a representative sites. Initially the cattle farm owner of Tearbond was in breakeven point as milk was the only product. To develop his farm as profitable one an initiatives has been taken by him and installed a community based bio-gas plant in techonological support of RDA. The facilities developed at Tearbond are a Bio-gas plant (130 m^3); Gas supply line; a Borehole; Overhead Tank; water supply main line; Organic manure dryung yeard, Bio-gas operated generator etc. The rural communities are trained on collection, handle & management waste, bio-gas and water supply, cattle rearing, feed production, organic manure production and processing. The cattle population of the village is increased by providing loans for cattele rearing and some cows are provided to the local benefeciaries as traditional sease basis.The monthly inputs and mixing ratio of waste materials supplied in Tearbond sub-project are given in Table-2 and Table-3.

Table 2: Daily Average Inputs Feeding to the Biogas Plant by Waste Category

Month	Amount (kg) of feeding materials used/day				
	Cow dung	**Poultry droppings**	**Kitchen waste**	**Others**	**Total**
January	2415	155	52	17	2639
February	2314	145	49	23	2531
March	2585	124	63	29	2801
April	2980	126	67	28	3201
May	2617	127	78	33	2855
June	2780	132	84	36	3032
July	2312	224	67	27	2630
August	2357	238	77	19	2691
September	2440	131	83	21	2675
October	1912	218	64	22	2216
November	2019	232	58	26	2335
December	2517	181	64	27	2789
Average	**2437**	**169**	**67**	**26**	**2700**

As there is no availability of gridline gas, most of the respondents depend on natural sources of biomass for cooking. Due to insufficiency of natural forests the farmers collect fuel wood from the homestead forestry. The major sources of biogas production feeding materials are from livestock waste (91%), poultry droppings (6%), kitchen waste (2%) and others (1%) etc. (Figure 1).

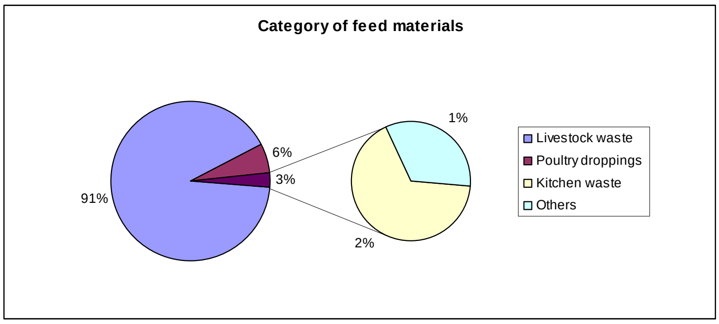

Figure 1: The Categorywise Input supplied to Tearband, Shahjadpur, Sirajgonj, Bangladesh

Table 3: The Input Ratio and Cost of Wastes Per (Kg) supplied to Tearband, Shahjadpur, Sirajgonj

Item	Category of raw materials				
	Cow dung	**Poultry droppings**	**Kitchen waste**	**Other**	**Comment**
Feeding to biogas plant (%)	91	6	2	1	Depends on availability
Input Ratio (Water : Waste)	1:1	1:2	1:0.5	1:1	Depends on raw materials
Average price $ per (kg)	0.005	0.007	0.0125	0.006	Including carrying cost

After introduction of community bio-gas 240 HHs are getting direct benefits out of the total population (500 HHs) of the village. Number of cattle increased 390 intotal with improved brid. Forty families are enjoying biogas connection and asked for $6.25 for double burner. Ensured water supply at 29 HHs and a cattle farm of 200 cattle in numbers. So the water borne diseased fom 60% to 10%. The utility facilities are prevailled in the village area are illustrated in Table 4.

