ENERGY AND EMISSION ANALYSIS OF EVACUATED TUBE SOLAR WATER HEATING SYSTEM AND OPTIONS STUDY FOR THE POTENTIAL IMPROVEMENT

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ABSTRACT: The availability of energy and environmental quality is the fundamental needs of modern living. Renewable energy technologies (RETs) are considered clean energy technology in the context of energy crisis and global environmental problems. Though RETs does not consume fossil energy and produce emissions during the operation but it consumes significant energy and produce emission during manufacture. This study investigated the life cycle energy consumption and environmental emission (air and water) of evacuated tube domestic solar water heating system (DSHWS) using life cycle assessment technique. SimaPro software was used for the estimation of life cycle results. The analysis was considered for existing system and alternative improvement options. The result showed that, the life cycle total energy consumption of evacuated tube DSHWS is 2,608 MJ_{eq}. CO_2 is the major air emission magnitude of 356 kg was estimated. Three alternative improvement scenarios were studied namely, wooden base frame, no base frame and reuse of materials. The average reductions of energy consumption found to be 2%, 2.5% and 76% for the scenarios of wooden frame, no frame and reuse respectively. The reductions of CO_2 emissions are 2.5%, 11% and 76% for the scenarios of wooden frame, no frame and reuse, respectively. Hence, the applications of alternative improvement options are attractive to reduce the energy consumption and environmental emissions.

Keywords: Evacuated tube solar water heating system; life cycle approach; energy; emission; improvement options.

1. INTRODUCTION

With increasing trend of world population painted the energy requirement now and in future. At the same time environmental better quality is essential for the living. The share of fossil energy (coal, oil and natural gas) on global energy consumption was about 87% in 2011 [1]. But the rates of findings of fossil energy sources are limited compared to current energy consumption rate (10,600 million ton oil equivalent in 2011). Currently, the reserves of fossil energy are oil 260,000 million barrels, gas 29,400 billion m^3 and coal 49,600 million tons [2].The future fossil energy consumption projection provided the exciting information of global energy crisis in near future. At the same time global environmental emissions are other serious problems. The present CO_2 concentration in the atmosphere is 394 ppm and is increasing 2 ppm per year. The global CO_2 emission is expected to be 45 Gt in 2030 which will be double the 1990s level [3]. The world GHG emission is projected to 70 Gt CO_2-eq in 2050 which would be danger for human living in near future [4].

To address the above issues, the application of renewable energy technologies (RETs) increasing worldwide. The researchers are working on renewable energy technologies as a replacement of fossil energy to minimize the energy crisis as well as to establish better environmental quality. Solar water heating system is one of the renewable energy technologies and is getting popular worldwide for the production of hot water [5-8]. To promote these technology and local production, analysis is required not only its performance stage but also its manufacture stages. The overall analysis gives an useful information of that product to researcher, designer, developer to make an efficient technology and customer choice as well.

Life Cycle Analysis (LCA) is a technique that estimates the energy consumption and emissions in the environment at different life cycle stages from cradle to grave for the given quantity of input raw materials, transportation, etc [9]. An evacuated tube domestic solar water heating system (DSHWS) was considered in this study. The objectives are to assess the life cycle energy consumption and emissions for the existing system and to study for the improvement potential options. The study was conducted using life cycle assessment technique from cradle to grave. SimaPro software and Eco-indicator 99 (H) method were used for the estimation of life cycle results. Two types of emissions were estimated namely, air emission and water emission. The air emissions are carbon monoxide (CO), carbon di oxide (CO_2), methane (CH_4), nitrogen oxide (NOx) and sulphur di oxide (Sox); water emissions are chemical oxygen demand (COD), dissolve organic carbon (DOC), inorganic solids, sulphate (SO_4) and phosphate (PO_4).

2. METHODOLOGY

The methodology to estimate the life cycle energy consumption and environmental emissions of evacuated tube DSHWS from cradle to grave is described as follows:

The life cycle analysis framework contains four phases namely, goals and scope identification, inventory analysis, assessment the results and interpretation [10]. Goals and scope is describes the objectives of the study and selection the product to be considered for LCA study. Inventory analysis describes the production stages from cradle to grave within the system boundary and the data to be considered for LCA results. Assessment the result is done for the given input data. The interpretation phase presents the results and describes. The methodology of this study includes the terms system description, system boundary, data and estimation.

2.1. System description

The component parts of evacuated tube DSHWS are absorber, frame and water storage tank (Figure 1). Galvanized steel frame is used for the system. The absorber is of glass tube. One copper heat pipe passes through the centre of each glass tube. There are 24 glass tubes in the system.

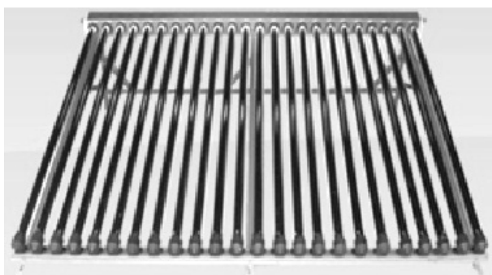

Fig.1: Evacuated tube domestic solar hot water system.

One end of the glass and copper tube joins with water flow pipe. The heat pipe media is a non toxic liquid to exchanges heat with flowing water by condensation and evaporation. The water flow pipe is well insulated and covered by aluminum sheet. The storage tank capacity of 160 liter is used in this system. The specification of the system is presented in Table 1.

Table 1. Specification of evacuated tube domestic solar hot water system

Parameters	Value
Dimension (cm)	184 ×149
Collector area (m^2)	2.74
Number of evacuated tube	24
Type	Thermosyphon
Life time (year)	15

2.2. System boundary

The system boundary stages of evacuated tube domestic solar hot water system (DSHWS) from cradle to grave is shown in Figure 2.

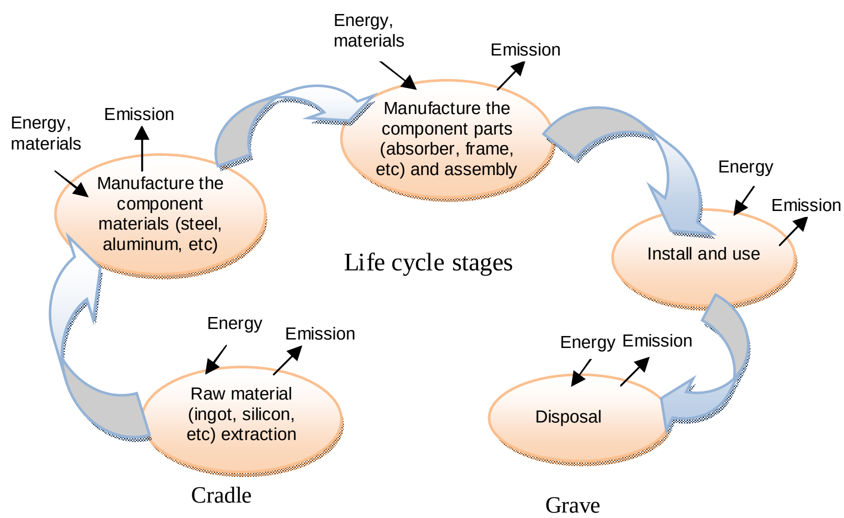

Fig.2: System boundary stages from cradle to grave

At stage 'cradle', the raw materials (ingot, silicon, etc) are extracted through extraction process. The extracted raw materials are then transported to component materials (steel, aluminum, etc) manufacture industry. The extraction process requires significant energy during the operation and produce emissions in the environment. The component materials manufacture industry consumes energy and raw materials during the process and produce finished component materials. Significant quantities of emissions released in the environment during the production of component materials. The component materials are then transported to component parts (absorber, frame, etc) manufacture and assembly industry. The assembly industry produced the hot water system and transported to installation sites. During the operation of the system it is assumed to be no energy consumes and emissions in the environment. At the end of life the system disassembled and disposed. Energy consumes and produced emissions in the environment during all the transportation entire the boundary stages were considered.

2.3. Data and estimation

The raw materials were estimated based on the quantities component materials required and industrial performance in Thailand for one unit system. The transportation was considered in local and abroad. Three modes of transportation namely, small truck (16 ton), delivery van (<3.5 ton) and transoceanic freight ship was considered for the estimation of life cycle results. Operating energy and raw materials data were collected from each of stage to estimate the life cycle results. The details of the raw materials, transportation are shown in Table 2.

Table 2. The raw materials and transportation details of evacuated tube DSHWS

Materials	Quantity
Glass (kg)	32
Galvanized steel (kg)	27
Copper (kg)	3.6
Aluminum (kg)	3
Insulator (kg)	0.3
Plastic (kg)	1
Welding rod (kg)	0.2
Transportation:	
Truck (tkm)	10.22
Delivery van (tkm)	0.78
Ship (tkm)	55

- Energy estimation

The life cycle total energy consumption is the sum of energy consumption during extraction the raw materials, energy consumption during transportation and operating energy for the manufacture. The energy for extraction was estimated using the SimaPro software for the given quantities raw material values input. The energy during transportation was estimated using the software for the given tkm values (ton materials × km travel). The operating energy was estimated from the manufacture industries in Thailand for the various life cycle stages.

- Emission estimation

The SimaPro software contains emission values for the different raw material extraction, types of transportation and for operating energy generated from different sources. The life cycle total emissions were estimated summing up the emission values from extraction process, transportation and operating energy consumption within the life cycle stages for the given quantities input.

3. RESULT AND DISCUSSIONS

This section describes the life cycle energy consumption and emissions of evacuated tube DSHWS. The results are presented for existing system and for alternative improvement options. The results are describes as follows:

3.1. Existing option study

The life cycle stages for existing system considered are extraction of raw materials, manufacture the component materials, manufacture the component parts and assembly, installation, use and disposal. It is assumed that 100% materials will be disposed to landfill.

- **Energy consumption**

The energy consumption at various life cycle stages is shown in Figure 3. The life cycle total energy consumption is 2,608 MJ_{eq}. It is seen that the extraction stage is the energy intensive stage compared to other life cycle stages.

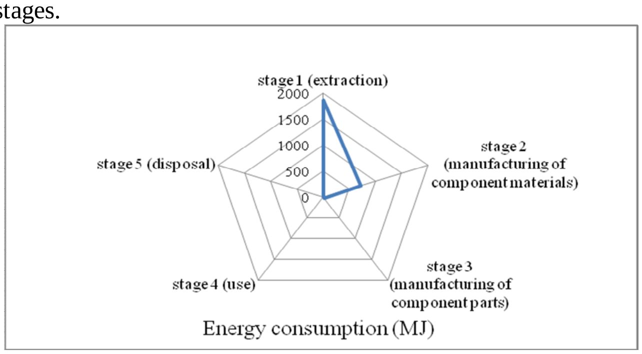

Fig.3: Energy consumption at various life cycle stages

The second intensive stage is manufacturing the component materials. This is due to the extraction of raw materials requires significant energy in the mining and manufacture process requires significant operating energy. Energy consumption is insignificant in the stages 3, 4 and 5 as the stages energy consumption only for assembly (stage 3) and transportation (stage 4, 5) which consume very less energy.

- **Environmental emissions**

The life cycle total environmental air emission of evacuated tube DSHWS is shown in Figure 4. It is seen that life cycle total CO_2 emission is significant magnitude of 356 kg was estimated. The other air emission found to lower compared to CO_2 emission. This is due to the CO_2 emission coefficient per unit production is higher than other air emissions. The role of CO_2 emission in the environment is dominated (green house effect) over the other air emissions.

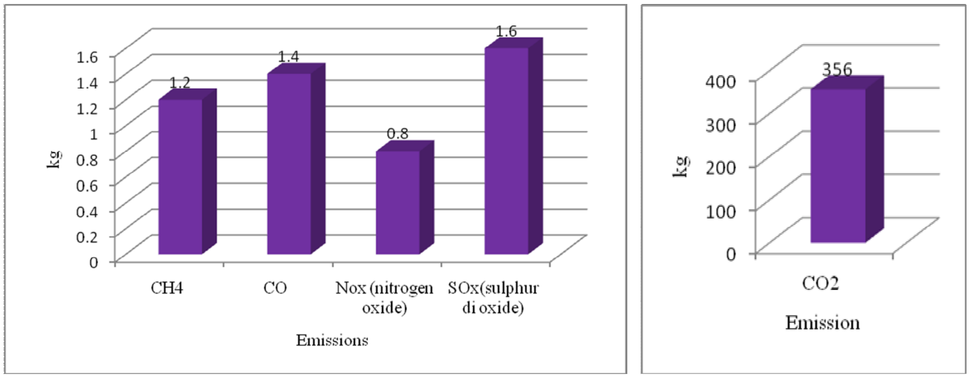

Fig.4: Life cycle air emissions

The life cycle total water emissions are shown in Figure 5. It is seen that the SO_4 emission is significant magnitude of 5 kg was estimated compared to other water emissions presented. The COD, DOC and PO_4 emission is in 'gm' intensity. This is due to the SO_4 emission coefficient is higher than other water emissions found in the software database. The SO_4 emission increases the acidity in the atmosphere and forms an acid rain. Acid rain kills the plant and pollutes the river water.

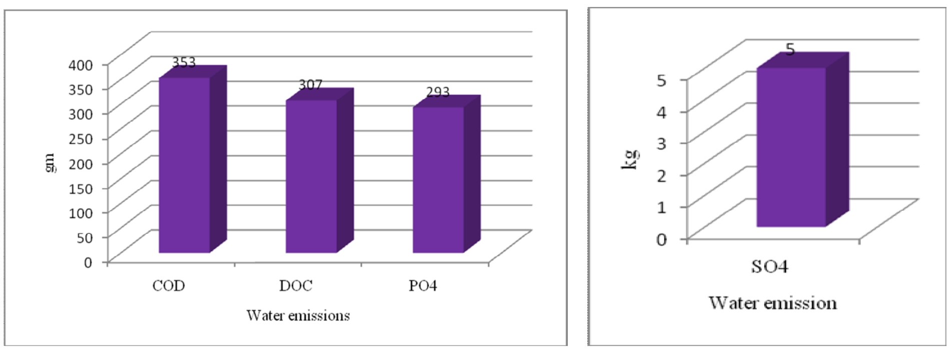

Fig.5: Life cycle water emissions

3.2. Alternative options study

The previous section analysis has shown that the extraction and manufacture the component materials are the energy intensive stages over the entire life cycle. Hence, the alternative options are considered in order to minimize the energy consumption and emissions. Three alternative cases namely, reuse of materials, wooden base frame and no base frame were studied for the reduction of energy consumption and emissions.

- In case of reuse of materials scenario, some of the materials (aluminum, steel, etc) could be reuse as a component material with negligible losses at the end life of the technology. The life cycle results were estimated neglecting the new materials replaced by reuse materials.
- In case of wooden frame scenario, the base frame is replaced by wooden frame with similar dimension of steel frame. Wood varnish was considered with the wooden frame to sustain longer. The life cycle results are estimated for wooden frame instead of steel base frame.
- In no frame scenario, the system is considered to install on top of the building (rooftop). Hence, the life cycle results are estimated neglecting the materials used for base frame.

The life cycle results for alternative options and comparison with existing options are described as follows:

- **Effect of alternative options on energy consumption**

The life cycle cradle to grave energy consumption of evacuated tube DSHWS for the options are shown in Figure 6.

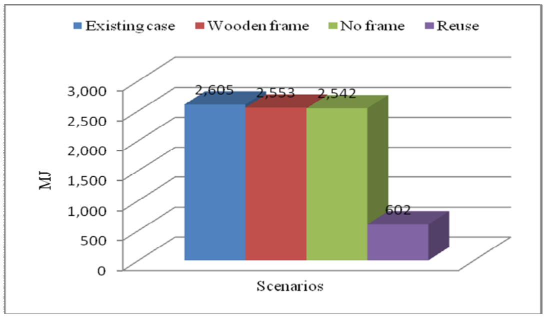

Fig.6: Life cycle energy consumption among the options

It is seen that the energy consumption could be possible to reduced by 2%, 2.5% and 76% for wooden frame, no frame and reuse scenarios respectively. Wood is very low energy intensive materials compared to steel. Figure 6 not shown significant reductions with wooden frame due to wood varnish was considered and is high energy intensive materials. The reuse scenario shows a significant reduction of energy consumption due to the estimation was done neglecting the manufacture of new materials.

- **Effect of alternative options on air emissions**

The life cycle air emissions for the options are presented in Figure 7. It is seen that the average reduction of air emissions are 4.5%, 13% and 70% for the scenario of wooden frame, no frame and reuse, respectively. The reduction of CO_2 emissions are 2.5%, 11% and 76% for the scenario of wooden frame, no frame and reuse, respectively. The effect of CO_2 emission is significant among all the air emissions.

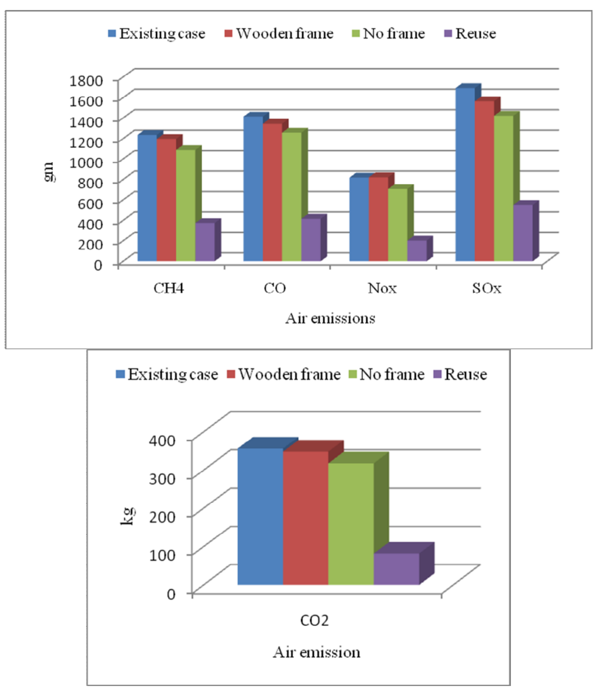

Fig.7: Life cycle air emission among the options

- **Effect of alternative options on water emissions**

The life cycle water emissions for the options are shown in Figure 8. It is seen that the average reduction of water emissions are 14% and 69% for no frame and reuse respectively, while it increases to about 5% for wooden frame due to wood varnish has its higher water emission coefficient. The

SO_4 emissions reduced are 4%, 5% and 84% for wooden frame, no frame and reuse, respectively. Hence, the environmental emission could be possible to reduce by the alternative options.

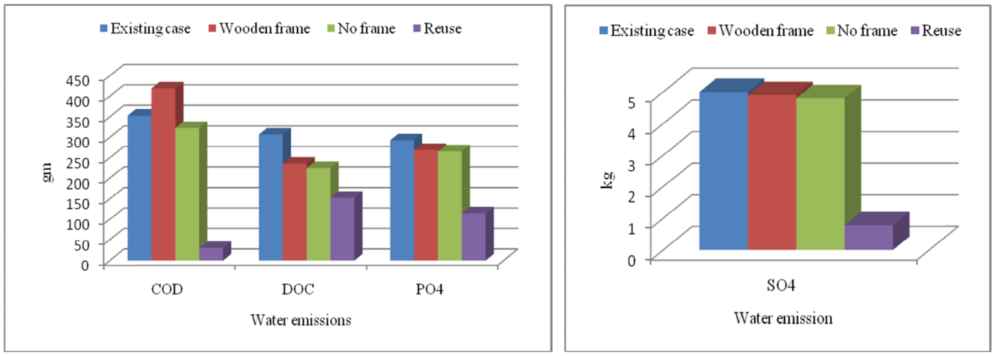

Fig.8: Life cycle water emissions among the options

4. CONCLUSIONS

Life cycle energy and emission analysis of a thermosyphon evacuated tube DSHWS collector area of 2.74 m^2 has been conducted using life cycle assessment technique. SimaPro software was used for the estimation of life cycle energy consumption and emission results. The analysis was done for the existing system and alternative improvement options. The life cycle total energy consumption found to be 2,605 MJ. The major air emission and water emission are CO_2 and SO_4 with the life cycle magnitude of 356 kg and 5 kg respectively were estimated for the existing system. The alternative improvement options study shows that the energy consumption and emissions could be possible to reduce significantly.

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A COMPARATIVE ANALYSIS BETWEEN BIOGAS AND SOLAR ENERGY IN THE PROSPECT OF BANGLADESH

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ABSTRACT: This study compares the return on investment and the future potential of biogas and solar energy in Bangladesh. With the depletion of conventional sources of energy, the need of renewable energy has become a prime concern. At present, the power generation in Bangladesh using conventional sources of energy fulfils 38% of energy demand. On the other hand, the power generation using solar energy fulfils less than 10% of country's current energy demand. However, the cost of installation and the return on investment period of solar energy is higher compared to the other forms of renewable energy. On the contrary, Biogas energy can be more advantageous over solar energy considering lower capital investment, continuous power production, constant employment opportunity, effective waste management and simplicity in construction. Biogas energy has several advantages, but it also has few pitfalls such as unavailability of good quality and sufficient quantity of raw materials. In this study it is found that the payback period of biogas energy is approximately 14-36% less than that of solar energy.

Keywords: Biogas, Solar Energy, Power Generation, Biogas, Payback period.

1. INTRODUCTION

Bangladesh is one of the promising developing countries in South-East Asia. There is abundance of natural gas, coal, petrol and several other non-renewable natural resources. The highest amount of natural resource found in Bangladesh is Natural Gas (24%). Unfortunately, with depleting sources of non-renewable energy and increase in consumption, these sources are going to decline by the year 2020 [1]. Currently, the main energy production in Bangladesh is based on natural gas (81.43%) [2]. According to our study renewable energy technology can be a better replacement of the nonrenewable sources of energy, but the cost of installation and operation is a concern while selecting it. With increase in consumption level day by day, it is assumed that after 2011 the supply of natural gas will start to decline. Currently the maximum power generation of Bangladesh is 6727 MW with 12% system loss. In the total generation of power, 53% is accompanied by public sector and 47% is supplied by private sector [3]. If this situation continues, supplying electricity to most of the rural people by national grid is almost impossible in near future. In this situation the need for a sustainable renewable energy is gaining utmost importance.

In order to resolve the situation of energy crisis, The Government of Bangladesh has adopted several policies [4]. Solar energy is one of the promising renewable energy sectors in Bangladesh. Bangladesh receives an average daily solar radiation of 4-6.5 kWh/m^2. Recently the Bangladesh Power Development Board (BPDB) is working on implementing a 500 MW solar project with assistance from Asian Development Bank [5]. The funding involved a huge amount of grant which is about USD $2-3 billion. On the other hand, the same amount would have been sufficient to establish biogas plants in almost all rural areas of Bangladesh. Thus, the generated off grid electricity would have been sufficient to meet the need of the remaining people of the country who does not have access to electricity. Biogas plant utilizes cattle dung, agricultural waste and several other biodegradable wastes to produce biogas. This gas can be utilized to generate electricity using a biogas generator. Comparing biogas with solar, the biggest disadvantage of solar energy is, the energy is available only when the sunlight is available. According to our study the payback period for biogas energy can be less than the solar energy by 14-36%.

2. SOLAR ENERGY

The principle of solar energy is, a photovoltaic technology receives solar radiation from sun and converts it to electrical energy. Fig. 1 shows a schematic of mechanism in solar energy conversion.

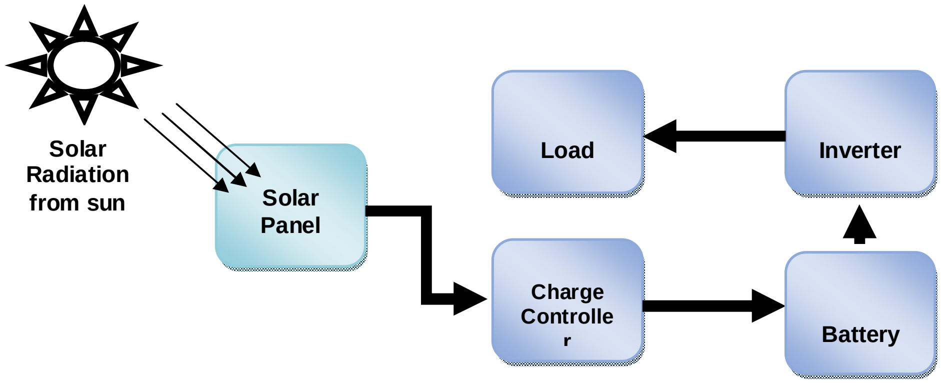

Fig. 1. Schematic of a typical solar energy conversion [8].

2.1. PRESENT SCENARIO OF SOLAR ENERGY IN BANGLADESH

Solar energy has a good potential in the energy sector of Bangladesh. Geographically Bangladesh is situated between 20.30^{O} and 26.38^{O} north latitude and 88.04^{O} and 92.44^{O} east which is an ideal location for solar energy utilization [6]. According to a recent study conducted by the Renewable Energy Research Centre, the daily average solar radiation received by Bangladesh is 4-6.5 kWh/m^2 per day [7]. The maximum amount of radiation is received in the months of March-April and minimum in December to January [6]. The monthly average solar radiation in Bangladesh can be understood from Fig. 2(a). The highest and lowest intensity of direct radiation in W/m^2 are also shown in Fig. 2(b).

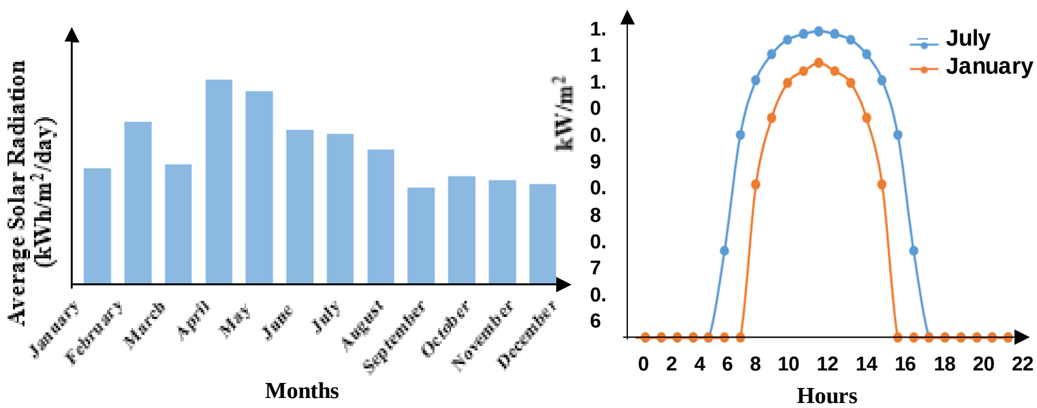

Fig.2: (a). Monthly average solar radiation profile in Bangladesh [7]; (b) The highest and lowest intensity of direct radiation in W/m^2 [1].

Along with thirty partner organizations in the country, as of August 2011, over one million solar home systems were installed in Bangladesh benefitting almost 6 million rural people. On average more than 35,000 systems are installed every month and within the next 1 to 3 years, the rate is likely to triple [9].

2.2. ADVANTAGES

There are several advantages of solar energy as follows:

1. Once a solar panel is installed it does not need any additional raw material to operate. The sunlight is the only source of energy needed for its operation.
2. Solar Energy is non-exhaustive form of energy.
3. Solar energy has no pollution. It directly converts the energy of sun into electrical energy without producing any harmful byproduct.

2.3. DISADVANTAGES

Even though Bangladesh has huge potential to collect solar energy, the installation of solar panel is very expensive. As most of the people in Bangladesh are still leading their life under poverty line it is very difficult to afford such costly equipment. Moreover, a majority of people belong to rural areas. The rural people do not have ability to afford solar home system on their own. The return on investment period is also longer comparing other renewable energy technology producing same amount of electricity.

3. BIOGAS ENERGY

Biogas can be formed from bacteria in the process of bio-degradation of organic material under anaerobic (without air) conditions. The natural generation of biogas is an important part of the biogeochemical carbon cycle [10]. The calorific value of biogas is about 6 kWh/m^3 which corresponds to about half a liter of diesel oil. [11]. There are several factors on which biogas production is affected. The various factors include toxic compounds, loading rate, nutrient concentration and input charge and so on. Fig. 3 represents the schematic of a typical biogas plant.

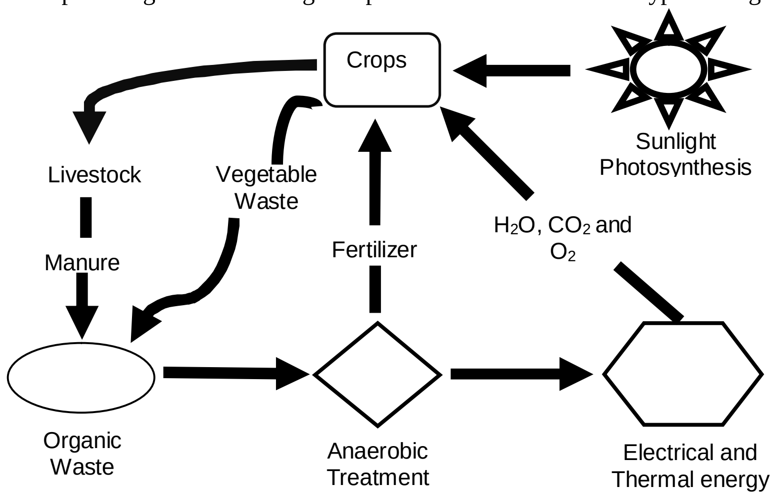

Fig.3: Schematic of a typical Biogas plant [14].

3.1. PRESENT SENARIO OF BIOGAS ENERGY IN BANGLADESH

Bangladesh has suitable climate for biogas production. The optimum temperature for biogas generation is 35^{0}C. The temperature of Bangladesh varies from 6^{O}C to 40^{O}C. But the inside temperature of a biogas digester remains at 22^{O}C to 30^{O}C, which is very near to the optimum temperature (i.e. 35^{O}C) [12]. On the other hand about 80% of the people in Bangladesh live in rural areas. The contribution of biomass energy is about 70% of the total national energy consumption in Bangladesh [13]. Being an agricultural country, Bangladesh has huge potential and access to biomass energy which can directly help to produce biomass energy. Fig. 4 shows the installed Biogas plants in Bangladesh up to year 2012.

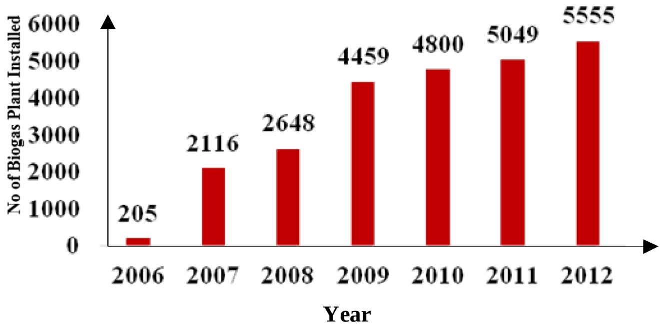

Fig.4: Number of Biogas plants installed by year in Bangladesh [1].

3.2. ADVANTAGES

Biogas technology serves the following advantages:

1. Biomass can be considered as a sustainable source of energy. It is a non-exhaustive form of energy.
2. It can be used at any time whenever there is enough waste to form biogas. Other than availability of raw materials for production it does not need to depend on environmental component like sunlight.
3. It helps to manage agricultural waste efficiently and simultaneously helps to generate electricity.
4. Gasification produce less harmful exhaust gas as biomass contains low levels of Sulphur, Chlorine or heavy metals which is harmful to environment.
5. It does not contribute to carbon-dioxide emission.
6. The collection of waste, installation of plant, operation of plant will give employment to a lot of people in rural areas.
7. The use of variety of feedstock and products as the syngas can also be used for chemical industry along with power generation.
8. The return on investment is quite fast. The installation of biogas plant is comparatively quite cheaper than other types of plants.

3.3. CHALLENGES

The main obstacle for efficient operation of a particular plant using biogas energy is the availability of good quality raw material in sufficient quantity for running the plant daily. Thus proper selection must be done while selecting raw material for producing biogas Fig. 5 shows an estimation of cubic meter of biogas production per ton of substrate [14].

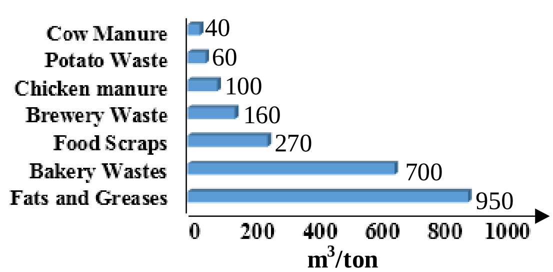

Fig.5: Cubic meters of biogas production per ton of substrate [14].

4. FUEL COST SAVINGS IN POWER GENERATION FOR BIOGAS PLANT

It can be estimated that, one liter of oil can be saved through use of either 3.5 to 4 kg of wood or approximately 5.5 kg of rice husk [16].
Price used for calculation is as follows:
Diesel: BDT 68 (USD 0.87) per liter
Rice Husk: BDT 2.34 (USD 0.03) per kg

1. A liter of diesel gives: 3.5 units of electricity
2. For generating a unit of power in the dual fuel mode we need: 0.08-0.1 liter of diesel and 1.4 kg of rice husk
3. To generate 1 unit of electricity in a 100% producer gas system, we need: 1.8 kg of rice husk

Fuel cost per unit of electricity in:
100% Diesel mode: BDT 20 (USD 0.26)
Dual Fuel mode: BDT 10 (USD 0.13)
100% Producer Gas mode: BDT 5 (USD 0.065)

Where USD 1 = BDT 78.06 (As on 14th October, 2013)

5. ECONOMIC ANALYSIS OF BIOGAS ENERGY AND SOLAR ENERGY

According to a case study performed on a Bangladeshi company named "Dreams Power Private Limited", the company uses a biomass gasifier-based decentralized power generation system implemented in Gaspur Village, Gazipur [11]. The installed capacity is about 250 kW. If the project runs in its full capacity, it is capable of earning Tk 900,000 per month whereas the operating cost is about Tk 600,000. Thus, the project has capacity of earning Tk 300,000 per month. However, this project is currently running under loss. It is operational on partial basis and the main technical difficulty of production is the unavailability of raw materials. This project could run smoothly if a rice mill was set up beside the plant.

On the basis of an article published on "The Financial Express", the material fabrication and assembly costs of solar cells are significantly higher, for a 3kW system the costs are in vicinity of USD 15,000-30,000 for a 1.5 kW to 3 kW system [15]. Thus, it can be estimated that the cost on installation per kW comes out to be USD 1,000 which is approximately Tk 80,000. Even though solar energy does not need any extra cost after installation, the return on investment takes around 20-25 years.

According to this study, a 250 kW plant was taken into consideration and the cost was estimated to produce power via solar energy and biogas energy. The cost estimation of biogas energy and solar energy (with and without battery) are shown in the Table 1, Table 2 and Table 3 respectively. At the end the cost per kW and the payback period was calculated. It is found that, there is need of proper maintenance and adequate supply of biomass. On the other hand, even though the installation cost of solar energy is very high but the operation cost can be very low compared to biogas energy.

The costs may vary place to place. The major variation can be observed in land cost. Beside there might be presence of subsidy and bank loans while buying the setups. The interest costs are omitted for simplicity of calculation. Similarly in solar energy the cost for replacing batteries and other miscellaneous components after a certain period is also ignored for simplicity of estimation.

Table 1: Rice husk Based Biogas Plant installation cost (250 kW)

Particulars	**Details/values**
Manufacturer of units	Ankur Scientific Energy Technologies Pvt. Ltd.
Considered Model	FBG 250
Land Cost Detail	
1. Required area (Approx.)	9,000 ft^2
2. Unit cost of 1 ft^2 land(Approx.)	BDT 400
3. Total Land Cost	BDT 3,600,000
Diesel Generator Details	
1. Generator Capacity(max)	250 kW
2. Maximum Gasification Efficiency	75%
3. Diesel and Biomass ratio in Dual Mode	
-Producer Gas	70%
-Diesel	30%

4. Average Run time /day	20 hrs
5. Number of Days in a year (Approx.)	360 days
6. Average annual Runtime	6,000 hrs
7. Monthly kWhr generated(20 hr operation per day)	1,50,000 kWhr
8. Yearly kWhr generated	1,800,000 kWhr
9. Cost of Generator, Power Network and Gas Purification units	BDT 22,000,000
10. Total installation Cost	
(Land Cost+ generator cost+Power network+Gas purifiation unit)	BDT 25,600,000
Power Distribution Capacity in the community	
1. Number of Household	200 household
2. Number of Commercial Units	100 industries
Workable life of Generator	15 years
Raw Material Specification	
1. Biomass(Rice Husk Procurement)	300 kg/hr
2. Rated Gas flow	625 Nm^3/hr
3. Average Gas Calorific Value	>1.05 Kcal/Nm^3
Operation and Maintenance Cost Details per month	
1. Mobil, filtering and other miscellaneous Costs(Per Month)	BDT 30,000
2. Diesel (Per Month)	BDT 150,000
3. Biomass Procurement Cost(Per Month)	BDT 400,000
4. Labor Cost(Per Month)	BDT 20,000
5. Total operation cost per month	BDT 600,000
Income Generation per month	
1. Cost per unit	BDT 5
2. Number of units in a month supplied to consumers	150,000 kWhr
3. Total income	BDT 750,000
4. Profit (Income- operation and maintenance cost)	BDT 150,000
Payback Period	14 years
Cost per kWhr generated	BDT 4 per kWhr
Cost per kW installed	BDT 102,400 per kW

Thus the payback period according to the study comes around 4 years and the initial cost of installation per kW is BDT 102,400 per kW.

Table 2: Solar Energy based Plant installation cost (With Battery)-250 kW

Particulars	**Details/ Values**
Supplier Company	Synergic Bangladesh Limited
Solar Panel Capacity	
1. Single Unit	250 W
2. Number of Single units to obtain 250 kW solar panel	1,000 units
3. Total Plant Capacity	250 kW
4. Cost of single 250 W solar panel	BDT 80,000
5. Total Cost of Solar panel required	BDT 80,000,000
Operating hours of the solar plant(Approx)	5 hrs per day
kWhr obtained per day	1,250 kWhr
Total Battery rating required(Ah)	104,167 Ah
Battery Rating of each battery taken	800 Ah
Working life of battery	5 years
Number of battery required	130 batteries
Cost of each battery	BDT 15,000
Total Cost of Battery	BDT 1,950,000
Rating of charge controller	100 A, 48 V
Total number of charge controller required	6 units
Working life of charge controller	5 years
Cost of single charge controller	BDT 30,000
Total Cost of charge controller	BDT 180,000
Wiring and panel mounting Cost (Approx.)	BDT 1,000,000

Cost of 250 W inverter	BDT 20,000
Number of inverters required(300 Household and 200 Industrial unit)	500 units
Total Cost of inverter	BDT 10,000,000
Plant Installation time	15 days
No of labors needed	12 persons
Per day labor cost	BDT 500
Total Cost of labor for installation	BDT 90,000
No of days for next Servicing	90 days
Service Charge	BDT 500
Operation cost per month	BDT 0
Land Cost	
1. Approx. Length of each solar panel	5.4 ft
2. Approx. Breadth of each solar panel	3.2 ft
3. Area covered by a single unit solar plant	17.28 ft^2
4. Total area covered by all panels	17,303 ft^2
5. Approx. area covered by control room including batteries and other materials	9,000 ft^2
6. Total area of plant in square feet	26,303 ft^2
7. Cost of each ft^2	BDT 400
8. Overall Land Cost	BDT 10,521,271
Total Cost of installation (Solar Panel+Charge Controller+Battery+Wiring+Inverter)	BDT 102,741,272
Average Cost per kWhr of Electricity from National grid	BDT 5.50
Selling cost for each kW (Assumed)	BDT 5
Total kWhr generated per month from solar plant	90,000 kWhr
Total income Generated Per month	BDT 450,000
Total Operating Cost Per month	BDT 0
Net Profit	BDT 450,000
Cost per kWhr generated per month	BDT 0
Payback Period	19 Years
Cost per kW installed	BDT 410,965

Thus, the payback period for solar energy with battery shows 36% longer payback time compared to Biogas plant with similar capacity.

Table 3: Solar Energy based Plant installation cost (Grid type)-250 kW

Particulars	**Details/Values**
Solar Panel Capacity	
1. Single Unit	250 W
2. Number of Single units to obtain 250 kW solar panel	1,000 units
3. Total Plant Capacity	250 kW
4. Cost of single 250 W solar panel	BDT 80,000
5. Total cost of solar panel required	BDT 80,000,000
Operating hours of the solar plant(Approx.)	5 hr per day
Wiring and mounting cost (Approx.)	BDT 700,000
Plant Installation time	15 days
No of labors needed	12 persons
Per day labor cost	BDT 500
Total cost of labor for installation	BDT 90,000
No of days for next servicing	90 days
Service Charge	BDT 500
Operation cost per month	BDT 0
Land Cost	
1. Approx. Length of each solar panel	5.4 ft
2. Approx. Breadth of each solar panel	3.2 ft
3. Area covered by a single unit solar plant	17.28 ft^2
4. Total area covered by all panels	17,303 ft^2

5. Cost of each ft^2 (Approx.)	BDT 400
6. Overall Land Cost (Approx.)	BDT 6,921,200
Total Cost of installation (Solar Panel+Wiring)	BDT 87,621,200
Maintenance cost per 3 month	BDT 500
Average Cost per kWhr of Electricity from National grid	BDT 5.5
Selling cost for each kW (Assumed)	BDT 5
Total kWhr generated per month from solar plant	90,000 kWhr
Total income generated per month	BDT 450,000
Total operating cost per month	BDT 0
Net profit	BDT 450,000
Cost per kWhr generated per month	BDT 0
Payback period	16 years
Cost per kW installed	BDT 350,485

Thus, the payback period for solar energy with battery shows 14% longer payback time compared to Biogas plant with similar capacity.

6. OVERALL COMPARISON BETWEEN BIOGAS AND SOLAR ENERGY

A quick comparison of the two technologies is as follows**:**

1. Biogas can be easily available whenever the raw material is available. For solar energy the power can only be obtained at daytime.
2. It is cheaper to install biogas plant than installing a similar capacity solar panel.
3. Once the solar panel is installed it has very little maintenance cost than biogas plant.
4. Even though the percentage of pollution is very low in biogas plant, solar panel helps to gain power with almost no pollution.
5. Biogas plant involves more workforces in operation for collecting biomass from the community, people's involvement in maintaining the livestock, time to time maintenance of the biogas plant etc. On the other hand, once a solar panel is installed it does not require any manpower until next maintenance operation.
6. For similar capacity Biogas and Solar energy plants, the payback period can be short by 14-36%.
7. There is no need of separate raw material other than solar energy for operating solar energy based plants whereas, there may be wide variety of raw materials for operation biogas energy based plants.

7. CONCLUSIONS

Bangladesh is one of the promising developing nation in South-East Asia. However Bangladesh requires a lot of management and efficient power generation plan to eliminate the power deficit problem. The main key points of this paper can be summarized as follows:

1. Generating power at minimum optimum cost must be given priority in policy making.
2. The access of power to rural population can be based on off grid condition but the selection of technology must be accepted by the local community.
3. Comparing solar and biogas technology, biogas technology would be more acceptable to the rural population due to low installation cost, available raw material and any time power generation capability in the prospect of Bangladesh.

Solar energy technology cannot be ignored since Bangladesh receives good amount of solar radiation. In Bangladesh, the major portion of solar energy is running in off grid condition. This includes a significant amount of cost for batteries. If the plants run in grid type configuration then the installation cost can be reduced drastically.

8. NOMENCLATURE

BDT – Bangladeshi Taka
USD- United States Dollar
hr – Hour
kW – kilowatt

kWhr- kilowatt hour
Nm^3/hr – Normal meter cube per hour
Kcal/Nm^{3} - kilo calorie per Normal meter cube

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STRATEGY OF WIND ENERGY WORKFORCE DEVELOPMENT: IMPLEMENTATION & COMPARE WITH CURRENT WIND SCENARIO OF BANGLADESH

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ABSTRACT: Now-a-days Energy crisis is intensifying in Bangladesh. For this reason experts are emphasizing on the sources of sustainable energy and its aspects. Researchers are enduring many experiments and collecting eminent data on Wind Energy as the future of this sector is very prosperous and highly potential. The main achievement of this sector lies in the improvement of aerodynamic efficiency and reliability, leading to lower cost per kWh generated. But the main problem is that there is no proper wind energy management system was developed. A model of the wind energy management system is developed and its outcomes have been given in this paper. It also shows the correlation among educational, industrial and government workforces. Wind energy sector will be revolutionarily changed with the implementation of wind energy workforce development.

Keywords: Wind Energy, Development, Energy, Workforce Development

1. INTRODUCTION

Bangladesh faces many challenges in the era of globalization on its quest to achieve developed nation status in 2010. Sustainable development of the energy sector is a potential factor to maintain economic competitiveness and progress. The world oil crisis in 1970, powerfully illustrated the concerns over the energy resources which exposed the vulnerability of the energy supply and the over dependence on oil as a fuel for energy. This condition leads to the necessity for the diversification of energy resources by triggering the development of The National Energy Policy which has the three main objectives that guide the future energy sectors development based on supply, utilization and the environment. Energy and environment are so linked at every level that it is required to assess the negative impact. Energy policies and regulations play an important role in achieving the goal of sustainable development in Bangladesh. The current demand for energy exceeds the available resources and this gap is projected to increase significantly in the upcoming future. In the case of the emerging energy problem in Bangladesh, renewable energy specially wind energy can play a significant role in this case.

2. LITERATURE REVIEW

Ian Baring-Gould [1] presented at his paper the infrastructure of wind based education in USA is not updated. Schools focused on mineral extraction have existed for many years. New energy education systems are not developing every day. Various industry groups/sectors (AWEA, Wind Alliance and industry) such as Educational organizations (universities, community colleges, NABCEP, NEED), Department of Energy (WWPP, EERE, OE, Science), National laboratories (NREL, INL, ORNL), State programs (state or federally funded), National Science Foundation (I/UCRC, Centers), U.S. Department of Labor, U.S. Department of Education and NGOs (ACORE, WoWE) are working but separately.

Alan Hardcastle et al [2] presented at their paper that Forty- eight percent of planned generating capacity additions in Washington through 2011 are renewable. But future growth in renewable will also depend on our ability to supply an adroit workforce to design, build, operate and to maintain renewable energy plants and equipments. They also addresses some of the key workforce development and training issues identified through a detailed interview survey of 27 state renewable energy employers and experts in four renewable sectors: wind, solar, bioenergy, hydro efficiency upgrades and small hydro. State renewable energy education and training programs as well as related technical programs are identified and a summary analysis of the renewable energy industry for the Pacific Mountain Workforce Development Area is provided.

The industry needs a trained workforce of technicians and university educated professionals in order to achieve national goals for wind energy development. Achieving 20% of the electric energy in the U.S. from wind by 2030 will require about 172,000 additional direct jobs. 20,000 to 30,000 of these jobs, as well as the wind energy industry, would benefit from candidates with university education and training in wind energy. He estimates 1,000 to 1,500 university graduates will be required each year to meet industry demand for university educated professionals is presented at this paper [3] by Andrew Swift. New energy education systems are not developing every day. Various industry groups/sectors (AWEA, Wind Alliance and industry) such as Educational organizations (universities, community colleges, NABCEP, NEED), Department of Energy (WWPP, EERE, OE, Science), National laboratories (NREL, INL, ORNL), State programs (state or federally funded), National Science Foundation (I/UCRC, Centers), U.S. Department of Labor, U.S. Department of Education and NGOs (ACORE, WoWE) are working but separately.

This document [4] outlines a roadmap for comprehensive workforce development in the U.S. wind industry. This roadmap describes the current state of the wind energy workforce, describes the educational needs and skill sets defined by the wind industry, provides insight into the current status of wind education institutions at all levels, describes some of the key findings of meetings with educators and wind industry representatives on the challenges of implementing an educational framework to support the wind industry and provides initial recommendations on projects and activities to support the expanded development of a wind workforce. To achieve the vision of 20% of the nation's energy from wind technology, over the next 15 years the wind industry must transform from a niche market to one of the nation's mainstream power generation technologies. Such a change has not occurred in the power sector for more than 40 years, since the rapid expansion of the nuclear industry in the 1960s and 1970s.

However, the history of US and others modern wind industry has given a pathway to take the advantage of modern technologies. Though a little initiative has been taken by Government of Bangladesh but this ensures define and secure job facilities for energy sectors. Grameen Shakti is experimenting with the possibility of developing systems to utilize wind energy with 4 hybrid power stations in four cyclone shelters of Grameen Bank for lighting of four cyclone shelters. BRAC under REP installed 11 small Wind Turbine at a capacity of 0.3 KW in various coastal area of Bangladesh. BCAS installed a wind pump in an agricultural field at Patenga .BPDB installed pilot basis 2MW at Muhuri Dam and Kutubdia and target to reach up to 10MW power. LGED has set up a power of 0.5 h.p. (385W) in Tangail, Kuslitia, Cox's Bazar and other places. LGED again installed 10Kwp in Wind-Solar hybrid system at St. Martins Island and another 400Wp at Kuakata LGED guest house.

3. WIND CONDITION OF BANGLADESH

Geographically, Bangladesh has approximately 724 km. long coastal belt, more than 200 km long hilly coast-line and more than 50 islands in the Bay of Bengal. The strong South/South- west monsoon wind coming from the Indian Ocean, after travelling a long distance over the water surfaces, enters into Asia over the coastal areas of Bangladesh. This trade-wind blows over our country from March to October. The wind is enhanced when it enters the V-shaped coastal regions of our country.

At present, Power is entrusted by the Ministry of Energy and Mineral Resources (MEMR) to foster development of RETs in Bangladesh. The following associations are working simultaneously are- Local Government Engineering Department (LGED); Renewable Energy Research Center- University of Dhaka; Center for Energy Studies, Bangladesh University of Engineering and Technology (BUET); Bangladesh Power Developement Board (BPDB); Bangladesh Center For

Advanced Studies (BCAS); Bangladesh Rural Advancement Committe(BRAC); Grameem Shakti(GS); Renewable Energy Program (REP). At present, several wind resource assessment program (WERM, SWERA, WRAP of BPDB) is ongoing in the country. But more importantly in Bangladesh separately research work is going on.

4. BARRIERS AT THE WAY OF SUCCESS

A. Policy Barriers

- Dedicated financial incentive policies are unavailable to encourage wind energy.
- Lack of legal, regulatory and policy frameworks for market oriented programs emphasize promotion and encouragement of commercialization.
- Private sector investment is carried on primary technology and R&D with a slow rate.
- Lack of standardized power purchase agreement and coordination between policy makers and promoters for utilizing limited human and financial resources efficiently.

B. Technical Barriers

- Main disadvantage - unreliability factor. The most common reason for failure of earlier wind energy project was that they were installed without appropriate wind energy resource survey.
- Bulk procurement of wind energy technologies is limited.
- Local manufacturing and/or assembly of wind energy technology components are currently very limited, although the knowledge, skills, expertise and facilities are available in the country.
- Limited technical capacity to design, install, operate, manage and maintain wind energy.

C. Business Barriers

- High initial capital costs and limited knowledge on the wind energy market potential.
- Market distortions by subsidizes or grant-based hardware installation programs but compare to others it is limited to various national priority areas (health, education, disaster management etc.).
- Small and dispersed size of the wind energy market in Bangladesh does not facilitate benefits such as economies of scale.
- Higher perceived risks of the renewable energy technology. Financial institutions biased and unfamiliarity with financing wind energy projects, lack of appropriate financing mechanisms for wind energy and no dedicate financing on wind energy.

D. Information Barriers

- Lack of information about wind energy resources, technical/economic information about wind energy, equipment suppliers, and potential financiers. Lack of capacity for data collection and analyzing. Scattered information regarding wind energy.
- Lack of awareness of wind energy in public, industry, utility, financial institutions and policymakers. Availability and access to existing wind energy resource information is limited.

E. Human Resource Barriers

- Lack of expertise in technical, business management and marketing.
- Lack of expertise in resource assessment, system design, installation, operation and maintenance of wind energy.

5. PROPOSED MODEL OF WIND ENERGY WORKFORCE DEVELOPMENT

A survey of industry members conducted by the American Wind Energy Association (AWEA) indicated the positions are most needed in the near to medium term: Accountants, Electrical and mechanical engineers, Business development and project managers and Wind technicians. These fields are expanded to include over the long term: Manufacturing and material engineers, Account, project, engineering and construction and business development managers, development directors. But these needs are in sharp contrast to changing energy and science fields. A survey shows that, more than 50% of the people entering the wind workforce do not have the technical skills to perform the job they were hired for. Not only that all engineering jobs in the utility sector could become vacant very soon due to retirements by the aging workforce and other forms of attrition. Thus, the nation will need to increase the number of students entering science and engineering just to keep pace. Explosive growth in the need for science and engineering skills in other sectors of the economy will require the energy field to compete for a limited talent pool.

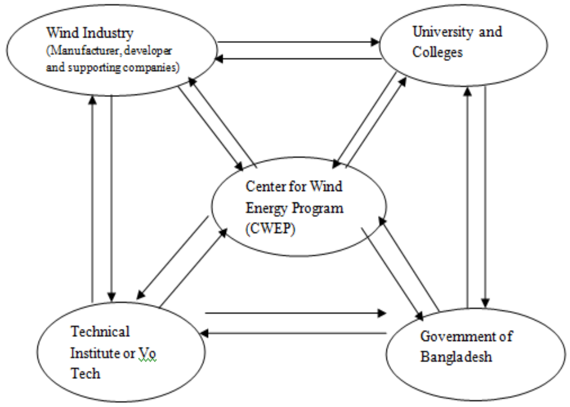

Fig.1: Wind energy workforce development model

This model makes the co ordination among the industry, education and government. A central point named center of Wind Energy Program (CWEP) is governed by the center of government of Bangladesh. All the major decision is taken by the government and implement by CWEP. Wind industry will get the Scientist, Engineers, Business people, Non-technical Staff directly from University, college, technical institute and vocational tech. The wind energy technical's share there views, experience with the university and technical institute and funding them to encourage in this sector. Students or researchers will get well arranged information from the center for wind energy program for easily accessible facilities. Government of Bangladesh provides curricula and funding to the University, college, technical institute and vocational tech. for research in this sector. The department of Education, energy, labor, finance are worked together to achieve the goal. The interrelation in between them also should be minimized and bureaucratic complexity should kept low. Aggressive work and focus on this sector ensure us for a better outcome from this sector.