Table 4: Impact of Tearbond Community Biogas Project during (2014)

Sl. no.	Item	Before Project	After Project	Remarks
1.	No. of beneficiaries	-	240	500 Families in the village
2.	No. of cattle	1000	1390	
3.	Vaccination (%)	70	90	Cattle
4.	Cross bred cattle (%)	44	78	
6.	Silage technology adoption	-	5	
7.	Organic fertilizer production	-	197 ton	140 ton marketed through ACI and 57 ton used in community land.
8.	No. of farmers in fodder cultivation	3	216	Napier, bucsha, khesari etc.
9.	Waste management	-	985 ton	Including household waste
10.	Bio-gas connection (Family)	-	40	Double burner
11.	Electric connection (Appliance)	-	49	45 Bulbs, 4 fan
12.	Water borne diseases	60%	10%	
13.	Production of biogas (Cubic meter)	-	34475 m^3	
14.	Safe water supply (Number)	-	30	1 Cattle farm (200 Cattle) 29 Family
15.	Trained manpower on different IGAs	-	80	Beef fattening, Livestock rearing, Silage production, Fertilizer processing etc.
16.	Awareness building	-	255	

4.1.2 Yearly Return

The yearly income and expenditure of the Tearband scheme is noticed in following Table 5. The net income from bio-gas supply secured $2725, electricity supply $412.5 and water supply $200. The income from organic manure and beef fattening sectors showed significant income $9355 and $2314.37 respectively. Finally deducting all expenditure ($18455.62) from the gross income ($33462.5) the net benefits of the farm captured $15006.87. So the farm earlier identified as breakeven has graduated as profitable farm by introduction of community bio-gas plant.

Table 5: Analysis of yearly Income & Expenditure of Tearbond Community Biogas Sub-project

Item	Yearly expenditure (USD)				Yearly income (USD)			
	Input (No.)	Labor (No.)	Other	Total	Household (No.)	Farm (No.)	Total	Net income
Deep tube well	200	300 (1)	50	550	450 (29)	300 (1)	750	200
Biogas generator	225	300 (1)	37.5	562.5	735 (49)	240 (1)	915	412.5
Biogas supply	225	300 (1)	50	575	3000 (40)	500 (1)	3300	2725
Organic fertilizer	4927.5	805 (322)	75	5807.5	15162.5	-	1516.25	9355
Beef fattening	10016.87 (16)	900 (1)	43.75	10960.62	13275	-	13275	2314.37
Total	**15594.37**	**2605**		**18455.62**	**32622.5**		**19756.25**	**15006.87**

NB: 1. Figures in the parenthesis indicate number of users

4.2 Two-Storied Agriculture with Solar Irrigation

Abundant sunshine in Bangladesh is a blessing of nature can be exploited to increase agricultural productivity in many fold. Combining knowledge and wisdom of agronomy and astronomy the concept of two storied cropping system has been evolved which can efficiently drive the non profitable rice cultivation to a profitable one. The present cropping intensity of Bangladesh (180 %) can increase the intensity by double and even triple through the innovation **Two-Storied Agriculture with Solar Irrigation in Bangladesh.** Moreover the cropping system for lifting ground water for irrigating rice as the base crop and cucurbits vegetable as the second layer, crop even during the driest period of the year. Moreover the two storied agriculture with solar panel requires zero or no electricity as the top layer is furnished with solar panel thus minimized load shading and creates less demand on national power grid.

Rural Development Academy, Bogra has conducted research on two storied cropping system keeping rice as the base crop and bottle gourd (Vegetables) on the 2^{nd} layer and solar panel for irrigation on the 3^{rd} layer. The gross additional income was US $ 1400 from one hectare of land where rice yield was not significantly decreased compared to single layer method of rice cultivation. Deducting the cost of trellis and other operational cost, a net additional income of US $ 1250 was obtained from one hectare of land by applying multistoried cropping system of RDA. More over, the solar panel irrigation system helps in reducing huge pressure on national power grid it harvests sunshine as 3^{rd} crop and generates power for lifting ground water using sunshine, and brings the electricity consumption and cost to zero. About 1.3 million units of small borehole used for irrigating rice each consuming 5 kW of electricity put huge load on power sector can be solved by popularizing two stored agriculture model. **Benefits of Solar Irrigation System**

The ultimate long term impact of two storied agriculture with solar irrigation is to reduce poverty and improve livelihood of farmers and limit dependency on ever crying electricity for irrigation.