A. Industry and Education Needs

Through meetings and discussions with the industry and educational organizations, the following overriding industry needs have been identified: Development of better or better-defined career ladders, pathways, and training programs. Better standards and skill categorization. Stronger alignment with academia at all levels. Educational pathway development. Teacher-training programs at all levels. Program development support to cover the costs of developing programs. Expanded national-level coordination of an academic system. Better understanding of available and required elements of a wind education system.

B. National Workforce Development Coordination and Definition

Expand wind energy skills analysis to better understand industry needs and existing infrastructure**.** Develop a cross- disciplinary advisory group and support structure **.**Develop teacher-training and support programs to train educators and keep them informed on the changing wind market**.** Support the development of wind energy education programs at all levels.

C. Development Needs of the Primary and Secondary Education System

Implement energy education programs to expand the pipeline of students interested in wind energy as a career. Expand teacher-training programs for teachers interested in wind energy. Expand efforts to coordinate and support curricula development. Expand the implementation of turbines at schools so that students and communities become familiar with wind technology and inspired by a new vision of the energy future. Spotlight programs, opportunities and successes to expand the understanding of wind energy. Implement state and national wind competitions to spark interest in wind. Develop secondary-school vocational training programs to allow students to rapidly enter the wind workforce. Develop programs to actively engage young women and minorities at the level.

D. Development Needs of Vocational, Technical Colleges and Technical Training Institution
Standardize curricula development. Create and support a community college Web portal to link interested programs, students, and the industry. Support wind energy infrastructure development at community colleges and vocational programs. Develop a program to recruit, train, and maintain the skills of wind energy instructors. Develop coordinated educational pathways for students to expand their skills throughout their career**.** Organize various seminars, training and technical support.

E. Development Needs of Higher Education
Identify required skills for an expanding wind industry and begin to develop programs in these fields. Support a national information clearinghouse for university programs to link students to programs and the industry. Expand Wind for Schools and other program development activities. Support industry-university collaboration to expand internships, scholarships, f0ellowships, postdoctoral appointments, endowed professorships and research opportunities. Launch university-level national wind competitions and organize various symposium, seminar and conferences. Develop a university collaborator (or consortium) similar to the European Wind Energy Academy. Expand university, industry, and community college collaboration programs.

6. CHALLENGES TO ESTABLISHMENT OF THE MODEL

- Arranging teacher training programs on specified field.
- Program development support due to inexperience.
- Coordinated educational pathways.
- Lack of defined career ladders, pathways, and training programs directed at industry; understanding the remote nature of the wind industry (technical skills) that people enter the field with experience from other energy sectors (advanced skills).
- Expand wind energy skills analysis –which will be needed when Lack of standards and skill categorization to understand which skills are needed for different personnel and job types. Need stronger industry alignment & collaboration with academia at all levels.
- Lack of energy literacy with few students entering the energy, engineering, and scientific fields.
- Shortage of science teachers at school level.
- Lack of engagement of women and minorities at appropriately young ages.

7. OUTCOMES OF THE MODEL

The following are the desired outcomes of a successful workforce development program:
- Rapid growth of the domestic wind industry in Bangladesh.
- Immediate training to staff new jobs in the wind industry and allocate them into the specified place and standardized curricula and certification for key jobs.
- Enhanced energy education that maps to the green energy economy, including the creation of a new generation of energy professionals and wind technologists.
- Pathways for development model from the primary level towards the post-graduate level and into industry.
- Creation of an infrastructure that in the near term helps the Bangladesh economy.
- Development of trained instructors and continuing education of instructors at all levels of the educational system.
- Actively expand the inclusion of women and minorities into the wind industry.

8. CONCLUSION

As the Bangladesh moves toward greatly expanded wind energy use, the need for skilled workers at all industry levels has been repeatedly identified as a critical issue. Additionally, if the industry and nation wish to capitalize on this rapid industry growth by becoming a major international green technology exporter, reversing current educational trends away from science, engineering, and technical skills must be achieved.

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DESALINATION USING SOLAR TECHNOLOGY FROM BANGLADESH'S PERSPECTIVE

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ABSTRACT*:* Scarcity of pure drinking water has been a problem all over the world. Being an overpopulated country Bangladesh also suffers from lack of fresh water. But as Bangladesh is near the Bay of Bengal, seawater is available in plenty. The main challenge of using this water is the salinity. The paper focuses on the discussion of desalination of the saline water using a renewable energy source, solar energy. In a developing country like Bangladesh integration of cheap and available solar energy with desalination technologies can solve the problem of scarcity of water efficiently.

Keywords: Desalination, Solar energy, Bangladesh, Solar thermal, Solar PV

1. INTRODUCTION

Huge amount of fresh water is necessary for all over the world as well as Bangladesh for agricultural, industrial and domestic uses [1]. Despite three fourth of earth's surface being covered with water, about 97% of the available water is salty and hence of little usefulness. Fresh and salt free water is therefore not accessible to many countries and these countries are facing the shortage of fresh water supply. But Bangladesh is little lucky here because fresh water is available here in spite of the coastal areas. Sundarbans, situated in the southern part of Bangladesh, is the largest mangrove ecosystem in the world. The Bangladeshi part of Sundarbans comprises 60 % of the whole area which is largely a flat coastal land. Scarcity of fresh water is a big problem for the people of these areas. Near about four million people in Sundarbans and its surrounding is now water insecure. As a result, desalinating water becomes the alternative solution as an important source of fresh water. The separation of salts from saline water requires considerable amount of energy. If fossil fuels are used for desalination, it can cause harm to the environment creating pollutions. Therefore, it is necessary to find environment-friendly and low cost energy sources in order to desalinate from saline water and as an alternative source the most obvious choice is the solar energy. About 5KWh/m^2 solar energy is available in Bangladesh; most of which is wasted. Government of Bangladesh is now taking some policies to use this renewable energy. Primarily Solar PV cell for producing electricity is taken in several projects of PDB and in near future solar cooling, solar water heating, desalination, food processing will also be taken. This paper focuses on the condition of recent developments in desalination of water in Bangladesh and the possible solution of energy requirement by using solar energy.

2. BACKGROUND STUDY

Desalination is a water-treatment process that separates salts from saline water to produce drinking water or water that is low in Total Dissolved Solids (TDS). Worldwide so far, more than 15,000 industrial-scale desalination units have been installed or contracted, and they account for a total capacity of more than 8.5 billion gallons/day [2]. Necessity of fresh water and presence of excessive Arsenic in ground water in Bangladesh increase the demand of alternative source of drinking water. On the other hand sea water is not usable due to large scale of salinity. The problem of pure drinking water in the arsenic affected coastal area of Bangladesh can be solved by solar desalination. The increased level of water salinity has some severe impacts on the livelihood operation in several ways. Salinity in water and soil is a threat for the livelihood and agricultural productivity. And last but not the least, it is destroying the ecosystem of Sundarbans, causing massive threats to the lives of various species living in this natural wonders. The salinity problem in Sundarbans and its surroundings has become more severe than before after the two great cyclones Sidor and Aila and consequent tidal surges. The Sundarbans and its surrounding regions such as Satkhira, Khulna, Pirojpur, Borguna, Potuakhali are the mostly affected areas that have been devastatingly swamped by sea-saline water after cycloneSidor,Aila, Mohasen attacked in the year 2007, 2009, 2013 respectively. Millions of people living around this region are struggling with this high saline water for their livelihood.

3. WATER SECURITY AND DESALINATION

As mentioned earlier desalination is the process of removing salt and other minerals, especially from sea water to produce drinking water source for household or irrigation purpose (AHSD, 2002). This process of water purification from saline water has become very popular in recent time. According to International Desalination Association, up to 2008 there were 13,080 desalinate plants all over the world producing more than 12 billion of gallons water per day [9]. Population growth, wasteful use of water, pollution, diversion of international river flow and climatic change cause the global warming and have played an vital role for endorsing desalination methods across the globe [8]. The common technologies for desalinating sea water are based on two main processes: evaporation and membrane separation. Any form of evaporating process needs large amount of energy and consequently this method of desalination only becomes feasible for a country that has cheap energy availability and has continuous supply of that[8]. Due to low energy consumption and production cost, a new method of desalination, Reverse Osmosis (RO) or a new technology of so called membrane process becomes the most efficient desalination mechanism at present time [8].Other technologies of membrane process includes Electro Dialysis (ED), Multi Stage Flash (MSF), Multi Effect Distillation (MED) and Vapor Compression Distillation (VCD).

4. DESALINATION USING SOLAR TECHNOLOGY

For seawater desalination, solar energy can be used either by producing the required amount of thermal energy to drive the phase change processes or by producing electricity required to drive the membrane processes. Thus desalination systems may be classified into two categories: (i) direct collection system and (ii) indirect collection system. The direct collection systems use solar energy to produce distillate directly in the solar collector, while in indirect collection systems, two sub-systems are engaged (one for solar energy collection and one for desalination). Every process requires a chemical pre-treatment of raw seawater to shun scaling, foaming, corrosion, biological growth, and fouling and also require a chemical post treatment [3]. Desalination process using solar energy can be divided into two categories. One that captures and uses the solar energy of sun and other uses photovoltaic devices to generate electricity [4].Recently more sophisticated desalting processes such as multistage flash (MSF) and multi-effect distillation (MED) plants solar energy is used.

5. SOLAR THERMAL APPLICATION FOR DESALINATION

Desalination processes based on the solar thermal can be accomplished by the multi-stage flash (MSF) distillation, multiple effect distillation (MED) and vapour compression (VC), which could be thermal (TVC) or mechanical (MVC).

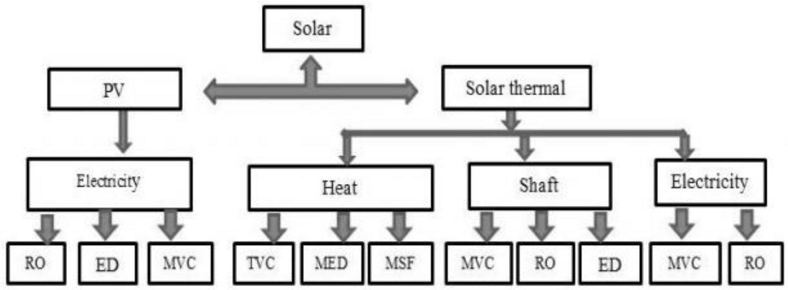

Fig. 1 Solar Desalination at a glance

5.1. MULTI-STAGE FLASH (MSF) DISTILLATION

The MSF process consists of a sequence of phases. In every phase, to preheat the salt water nourish compressing steam is used. The overall latent heat recovery approaches by fractionating in general temperature difference between the temperature sources and saltwater into large number of stages. Pressure gradients are required for operation in this plant system.

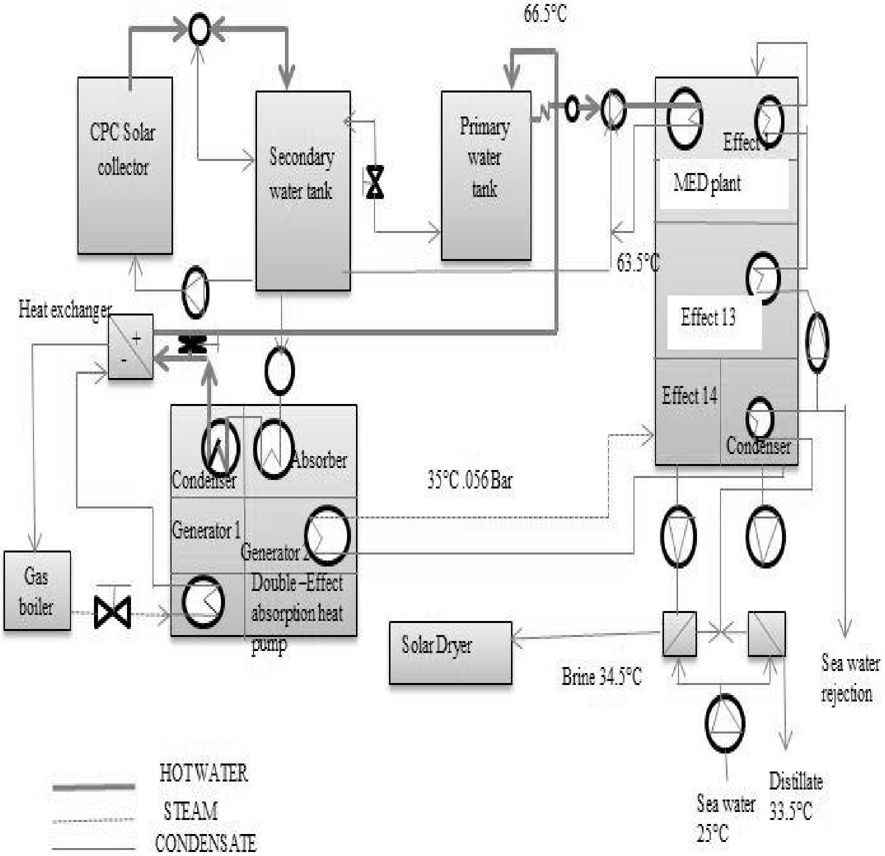

Fig. 2 configuration and interconnection of MSF main subsystems

5.2. MULTIPLE EFFECT DISTILLATION (MED)

The most important characteristic of the MED process is that it functions at low salt water temperature from 60 to 700C.The majority of the big MED divisions are based on the flat falling film arrangement. Though existing MED plants function at low temperatures, the flat falling film pattern gives a very high heat transfer coefficient. As a result vapor condensation arises on the pipe side and a thin film of saturated water is formed on the outside surface of the pipes. To contain soaked to nourish salt water the scheme is considered for all effects. Heating steam is fed to the first effect. This results in formation of a small quantity of water vapor, which is used to heat the second effect. The steam would let go to its dormant heat and condensate. The released dormant heat would result in formation of a lesser quantity of steam in the second effect. This procedure is repeated in consequent effects, until the steam heat becomes close to nourish salt water temperature. It is essential to rise the nourish heat to the saturation heat of every effect. To let go of latent temperature from the heating steam and latent temperature gain from the formed steam, it is essential to keep a high heat transfer coefficient and to limit the heat transfer procedure. This is completed through utilization of the soaked salt water achieved through utilization of the soaked salt water stream exit the low temperature effects. This system is applied in most of the commercial installation because the increase in the salt water salinity, especially, at low temperature effect is small because of the little amounts of the formed steam [5]. This technology can be easily implemented in Bangladesh and it is also low in cost compared to Solar PV technology.

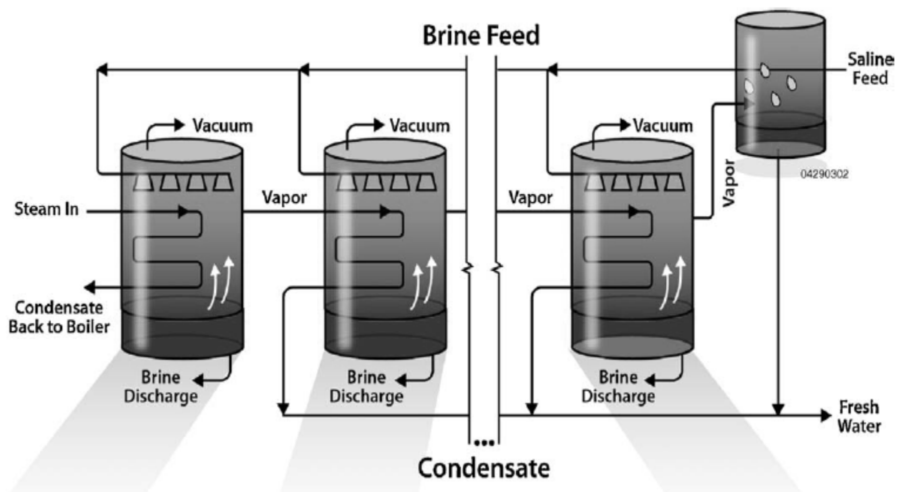

Fig. 3 Diagram of a multi-effect desalination (MED) unit [3]

6. SOLAR PHOTOVOLTAIC SYSTEM FOR DESALINATION

Solar Photovoltaic (PV) cell converts the solar energy into electrical form which can meet the demand to run a water desalination plant. Basically the solar PV cell can work both in AC and DC system. PV cells are equipped with inverters and a storage battery to meet the demand continuously and make the power supply reliable. There are two kinds of PV driven membrane processes, reverse-osmosis (RO) and electro-dialysis (ED). Eltawilet et al. [4] described the process elaborately. In the figure shown below describes the full desalination process by PV solar cell.

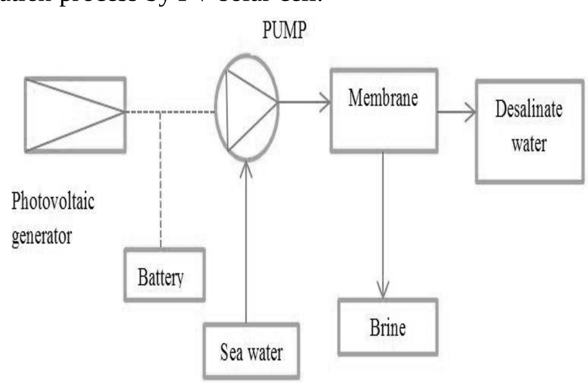

Fig. 4 Desalination process using solar PV technology

The electricity generated by the solar PV cell is stored in a Battery and then it runs a pump which drives the water from the sea and after that the water goes through a membrane which separates it in desalinated water and battery. For this technology Two-membrane separation process is more efficient than one stage and three stage membrane can also be applied for higher desalination rate.

These technologies have several drawbacks. First of all cost is higher for it and after a certain time the membrane needs to be changed. So a proper maintenance is required. In Bangladesh almost all the solar energy is unused. So PV solar desalination process can be introduced to meet the challenges. Still the cost of PV cell is a major factor for a poor country like Bangladesh. But this technology has a great potential. The feasibility of PV technology in desalination is also proved.

7. ECONOMIC STUDY

Desalination of water is one of the basic needs in the coastal area. Desalination process requires a lot of energy which is generally supplied from the electrical or conventional fossil fuel both of which are nonrenewable and costly technology. But using solar energy for this purpose is an elegant solution to this problem. A recent study by Faruq et al. [6] shows that a plant can be made for 10 years only in Tk. 1200, and they calculated the production cost to be only 0.33Tk./litre. As the socio economic condition of Bangladesh is not so improved a low cost technology is a must. The inhabitants of the area affected by saline water are not so rich. As a result the goal of engineers should be to provide an affordable technology for the people living in affected areas. Solar desalination has every potential to be that technology.

8. ENVIRONMENTAL FEASIBILITY

Solar energy is the most predictable renewable energy. Importance is given on utilizing this energy in different sectors by the Government of Bangladesh and the world community. Huge amounts of fossil fuel, electricity are used worldwide to desalinate the water. In Bangladesh this technology is not so familiar yet. Salinity is a serious problem which can affect the full ecosystem and this is dangerous to human life, animal life as well as for the environment. A brief depiction of the environmental effects caused by salinity is shown in the following figure If the conventional fuel and electricity based energy supply system can be replaced by the solar desalination system it can help the environment. Solar energy can be branded as green energy as it has zero carbon emission.

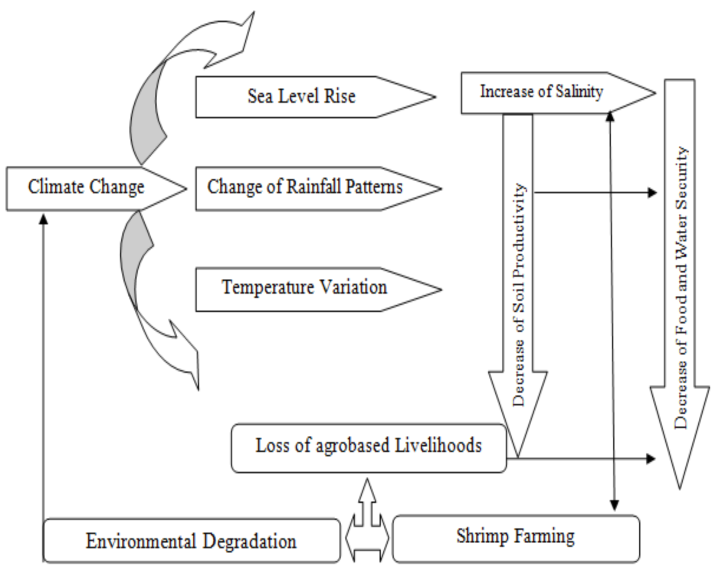

Fig. 5 The impact of climate change on livelihood operation [7]

It can save the environment and at the same time it reduces the greenhouse gas emission. So desalination using solar system is very much environment friendly and should be implemented properly. In case of Bangladesh where environmental pollution occurs frequently, the introduction of solar energy for a process like desalination has every justification. Bangladesh is a country of natural disasters. After the natural disaster of Sidor, Aila and Mohasen which took place in December 2007, May 2009 and June 2013 respectively many areas of the Sunderbans region and some coastal districts of Bangladesh got submerged. Still the water of that place are very much salty as a result people of that place are suffering for drinking water and by drinking this water cause them different type of health problem like cholera, diarrhea, kidney and several skin diseases. So desalination has become a necessity. And the demand of the fresh water is increasing day by day. The southern and western regions of Bangladesh face this problem of salinity too.

Different desalination processes exist in nowadays. Among this various techniques solar desalination system is very cost effective and environment friendly. So the solar desalination process is becoming popular day by day. A recent study of faruq et al. [6] shows that the production rate is higher in the summer than winter as the sun light is available for a longer period in summer. They also observed that the production is higher around 1 to 4pm. The performance of a desalination plant is shown in the following figure. From the figure it is evident that the performance of solar desalination process is higher in summer than winter and the production of pure water is high in the mid-day.

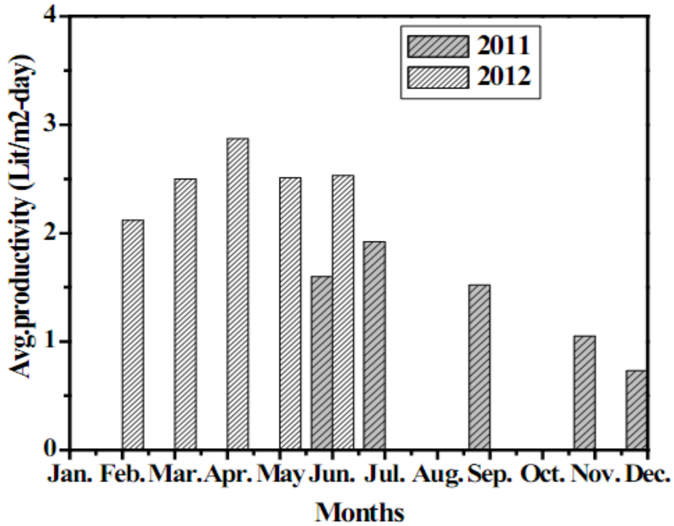

Fig. 6: Comparison of monthly production rate (faruq et al.)

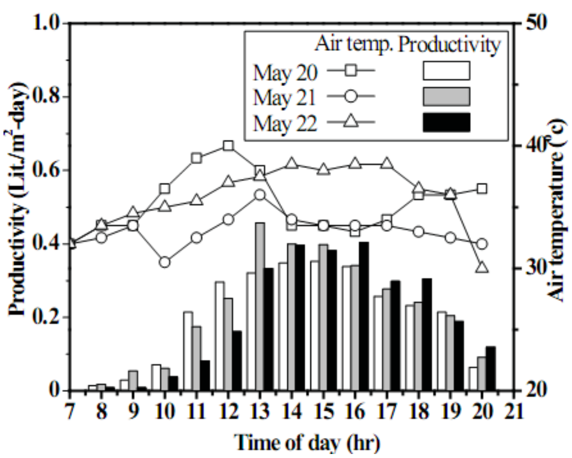

Fig. 7: Variation of hourly productivity [faruq et al.]

However one of the problems of this technology is this is fully solar dependent. It performs only during day time if there is no backup power system provided. Solar desalination process is widely used in the Middle-east Asian countries among which Saudi Arabia, UAE, Kuwait, Qatarand Bahrain constitute almost 70% of the total world production. Also the USA, Australia, Israel, Spain, Korea, Japan, Singapore, Greece, Cyprus are nowadays using this technology. In Asia, India and Pakistan are emphasizing on this technology. Already different projects are undertaken by the Indian government to supply pure drinking water by this technology. As Bangladesh is facing a crisis in pure drinking water it will be important for Bangladesh to use this technology in a wide range and Government should take a certain policy on this regard to make this technology viable in Bangladesh.

9. CONCLUSIONS

Salinity in water is a serious problem for the coastal districts of Bangladesh and is posing a threat to the human life, agriculture system and the full ecosystem. Conventional process of desalination causes a huge amount of greenhouse gas emission which destroys the ozone layer. Solar energy is an excellent solution for the energy required of desalination. It is also cost effective and environment-friendly. As Bangladesh is facing both the energy crisis and pure drinking water crisis this green technology should be implemented in a wide range.

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PRODUCTION OF BIOGAS FROM CO-DIGESTION OF CHICKEN EXCRETA AND WATER HYACINTH

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ABSTRACT: Bangladesh is a tropical country and its temperature condition is very suitable for the fermentation of organic materials throughout the year. Therefore, there is a great prospect of biogas to be used as an alternative source of energy in Bangladesh. As biogas can be produced in significant volumes from various locally available waste materials, there is a strong political drive to develop as an important energy source for the near future energy system to increase the security of energy supply. With fuel wood becoming increasingly expensive and also scarce in some parts of the country, there is a need to look for alternative cooking fuel. A research work has been done to produce biogas from co-digestion of chicken excreta and water hyacinth. A laboratory scale digester was fabricated to produce biogas from locally available chicken excreta and water hyacinth. Five experimental set up has developed for the co-digestion of raw materials in different proportions and the result is observed. The experiments gave a satisfactory result. The composition of 75% chicken excreta and 25% water hyacinth has given the better result and total 18.822 L/kg gas was produced on that observation with the retention time of 55days under the optimum Total Solid (TS) content of 8%.

Keywords: Biogas, Co-digestion, Chicken Excreta, Water Hyacinth.

1. INTRODUCTION

The use of waste as a major component of renewable energy is suitable for improving energy security and decreasing environmental disruption caused by carbon emissions [1, 2]. Biogas is one of the most important alternate sources of conventional energy that can be produced from the anaerobic digestion of wastes. The biogas generally composes of 55-65% methane, 35-45% carbon dioxide, 0-3% nitrogen, 0-1% hydrogen, and 0-1% hydrogen sulfide [3]. Anaerobic digestion (AD) is a biological process from bio-degradable wastes by bacteria under poor or no oxygen conditions. In the past two decades, AD has been applied as an effective technology for solving the energy shortage and environmental pollution problems of biotechnology industries and residential activities caused by heating and electricity generation [4, 5, 6]. Production of biogas from organic fraction of municipal solid wastes, different animal manures, fish waste, agricultural waste etc. were reported by different researchers. Biogas from rainbow trout biomass (faecal sludge) was produced by Lanari and Franci [7] using up-flow anaerobic recirculating digester made from fiber-glass cylindrical tank of 1.5 m height and 0.6 m diameter. McDermott et al. [8] reported biogas production from the aquaculture waste for anaerobic digestion. The preferred method of stabilization and hygienization of sludge from saline fish farm effluents was reported by Gebaur [9]. Gebaur carried out mesophilic treatment of sludge of total solids (TS) 8.2-10.2 (wt.%) in 15 L continuous stirred tank reactors at 35^{o}C. Mshandete et al. [10] wastudied the batchwise digestion of fish waste and sisul pulp by mixing the wastes in various proportions in 1000 mL bioreactors constructed by using conical glass flasks. Gebaur and Eikebrokk [11] investigated the treatment of concentrated sludge (10–12 wt.% TS) collected from Atlantic Salmon smolt hatchery with biogas production in order to reduce the high energy demands of smolt hatcheries. The scope of this present work was to conduct research work in laboratory scale to produce biogas from co-digestion of Chicken Excreta (CE) and Water Hyacinth (WH).

2. MATERIALS AND METHODS

2.1: Sources of raw materials:

The raw materials for this research work were collected from the local area around Chittagong University of Engineering and Technology (CUET). The total solid content in CE and WH were considered to be 18% (wt.) and 4.76% respectively [12]. To optimize the gas generation, total solid content in the slurry was maintained 8% (wt.) [12, 13]. For each experiment slurry of 700 gm amount was prepared.

2.2 Experimental set-up and procedure:

Co-digestion of CE and WH were tested in 1 L conical flask digesters with working volumes around 700 mL. Five laboratory scale digesters were made for the co-digestion of CE and WH mixture in various proportions. The proportions were 100% WH, 100% CE, 50% WH and 50% CE, 25% WH and 75% CE, and 75% WH and 25% CE. Water hyacinth was used 0-700 gm and chicken excreta were used 0 - 308 gm to make chicken excreta to water hyacinth ratios (wt.). The schematic diagram of the set-up is shown in Fig. 1.

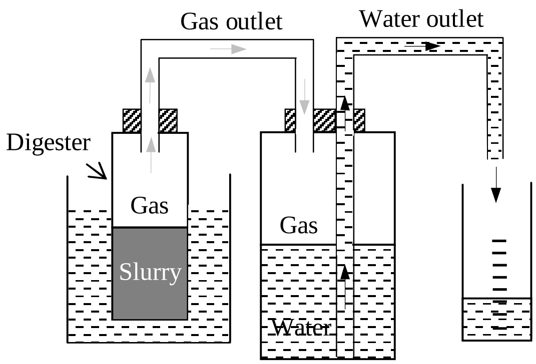

Fig.1: Schematic diagram of the experimental set-up for anaerobic digestion

The digesters were set-up with other equipments such as displacement tank/gas collector and water collector. Plastic pipe was used to connect digester and displacement tank. The pipe allowed the gas produced in the digester to pass to displacement tank and was fitted air tight in both the tanks and inserted at top positions. The gas was collected by water displacement method [8, 9]. The digesters were operated in batch mode at room temperature for 59 days and fed manually. Total solid contents of 8% (wt.) [12, 13] were used for all the experiments. To make the slurry of total solid content 8% (wt.), required amount of water was added. In water displacement method, initially the displacement tank/gas collector was kept full of water. When the gas started coming to the gas collector it displaced the water out of the collector to make its space inside. Another plastic pipe was used to take the displaced water from the displacement tank to the water collector which was fitted air tight in the displacement tank and inserted up to bottom part of it. The gaseous yield was measured by measuring the displaced water volume.

3. RESULTS AND DISCUSSION:

The experiments were conducted between 27/5/2013 and 27/7/2013. During the research work, main findings were the daily gas production and total gas production for different proportions of raw materials. Figure 2 shows the daily gas production for each proportion. It was observed that, for 100% WH, maximum gas yield was 710 ml/kg water hyacinth (8% TS) obtained on the 23rd day for the composition of 700 gm dried (8% TS) water hyacinth. For 100% CE, maximum gas yield was 932 ml/kg chicken excreta obtained on the 44th day for the composition of 308 gm chicken excreta and 392 gm water. For co-digestion of 50% CE and 50% WH, maximum 858 ml gas/kg chicken excreta and water hyacinth was produced on the 22nd day for the composition of 244.75 gm chicken excreta, 244.75 gm water hyacinth and 210.5 gm water. For co-digestion of 75% CE and 25% WH, maximum 828 ml gas/kg chicken excreta and water hyacinth was produced on the 42nd day for the composition of 283.59 gm chicken excreta, 94.53 gm water hyacinth and 321.88 gm water. For co-digestion of 25% CE and 75% WH, maximum 535 ml gas/kg chicken excreta and water hyacinth was produced on the 57th day for the composition of 173.48 gm chicken excreta, 520.44 gm water hyacinth and 6.08 gm water.

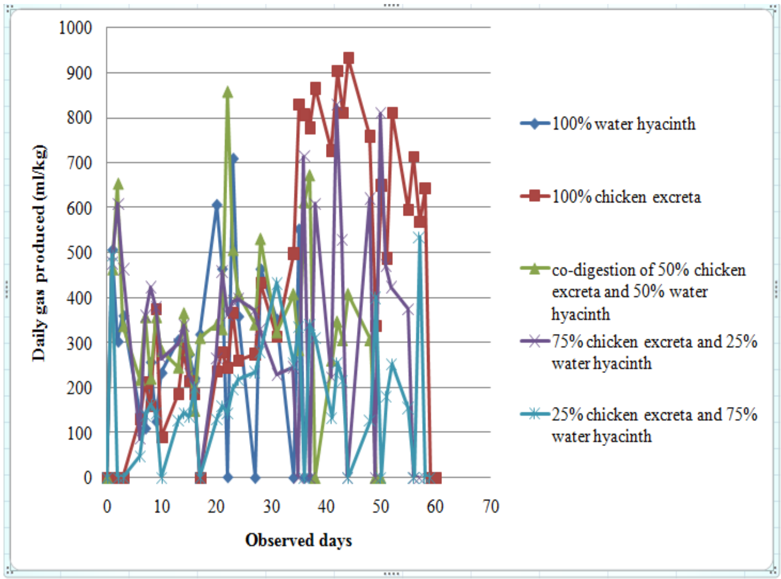

Fig.2: Daily gas produced (ml/kg) against observed day

It was also observed that, total gas produced for 100% chicken excreta is 7752.50 ml, for 100% water hyacinth is 7758.30 ml, for co-digestion of 75% chicken excreta and 25 % water hyacinth is 7117.00 ml, for co-digestion of 50% chicken excreta and 50 % water hyacinth is 8169.00 ml and for co-digestion of 25% chicken excreta and 75 % water hyacinth is 7148.00 ml. Figure 3 shows the total gas production for all proportions of CE and WH mixture

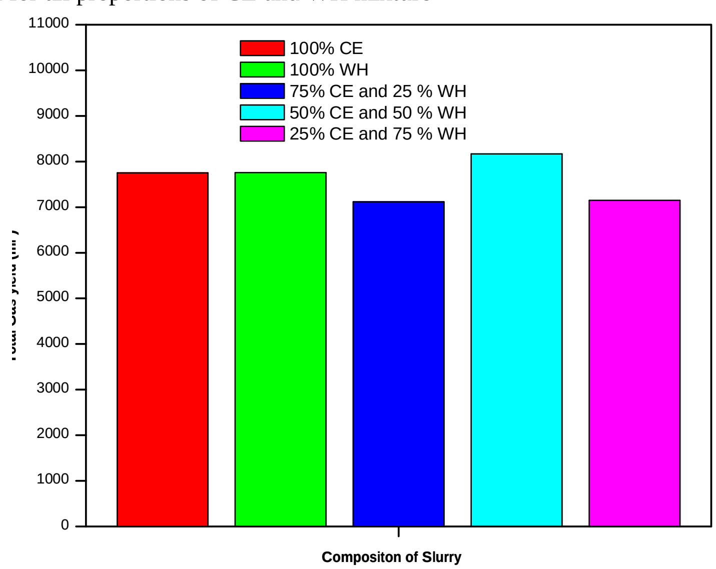

Fig.3: Total gas produced

4. CONCLUSION

The anaerobic co-digestion of CE with WH was a promising way for improving biogas production. The biogas production depended upon the proportion of chicken excreta, water hyacinth and water. Gas production also depends on continuous feed in process with high retention time and fixed feed. Our results showed that the anaerobic co-digestions were efficient for different mixing ratio. It is observed that, the best ratio was CE/WH 50:50 and gave the highest gas yield of about 8169 ml. More work should be done with proper slurry volume to digester volume ratio for the purpose of producing more gas.

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PROSPECTS AND HINDRANCES OF WIND ENERGY IN THE COASTAL REGION OF BANGLADESH

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ABSTRACT: Renewable energy has great potential to combat against power crisis in Bangladesh. Among all renewable energy resources utilization of wind power is one of the promising ways to lessen energy scarcity. In Bangladesh, we have different locations like Teknaf, Kutubdia, Sandwip, Kuakata are very much friendly to generate electricity.Different private organizations like Grameen Shakti, IFRD, BRAC, LGED has taken initiatives to install wind turbine in Bangladesh. The statistics shows that after Solar Energy it is the most significant alternative source of energy. As the world's fossil fuel is depleted day by day in future we need to much rely on this resource. Vertical axis wind turbine has much potential than horizontal axis wind turbine. It is user friendly, needs less wind rather than horizontal one to generate electricity, can be easily maintained and installed. This paper will disseminate the energy crisis in Bangladesh, prospects of wind power and a brief discussion on the plausibility of wind energy in the coastal region of Bangladesh.

Keywords:*Power inadequacy in Bangladesh, Wind energy, Installation of wind power plant, Coastal Bangladesh, Barriers of wind power plant, Grameen Shakti, Barriers of wind power plant.*

1. INTRODUCTION

Bangladesh is situated in north-eastern part of south Asia and shares its longest border (4000 km) with neighboring country India. Myanmar is the extreme southeast neighbor of Bangladesh and the Bay of Bengal is the southern boundary of it. With a land area of 147,570 km2 and population of 162.20 million in 2011, Bangladesh is among the world's most densely populated nations (1099 people/km2 in 2010) [1]. Almost 90% of total electricity is generated in Bangladesh from conventional sources. In Bangladesh Budget 2009-10 depicts our per capita power consumption is 172 kwh whereas in India it is 665 kwh. It states our power demand is 5000 MW against existing power plant can generate only 3800 MW and assuming that the demand will be 20000 MW by 2021. Wind energy has maintained the characteristics of being cheaper and cleaner and produce less defilement. Bangladesh has a 724 kilometer long coastline and also has many small islands that are capable of collecting strong winds provided by its northeast region and winter month breezes. Wind turbines supply electricity to national grids. The wind is free and with modern technology it can be captured efficiently. Wind turbines are available in a range of sizes which means a vast range of people and businesses can use them. Single households to small towns and villages can make good use of range of wind turbines available today. Wind speeds in the coastal regions of Bangladesh are greater than 6.5 m/s at the height of 20 meters.

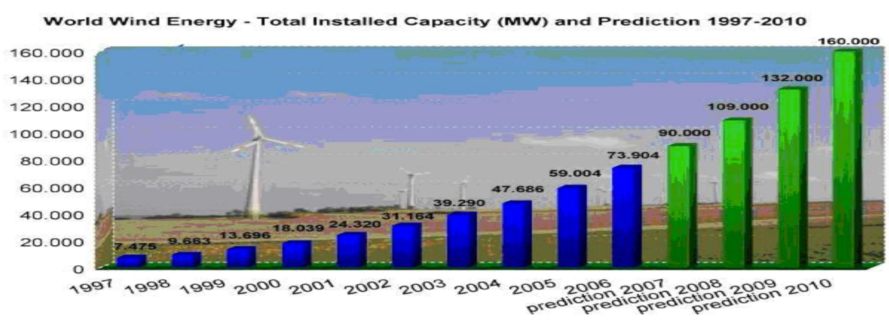

Fig. 1: World Wind Energy-Total Installed Capacity and Prediction.

It has been observed that during day times (8 a.m. to 7 p.m.) wind speeds are about 30 to 40% higher than the average values. The value of the power exponent α has been determined in the above sites and it is 0.139. So, at 40 meters height the annual average wind speed is about 7.15 m/s. So, wind speeds in the coastal regions of Bangladesh are suitable for both water pumping and electricity generation.

2. FUNCTIONALITY OF WIND TURBINE

Wind turbine design is the process of defining the form and specifications of a wind turbine to extract energy from the wind. A wind turbine installation consists of the necessary systems needed to capture the wind's energy, point the turbine into the wind, convexity of air rt mechanical rotation into electrical power, and other systems to start, stop, and control the turbine. Kinetic energy of the wind flowing across a wind turbine is used to derive electrical energy from wind.
The power (energy per second) in the wind hitting a wind turbine with a certain swept area is given by simply inserting the *mass per second* calculation into the standard kinetic energy equation given above resulting in the following **vital** equation:

$$P = \rho A v^3 \text{in watts} \ldots \qquad (1)$$

There are different types of wind turbine that can convert wind energy into useful form of power. These comprise propeller type wind turbine (mostly used for power generation), multi blade wind turbine, savonius wind turbine and darreius wind turbine. The power available to wind turbine is equal to change in kinetic energy of wind. The higher the change in the kinetic energy of the wind flowing across the turbine, the larger will be the power conversion. According to the Betz limit, at most only 59% of the wind power can be converted into useful power. The coefficient of performance, C_p is known as actual power output from a wind machine divided by the available wind power which is expressed as :

$$C_p = P\,(\text{real})/0.6V^3A \ldots \qquad (2)$$

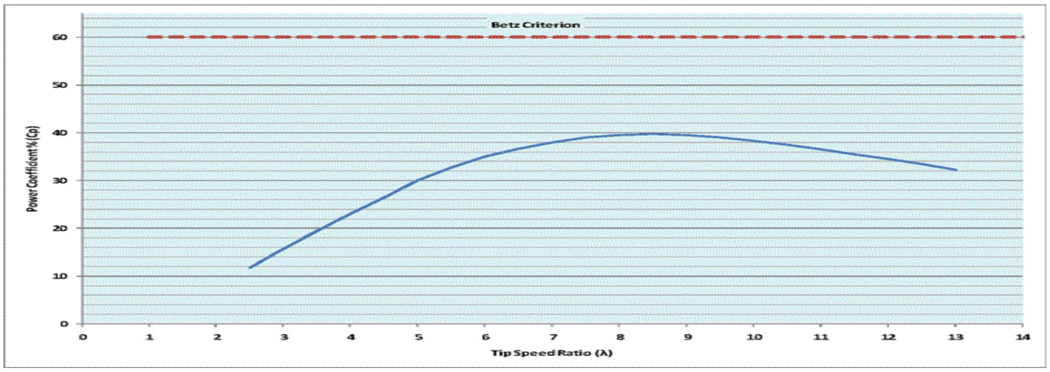

Fig 2: A Generic Cpvs λ characteristic curve

The major components of a wind turbine for electricity generation are: rotor, transmission system, generator, yaw and control system. Apart from the rotor, most of the components are kept inside the 'nacelle' which is designed to rotate according to wind speed direction. The nacelle is mounted on the tower. Rotor converts kinetic energy of the wind flow to mechanical energy. Very large wind turbines with 4-5 MW power rating have rotor diameter in the range of about 100 meters or even higher. Transmission system is used to transmit the mechanical power generated by the blades to the generator. It comprises shaft, gearbox, braking system. A generator converts mechanical motion of the rotor to electrical energy. It works on the principle of electromagnetic induction. It can be synchronous generator or asynchronous generator. The yaw system is used to cut off the rotor from the wind in case of strong wind. This is done on the basis of protecting the machine.The BPDB installed a 160-foot tower at the Muhuri Dam site in the Feni district in May 2003. Two high resolution anemometers were installed on this tower, one anemometer at 80 feet and the other at a height of 160 feet. One wind vane was installed at 80 feet height.LGED has designed and manufactured low cost wind pumps with a rated capacity of 20,000 litres of water per day at 4.0 m/s wind speed. Six such prototypes are already installed at different parts of the country. Computational models are developed for the simulation of horizontal and vertical axis wind turbines. In Gazipur analysis of wind data were recorded from August1997 to July 1999 as a daily basis and recorded by a data logger. The wind speed frequency distribution is processed from this data [6]. It disseminates that the wind speed and velocity is poor in the month of October and November.

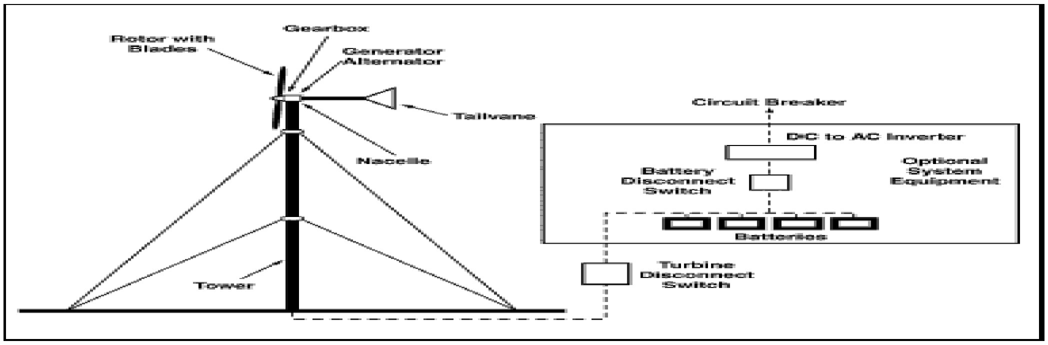

Fig 3: Schematic Diagram of Wind Turbine

3. INSTALLATION OF WIND POWER PLANT INCOASTAL REGION OF BANGLADESH

Grameen Shakti is a not-for-profit company in Bangladesh established in 1996 to promote, develop and popularize renewable energy technologies in remote, rural areas of Bangladesh. Grameen Shakti into one of the largest and fastest-growing renewable energy companies in the world. It has installed small wind generators in coastal areas. One of the implemented projects is two small wind turbines (300W and 1KW) at Sitakunda and Chokoria of Chittagong district to provide power for fish farms established by Grameen Bank. The other one is Four hybrid power stations (combination of wind, diesel and PV) which have been installed in four cyclone shelters (set up by Grameen Bank) to provide power for Grameen Bank members to start micro enterprises in and around the shelters[2]. Three of which are Grameen Bank branches and one exclusively used as a cyclone shelter. Appliances powered with this system are light, Fan, water pump etc [3]. IFRD (Institute of Fuel Research & Development) is stored wind data in Saint Martin, Technaf and Meghnaghat, Dhaka. The maximum velocity obtained at Saint Martins is 20m/s and yearly average wind speed in 4.6 m/s. The 1100 watt turbine is installed at the sea beach of Tecknaf and 600 watt turbine is installed at Meghnaghat. It has been observed that maximum 600 watt and 200 Watt power has been collected from Teknaf and Meghnaghat respectively.

Hybrid System of GrameenShakti :

- Energy Resource : Wind-Diesel Hybrid System
- Type of installation : Hybrid
- No of installation : 7
- Capacity of installation : 4.32 KW
- Cost of Installation : 4.5 lacs
- Location of Installation :Coastal Area of Bangladesh
- Functional Status : Functioning

Summary of the current utilization average wind speed and theoretical available power of different locations in coastal region of Bangladesh are shown respectively in the Table 1,2& 3.

Table 1: Average wind speed in m/s at different locations in coastal region of Bangladesh (2003).

Location				Month		
	March	April	May	June	July	August
Teknaf	2.85	2.56	2.39	4.71	2.83	4.14
Kutubdia	3.8	12.02	2.37	4.71	5.73	4.78
Sandwip	6.23	8.34	2.28	3.93	5.44	4.44
Kuakata	3.07	5.26	3.10	3.69	4.28	3.37
Mongla	3.07	2.41	2.94	4.23	4.38	4.44

Table 2. Theoretical available power of different locations in coastal region of Bangladesh (2003).

Locations	Months	Avg. Wind Speed (m/s)	Theoretical Available Power (W/m2)
Teknaf	March to Spetember	3.23	20.17
Kutubdia		5.19	83.74
Sandwip		5.12	80.53
Kuakata		3.54	26.68
		3.48	25.26

Table 3. Average wind speed.

Average Wind Speed km/h (mph)	Suitability
Upto 15	Not Good
18	Poor
22	Moderate
25	Good
29	Excellent

Average wind speed and its suitability is shown in the table 3. The average wind speed, up to now, at the Muhuri Dam areas is found to be 6.50 m/s and the wind power density varies from 100 to 250 Watt/m2 in the coastal regions of Bangladesh (Kaiser, Rahman, Rahman&Sharna, 2006).They have planned to expand wind power (100-200 MW in offshore) in coastal areas at Anaweara. This installation involved the commissioning and erection of 4 units of 225 kW GCWE turbines and these were completed in 2004[4].

Bangladesh Power Development Board (BPDB) Installed wind turbines. They are promoting wind resource assessment program (WRAP). Wind energy installation under renewable Energy Programme (REP):

* Energy Resource: Wind Turbine
* Type of installation: Water pumping wind mill Irrigation
* No of installation: 1
* Capacity of installation: 1X1.0 Kw, 3X1.5 Kw, 1X10 Kw
* Cost of Installation:
* Location of Installation: Patenga (Coastal Area), Chittagong)
* Functional Status: Functioning
* Energy Resource: Wind
* Type of installation: Resource Assessment
* Location of Installation: Coastal Districts [5]

.
Wind Energy Programme under Bangladesh Rural Advancement Committee (BRAC):
Energy Resource: Wind Turbine
Type of installation: Stand-alone
No of installation: 10
Capacity of installation: 0.3 KW
Cost of Installation:
Location of Installation: Coastal Area of Bangladesh
Functional Status: Functioning

Wind power generating capacity growth accelerated to 31% in 2009 throughout the whole world, with capacity increasing by a record 38 GW to reach 160 GW by the end of 2009. Wind turbines for grid-connected systems are the most highly demanded on the market and the rate of capacity growth was 28% per year between 1999 and 2009 (British Petroleum website, 2011). The operation and maintenance expenditure is scanty for whole span of wind turbines. Many people find wind farms an interesting feature of the landscape and no fuel will be required for producing electricity from wind turbine.

4. PROSPECTS OF WIND ENERGY IN BANGLADESH AND URGE FOR PRODUCTIVE TACTICS

Initial reports of the wind-mapping project launched by the government indicate that areas in the southern coastal region are suitable for setting up wind turbines. Wind energy can potentially generate more than 2000 megawatts of electricity in the coastal regions. The growth of wind energy in the underdeveloped, coastal areas of the country holds hope for poor, isolated communities that are not connected to the national electricity grid and who are also unlikely to receive grid connection in the near future due to the high cost of establishing infrastructure, and growing scarcity of traditional energy inputs. Going ahead, wind energy also holds promise for the fishing and shrimp industries, especially for small-scale fishermen in the coastal regions of Bangladesh. Due to the scarcity of ice asignificant percentage of netted fish caught by small fishermen rot. Decentralized electricity from wind, used in ice as well as salt production, could aid fish preservation and hence, increase incomes of fishermen and intermediary vendors. Further, it is not possible to apply modern methods of shrimp cultivation in Bangladesh due to shortage of electricity. With the influx of electricity, application of semi-intensive methods of shrimp and fish cultivation can increase production by 25-30 times, resulting in the creation of new jobs in processing industries. Grameen Shakti has already started providing electricity to fish and prawn farms in Cox Bazaar, an important fishing port.

The Bangladesh Power Development Board has estimated that wind energy can contribute to 10% of the energy needs of the country. The Board has also calculated the cost to generate one kilowatt hour of power (kWh) from wind energy to be about half the cost of generating an equivalent unit of power from solar energy. As sometimes wind speed is found low which can decrease the production of power from wind. A countable amount additional power is available which can be capitalized by controlling the peak load and using other mechanisms like fan during the summer period. It will induce optimistic outcomes in the coastal remote areas.

Table 4: Summary of new RETs in Bangladesh

Technology	Installed Capacity
Solar PV	800 kwp/15,000 SHS
Wind Turbine	20 KW
Wind Pump	6 nos.
Biogas Plants	10,000 nos.
Micro Hydro	10 KW

Table 5: Wind Turbine Installations in Bangladesh

Organization	Application	Installed capacity (W)	Location	Status
Grameen Shakti	3 Hybrid	4,500	Grameen Offices	Functioning
	Hybrid	7,500	Cyclone Shelter	Functioning
BRAC	Standalone	900	Coastal Region	Functioning
	Hybrid	4,320	Coastal Region	Functioning
IFRD	Stand-alone	1100	Teknaf	Functioning
	Stand-alone	600	Meghnaghat	Functioning
LGED	Wind PV-Hybrid	400	Kuakata	Functioning
Total 19,720				

5. BARRIERS OF ESTABLISHING WIND POWER PLANT IN COASTAL REGION OF BANGLADESH

In Bangladesh as the demand of power is mounting, seems to be that wind power would be auspicious for accelerate the production but it possess some ominous direction also. Wind turbines are noisy. Each one can generate the same level of noise as a family car travelling at 70 mph. When wind turbines are being manufactured some pollution is produced. Therefore wind power does produce some pollution. Wind turbines give off interference to television and radio signals and also can kill birds. The major drawbacks are the intermittent availability of the wind producing an variable energy output; low energy density; damaging effects on local wildlife and concerns of ruining the appearance of the countryside. Some coastal inlands like Patenga, Kuakata wind home system may not be feasible due to very low wind speed in October and November[7]. Due to these drawbacks Bangladesh has generated scanty amount of power from wind. The chart shows very low amount of energy is generated from wind in our country whereas global wind power cumulative capacity is accelerated every year in satisfactory range. In 2010, the capacity was 197.6 MW and in 2011 it elevates to 238.3 MW. The major barriers which are retarded the acceleration of wind power in Bangladesh are marketing barriers, technical barriers, policy barriers, institutional barriers, financing barriers and informational barriers.

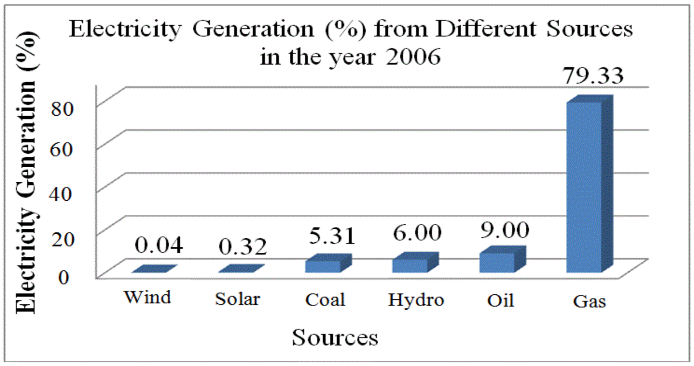

Fig 4: Electricity generation from different sources in Bangladesh (2006)

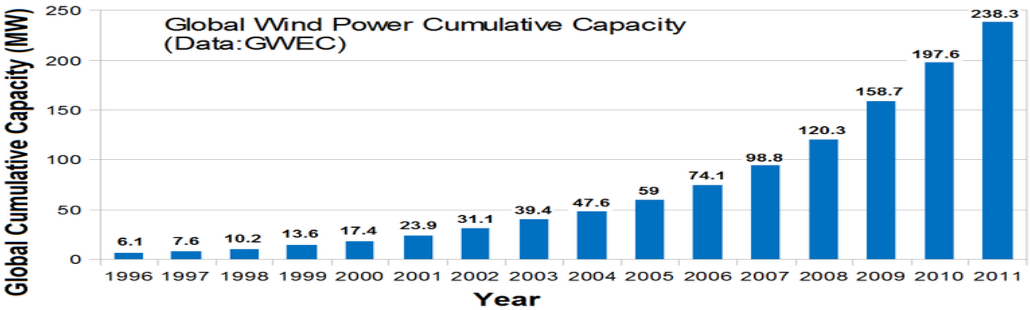

Fig 5: Global Wind Power Cumulative Capacity (MW)

6. CONCLUSION

Energy is pre-requisite for human sustenance and development. Scarcity of energy is one of the major hindrances to the development of a nation. Currently, Bangladesh has a population about 160 million and it will be raise to 180 million by 2020. At present per capita energy consumption in Bangladesh is 170 kg-0e3,which is very low compared to South Asian nations. The country is endowed with vast renewable energy sources, wind energy is pivotal part of renewable energy technology. In perspective of technical analysis WHS for coastal islands is quite better than SHS. But the production will fluctuate due to the variation of wind speed in different seasons. At present several wind resource assessment program (WERM, SWERA,WRAP, of BPDB) is ongoing in the country. BPDB has planned to install 12 nos. of wind monitoring stations of different coastal zones of Bangladesh. In Bangladesh considering energy consumption, environmental effects and remote accessibility most of the coastal regions are viable for wind home system. So, for meet up the challenge of energy crisis in 2020, wind power will be a plausible alternative for power inadequacy in Bangladesh.