Round the year farmers can produce' sale and consume paddy and vegetables on the same piece of land by efficient utilization of abundant sunshine. Through this system, Cropping intensity can be increase from 180% to 360% and even 500% in Banglades

4.2.1 Instruments used

In our study total number of 24 solar panels was set up where each panel's capacity was 270 watt, and the total capacity of these panels was 6.48 KW (Table 1). Panels were installed in scattered manner at $\angle 24^0$ with a height of 2.13m. Depth of DTW was 27.44m where housing pipe was 12.20m. With the DTW a D.C submersible pump of 3.5 KW was set up (Table 6).

Table 6: Technical Information of Solar Irrigation System

Instruments	Description
Solar panel	Polycrystalline (270 Wp; 18.20% efficiency)
Panel capacity	24 X 270 Wp = 6480 Watt (6.48 kW)
Placement of panel	Panels are installed in scattered manner North-south = 5.18m; East-west = 4.27m Panel height = 2.13m, at $\angle 24^0$
Deep tube-well (Borehole)	Depth- 27.44m; Housing pipe-12.20, dia-35.56cm; Strainer-12.20m, dia- 101.6cm; Bail plug- 3.05m, dia- 35.56cm
Pillars for cucurbit production	Wide = 1.22m; Height – 1.52m.
Raised pit for cucurbit production	0.46m X 0.46m X 0.46m
Distance raise pit to pit	5.18m
Pump	D.C submersible pump (H = 8-16m; Q = 35-60 m3/hr; 3.5 kW);
Groundwater level	Static water level (SWL) = 9.15m; Pumping water level (PWL) = 11.80m; Drawdown = 2.13m.
Charge regulator and panel board	Over load/voltage, low voltage protection and dry protection
Irrigation area	6.07ha.

4.2.2 Opportunity for solar power: sunshine hour and solar intensity

Geographically Bangladesh is a subtropical country where sunshine does not fluctuate too much like high latitudes' countries. The total sunshine hour in the country lies 10 to 13 hours per day throughout the year, during January to December shown in figure 2 (Shariar*et. al*., 2011). It is a great opportunity that sunlight remains almost same throughout the year. Solar radiation also varies from season to season in Bangladesh. Annual average solar radiation varies 3.5 to 6.0 $KWhm^{-2}day^{-1}$ and in our study period on April 4.5 to 6.5 $kWhm^{-2}day^{-1}$, on May 4.5 to 6.0 $kWhm^{-2}day^{-1}$and on June 3.5 to 5.5 $kWhm^{-2}day^{-1}$ (*NREL, 2010)*. Bangladesh receives the maximum amount of solar radiation on April and minimum on November-December-January are shown in the following figure 3 (Anam and Bustam, 2011). Solar intensity in Bangladesh on January and July are 0.95 KWm^{-2} and 1.05 KWm^{-2} respectively shown in figure 4 (Shariar *et. al*., 2011).

Bangladesh is located between 20.30 and 26.38 degrees north latitude and 88.04 and 92.44 degrees east longitude which is an ideal location for solar energy utilization. As a subtropical country, 70% of sunlight of year dropped in Bangladesh (Rahman et. al., 2013) For this reason, we can use solar panels to produce electricity largely. Solar radiation and solar intensity does not fluctuate too much in Bangladesh, it fluctuates very little and therefore, solar power would be very much feasible in Bangladesh. Solar radiation and solar intensity is comparatively high in the north and north-eastern part of the country. So Bangladesh is the ideal country for solar power as well as solar powered irrigation.