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PRESENT SCENARIO OF BIOGAS TECHNOLOGY IN BANGLADESH- PROSPECTS, POTENTIALS AND BARRIERS

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ABSTRACT: Bangladesh is in the midst of a severe and worsening energy crisis. With a population of about 160 million living in an area of 147,000 sq. km. it is one of the most densely populated countries too. Around 33% of the total population is covered by electricity network and 4% are covered under natural gas network. About 82% of total electricity comes from natural gas. As the demand is increasing and the reserve of the natural gas is decreasing, it is assumed that very early the supply of the natural gas will start to decline. The continuous depletion of fossil fuel is sticking the concern into the search for new energy source is mandatory. So we should focus our view on the alternative renewable energy sources such as solar energy, biogas, biodiesel, wind power, tidal energy etc. Here biogas is one of the promising renewable energy sources in Bangladesh. As an agricultural country, Bangladesh has embedded with plenty of biomass which has been used for extracting energy by burning directly or making biogas. Biogas mainly from animal and municipal wastes may be one of the promising renewable energy resources. This paper presents a contemporary scenario of the biogas technology in Bangladesh. The goal of study is to investigate the prospects, potentials and barriers of biogas technology and also evaluates the research, development and dissemination drives for biogas plants in Bangladesh.

Keywords: Renewable Energy, Biogas, Biogas Plants, Bangladesh, Dissemination.

1. INTRODUCTION

Bangladesh situated in the north-eastern part of south Asia is among the world's most densely populated nations (1099 people/km^2 in 2010) with a population of 162.20 million in 2011 and about 72% of which live in the rural areas. Rural people meet up the energy needs mostly from traditional biomass fuels comprising of agricultural residues (45%), wood and wood wastes (35%), and animal dung (20%). Generally biomass is estimated to account for over half (~62%) of the country's energy consumption [1]. The energy situation in Bangladesh is extremely critical and at present the major energy production in Bangladesh is based on natural gas. Since 2005, the increased gas demand outpaced gas supply resulting a gas shortage. As major power stations here are run by natural gas; as a result the gas reserve has fallen to such an alarming level and it is assumed that very early the supply of the nature gas will start to decline [2]. Burning of fuel woods as a fuel over decades has reduced the forest areas in developing countries like Bangladesh caused deforestation in an alarming rate. According to an estimate about 7 million tons of fuel woods are consumed annually in Bangladesh and the consumption is increasing each year. As a result, the country has reduced the forest area to a low of 9% of its total area. On the other hand, according to BCSIR report, the annual biomass consumption in Bangladesh is about 40 million tons which causes deforestation and pollutes environment. Agriculture, animal waste and fuel wood are burnt in-efficiently (efficiency less than 10%). Use of garbage, fuel woods, agriculture residues as a fuel is harmful for both environment and health due to the smoke arising from them cause air pollution [3]. So generation of energy from the alternative sources has become the crying need for Bangladesh. Biogas is one of the promising renewable energy sources in Bangladesh.

Bangladesh produces huge amount of municipal solid waste i.e. kitchen waste, poultry waste, sewage sludge, cow manure, agriculture residues, food scrap, etc. The municipal solid generation capacity of Bangladesh on daily basis was 0.5 Kg/capita/day [4]. In Bangladesh, disposal of municipal solid waste (MSW) is a major concern in large cities from the management perspective. These wastes are always damped in the open land field and river which pollutes environment seriously and causes the public health disease like malaria, cholera, typhoid etc. This research work was conducted to investigate the potentials & prospects of these wastes for biogas production in Bangladesh. This paper presents a contemporary scenario of the biogas technology in Bangladesh. The scientific contributions of this paper are following:

- Identifying different sources of raw materials for producing biogas
- Potentials & prospects of biogas in Bangladesh
- Current energy status of Bangladesh
- Current status of biogas plant in Bangladesh
- Evolution of the current research and dissemination of biogas technology in Bangladesh
- Barriers to dissemination of biogas technology in Bangladesh

2. RAW MATERIALS OF BIOGAS

Biogas can be produced from a broad range of feedstock that is suitable for anaerobic digestion. The use of low-cost feedstock is crucial to obtain cost-effective bio-technologies for biogas production. The feedstock needs to be a liquid mixture with appropriate moisture content. This includes biodegradable waste materials such as agricultural feedstock(animal manure, energy crops, crop residues etc.); community-based feedstock(organic fraction of MSW, sewage sludge, garden waste, food remains, institutional wastes etc); industrial feedstock (food/beverage processing, dairy, starch industry, sugar industry, pharmaceutical industry, cosmetic industry, biochemical industry, pulp and paper, slaughterhouse/rendering plant etc.)[5].

3. BIOGAS AND ITS COMPOSITION

Biogas is a renewable gas fuel which can be produced by the anaerobic digestion process of biodegradable material that takes place in the digester by anaerobic organism in absence of oxygen. In its pure state it is odorless, tasteless, and colorless and burns with a clear blue flame without smoke. It has very high octane number approximately 130. It has combustion properties like natural gas(NG) and it burns at about 800°C.It is about 20% lighter than air. Its calorific value is 20 mega Joules $(MJ)/m^3$ and it usually burns with 60% efficiency in a conventional biogas stove. The composition of biogas is about 60 to 75% methane and 25 to 35% CO_2 with insignificant to trace nitrogen, oxygen, hydrogen sulfide and hydrogen. The production of biogas is influenced by various factors such as temperature, pH condition of the input charges, nutrient concentration, loading rate, toxic compound etc. Temperature: The temperature range required for anaerobic digestion is 3°C-70°C. Temperature between 35°C-38°C is considered optimal. Three temperature ranges are common, the psychrophilic (below 20°C), the mesophilic (between 20°C and 40°C) and the thermophilic (above 40°C) ranges. pH value: To provide the better existence of methane producing bacteria, the optimal range is 6 to 7 [6].

4. POTENTIAL OF BIOGAS IN BANGLADESH

Biogas mainly from animal and MSW may be one of the promising renewable energy resources for Bangladesh. MSW contains an easily biodegradable organic fraction (OF) of up to 40%. It is a potential source to harness basic biogas technology for cooking, rural and peri-urban electrification to provide electricity during periods of power shortfalls. On feasibility study prepared for the Danish investors about the market potential of Bangladesh it has been indicated up to 800 MW of electricity could be produced in Bangladesh using organic city waste and poultry litter. 12 gasification-based biogas plants equivalent to 5 MW capacities are now being considered by donor-financed IDCOL. As on 2012, only a fraction of the total of 15,000 tons of waste is being recycled annually. About 80% of produced waste is organic which have a high potential for biogas production. The amount is expected to rise up to 47,000 tons in 2025[7]. Bangladesh is predominantly an agrarian economy. Agricultural sector still dominates the economy accommodating major rural labor force. As an agricultural country, Bangladesh has embedded with plenty of renewable sources of energy and has huge potentials for utilizing biogas technologies. During winter seasons, huge amounts of vegetables are cultivated in our country which will be a potential source of kitchen waste (KW). Due to lack of efficient transportation and preservation, huge amounts of vegetables are wasted, which may be a source of biogas [8].

Cow manure (CM) is the undigested residue of plant matter which has passed through the animal's gut. CM is used to produce biogas to generate electricity and heat. The gas is rich in methane and is used in rural areas of Bangladesh to provide a renewable and stable source of electricity. According to FAOSTAT (2011), it is estimated that there are 23 million cattle in Bangladesh which produce 230 million Kg of cow dung each day [9]. According to the IFRD, there is potential of about 4 million biogas plants in our country, which can produce 105 billion cubic feet of biogas per year (at a rate of 1.3 cubic feet of gas per kg of dung) which is equivalent to 1.5 million ton kerosene or 3.08 million tons of coal. It has been estimated that about 20% of the total number of families can be supplied with enough biogas for their household cooking and lightings by the above [10]. According to FAOSTAT (2011), the country has a population of approximately 234.7 million chickens and 44.12 million ducks respectively [9]. Poultry waste has the highest per ton energy potential of electricity per ton but livestock have the greatest potential for energy generation in the agricultural sector. It has been estimated that 10% of the larger dairy and poultry farms alone could produce about 50 MW of electric power with biogas technology. Implementation plan 2010-2012 of National Domestic Biogas and Manure Program of IDCOL mentioned that total technical potential of domestic biogas plants is 3 million. "Mobilizing market for the biogas technology" of GIZ study and other studies explained that the large potential market for the biogas digester in 100,000 poultry farms could benefit from the technology through the savings of traditional cooking fuel as well as prevention of disease and pathogen free fertilizer and also meet the energy crisis. Therefore, Bangladesh has a wonderful climate for biogas production. The ideal temperature for biogas is around 35°C. The temperature in Bangladesh usually varies from 6°C to 40°C. But the inside temperature of a biogas digester remains at 22°C-30°C, which is very near to the optimum requirement [11]. An estimate of the total biogas potential in the country is presented below [9].

A. Cattle Dung
1) Total cattle population of Bangladesh = 23 million
2) Dung available = 230 million Kg/day
3) Gas that may be obtained = 3106 million m^3 (Mm^3)/year
4) (1 kg of dung yields = 0.037 m^3 gas, each cow yields= 10 Kg dung/day)

B. Poultry Litter
1) Total poultry population (Chickens+ Ducks) of Bangladesh, (234+44) =278 million
2) Total poultry litter that may be obtained = 27.8 million Kg/day
3) Gas that may be obtained = 750 Mm^3/year
4) (1 kg litter yields = 0.074 m^3 gas, each bird yields = 0.1 Kg litter/day)

C. Human Excreta
1) Total human population of Bangladesh = 140 million
2) Excreta available = 56 million Kg/day
3) Gas that may be obtained = 1512 Mm^3/year
4) (1 kg excreta yields = 0.074 m^3 gas, Excreta per person = 0.4 Kg per day)

Therefore total biogas potential in the country = 5368 Mm^3/year.

5. CURRENT ENERGY STATUS OF BANGLADESH

Bangladesh has limited proven natural gas reserve but for its energy need it hugely depends on imported fossil fuel. With the increase in the fuel price in the international market and reduction of gas reserve in the country, Bangladesh is forced to look for alternative sources of energy i.e., renewable energy resources. At present the main energy production in Bangladesh is based on natural gas (85%) and major power stations here are run by natural gas. Electricity production is only about 272 kWh per capita. As the demand is increasing and the gas reserve has fallen to such an alarming level that if no new reserves are discovered then it is assumed that after 2016 the supply of the natural gas will start to decline. Bangladesh as a country of low GDP is contemplating more on the renewable energy sources which are relatively cheap to extract. About 75 million people of our country have no access to the national power grid & most of them (87%) live in rural areas. Only 53% of the area is connected to the natural grid [12]. Majority of rural people depend on inefficient, primitive sources of energy such as fuel wood, agricultural residues, cow dung and kerosene. About 90% households use biomass for cooking. The rest 10% use natural gas, LPG and biogas. Only 3% of the people enjoy natural gas facilities connected to their home through pipelines mostly in eastern part of the country in big cities. Lack of energy is the main hindering force for poverty alleviation. To make the energy system of the country sustainable, generation of energy from the alternative sources has become the crying need for Bangladesh [13]. In view of above vulnerable situations Bangladesh needs to adopt renewable energy technologies to protect its environment from further degradation, pollution and man-made and natural disasters.

6. CURRENT STATUS OF BIOGAS PLANT IN BANGLADESH

Although biogas plants were initiated by individual supports during 1970s, development of biogas technology in Bangladesh has received serious attention since 2000. Biogas pilot plant project has been implemented by the Institute of Fuel Research & Development (IFRD) since 1995. Under the project up to 2004, 17,200 biogas plants were constructed. According to an assessment report it has been seen that 99% of the plants installed under the project are in operation and 91% of the owners could meet their household fuel demand from the plants. To date, biogas plant has been one of the fast growing renewable energy technology in the country. The total number of biogas plants installed in the country by various organizations by 2009 has reached nearly 45,000 [14]. Among them, about 30,000 plants have been constructed by the public agencies with the BCSIR(Bangladesh Council of Scientific and Industrial Research) having made the most significant contribution(22,000 plants) in the development and dissemination of the technology. Besides, Bangladesh Rural Advancement Committee has installed about 1200 and Department of Environment has installed about 260 biogas plants in the country. However, the number of biogas plants in the poultry sector is not significant. Out of the total number of biogas plants, in the poultry sector BCSIR has installed about 3000 to 3500 biogas plants, whereas the number of biogas plants installed in poultry sector by LGED and Grameen Shakti (GS) are 2014 and 15015 respectively [15]. The Dhaka City Zoo has also installed one large and three smaller biogas plants that use the animal dung and slaughterhouse waste produced in the zoo. However, the Sustainable Energy for Development (SED) Program, working with several partner organizations, has been working to promote the use of larger (gas production of more than 4.8 cubic meters per day) biogas plants by dairy and layer poultry farms. As a result, about 1500 biogas plants in Bangladesh today use cow dung or poultry litter to produce biogas on a commercial scale. This is peanut compared to about 1900 million cubic feet of gas commercially produced per day from gas fields of the country during this time. As on 31 December 2012, a total of around 65,317 biogas plants have already been installed in Bangladesh [16]. Figure 1 shows cumulative number of biogas plants from 1985 to December 2012 in Bangladesh.

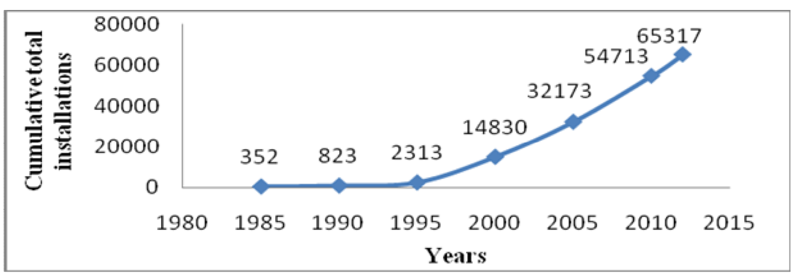

Fig.1: Cumulative number of biogas plants installed in Bangladesh

7. PIONEERING ORGANIZATIONS IN PROMOTING RENEWABLE ENERGY SECTOR OF BANGLADESH

Different government, semi-government and nongovernment organizations (NGOs) such as Bangladesh Council of Scientific & Industrial Research (BCSIR); Local Government & Engineering Department (LGED); Environment & Pollution Control Department (EPCD); Danish International Development Assistance(DANIDA); Bangladesh Small & Cottage Industries Corporation (BSCIC); BRAC; BUET; Grameen Shakti (GS); Infrastructure Development Company Limited (IDCOL); some NGOs; department of Youth & Sports etc. are involved in disseminating the biogas technology throughout the country [17].

7.1. INFRASTRUCTURE DEVELOPMENT COMPANY LIMITED (IDCOL)

Infrastructure Development Company Limited (IDCOL) was established on 14 May 1997 by the Government of Bangladesh (GOB) is playing the central role for dissemination of biogas plants in Bangladesh. The objective of IDCOL is to develop and disseminate domestic biogas plants in rural areas with the ultimate goal to establish a sustainable and commercial biogas sector in Bangladesh. In 2006, IDCOL launched a large scale extension program on domestic biogas plant through 30 partner organizations. The target of IDCOL up to 2012 was to install 60,000 biogas plants in our country with total capacity of 48 MW, under its National Domestic Biogas and Manure Programme (NDBMP). It has also set a target of 25% of the total target of biogas plants in the northern region which is yet to be brought under the national gas grid. IDCOL is promoting biogas plants of sizes 1.2 m^3, 1.6 m^3, 2 m^3, 2.4 m^3, 3.2 m^3 and 4.8 m^3 both for cattle and poultry owners. Biogas plants of size 2.4 m^3 are most common. Approximately 1 MW biogas based electricity plant has been installed in our country [18]. IDCOL is financing setting up of three biogas based electricity generation plants, one in Mymensingh and two in Gazipur, and one organic fertilizer plant in Gazipur by Paragon Agro Ltd. Electricity generated from these plants will be supplied to the adjacent poultry farms of Paragon Poultry Ltd. (PPL) at BDT 4 / kWh, while organic fertilizer will be sold in the market at BDT 15 per 1 Kg packet and BDT 400 per 40 Kg packet. Total project cost is BDT 149.40 million [19]. At present 38 NGO/MFIs/private firms are working under the program & IDCOL provides grant and refinancing facility and technical assistance to its partner organizations. A total of 1,00,000 biogas plants will be financed by 2016[18]. Moreover, since April 2012, IDCOL along with its partner organizations; has installed 22,549 biogas plants in different parts of Bangladesh [20]. Figure 2 shows year-wise number of installed biogas plants under IDCOL program. It shows a continuous rise in the number of installations marking the success of this current drive. However, a slight drop in number is observed in 2011. This is due to the prolonged rainy season in 2011 which restricted the construction of biogas plants.

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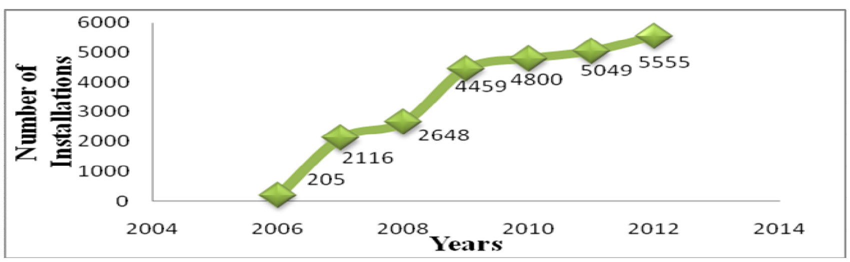

Fig.2: Year-wise installations by IDCOL

7.2. GRAMEEN SHAKTI (GS)

Grameen Shakti (shakti meaning "energy" in Bengali) was created in 1996 as a not-for-profit company under the Grameen Bank. The goal of Grameen Shakti is to promote and supply renewable energy technology at an affordable rate to rural households of Bangladesh. Recently, GS also works as a partner organization of IDCOL for construction of small family size biogas plants i.e. 1.6 - 4.8 m^3 of gas production per day. They have constructed over 13,000 biogas plants as partner organization under IDCOL's program. GS has constructed 26,298 biogas plants up to 31 August, 2013. Grameen Shakti future plan is to install 6,000 biogas plants in 2013; 8,000 in 2014 & 12,000 in 2015[21]. At present there are about 200 biogas based generators in the country of size 1KW to 1MW and among them Grameen Shakti alone has about 100 biogas based generators. As a pilot project Grameen Shakti imported 10 fiberglass digesters from China and installed them in different customers' households [12]. Figure 3 shows year-wise number of installed biogas plants under Grameen Shakti.

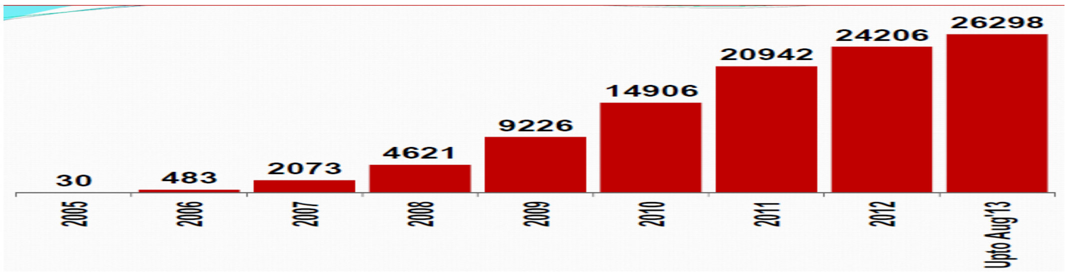

Fig.3: Year-wise installations by Grameen Shakti

8. OVERALL PROGRESS IN DISSEMINATION

As on 31 December 2012, a total of around 65,317 biogas plants have already been installed in Bangladesh [16].Table 1 shows the number of domestic biogas plants installed by major organizations in Bangladesh as of December 2012.

Table 1. Organization-wise Installations

Organization	Number
IDCOL	26,311
BCSIR	22,334*
GS(outside of IDCOL)	7,000**
NGOs and Others	9,672
Total	65,317

*This figure does not include BCSIR's latest ongoing project; **Approximate figure

9. BARRIERS TO DISSEMINATION OF BIOGAS TECHNOLOGY IN BANGLADESH

Key barriers of biogas technology dissemination included high installation cost of plant, uncertainties about post-warranty services, lack of sufficient funds, technical difficulties, lack of trained manpower, lack of public awareness & social prejudices, lack of policy for dissemination, lack of proper application of standardized technology, scarcity of feedstock and the general reduction in the number of domestic animals, particularly cows. Inadequate gas production was one of the most common problems facing biogas users. As a result of inadequate gas supply, household's often resorted to use traditional cook stoves to meet their cooking needs. Therefore, a large part of Bangladesh experiences flood almost every year. It is extremely difficult to prevent floodwater entering into the digester in flood prone areas, which will collapse the gas production capacity. Entering of flood water into the digester will break down its operational capacity. Sometimes, the rainy season prolongs in Bangladesh and high water table limits the construction season from six to seven months per year. The idea of attaching the latrine to the biogas plant is not getting social acceptance among the rural people due to unawareness of health and environmental benefits. Bangladesh currently does not have any central database for the primary survey report that will be reviewed on the pre-feasibility study before any new installation on the commercial scale. Nevertheless, the current environmental goals have not clearly considered on the environmental laws and acts of this country, as they were brought into force quiet a long time ago. Currently GOB is only focusing on the quick rental power generation which can only be considered as a short term solution for the projected energy crisis of the country. Investment on every renewable energy sources will be a certain encouragement for the private investors, but the initial investment for those projects with the current economic condition will be a challenging job for the government. However, the implementation of family size biogas plants (currently available system) was not successful in the past two decades in many rural parts of Bangladesh, mainly because of design, construction and maintenance problems, and limited research and development capabilities as well as limited coordination among researchers and implementing authorities [22].

10. CONCLUSION

Energy recovery from available biomass materials through biogas production can be a strong alternative option to supplement rural energy demand, which can consequently reduce higher level of deforestation, net greenhouse gas emissions as well as use of fossil fuels. By generating biomass fuel from the abundance sources, Bangladesh can solve a big portion of energy deficiency. Research and dissemination of biomass fuel throughout the country should be given priority in solving our energy crisis. However, the barriers and limitations should be accounted as the encouraging factor for the area of future improvement, as the idea of renewable energy sources is still in the early days in Bangladesh. The ongoing projects could be a motivating factor for the future planning in this area. In spite of having limited natural resources and technological drawbacks, the current initiatives and upcoming opportunities have clearly set up a convenient platform for a better solution the energy crisis. A coordinated effort of the concerned authorities and stakeholders and effective implementation of the action plan may surely improve the adaptation approach to mitigate the challenges of energy crisis in Bangladesh.

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DESIGN, CONSTRUCTION AND PERFORMANCE TEST OF A STORAGE TYPE SOLAR WATER

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ABSTRACT: Countries lying within the tropical region, like Bangladesh, where natural resources are scarce may be partly dependent on solar energy. Solar energy is an essentially inexhaustible source potentially capable of meeting a significant portion of the nation's future energy needs with a minimum of adverse environmental consequence. The indications are that solar energy the most promising of the unconventional energy sources. This literature completely explains the design, fabrication and performance study of solar water heater using solar energy and the purpose of this project work is to heat water by passive means where no additional energy is required to run the system. The main point of view to build this solar water heater is to minimize the cost, proper use of available local materials and get the possible highest efficiency with the simple design and construction and the highest efficiency is 45%.

Keywords: Air pollution, particulate matter, Human respiration, Dust mask

1. INTRODUCTION

The rate of energy consumption is increased day by day. Solar energy is the most popular and abundant continuing energy source available to human wooer. From environmental point, to-days use of conventional exhaustible energy sources is leading the world to its ultimate destruction. Hence it is a matter of concern, not only for better living standard but also for very survival of the world, to device, develop and deploy all possible techniques to extract energy from renewable energy sources. All countries in the world receive some solar energy .This amount varies from a few hundred hours per year as in the northern countries and the lower part of South America, to four thousands hours per year as in the case in most of the Arabian peninsula and the Sahara Desert. In addition to the thousands of ways in which the sun's energy has been by both nature. Solar energy is used to heat and cool buildings, to heat water and swimming pools, to power refrigerators; and to operate engine, pumps and sewage treatment plants. Solar energy much greater present and future potential because it produces large quantities of energy at low cost with minimal impact on the environment i.e. it satisfies three "E's" (energy, economy and ecology).

2. CLASSIFICATION OF METHOD FOR SOLAR ENERGY UTILIZATION

A broad classification of the various methods of solar energy utilization is presented in figure 1.1. It can be seen that energy from the sun can be used directly and indirectly. The direct means include thermal and photovoltaic conversion, while the indirect means include the use of waterpower, the wind, Biomass, wave energy and the temperature difference in ocean.

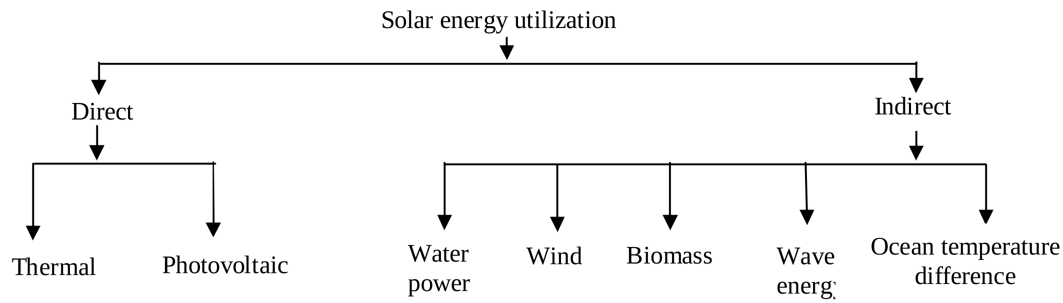

Fig.1: Classification of the various methods of solar energy utilization

3. SOLAR COLLECTORS

A solar collector is a device designed to absorb incident solar radiation and to transfer the energy`radiation and to transfer the energy` to fluid passing in contact with it.Utilization of solar energy requires solar collectors. Depending on the method of collector technology, all solar collector can be classified in the three classes, namely,

I. Flat plate collectors
II. Concentrating or Focusing collectors, and
III. Intermittently turned concentrating collectors.