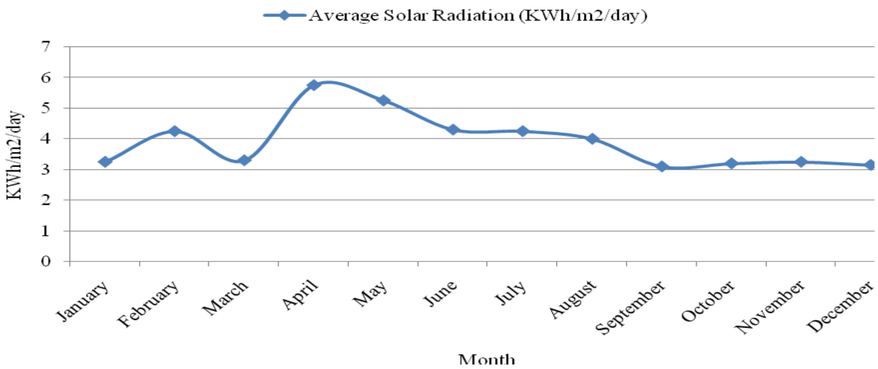

Figure 2: Monthly average solar radiation profile in Bangladesh

4.2.3 Capacity of the solar panel: volt and ampere loaded by pump

Considering the opportunity of direct solar power irrigation, a solar plant as well as deep tube well (DTW) was set up on RDA demonstration farm. In our study total number of 24 solar panels was set up where each panel's capacity was 270 watt, and the total capacity of these panels was 6.48 KW (Table 1). A 3.2 KW submersible pump was set up at the DTW with direct connection to the solar power. Loaded volt by the pump varies from 160V to 272V and ampere varies from 7.76 to 12.68 (Figure 5). The average loaded volt and ampere was 220.88V and 10.5 ampere respectively. The generation of ampere and volt directly related to the absorption of sunlight as well as solar intensity by solar panel or photo-voltaic (PV) cells. For maximum ampere and voltage, PV cells need to absorb higher intensity of sunlight. In a cloudy weather lower the solar intensity of sunlight as a result lower the production of voltage as well as ampere by the solar panel.

4.2.4 Drawdown: Static and Pumping water level

The static water level of the study area was 9.15m from March 31 to May 21, it moves up to 7.78m and 12.7cm from May 24 to June 9 and then downs again on 9.15m. Static water level moves up due to rain fall as well as recharges the aquifer. Average pumping water level of a day varies from 8.84m and 20.32cm to 11.28m and 7.62cm, therefore drawdown varies from 2.13 to 2.74m .The water level of pumping depends on the static water level also. Lower the static water level; lower the average water level of pumping.

4.2.5 Pumping time and water discharge

On our study pump was run up to ten (10) hour and few days it did not run due to unfavorable weather condition as rainfall and the average running time of pump was eight (08) hours. Full flow of water discharged six (06) hours in maximum and one (01) hour in minimum on a day of pump run. For the full flow of water discharge pump had to load maximum voltage, for maximum voltage solar panel of PV cell need to absorbed higher intensity of sunlight. A cloudy weather hampers absorption of higher intensity of sunlight. As a result the times of full flow varies as well as lower down. Average water flow or discharge varies from 27202 to 48397 liter per hour of a day. On an average 40710 liter per hour water was discharged by the pump. Water discharge also depends on the total run time of pump, full flow by pump as well as solar intensity. The higher the solar intensity higher the water discharges per hour.

4.2.6 Total water discharge and irrigated land area

Total water discharge varies from 96 m^3 to 477 m^3 per day and average discharge of a day was 310.08 m^3 (Figure 8). Through this discharged water 0.08 to 0.89ha. of land could irrigated and its average was 0.53ha. Total discharge of water depends on total run time of pump as well as full flow of water. When pump run more time with a full flow, it discharge more water and covered more land to irrigation. From figure 10 in the month of June water discharge more but land covered less due to some water store on pond and lake. On average 0.53ha. of land can irrigated per day from this system, the solar powered irrigation, with free of cost.

4.2.7 Comparison of yield between Experimental Plot and Control Plot

Two pieces of land were selected to evaluate the comparison of production of base crop (rice), while both plots were in same size (10 decimal). The plot where solar panel were set up and applied two-storied cropping system named experiment plot and other called control plot where cultivate traditionally. In the experimental plot some portion of cultivable land could not planted due to occupied by the pillar of solar panel. Treatments viz. plough, irrigation, weeding, application of fertilizer were same in terms of time and quantity. Rice variety of Hybrid (HIRA) was cultivated as Raised Bed method. The comparison of yield of base crop (rice) between experiment plot and control plot. In the experiment plot base crop (rice) production was lower (146 Kg) than the control plot (153 Kg) and it decreased 4.79% but it produces secondary crop as an extra production. Some portion of land occupied by the pillar of solar panel in experiment plot as a result total number of rice bunch was fewer in experiment plot than control plot. In these causes production of base crop decreased in the experiment plot while nourish treatment was same to the both plots. Though some portion of land in the experimental plot could not plant due to occupied by the pillar of solar panel, so it is natural that total production of experimental plot would less than the control plot. Therefore, total production of base crop (rice) in the experiment plot decrease only 4.79%. But experiment plot produces secondary crop, 127 Bottle Guard, as extra production where control plot produce only rice (Table 7). It would be a good practice for more production to meet the food demand.

Table 7: Yield comparison between experiment and control plot

Component	Experimental Plot	Control Plot	% Increase or Decrease
Yield/10 Decimal (Weight in m. ton)	**0.146**	**0.153**	4.79
Yield/Decimal (Weight in m. ton)	0.0146	0.0153	4.79
Yield/ha (Weight in m. ton)	3.57	3.741	4.79
Total bundle of paddy	301	310	3
Total weight of paddy tree (in m. ton)	0.274	0.295	7
No. Bottle Guard	**127**	**--**	

4.2.8 Cost Benefit Analysis

Total cost for the installation of a solar operated irrigation system was $22201.56 only. Among the cost, deep tube well boring was $4687.5; solar panel, DC pump, fitting etc. was $16125 and panel holding was $1150 only. In addition with installation coast as a fixed cost variable cost, $4250 per year, for operation and maintenance were also calculated. For income, saving cost for fuel (diesel or electricity), irrigation charge, value of base crop (rice) and cucurbit vegetable (Bottle Guard) was calculated. We assumed the economic project life is 25 years and the salvage value is 10% of the total investment. We assumed here the lower discount rate is 15%. The detailed financial and economic analyses sheet the projects with income and expenditure was calculated. The study finding of financial value of NPV was $58437.5. The value was > 0 so the project would be acceptable and should be pursued. In addition to this the Financial value of BCR was 2.26**,** which is >1 so the project is acceptable and should be pursued. Furthermore the Financial value of IRR was 32%.

Table **8**: Overall summary cost of installation of a solar operated irrigation system

Item	**Cost (USD)**
Deep tube well boring	6887.5
Solar panel (6480Wp) with submersible DC pump including controller module, sensor, connecting cable, fitting and fixing	16125
Panel holding frame with bamboo pole fitting and fixing	1150
Total	**24162.5**

4.3 Cooperative Based Multi-storied Rural Housing "Palli Janapad" (RDA Proposed)

The main difficulties of the community bio-gas sub-project sites are to accumulate, transport, handle and manage the total amount of waste produced in a village community. RDA's experience on opportunities of using renewable energy (biogas and solar power) in irrigation, water lifting, load shedding. Besides this every year about 1% of our agricultural land is being decreased for housing and other urbanization activities and the percentage of organic materials of our farming land is decreasing day by day that stands less than 1% but the standard is 5%.

Addressing the discussed issues a model of Community Based Multi-storied Rural Housing will be constructed to accumulate total of 288 farm families in a common tower with all modern urban amenities (piped water supply, biogas connection, biogas and solar based electricity, best solid waste management). If such amount of families constructs their house in agriculture land, a huge amount of crop field will be loosed for housing as well as approach road. The flat owners have the scope of rearing 500 cows and 16126 poultry birds. The total generated wastes (human excreta, cow dung, poultry drop and kitchen waste) of 3.8512 million tons/year are used to generate bio-gas, supplied to the individual household for cooking and a portion is used to produce electricity for ensuring water supply. The decomposed waste will be converted to organic manure (Palli Joibo Sar) and yearly produced 145152 m^3 of bio-gas. A good amount (Two ton) of organic manure will be produced daily of market price $59312.5 per year. In the roof top of Palli Janapad 50kW of electric power will be produced using solar energy. In the time of load shedding every flat owner will be enjoyed three light and one fan facilities. The solar power will be used for lifting water and domestic supply to reduce the extra thrust on national grid. The dwellers are trained on income generating activities (IGAs) get flexible loan, security for their economic improvement.