4. STORAGE TYPE SOLAR WATER HEATER

The built in storage type solar water heater is one which the collectors and storage tank are combined in one unit where water is heated and stored.The advantage of built in storage type solaro water heater are absence of intricate mechanism to follow the sun and the ability to both beam and diffuse components of solar radiation

A solar water heater absorbs the solar radiation falling on it, converts this energy to heat and transfer this heat to water flowing through the heater. In passive solar water heating system, the absorber pipe is generally coated with a material that absorbs a high fraction of the solar radiation falling on it. In a storage type solar water heating system there has two portions, the lower portion is tank and the upper portion is a glass plate. The upper portion of the tank in collector. The collector surface is coated with black paint can absorb as much as the solar radiation than any others. Most of the solar radiation is absorbed and converted to heat. Some of this absorbed heat is conducted through the collector to the water. The transfer of heat to the water rises the water temperature. Some of the heat is lost to the surroundings. The heat losses should keep as low as possible.

5. MAIN PARTS OF THE STORAGE TYPE SOLAR WATER HEATER

5.1 INSULATION:

Insulation is necessary to reduce heat losses from the upper and lower portion of the storage type solar water heater. Cotton is widely used because of its low thermal conductivity and moderate cost, as insulation having a thickness of 2 cm at the bottom surface and 1 cm at the sides.

5.2 CASING:

The built-in-storage solar collector with insulation is contained in a wooden casing of having external dimensions of 42cm × 27cm×10cm.

5.3 STAND STRUCTURE:

The supplying stand structure consists of two hollow pipe, inside it move another pipe. The stand contain different portion for inclining the total arrangement in desired angle.

6. DESIGN AND FABRICATION OF THE STORAGE TYPE SOLAR WATER HEATER

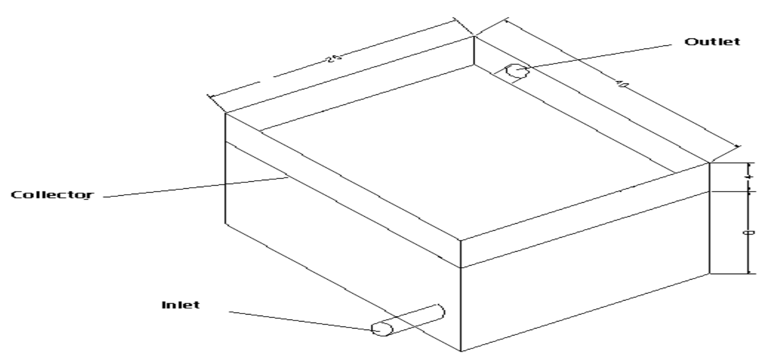

Fig.11: Designed mask.

Fig. 12: Fabricated mask.

Built-in-Storage Solar Collector: The storage tank and the solar collector were combined , and built as one unit. The top surface of the absorber plate was blackened with a dull paint in order to increase the absorptance of shortwave solar radiation. The wooden frame, made by wood, supports the plate and, to avoid leakage of water

The length of the storage tank= 40 inch
The width of the storage tank =24 inch
The height of the storage tank =8 inch

7. EXPERIMENTAL DATA

Table 1: For mass flow rate $\overset{\circ}{m}$ = 70gm/min (Date 06.04.10)

Day Time	Water inlet Temp. (°C)	Water outlet Temp. (°C)	Temperature Difference (°C)	solar intensity, $I_T (W/m^2)$	Efficiency %
10.30a.m	31	39	8	700	11.36
11.00 a.m.	31	44	13	850	16.86
11.30 a.m.	31	50	19	1120	19.02
12.00 p.m.	31	55	24	1340	22.34
12.30 p.m.	31	62	31	1510	26.32
1.00 p.m.	31	69	38	1494	30.02
1.30 p.m.	31	73	42	1600	33
2.00 p.m.	31	75	44	1544	35.12
2.30 p.m.	31	76	45	1322	37.25
3.00 p.m.	31	77	46	1220	39.12
3.30 p.m.	31	77	46	1130	41.08
4.00 p.m.	31	77	46	940	42
4.30 p.m.	31	76	45	860	43.22
5.00 p.m.	31	76	45	790	44

8. SAMPLE CALCULATION:(for table 1)

We know that,

The efficiency, $\eta = Q / A_c I_T \sin(90-\theta)$

$= m C_P (T_{out} - T_{in}) / A_c I_T \sin(90-\theta)$

$= 4.2\times1.006\times(39-31) / 0.6\times700 \sin(90-\theta)$

$= 0.1136$

$= 11.36\%$

Again,

$\eta = Q / A_c I_T \sin(90-\theta)$

$= m C_P (T_{out} - T_{in}) / A_c I_T \sin(90-\theta)$

$= 4.2\times1.006\times(44-31) / 0.6\times850 \sin(90-\theta)$

$= 0.1886$

$= 18.86\%$

$\eta = Q / A_c I_T \sin(90-\theta)$

$= m C_P (T_{out} - T_{in}) / A_c I_T \sin(90-\theta)$

$= 4.2\times1.006\times(50-31) / 0.6\times1120 \sin(90-\theta)$

$= 0.2400$

$= 24\%$

$\eta = Q / A_c I_T \sin(90-\theta)$

$= m C_P (T_{out} - T_{in}) / A_c I_T \sin(90-\theta)$

$= 4.2\times1.006\times(55-31) / 0.6\times1340 \sin(90-\theta)$

$= 0.2522$

$= 25.22\%$

9. RESULTS AND DISCUSSION

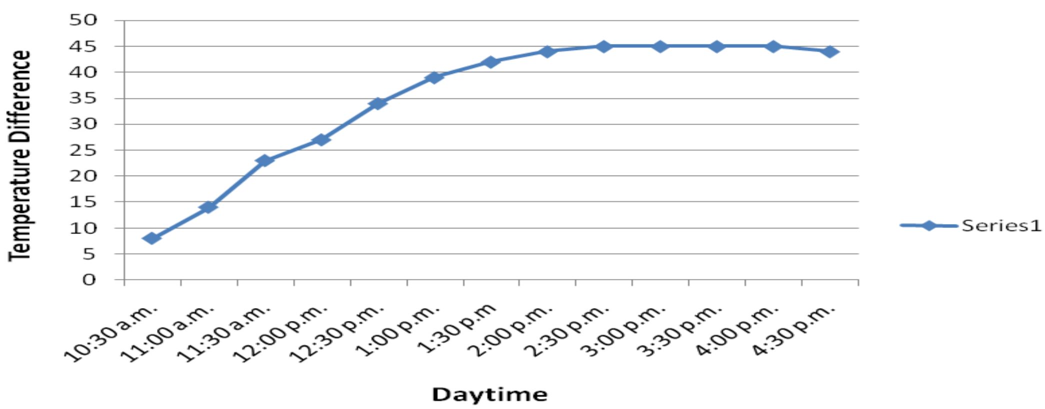

Fig.15: Histogram of 0.5μm diameter particles passing through different types of mask tested at RUET campus.

10. CONCLUSION

The project work was started with the three main objectives and those were design, fabrication and performance test of a storage type solar water heater and all the objectives have been fulfilled. The main point of view was to make a simple design and to minimize the cost and to use the local available matoragerials properly. The design of the strage type solar water heater was made carefully and the materials required for fabrication were selected, which were inexpensive comparison with the other materials. The highest intensity was found at noon.The temperature difference increases very fast up to the maximum intensity, then the rate of rising temperature is very less. Due to discontinuity of flow rate and variation of intensity the efficiency was not found accurately. The efficiency was found different at different temperature difference.

11. RECOMMENDATION

The storage type solar water heater was made according to the design. For obtaining proper efficiency the distance between transparent and collector should not more. Collector material is very important for storage type solar water heater. Collector material should have good heat conductivity. The design of tank is very important factor. It should be leakage proff.The height of tank should be considered properly according to the collector area. For using maximum intensity the stand should moveable.In the present heater no reflector is used. But the use of a reflector such as mirror can trap more sun radiation which will increase the heat gaining capacity.

By arranging A storage unit with the heater to store hot water.Due to the crisis of conventional energy, it is must for every energy expert to find out the possible ways of extracting pure and less costly renewable sources of energy. In a poor country like Bangladesh they are need simple technology without affecting the hard earned foreign currency.

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BIOGAS: AN ALTERNATIVE SIGNIFICANT SOURCE OF ENERGY FOR SUSTAINABLE DEVELOPMENT IN RURAL BANGLADESH

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ABSTRACT: Bangladesh is one of the low energy consuming countries in the world. Most of the people depend on traditional energy sources, which are very confined and have environmental imperilment. Out of 22 gas fields discovered so far, 2 abandoned, 5 exhausted and the rests are going to be finished soon. 90% of the country's electricity is gas based. It means, when gas is finished, there will be no electricity in the country. In the quest for alternative energy-dictated both by science and the geo-politics of fossil fuels the biggest global consumers have concentrated their efforts on developing technologies to harvest other viable sources like wind, geo-thermal, solar power, biogas and so on. Biogas could be the solution to this energy problem for the poor villagers. The technology is rather simple and construction materials are available. This gas could be used for any purposes from cooking to household lighting, heating and even to run a television or radio or even running small machines. As an agricultural based country Bangladesh has vast potentials to capitalize the biogas technology as source of electricity to minimize the demand of power. Moreover biogas could imprint its footstep in sustainable development in the village environment, society and economy. It could enhance the civic life of the villagers by diminishing health problems, promoting education and providing the scope of entertainments. Biogas system is an efficient way of dealing with organic wastes, dung, crop residues and dead cattle organs while making optimal use of their nutrient content. Biogas plants lower the green house effects on the earth's atmosphere due to having lower methane emission. Climate in Bangladesh is suitable for biogas production. All hazardous organic wastes are the raw materials for biogas production. Technology is simple and locally available. This paper articulates the prospects & projects of biogas power plant in Bangladesh, the confinements of the projects should be addressed critically to have a proper solution for the energy crisis in the country.

Keywords: Sustainable Development, Biogas Technology, Green House Effect, Organic Wastes, Energy Crisis.

1. INTRODUCTION

Bangladesh is one of the world's most densely populated nations (162.20 million in2011), situated in the north-eastern parts of south Asia, with a land area of 147,570 km^2 (around 1099 people/km^2). Bangladesh is one of the least urbanized nations in that 72% of its people live in rural areas. It is also one of the world's poorest nations with a Gross Domestic Product (GDP) per capita of US$1,700 in 2010; average annual growth of GDP is expected to be 6% this year (CIA,2011)[1]. Only 15% of the total population has access to electricity. In 1990 only 2.2% of total households had piped natural gas connections for cooking and only 3.9% of total households used kerosene for cooking. In 1990, more than 73% of total final energy consumption was met by different type of biomass fuels, for example agricultural residues, wood fuels, animal dung, etc. The 18th century discovery of biogas as a cooking fuel seems to be an effective answer to the likely energy crisis of the developing countries in the next century. The 1991government task force on energy emphasized on energy audit and suggested the integration of biogas as an energy source within the overall development policy of Bangladesh. Though the use of biogas is limited in Bangladesh, it is believed to have a wide prospect here [2]. In Bangladesh from over 22 x 106 cattle heads, assuming 80% collection of cow-dung (currently, 34% of raw dung is dried for burning as fuel), the total gas obtainable is 2,377x 106 m3(0.037 m3 per kg fresh dung) per year. Processing of human excreta will yield biogas to the tune of 1200 x 106 m3 per year. 24% of the total population i.e. 0.24 x 130 =31.2 million people live in the urban areas producing some 31.2 x 106 x 0.3 x 365 = 3.42 x 109 kgs of household wastes annually. This has a potential of producing 3.42 x 109 x0.046 m3 = 157.3 x 106 m3 of biogas [3].

Fig.1: Bangladesh Biogas system at Rupantar

2. OPERATIONS OF BIOGAS PLANT

Biogas typically refers to a gas produced by the biological breakdown of organic matter in the absence of oxygen. Biogas originates from biogenic material and is a type of bio fuels [4]. It is mainly composed of methane & CO_2. The biogas typically has 60% methane &b 35% CO_2. There is also some percentage of hydrogen, nitrogen, oxygen, ammonia, moisture etc. The feedstock that is used for biogas production is mainly animal dung and wastage materials. Biogas production can be aerobic (presence of oxygen) and anaerobic. In anaerobic
decomposition (absence of oxygen) of biomass in presence of bacteria. The bacterial decomposition of biomass takes place in three phases. They are hydrolysis phase, acid phase,
methane phase. The following are the three processes that take place in biogas formation.

Hydrolysis phase: $(C_5H_{10}O_5)n + H_2O$ _ $n(C_5H_{12}O_6)$
Acid phase: $n(C_5H_{12}O_6)$ _ $CH_3CH(OH)COOH$
Methane phase: $4H_2 + CO_2$_ $2H_2O + CH_4$
$CH_3CH(OH)COOH + H_2O + CO_2$_ $CH_3COOH + CH_4$

These three phase run in parallel in a biogas plant. But for the efficient production of biogas, all three processes should happen in equal amount. The acid production should not occur in large amount as it seriously affects the production of biogas. The pH value of the slurry in the digester tank should be between 6.8 & 7.2. The whole process of anaerobic decomposition of biomass into biogas takes several weeks. The retention period of biomass inside a biogas chamber varies between 20 to 50 days. For example the retention period of cow dung is 50 days. A biogas production system must be specially designed and requires regular attention by someone familiar with the needs and operation of the digester. And associated manure handling equipment and gas utilization components are also required. The digester does not remove significant nutrients and requires environmentally responsible manure storage and handling system.

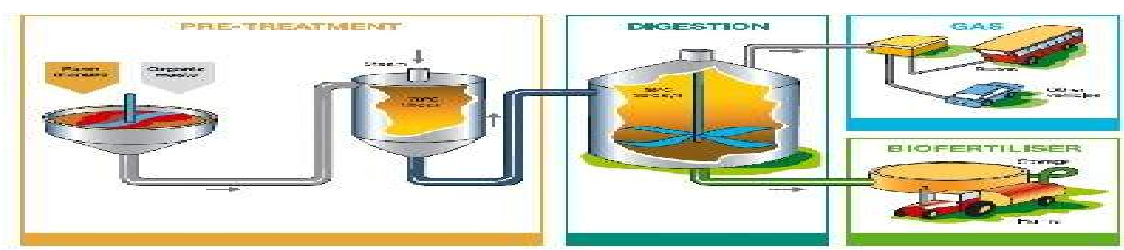

Fig.2: Biogas Production Process

The well designed and operated digester will require modest daily attention and maintenance. The care and feeding of a digester is not unlike feeding a cow or a pig; it responds best to consistent feeding and the appropriate environmental (temperature and anaerobic- without oxygen) conditions. Biomass accounted nearly 50% of total energy supply in 2004 and supplied 98% of total renewable energy [5].

3. FEASIBILITY OF BIOGAS PLANTS IN BANGLADESH

The major part of energy consumed comes from biomass which is used mostly for cooking in rural areas and for rural industries. It forms 68% of total energy supply while 32% is supplied by commercial energy (including hydro power). At present 12 million tons of coal equivalent biomass is consumed in the industrial and domestic sectors along with commercial energy.

- Biogas for domestic cooking, lighting and fertilizer
- Biogas from poultry waste for electricity
- Biogas gasifiers

Biomass is the most significant energy source in Bangladesh which accounts for 70% of the total final
energy consumption. This technology can be disseminated on a larger scale for electricity generation. The main sources of biomass fuels are: Trees (wood fuels, twigs, leaves, plant residues), Agricultural Residues (paddy husk, bran, bagasse, jute stick etc.), and Livestock (animal dung) [6]

Table 1. Estimates Of Energy Supplied By Traditional Biomass Fuels (‘000 Tons Of Coal Equivalent)

Fuels	2000-01	2001-02	2002-03	2003-04
Cow-dung	2471	2471	2471	2502
Jute stick	966	1010	966	922
Rice straw	1429	1409	1418	1218
Rice hulls	2810	2854	2898	2854
Bagasse	3-10	366	366	392
Fire wood	1166	1219	1219	1272
Twigs and leaves	1378	1431	1484	1537
Other wastes	1230	1273	11317	1361
Total	**11790**	**12033**	**12139**	**12258**

So the total potential of biogas from cowdung, human excreta and urban wastes stands at 3675 x 106 m3 which is equivalent to 1.95 million tons of oil (1 m3 biogas= 22.31 x 106 Joules) . By using biogas technology we can reduce the cooking time by 80% & can also reduce household fuel costs & health hazards. Besides the animal dung & wastage materials used to generate methane leaves behind rich, organic slurry that can supplement chemical fertilizers. The use of slurry can improve soil fertility &and mitigate the environmental risks associated with chemical fertilizers. Bangladesh government promotes use of in-house biogas systems (IBS) that can process excrements of livestock and poultry into biogas. In four years from FY2006 to FY2009, the government plans to popularize IBS as many as 60,000 units all over the country.

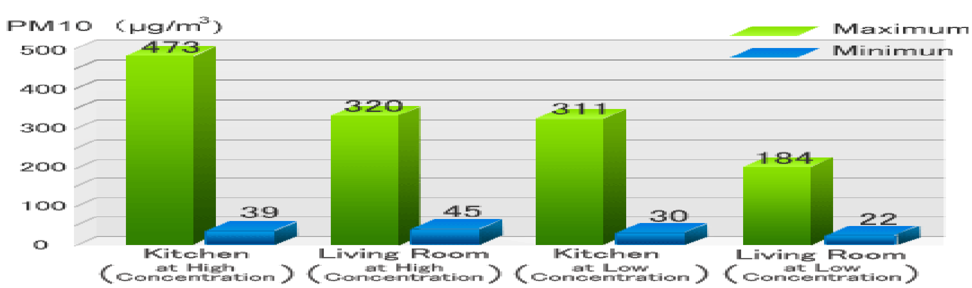

Fig. 3: Result of Measurement on PM10 in Bangladesh Houses (24Hr mean)(Note: WHO standard is $50 \mu g/m^3$ or less)

4. DISPERSION OF BIOGAS PLANTS IN BANGLADESH

In 1992, BCSIR in collaboration with Dhaka City Corporation built an experimental biogas plant of 85 m3 digester volume at Saidabad, Dhaka, for treatment of city garbage. Per day on the average, charging of 525 t of garbage plus 2 t of cowdung produced 57 m3 of biogas and 40 t of residue (bio-fertilizer) rich in plant nutrients over a period of two months. The residue had no bad smell. In 1994 Government of Bangladesh created a public limited company named Infrastructure Development Company (IDCOL) with the financial assistance from World Bank to support all kinds of infrastructure development with focus to energy related infrastructures. They successfully established 450 MW power plants at Meghna Ghat, installed 800,000 solar home systems since 2003 and from 2006 with the support from Netherlands Development Cooperation (SNV) launched a project for the extension of biogas technology in Bangladesh. Under the program, 37,000 biogas plants will be built by the year 2012. 28 partner organizations have been identified for the implementation of the project. By now, they have constructed about 18,000 biogas plants. 95% of the plants are in operation. There are three million potential household with adequate cattle or poultry. In Bangladesh biogas is being used mainly for cooking purpose. From 1971 to October 2009 About 41000 biogas plants has been constructed by different NGOs, under national domestic biogas and manure programme (NDBMP) of IDCOL, sustainable energy for development (SED) program of German technical cooperation (GTZ), and other government organizations e.g. local government engineering department (LGED), Bangladesh council of scientific and industrial research (BCSIR) [24]. Biomass is the most significant energy source in Bangladesh which accounts for 70% of the total final energy consumption [4]. This technology can be disseminated on a larger scale for electricity generation. IDCOL financed a 250 kW Biomass based power plant at Kapasia, Gazipur. The plant uses locally available agricultural residues i.e. rice husk as fuel for power generation. Being located in an unelectrified area, the plant is expected to supply environment friendly grid quality power to 300 households and commercial entities of that areaUnder NDBMP of IDCOL, 5688 biogas plants have been constructed in Bangladesh in the year of 2010. In the first half of 2012, more than 46,000 biogas plants were installed in various countries in Asia and Africa supported by SNV. In Bangladesh, Pakistan and Indonesia, the domestic biogas programmes perform in the first half of 2012 less than forecasted. The table provides an overview of the unofficial production numbers of biogas plants installed in the first half of 2012, as well as cumulative numbers.

Table 2. Numbers of biogas plants installed in the first half of 2012

Country	Programme took off in	2011 (official)	1st half of 2012 (officious)	Cumulative up to 1st half of 2012
Asia				
Nepal[1]	1992	19,246	17,942	268,418
Vietnam[2]	2003	23,309	16,984	140,698
Bangladesh	2006	5,049	2,855	23,611
Cambodia	2006	4,826	2,478	17,450
Lao PDR	2006	439	310	2,715
Pakistan	2009	860	650	2,097
Indonesia	2009	2,970	959	5,572
Bhutan	2011	40	115	155
Africa				
Rwanda	2007	785	325	2,171
Ethiopia	2008	1,641	732	3,232
Tanzania	2008	1,444	763	3,334
Kenya	2009	2,399	1,678	4,917
Uganda	2009	1,276	423	2,325
Burkina Faso	2009	609	456	1,177
Cameroon	2009	33	6	111
Benin	2010	20	0	42
Senegal	2010	225	95	334
	Total	***65,171***	***46,771***	***478,359***

[1] Including plants financially supported by WWF between 2007-2011; total 7,915
[2] Including plants under ADB and WB supported programmes between 2010-2012; total 18,969

5. PROSPECTS & CHALLENGES OF BIOGAS PLANTS IN BANGLADESH

Biogas is advantageous compared to burning of wood & crop residues for cooking because it is clean & does not make any kinds of marks on cooking vessels or cloths. Most of the Bangladeshi households in rural areas (99%) as well as urban areas (66%) use biomass such as wood, cow dung, jute stick or other agricultural wastes for cooking. 40 million tons of firewood are consumed annually as cooking fuel , contributing to deforestation , erosion, & flooding. And only 3% of the total population has the aces to the pipeline supplied gas. Biogas systems all over the world are functioning under a variety of climatic conditions. However, a widespread acceptance and dissemination of biogas technology has not yet materialized in many countries. Biogas plants and gas upgrading plants both have a relatively high heat and energy demand which demand some of the biogas produced to be used on-site there is little or no control on the rate of gas production, although the gas can, to some extent be stored and used as required. So, these kinds of challenges should be considered for production energy by using biogas and biomass. Biogas contains contaminant gases which can be corrosive to gas engines and boilers. It generates methane that can be captured and used to produce energy that might otherwise leak into the atmosphere and increase the greenhouse effect; The process fixes nitrogen in the digestive and reduces emissions of nitrous oxide (a strong greenhouse gas) compared to composting or landfill. The Combustible renewable and waste (% of total energy) in Bangladesh was 29.77 in 2009, according to a World Bank report, published in 2010. Combustible renewables and waste comprise solid biomass, liquid biomass, biogas, industrial waste, and municipal waste, measured as a percentage of total energy use.

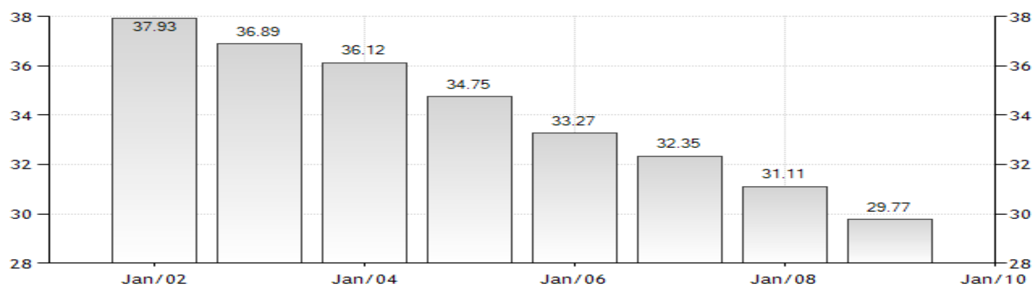

Fig.4: COMBUSTIBLE RENEWABLE AND WASTE (% OF TOTAL ENERGY) IN BANGLADESH

6. CONCLUDING REMARKS

Bangladesh is considered extremely vulnerable to the impacts of energy issues. The power demand of this small country is accelerated in a wide range. Power crisis is one of the rudimental problems of Bangladesh. Biomass is the fourth largest source of energy worldwide and provides basic energy requirements for cooking and heating of rural households in developing countries. Biomass covers all kinds of organic matter from fuel wood to marine vegetation. Energy generation using biomass offers a promising solution to environmental problems by reducing the emission of common greenhouse gases. For meeting the acrimonious power crisis in Bangladesh biogas will be a salient alternative source of energy.

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COMMERCIALLY FEASIBLE SOLAR WATER PUMPING SYSTEM EFFECTIVE FOR SUSTAINABLE RURAL DEVELOPMENT

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ABSTRACT: This paper deals with the design and analysis of commercially feasible Solar Water pumping system for irrigation in Bangladesh. A model having a solar powered pump with supply capacity of 1 million litre/day was considered for this analysis. Practical data from existing relevant project was taken into account to make this study more effective and feasible. This paper also deals with technology and management development to find out alternate use of the unused energy. Appropriate technology based on water storage system is used instead of storing energy in batteries. Employment creation and effective sustainable rural development is the key issue of this paper.

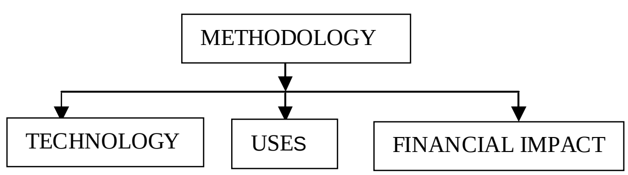
Keywords: Solar Energy, Pump, Water distribution system, Storage tank, Alternate application, Sustainable development.

1. INTRODUCTION

Bangladesh is blessed with abundant solar irradiation (on an average 4.65 KWh/m2-day) [1]. As an alternative to the conventional water pumping system for irrigation, solar photovoltaic (PV) pumping system has great potential for large scale applications. There is deficiency in electricity generation according to the demand in Bangladesh and therefore electricity crisis becomes severe during summer when the electricity demand of the country increase significantly. This paper will find out the feasibility of Solar pumping system for the large scale use. Analysis will be taken under three different methodologies including technology, use and financial impact.

2. METHODOLOGY

To analysis the commercially feasible Solar Pumping system, here we studied the process in three different sectors.
1) Technology; 2) Uses; 3) Financial Impact.