4.3.1 Facilities and Benefits of Cooperative Based Rural Housing (Palli Janapad)

The following utility facilities will be ensured if someone live in Community Based Rural Housing (Palli Janapad) and secured the following amount (Matin *et.al.* 2013)

- Rehabilitating 288 households into a multi-storied building of 1.52ha. saves 7.81ha. of land.
- Developed modern facilities of rearing 500 cows and 16126 poultry birds with drying yard and storage facilities for grains.
- Scope of handling waste (accumulating all drops, cow dung and excreta in gravity flow) become easier and produce bio-gas and organic manure, finally converted waste as value.
- Total generated waste of 3.8512 million tons/year will be received from a single point by gravity flow, that can produce biogas of 145152 m^3/yr and two tons of organic fertilizer daily of market value $59312.5/year.
- The study revealed that 57.56% of the respondents have plan for building new house. On an average 0.03ha. agricultural land per household is going to be turned into homestead area. This proposed project will restore 7.81ha. of land from being converted to homestead area very soon.
- Installation of the community bio-gas plant will save annual fuel cost of $102000 and minimize the carbon emission as well
- Connecting metal road construction cost of about $1.36 million at per LGED rate on 6.55ha. of land will be saved by constructing a single metal road of $5000 on 0.24ha. of land.
- Saves 6.15 km of overhead electric cable line.
- Comparison of construction cost building using Ferro-cement/EPS technology with PWD rate schedule revealed that it was about 30% less than traditional one.

5.0 Conclusion & Recommendations

Community based biogas is more suitable to organize in a comprehensive manner of community participation which creates new opportunities for waste management with energy, organic fertilizer, economic benefits as well as friendly environment.

Bangladesh as a sub-tropical country is suitable place for the generation of solar power. The country received sunlight, solar radiation as well as solar intensity more or less same throughout the year. Although, the installment cost of solar systems is very much costly, but once installed it can give service up to 20-25 years with proper maintenance.

Integrated introduction of bio-gas and solar energy in a model building of Palli Janapad change the livelihood and income of the rural people as well as the scenario of rural Bangladesh.

1. Community biogas technology might be one of the best ways for meeting up energy crisis in Bangladesh.
2. Community based organic manure production & utilization is very much effective for soil health improvement and quality crop production.
3. In the northern territories of Bangladesh where the solar intensity is very high, solar thermal power plant can be installed for both photovoltaic and solar thermal technology, Bangladesh is a perfect location.
4. RDA developed Community based Biogas Plant (CBP) and Two-storied Agriculture with Solar Irrigation System found as the best options to be replicated at each village of Bangladesh for sustainable technology as a means of socio economic change in rural livelihood.

5. The success of Green Building of RDA (Palli Janapad) will be a Model building for better waste management, restoration of agricultural land and optimal use of renewable energy for rural Bangladesh and similar countries over the globe.

To explore the technology as well as make more profitable to the country following measures would be taken

- To know the better result it needs further study and wide replication of the mentioned model.
- Before implement to the farmer level it needs to consider the installment cost; it will be better for community base implementation and give subsidy or credit.
- To minimize the installment cost, it may require further study.
- It will be better to develop multiple use of solar power with the irrigation practice and for this it require further study.

6.0 Observation

To minimized the problems on renewable energy sector in Bangladesh for continuous quick extension, popularization and replication of RDA’s experience in the filed level and as well as new technologist development in this connection Board of Governors (BoG) 41st Meeting of RDA approved Renewable Energy Research Center in 2012 under the administrative control of RDA.

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