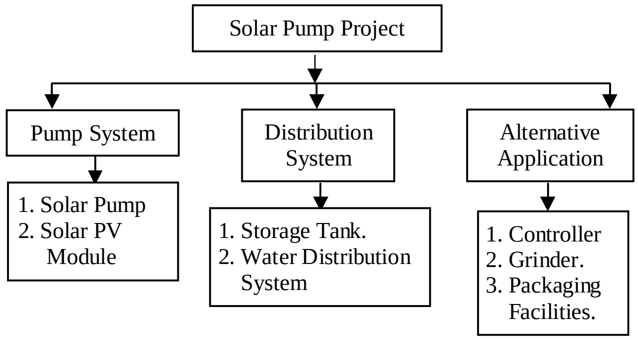


A. Technology:

Adoption of Sustainable Technology for rural development has a feasible impact throughout the world. In case of Bangladesh where continuous electricity supply is a major problem of day to day rural life and also for remote areas this is the most reasonable. Our proposed Solar Pump Project Consists of three different sections as shown below:

Pump: Since pump will be installed in rural areas and also often in remote areas, a good quality less maintenance pump need to be used. Consequently, a good European brand pump can be used. Also, pump need to have the properties to run both in DC and AC electricity. 12.25 kWp Solar System with 10Hp Pump can be used for supplying sufficient amount of water for irrigation for 150 Bigha of land.

Solar PV Module: Like pump, here we also need to select reliable PV Modules preferably from a vertically integrated manufacturing company having all the international quality certificates.



Storage Tank: Normally in Bangladesh 5,000/10,000 Litre Storage capacity tank is now being used for irrigation purpose. Here it is suggested to use a tank having a capacity of 100,000 litre which will be used for emergency Water Supply & distribute water as well throughout the 150 Bigha of irrigated Land.

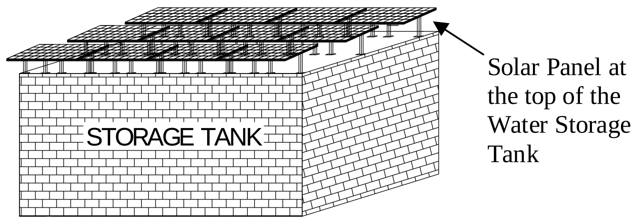
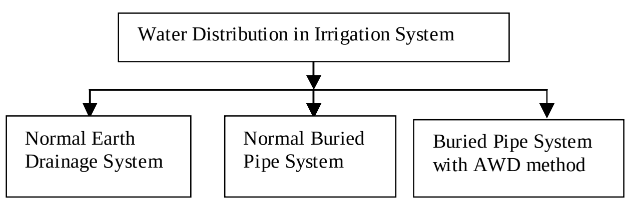


Fig.1: Water Storage Tank

This big size tank with lots of water will help to generate the pressure to flow it for 150 Bigha land. Solar panels are considered to put above the storage tank. If installed in the ground, panels will take a lot of space, why not we set the panels above the big storage tank and use that space to keep water for supplying water. In this way, we can also protect tank water to flow away as steam from the tank. This storage water will also help to serve the irrigation on a gloomy day or for some certain cases like for a rainy day just after a rainstorm. With the help of this storage water owner can earn some extra amount of money by supplying water to the land which is not under the coverage of this project area. A hose pipe can be used for distributing water from tank for this purpose to supply water beyond the 150 Bigha land.

Water Distribution System: Normally, for irrigation purpose, three different types of water distribution systems are used:



Amount of water losses also varies in different distribution systems.

Distribution System	Water loss
Buried Pipe system	5~12%
Normal Earth Drainage System	42%

In case of Safe AWD (Alternate Wetting and Drying), water savings are in the order of 15-30%. This study recommends buried pipe distribution system with AWD Method for optimum savings of water and for covering largest area of irrigation.

<u>Alternative Application:</u> As per the design here, we can supply required amount of water for crop production. For the rainy season, pump has no use for the irrigation. Moreover, crops do not need water for irrigation throughout all the time in a year. Studies show that, about 40% time in a year water pump is not utilized. But, solar panel will keep producing energy throughout all the time in a year as long as it is getting sunlight. Considering this issue, here we emphasise on optimum use of generated power. The unutilized energy can be used to make a facility for wheat grinding, lentil and spice grinding machine. This power can also be used for packaging services like packing of fresh vegetables or fruits which will be cultivated in nearby land under this project. The brief project description is shown below:

<u>Project Description:</u>
Water Flow Capacity: 10 Lac Liter/Day.
Solar Array Rated Power: 12 .25 kWp
Pump Size: 10 HP
Having a Storage Tank Capacity: 1 Lac liter
There will also be cleaning arrangement of the panels. Below picture can describe the project scenario.

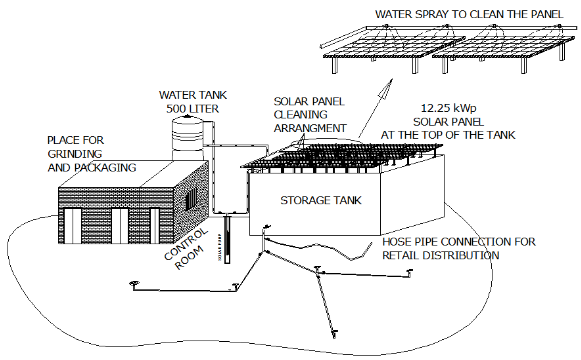
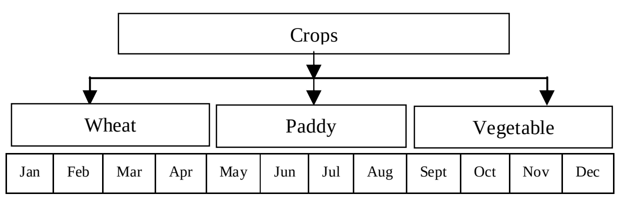


Fig.2: Project Detail

B. Uses:

Beyond using for specified irrigated land, by using hose pipe we can supply water to the other land beyond the 150 Bigha project. 8.31 MWh unused Solar Energy can be used for alternative Purposes. To get an optimum result for irrigation purpose, right crops need to be selected for right time.



A possible combination of feasible selection of crops is shown above. Selection of suitable corps is important here. To make this project as commercially feasible, we used the excess unutilized energy for various purposes like Grinding of Rice, Wheat, and Spices etc. We can also do packaging of fruits or vegetables and thus create employment.

<u>Sustainable Development:-</u>
- Solar Array Rated Power Capacity: 12 .25 kWp
- After Accumulating Plant Requirement, almost 40% time of the year, Pump is not being used.
- 40% of 365 days = 146 days.
- Per day Power Production : 12.25 X 4.65 kWh = 56.96 KWh
- Total unutilized power/year: 146 X 56.96 kWh= 8316.16 kWh= 8.31 MWh.

We can use this Energy for other applications like Grinding Wheat, Spices, packaging fresh vegetables and etc. Utilizing as above we can earn around 5 to 6 lac BDT in a year by using this unutilized power.

C. Financial Impact:-

Particular s	Propose Solar Pump
Pump Output	10 lac liter/day
Investment	Same
Water distribution System	Standard buried pipe systems with AWD
Project area coverage	More than 150 bigha
Alternate usage facility	Yes
Employment Generation	High
Finance	As per IDCOL
Estimated Yearly Revenue	BDT 1434,200/-
Estimated yearly avg. expenditure	BDT 914,482/-
Estimated net profit/year	BDT 519,718/-
Return on Equity Investment	43%
Pay Back period	1.78

*IDCOL= Infrastructure Development Company Limited.

3. RECOMMENDATION:

150 bigha or 20 hectors cultivatable lands need to be consider under this project for 20 years.

Land owner will be the owner of this project after 10 years.

Need partnership between corporations, NGO's and Land owners.

Counseling and educate land owners to select right crops at right time.

Diversify the usage of unused power . For example: Grinding machine , mobile charging , Battery charging , Drinking water supply and etc.

4. CONCLUSIONS

The use of photovoltaic power for irrigation is a well-matched application of solar energy supply to energy need, because both the plant water needed and the availability of water supplied by a photovoltaic system depend upon the solar irradiance available. Sustainable in our personal lives and giving something back to the society will help to make Bangladesh a holistic and sustainable society.

ACKNOWLEDGMENT

We acknowledge, with gratitude to all our colleagues and the people in the rural level without whom, this work will not have appeared into an improved one.

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ANALYSIS OF PALM OIL EMPTY FRUIT BUNCHES (EFB) FOR MITIGATING ENERGY DEMAND OF MALAYSIA AND INDONESIA

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ABSTRACT: Renewable energy is an important research topic at the present world energy scenario due to the increasing prices of fossil fuels and its environmental impact. Worldwide searching is going on for renewable and sustainable sources of energy. Indonesia and Malaysia are most developing ASEAN countries. Palm oil is one of the most revenue earning sectors for both countries. Oil palm plantation not only produces crude palm oil (CPO) but also a huge amount of biomass residues. Empty fruit bunches (EFB) is an attractive lingo-cellulosic biomass that is used to produce bio-ethanol or electricity by using chemical or thermo-chemical conversion processes respectively. It is possible to reduce the dependency on fossil fuels and reduce environmental pollution by using bio-ethanol in the transport sector. And this bio-ethanol can easily be derived from lingo-cellulosic biomass by chemical conversion. Maximum amount of curd oil not only used as transport fuels but also increase GHG emission. According to the calculation presented in this paper, the amount of ethanol comes from conversion of palm oil EFB can reduce GHG emission caused by transport vehicle to an amount of 4.55 million tons. That is equivalent to removing 0.7083 million cars from the road for one years. In the transport sector in Indonesia almost one fourth of energy consumed, that is equivalent 28.632 billion kWh in 2010. The palm oil EFB wastage produced in Indonesia and Malaysia presented in details and proposed a scheme to produce bio-ethanol that is equivalent to 2.3 times of the transport fuel needed in Indonesia in the year 2010.

1. INTRODUCTION

Renewables are economically viable and environmentally suitable sources of energy. This is a clean source of energy, which have a lower environmental impact than conventional energy technology. The energy safety concerns along with growth of demand in the world [1]. Renewable energy reduces the dependency on fossil fuel and GHG emission. Biomass is alternative source of energy especially lignocellulosic biomass is most important source of bio-fuels. Due to the increasing demand of transport fuels, bio-ethanol is important source of alternative fuel. The use of ethanol as an alternative to traditional fossil fuel can reduce GHG emission around 48-59% [2]. In 2012, the 13.2 billion gallons of ethanol reduced greenhouse gas emissions from on-road vehicles by 33.4 million tons. That's equivalent to removing 5.2 million cars and pickups from the road for one year [3].

There are abundant sources of biomass in the environment. Palm oil EFB is greatest sources of oilseed crop. Indonesia and Malaysia produces maximum part of palm oil, which is about 84% of total palm oil production in the world. Only in Malaysia, about 500 palm oil mills are operating [4]. The palm oil industry accounts for the largest biomass production in Malaysia and Indonesia, all palm oil mills have depended on their own biomass for fuel, using mainly the shells and fibres. About hundred millions tones of Fresh Fruit Bunches (FFB) are harvested and processing in the palm oil mills every year and are produced million tons of solid waste residuals [5]. The empty fruit bunches has not been used properly due to huge volume and expenses to handle. They left it as wastage. Palm oil mill effluent (POME) represents the largest potential for biomass energy utilization in the country, but this resource is readily available and in need of an efficient and effective means of utilization [6]. In order to improve the environmental performance of palm oil production, the industry must start being concerned with using all resources from the oil palm in an optimal way, while at the same time minimizing the environmental impact of the recycling systems in or outside of the mill. Bio-Centrum at Denmark's Technical University estimated that one tone dry EFB is able to produce 0.39 m^3 of ethanol using a new process (wet explosion) for pre-treatment [7]. Other techniques, however, have proven to be less efficient.

Piarpuzán et al. [8] demonstrated a method of ethanol production from EFB using alkaline pre-treatment and enzymatic hydrolysis approach, which yielded ethanol at only 0.067 $m^3 t^{-1}$ of dry EFB. Millati et al. [9] also using dilute sulphuric acid pre-treatment, achieved a yield of 0.112 $m^3 t^{-1}$ of dry EFB. Yano et al.[10] developed new yeast strains, and utilized milling pre-treatment, with enzyme hydrolysis, resulting ethanol yield 0.13 $m^3 t^{-1}$ of dry EFB. In this research article

This article is prepared based on the following sections. Production of palm oil and palm oil based residues are reviewed in the section 2 and 3 respectively. Section 4, describes the palm oil EFB conversion processes mainly to bio-ethanol and an estimation of bio-ethanol that comes from palm oil EFB. A comparison is presented to traditional transport fuel used in Malaysia and Indonesia along with the expected amount GHG emission reduction. The calculations are made based on data of FAOSTAT, and published information.

2. PALM OIL PRODUCTION IN THE WORLD

According to data of FAOSTAT, the total palm oil production in the world is presented in Table 1. Maximum amount of palm oil produces in Indonesia and Malaysia, which are 44% and 39% respectively. About 83% of total palm oil in the world produced in Indonesia and Malaysia. It is estimated that one kg of palm oil, approximately produces 4 kg of dry biomass amongst which one third palm oil empty fruit bunch (EFB) and the other two thirds are oil palm trunks and fronds [12-14]. Among the oil palm biomass, palm oil EFB is the most often investigated biomass for bio-fuel production. The conversion of palm oil EFB to bio-fuels, such as syngas, ethanol, butanol, bio-oil, hydrogen etc. might be other good alternatives.

Table 1: Total palm oil production in the world [11]

Total Palm Oil production in 2011 in the world		
Name of Country	**Production in tons**	**Production , %**
Indonesia	21,449,000.00	44%
Malaysia	18,912,000.00	39%
Thailand	1,530,000.00	3%
Colombia	941,400.00	2%
Germany	555,165.00	1%
Papua New Guinea	520,000.00	1%
Côte d Ivoire	400,000.00	1%
Honduras	320,000.00	1%
Ecuador	289,900.00	1%
Brazil	270,000.00	1%
Cameroon	254,000.00	1%
China	250,000.00	1%
Others	2,859,785.50	6%
Total (world)	**48,551,250.50**	**100%**

3. GENERATION OF EFB IN THE WORLD

In the milling processes, a fresh fruit bunches produces 22% of empty fruit bunches and 23% palm crude oil [15, 16]. According to data of FAOSTAT [11] the total palm oil production in the world are shown in Table 1. The world first palm oil producer country is Indonesia, which is 44% of total production in the world in 2011[11]. Each ton of wet empty fruit bunches equivalent 0.48 ton of dry empty fruit bunches

[16]. Bio-Centrum at Denmark's Technical University estimated that one tone dry EFB is able to produce 0.39 m3 of ethanol using a new process (wet explosion) for pre-treatment [7]. Other techniques, however, have proven to be less efficient. Piarpuzán et al.[8]. Table 2 is prepared analytically base on above result.

Table 2: Total palm oil EFB production from FFB in 2011

Name of Country	Production of Wet EEB	Production of Dry EEB
Indonesia	20,516,434.78	9,847,888.70
Malaysia	18,089,739.13	8,683,074.78
Thailand	1,463,478.26	702,469.57
Colombia	900,469.57	432,225.39
Germany	531,027.39	254,893.15
Papua New Guinea	497,391.30	238,747.83
Côte d Ivoire	382,608.70	183,652.17
Honduras	306,086.96	146,921.74
Ecuador	277,295.65	133,101.91
Brazil	258,260.87	123,965.22
Cameroon	242,956.52	116,619.13
China	239,130.43	114,782.61
Others	2,735,447.00	1,313,014.56
Total (world)	**46,440,326.57**	**22,291,356.75**

4. PALM OIL EFB CONVERSION INTO BIO-ETHANOL

Biomass is biological material derived from industries, living. It most often refers to plants or plant-derived materials, which are specifically called lignocellulosic biomass. This biomass either used directly to produce electricity via combustion or converted into various bio-fuels. Even in today's modern era, biomass is the only source of fuels for domestic use in many developing countries. Palm oil EFB is a source of lignocellulosic biomass in the world, especially for Indonesia and Malaysia. Almost 87% of palm oil produces in Indonesia and Malaysia.

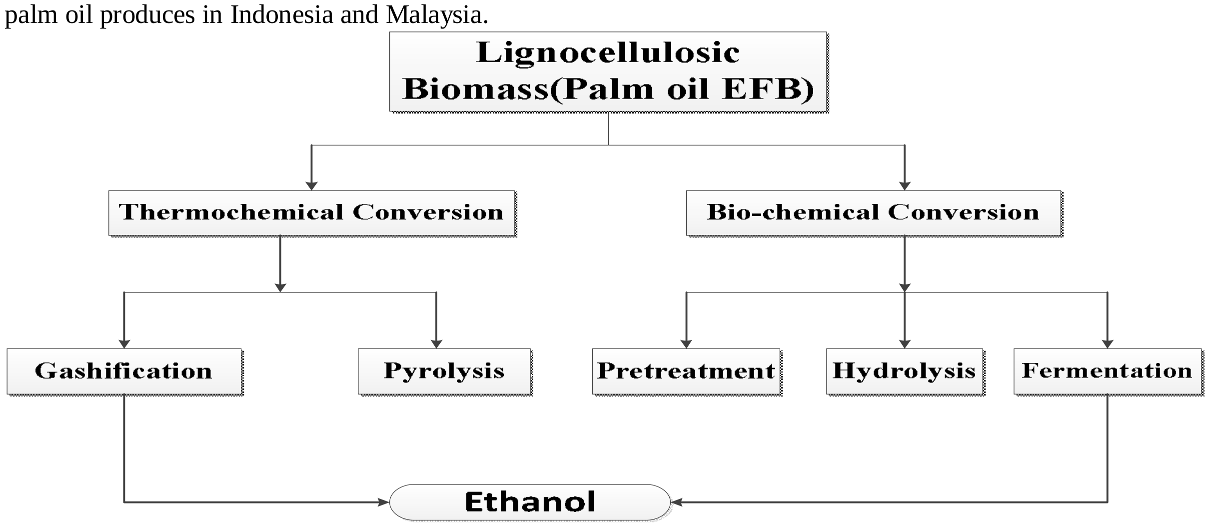

Fig.1: Palm oil EFB conversion to bio-fuel

4.1 BIO-CHEMICAL CONVERSION OF EFB INTO BIO-ETHANOL

According to Bio-Centrum at Denmark's Technical University, estimate that one tone dry EFB is able to produce 0.39 m^3 of ethanol using a new process (wet explosion) for pre-treatment [7]. So possible ethanol production from palm oil EFB easily calculated by multiplying dry weight EFB with 0.39, which is shown in the Table 3.

Table 3: Ethanol production from palm oil EFB in 2011

Name of Country	Estimated Ethanol comes from palm oil EFB, m^3
Indonesia	3,840,676.59
Malaysia	3,386,399.17
Thailand	273,963.13
Colombia	168,567.90
Germany	99,408.33
Papua New Guinea	93,111.65
Côte d Ivoire	71,624.35
Honduras	57,299.48
Ecuador	51,909.75
Brazil	48,346.43
Cameroon	45,481.46
China	44,765.22
Others	512,075.68
Total (world)	**8,693,629.13**

It has been found from unit conversion data that one cubic meter ethanol equal to 208.49 gallon. Therefore, 1.8125 billion gallons ethanol considering all over the world and 1.5068 billion gallons ethanol for considering Malaysia and Indonesia produced from palm oil EFB**.** In the below pie chart represented the energy consumption by sector wise at Indonesia in 2010. There are five different energy consumption segment, which are industry, household, commercial, transport and other. In the transport sector in Indonesia almost one fourth of energy consumed, that is equivalent 28.632 billion kWh where total amount of energy used 119.3 billion kWh. According to calculation of palm oil EFB wastage produce in Indonesia and Malaysia resented in the Table 2 can used to produce bio-ethanol that are equivalent to 2.3 times of transport fuel has been used in 2010 at Indonesia [18].

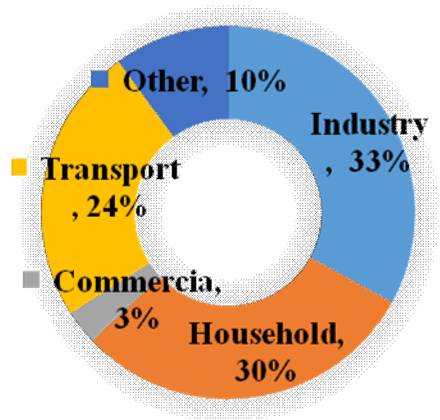

Fig.2: Indonesia's energy consumption by sector, 2010 [18]

4.2 TRANSPORT OIL AND ENVIRONMENTAL BENEFIT OF ETHANOL

World Oil Energy Consumption by Sector with transportation accounting for a growing share of the oil consumed. While the transport sector consumed 42% of the oil in 1973, this share climbed to 61.5% in 2010. The growing level of global motorization is a core component behind this relative growth, particularly the growth of international trade [19].

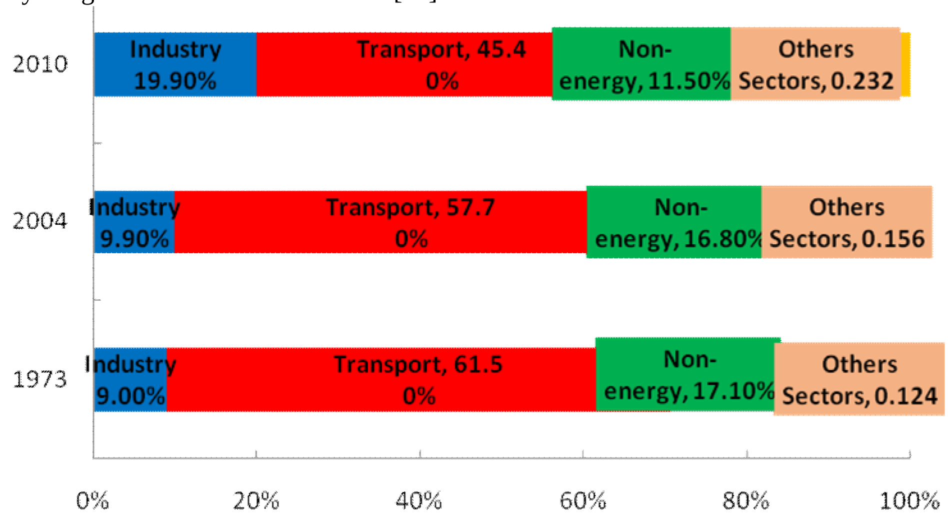

Fig.3: world oil consumption by sector, 1973-2010 [18]

Bio-ethanol is the best tool to reduce air pollution from vehicles. In addition, there is no available environment friendly fuel today that matches bio-ethanol's ability to improve the environment quality. If it is compared to gasoline, bio-ethanol contains 35% oxygen [3] where as gasoline contain 2.7% oxygen [20]. Therefore, the combustion of bio-ethanol results complete combustion and thereby reducing the harmful emissions. Using bio-ethanol replacing gasoline helps to reduce the carbon dioxide emission by 30-50 % using the technology now available [3]. It is now established that bio-ethanol production reduces GHG emission compared to gasoline around 48-59% [2]. In the year 2012, 13.2 billion gallons of ethanol produced worldwide and that reduced 33.4 million tons of greenhouse gas emissions only from on-road vehicles. That's equivalent to removing 5.2 million cars and pickups from the road for one year [3]. According to calculation presented at section 4.3, the amount of bio-ethanol comes from conversion of palm oil EFB can reduce GHG emission from on-road vehicles by 4.55 million tons. That is equivalent to removing 0.7083 million cars from the road for one years. According to Jabatan Pengangkutan Jalan (JPJ), Malaysia, the total number of cars registered as on October, 2010 is 14.35 million [21]. This number of cars produced about 89.92 million tons of GHG for one year. To reduce the GHG emission from transport sector bio-ethanol is the best solution.

5. CONCLUSION

Today one of the important factors for energy security and clean environment is alternative source of energy. With the rapid growth of world economy the transpiration needs are also developing simultaneously. The main source of transport fuel is imported fossil fuel that would come to end in the near future. Lignocellulosic biomass is used to produce second-generation bio-fuels, which are used as a transport fuels. Palm oil EFB is the biggest source of lignocellulosic biomass for Indonesia and Malaysia. Due to economic growth and dependency of imported fuel in Malaysia and Indonesia, bio-fuel generation from palm oil EFB can be an important part of energy policies in future. At the same time, modern world is so much concerned about GHG emissions. The main sources of GHG emission are the use of fossil fuels. Depending on the energy security and environmental pollution reduction bio-ethanol from palm oil EFB could be a better solution for Malaysia and Indonesia.

ACKNOWLEDGEMENTS

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FUEL CELL EFFICIENCY, VOLTAGE ANALYSIS AND PERFORMANCE OPTIMIZATION

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ABSTRACT: High electrical efficiency is one of the desirable properties of fuel cells. Since the energy conversion process is electrochemical in nature, fuel cells are not bound by the Carnot law of efficiency heat engines are subject to. Therefore, the same equation for efficiency cannot be used, but there are several defined efficiencies for fuel cells that make up the total efficiency Here theoretical and actual all are considered and their differences causes of irreversibility, minimum loss capability and optimizations are shown which are the objectives.
Key words: *Gibbs free energy, Tafel equation, Irreversibilities, EMF, Stoichiometric factor.*

1.INTRODUCTION

Fuel cells are self-contained power generation devices that are able to produce reliable electricity for residential, commercial, industrial and transportation applications. A fuel cell can convert hydrogen directly into electricity that can be used to power consumption.
Basic energy conversion of a fuel cell was described as:

Chemical energy of fuel = Electrical energy + Heat energy

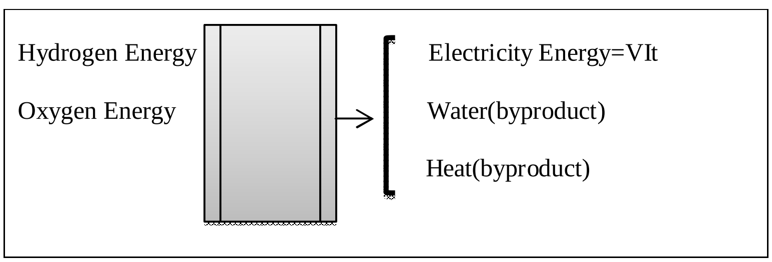

Fig.1: Basic energy conversion of a fuel cell

The electrical power and energy output are calculated from Power = VI and Energy = VIt

In a fuel cell, it is the change in this Gibbs free energy of formation, gf , that gives us the energy released.
The activities of the reactants and products by the Gibbs free energy change of hydrogen fuel cell the equation becomes,

$gf = gf^0 - RT \ln(aH_2 \cdot ao_2^{1/2}/aH_2O)$
where gf^0 is the change in molar Gibbs free energy of formation at standard pressure.

If the activity of the reactants increases, gf becomes more negative, that is, more energy is released. On the other hand, if the activity of the product increases, gf increases, so becomes less negative, and less energy is released. To see how this equation affects voltage,

$$E = -gf_0/2F + RT/2F.\ln(aH_2 \cdot ao_2^{1/2}/aH_2O)$$

$$E = E_0 + RT/2F.\ln(aH_2 \cdot ao_2^{1/2}/aH_2O)$$

where E_0 is the EMF at standard pressure and is the number given in Table 4.2. The equation shows precisely how raising the activity of the reactants increases the voltage. Consider the basic reaction for the hydrogen/oxygen fuel cell:

$H_2 + 1/2O_2 \rightarrow H_2O$

By Gibbes form, $gf = (gf)H_2O - (gf)H_2 - 1/2(gf)O_2$

Two electrons pass round the external circuit for each water molecule produced and each molecule of hydrogen used. So, for one mole of hydrogen used, 2N electrons pass round the external circuit where N is Avogadro's number. If −e is the charge on one electron, then the charge that flows is,

$$-2Ne = -2F \text{ coulombs}$$

F being the Faraday constant, or the charge on one mole of electrons. If E is the voltage of the fuel cell, then the electrical work done round the circuit is,

$$\text{Electrical work done} = \text{charge} \times \text{voltage} = -2FE \text{ joule}$$

If the system is reversible (or has no losses), then this electrical work done will be equal to the Gibbs free energy released gf .So $gf = -2F \cdot E$

$$\text{Thus, } E = -gf/2F$$

This fundamental equation gives the electromotive force (EMF) or reversible open circuit voltage of the hydrogen fuel cell.

2.THE OPEN CIRCUIT VOLTAGE(OCV) OF OTHER FUEL CELL BATTERIES

The equation that have discussed for the OCV of the hydrogen fuel cell, If generalize it to any number of electrons per molecule, have the formula, $E = -gf/zF$

where z is the number of electrons transferred for each molecule of fuel.

3. EFFICIENCY AND EFFICIENCY LIMITS

Fuel cell uses materials that are usually burnt to release their energy, it would make sense to compare the electrical energy produced with the heat that would be produced by burning the fuel. This is sometimes called the calorific value, though a more precise description is the change in ' enthalpy of formation'. Its symbol is h_f . As with the Gibbs free energy, the convention is that h_f is negative when energy is released. So to get a good comparison with other fuel-using technologies, the efficiency of the fuel cell is usually defined as,

$$\frac{\text{electrical energy produced per mole of fuel}}{-h_f}$$

The maximum electrical energy available is equal to the change in Gibbs free energy, so Maximum efficiency possible $= gf/hf \times 100\%$

This maximum efficiency limit is sometimes known as the 'thermodynamic efficiency'.

Table 1: gf, maximum EMF (or reversible open circuit voltage), and efficiency limit (HHV basis) for H-fuel cell

Form of Water product	Temp ºC	Δg_f Kj/mol	Max emf V	Efficiency Limit%
liquid	25	-231.2	1.211	83
liquid	80	-226.4	1.20	81
gas	100	-225.2	1.17	79
gas	200	-220.5	1.15	74
gas	400	-211.2	1.11	71
gas	600	-195.9	1.00	68
gas	800	-189.1	0.97	67
gas	1000	-180.0	0.92	60

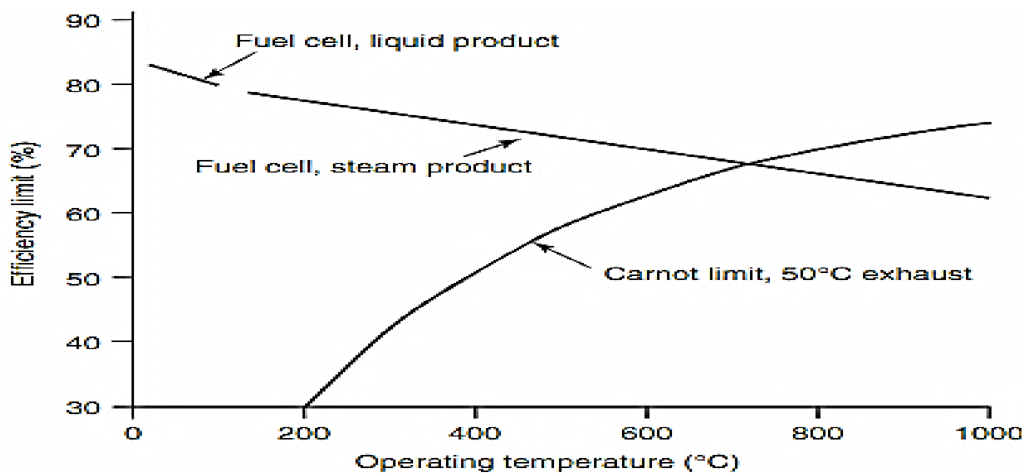

Fig.2: Maximum H_2 fuel cell efficiency at standard pressure, with reference to higher heating value. The Carnot limit is shown for comparison, with a 50◦C exhaust temperature.

4. EFFICIENCY AND THE FUEL CELL VOLTAGE

It is clear from Table 1 that there is a connection between the maximum EMF of a cell and its maximum efficiency. The operating voltage of a fuel cell can also be very easily related to its efficiency. If all the energy from the hydrogen fuel, its 'calorific value', heating value, or enthalpy of formation, were transformed into electrical energy, then the EMF would be given by

$E = -hf/2F = 1.48V$ if using the HHV
Or $= 1.25V$ if using the LHV

These are the voltages that would be obtained from a 100% efficient system, with reference to the HHV or LHV.

The actual Cell efficiency = (Vc/1.48)100% (with reference to HHV)

Some fuel usually has to pass through unreacted. A fuel utilization coefficient can be defined as

μ_f = mass of fuel reacted in cell/mass of fuel input to cell.

This is equivalent to the ratio of fuel cell current and the current that would be obtained if all the fuel were reacted. The fuel cell efficiency is therefore given by, Efficiency, $\eta = \mu_f(Vc/1.48)100\%$

5. OPERATIONAL FUEL CELL VOLTAGE

The theoretical value of the open circuit voltage(OCV) of a hydrogen fuel cell is given by the formula E=−gf/2F

This gives a value of about 1.2~2V for a cell operating below 100◦C. However, when a fuel cell is made and put to use, it is found that the voltage is less than this, often considerably less. When electrical energy is drawn from a fuel cell, cell voltage drops due to various losses. Voltage efficiency $_V$ takes into account these losses and is defined as ratio of the actual cell voltage to the theoretical voltage. $_v$=E/Erev = zFE/-G
Figure 3 below shows the performance of a typical single cell operating at about 70◦C, at normal air pressure. The key points to notice about this graph of the cell voltage against current density are as follows:

- Even the open circuit voltage is less than the theoretical value.
- There is a rapid initial fall in voltage.
- The voltage then falls less rapidly, and more linearly.
- There is sometimes a higher current density at which the voltage falls rapidly.

The performance of a fuel cell is governed by its Polarization Curve. If a fuel cell is operated at higher temperatures, the shape of the voltage/current density graph changes.

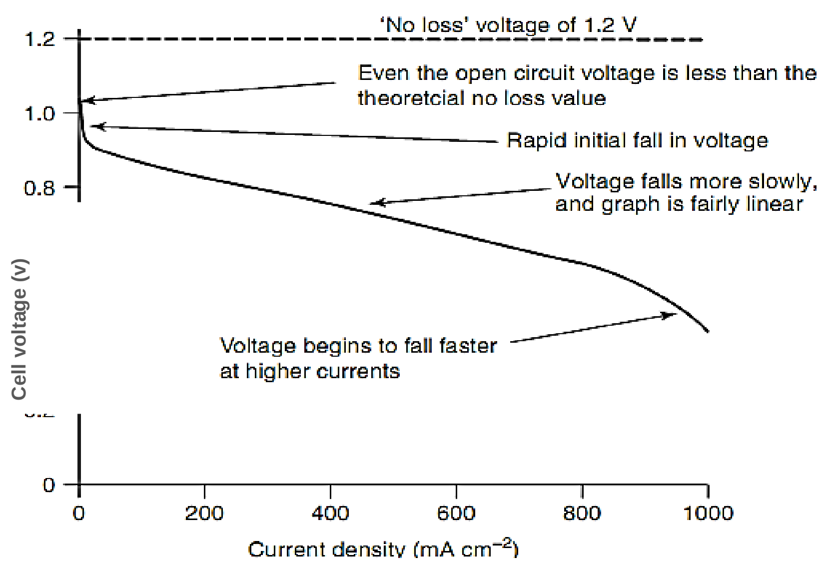

Fig.3: Graph showing the voltage for a typical low temperature, air pressure, fuel cell.

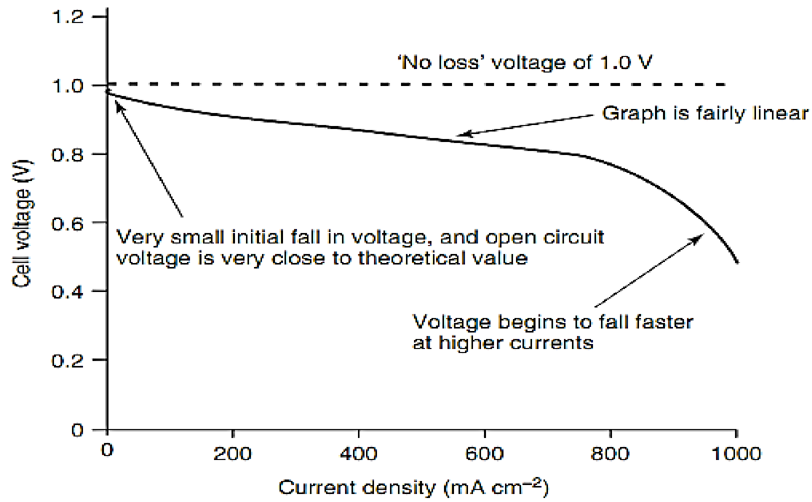

Fig.4: Graph showing the voltage of a typical air pressure fuel cell operating at about 800◦C.

6. IRREVERSIBILITY'S – CAUSES OF VOLTAGE DROP ACTIVATION LOSSES

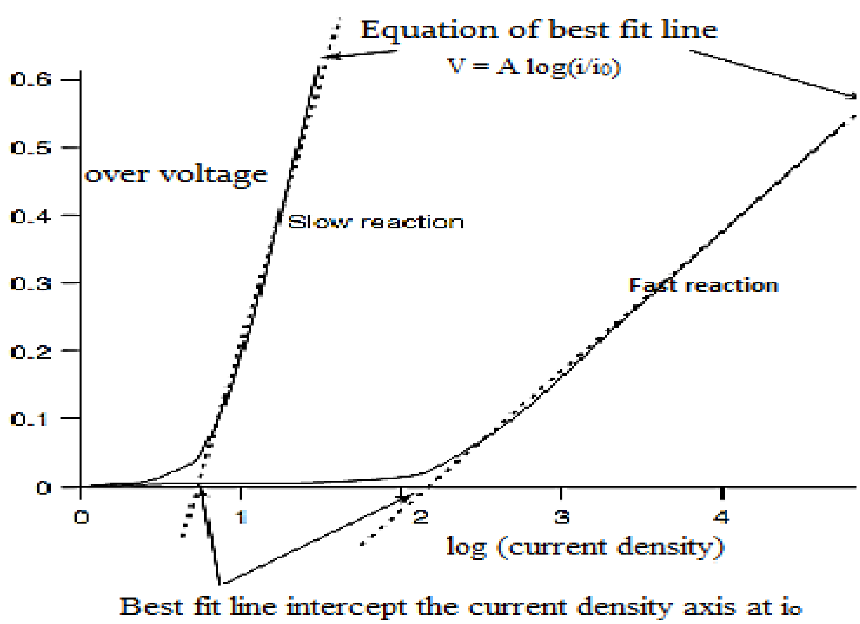

Fig.5: Tafel plots for slow and fast electrochemical reactions.

It shows that if a graph of overvoltage against log of current density is plotted, then, for most values of overvoltage, the graph approximates to a straight line. Such plots of overvoltage against log of current density are known as 'Tafel Plots'.

The diagram shows two typical plots. For most values of overvoltage its value is given by the equation, $Vact = A \log(i/i_0)$

This equation is known as the Tafel equation.

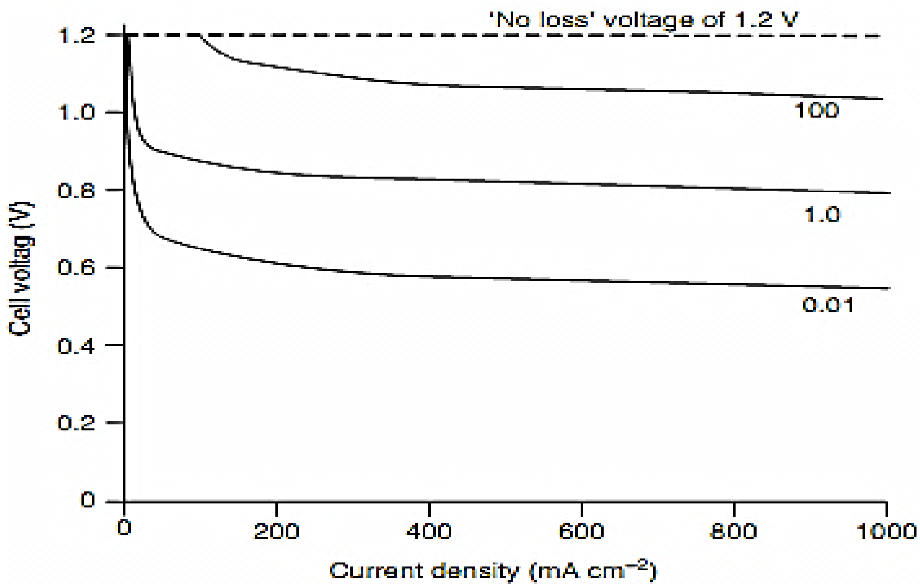

Figure 6: Graphs of cell voltage against current density, assuming losses are due only to the activation overvoltage at one electrode.

The constant i_0 is higher if the reaction is faster. The current density i_0 can be considered as the current density at which the overvoltage begins to move from zero. It is important to remember that the Tafel equation only holds true when $i>i_0$. This current density i_0 is usually called the exchange current density.

Table 2**:** i_0 for the hydrogen electrode at 25◦C, for various metals.

Metal	**i_0(Acm^{-2})**
Pt	5×10^{-4}
Ag	4×10^{-7}
Ni	6×10^{-6}
Pb	2×10^{-13}
Pd	4×10^{-3}
Zn	3×10^{-11}

7. REDUCING THE ACTIVATION OVERVOLTAGE

The exchange current density i_0 is the crucial factor in reducing the activation overvoltage. A crucial factor in improving fuel cell performance is, therefore, to increase the value of i_0, especially at the cathode. This can be done in the following ways:

- Raising the cell temperature. This fully explains the different shape of the voltage/current density graphs of low- and high-temperature fuel cells illustrated in Figures 4.5 and 4.6. For a low-temperature cell, i_0 at the cathode will be about $0.1 mAcm^{-2}$, whereas for a typical 800◦ C cell, it will be about $10 mAcm^{-2}$, a 100-fold improvement. The effect of different metals in the electrode is shown clearly by the figures in Table 2.
- Increasing the roughness of the electrodes. This increases the real surface area of each nominal 1 cm^2 , and this increases i_0.
- Increasing reactant concentration, for example, using pure O_2 instead of air. This works because the catalyst sites are more effectively occupied by reactants.
- Increasing pressure.

8. FUEL CROSSOVER AND INTERNAL CURRENTS

Although the electrolyte of a fuel cell would have been chosen for its ion conducting properties, it will always be able to support very small amounts of electron conduction. The situation is akin to minority carrier conduction in semiconductors. Here, because of the catalyst, it will react directly with the oxygen, producing no current from the cell. This small amount of wasted fuel that migrates through the electrolyte is known as fuel crossover. These effects 'fuel crossover and internal currents' are essentially equivalent. The crossing over of one hydrogen molecule from anode to cathode where it reacts, wasting two electrons, amounts to exactly the same as two electrons crossing from anode to cathode internally, rather than as an external current. Furthermore, if the major loss in the cell is the transfer of electrons at the cathode interface, which is the case in hydrogen fuel cells, then the effect of both these phenomena on the cell voltage is also the same. Users of fuel cells can readily accept that the working voltage of a cell will be less than the theoretical 'no loss' reversible voltage. With low-temperature cells, such as PEM cells, if operating on air at ambient pressure, the voltage will usually be at least 0.2V less than the ∼1.2V reversible voltage that might be expected. If fuel cell that only has losses caused by the 'activation overvoltage' on the cathode, then the voltage will be , $V = E - A.\ln(i/i_0)$
So, to sum up, the internal current and/or diffusion of hydrogen through the electrolyte of a fuel cell is not usually of great importance in terms of operating efficiency.

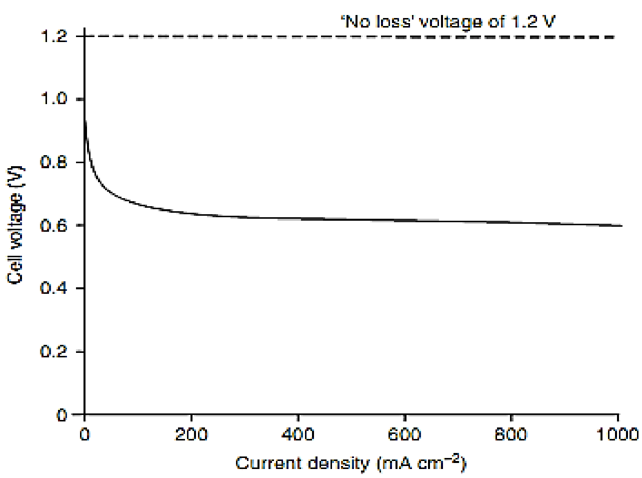

Figure 7: Graph showing the fuel cell voltage modeled using activation & fuel crossover/internal current losses only.

9. OHMIC LOSSES

The amount of the voltage drop is proportional to the current, that is, $V = IR$

In most fuel cells the resistance is mainly caused by the electrolyte, though the cell interconnects or bipolar plates can also be important.

Three ways of reducing the internal resistance of the cell are as follows:

- The use of electrodes with the highest possible conductivity.
- Good design and use of appropriate materials for the bipolar plates or cell interconnects.
- Making the electrolyte as thin as possible.

10. MASS TRANSPORT OR CONCENTRATION LOSSES

During fuel cell operation there will be a slight reduction in the concentration of the oxygen in the region of the electrode, as the oxygen is extracted. The extent of this change in concentration will depend on the current being taken from the fuel cell, and on physical factors relating to how well the air around the cathode can circulate, and how quickly the oxygen can be replenished. This change in concentration will cause a reduction in the partial pressure of the oxygen. Similarly, if the anode of a fuel cell is supplied with hydrogen, then there will be a slight drop in pressure if the hydrogen is consumed as a result of a current being drawn from the cell. This reduction in pressure will depend on the electric current from the cell (and hence H_2 consumption) and the physical characteristics of the hydrogen supply system. In both cases, the reduction in gas pressure will result in a reduction in voltage. The change in voltage caused by a change in hydrogen pressure only is

$$V = RT/2F.\ln(P_2/P_1)$$

If P_1 is the pressure when the current density is zero, and assume that the pressure falls linearly down to zero at the current density i_1, then the pressure P_2 at any current density is given by the formula, $P_2 = P_1(1 - i/i_1)$

If we substitute this into equation 2.10 (given above), we obtain, $V = RT/2F.\ln(1 - i/i_1)$

This gives us the voltage change due to the mass transport losses, $V_{trans} = -RT/2F.\ln(1 - i/i_1)$

Now the term that in this case is RT/2F will be different for different reactants. In general, we may say that the concentration or mass transport losses are given by, $V_{trans} = -B.\ln(1 - i/i_1)$
where B is a constant that depends on the fuel cell and its operating state.

Mass transport problems force to supply fuel cells with more fuel than consumed in the cell reaction. Fuel or current efficiency η_I is defined as the ratio of actual current to theoretical current, which can be calculated from Faraday's equation using the actual molar flow of fuel. $\eta_I = I/I_{theory} = I/zFn_{H2}$

Where, I = current drawn from the cell and n_{H2} = molar flow rate of hydrogen. Again, a small fraction of the fuel diffuses through the electrolyte, further decreasing fuel efficiency and generating mixed potentials, which decrease cell voltage. Fuel efficiency is closely related to the stoichiometric factor λ, which is used to describe the amount of excess fuel fed into the cell. Stoichiometric factor,

$$\lambda = zFn_{H2} / I$$

Total efficiency of a fuel cell, η_{total}, is calculated as the product of reversible, voltage and current efficiencies, i.e. $\eta_{total} = \eta_{rev}.\eta_{v}.\eta_I = EI/-\Delta HnH_2$

In the nominator of equation is the electrical power of the fuel cell and in the denominator the rate at which chemical energy is fed into the cell.

For complete fuel cell systems, System efficiency η_{system} takes into account the parasitic losses by auxiliary devices, P_{aux}, which decrease efficiency. $\eta_{system} = [EI - P_{aux}]/-\Delta HnH_2$

11. COMBINING THE IRREVERSIBILITY'S

To construct an equation is useful that brings together all these irreversibilities. It can be done so and arrive at the following equation for the operating voltage of a fuel cell at a current density i.

$V = E - Vohm - Vact - Vtrans$

$V = E - ir - A.\ \ln/(i + i_n)/i_0 + m.\exp(ni)$

In this equation, E is the reversible OCV, i_n is the internal and fuel crossover equivalent current density .A is the slope of the Tafel line . I_0 is either the exchange current density at the cathode if the cathodic overvoltage is much greater than the anodic or it is a function of both exchange current densities . m and n are the constants in the mass-transfer overvoltage equation. r is the area-specific resistance. By drawing up a table of the values of V at low values of current density, gives the following data.

Table 3: variation of voltage at lower current density

Current density($mAcm^{-2}$)	Voltage (V)
0	1.2
0.25	1.05
0.5	1.01
1.0	0.97
2.0	0.92
3.0	0.90
4.0	0.88
5.0	0.87
6.0	0.86
7.0	0.85
8.0	0.84

12. CONCLUSIONS

The concern for the efficient use of clean energy all over the world has gathered high priority and there is awareness on the advantages of electrochemical power as source of clean energy. High fuel efficiency over a wide range of loads and elimination of emissions of SO_X, NO_X, and PM, thereby avoiding local consequences of air pollution In this study optimization of voltage, maximum possible efficiency and reducing different losses through data analysis are exhibited. It is concluded that fuel cells require further R&D before this technology can complement existing powering technologies. However, in the near future we might expect to see successful fuel cell system.

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NOMENCLATURE

Symbol	**Meaning**	**Unit**
T	Temperature	(K)
P	Pressure	(Pa)
gf	Gibbs free energy	Kj/mol
hf	Enthalpy of formation	kcal
λ	Stoichiometric factor	dimensionless
E	Electromotive force	Joule
V	Cell voltage	volt
$Paux$	Parasitic losses	watt
I	Current density	amp
R	Resistance	ohm
t	Time	second
F	Faraday's constant	coulombs / mole
[illegible]	Efficiency	dimensionless

PRESENT SCENARIO AND PROSPECT OF THE POWER AND ENERGY SECTOR IN BANGLADESH

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ABSTRACT: This paper highlights the present scenario and prospects of the power and energy sector in Bangladesh. The purpose of this study is to provide a general overview of power and energy sector in Bangladesh. In Bangladesh the contribution of power sector to GDP was 1.45 percent at constant price in FY 2011-12. The total power produced in the country is not enough to ensure adequate access to electricity. Some of the major findings of this work are fuel consumption analysis for power generation, different sources of alternative energy and distribution system loss in power sector. This study also indicates the demand and supply gap of electricity and urges the necessary implementations which can reduce the gap. Also this paper shows some prospective power generation projects which will facilitate to fill up the ever increasing demand for electricity. These findings have significant implications with respect to energy conservation and socio-economic development.

Keywords: Power and Energy, Bangladesh, Energy Consumption, Energy Scenario

1. INTRODUCTION

Energy is recognized as a critical input parameter for national economic development. Power and energy are critical to the development of the country as well as to the enhancement of living standard. Bangladesh's per capita energy generation is 272 kWh which is very low compared to that of other developing countries. Sufficient amount of energy ensures sustainable operation of the energy utilities and optimum development of all the indigenous energy sources. Also it enables to meet the energy needs of different zones of the country and socio-economic groups. In this paper an overall analysis of the present status of Bangladesh energy sector is given. Proper utilization of the available resources is the only way to make up the ever increasing demand of energy in this country.

Share of Energy: Bangladesh is enriched with vast resource of energy. Two major kinds are the fossil fuels and renewable energy sources. Contribution of biomass in total primary energy consumption of Bangladesh is around 60% [1]. Primarily biomass and kerosene are used by majority of the households. Natural gas, LPG, electricity, biomass are used to meet the house hold cooking needs. Fig. 1 shows the share of energy in Bangladesh.

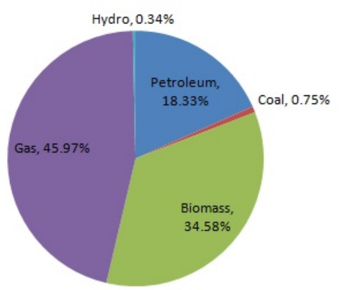


Fig. 1: Share of Energy

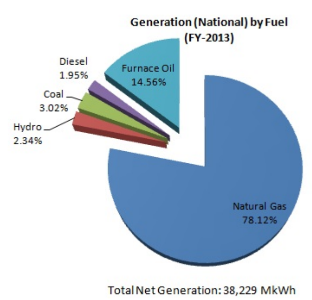


Fig. 2: Fuel Mix for Net Generation: FY-2013 [2, 3]

Fossil Fuels: Fossil fuel comprises natural gas, coal and imported petroleum products.

Natural Gas: Natural gas is currently the only indigenous non-renewable energy resources of the country. In Bangladesh, natural gas is most important indigenous source of energy that accounts for 75% of the commercial energy of the country. So far in Bangladesh 23 gas fields have been discovered of which two of the gas fields are located in offshore area. Gas is produced from 17 gas fields (79 gas wells). Oil was tested in two of the gas fields (Sylhet and Kailashtila). Year-wise/sector-wise natural gas production and consumption are shown in Table 1.

Table 1: Production and Consumption of Natural Gas by Sector

Fiscal Years	Production	Sectors								Total Sales
		Power	Fertilizers	Industry	Captive Power	Tea States	Commercial	Domestic	CNG	
2007/08	600.86	234.3	78.67	92.19	80.23	0.71	6.60	69.02	22.82	584.5
2008/09	653.75	256.3	74.85	104.4	94.7	0.65	7.46	73.78	31.02	643.1
2009/10	703.60	283.1	64.719	64.72	118.8	0.804	8.12	82.69	39.33	710.2
2010/11	708.90	273.8	121.20	62.80	121.5	0.80	8.50	87.40	38.50	714.4
2011/12	743.57	304.3	123.56	58.39	128.5	0.76	8.55	89.15	38.5	751.8

Source: Petrobangla, Energy and Mineral Resources Division [4]

Petroleum Product: Bangladesh imports annually about 1.3 million metric Tons of crude oil. In addition to this, another 2.7 million metric Tons (approx) of refined petroleum products per annum is imported. Information on imported crude from 2007-08 to 2011-12 is shown in the Table 2:

Table 2: Import of Crude Oil

Financial Yeal	Quantity (Metric Ton)	C & F Value/Million US$	Crore Taka
2007-08	10,40,084	762.08	5288.85
2008-09	8,60,877	494.44	3431.40
2009-10	11,36,567	646.21	4491.41
2010-11	14,09,302	918.81	7037.00
2011-12	10,85,937	919.26	7053.51

Source: Energy and Mineral Resource Division [4]

Coal: Coal reserves of about 3.3 billion tons comprising 5 deposits at depths of 118-1158 meters have been discovered so far in the north-western part of Bangladesh [5]. As an alternative fuel to natural gas, coal can be extensively used. Possibilities of extraction of Coal Bed Methane (CBM) need to be explored from this coal deposits. Government is actively reviewing law to be applicable for Exploration and Production of Coal Bed Methane. So far, only Barapukuria coal field is under production.

CNG: Total number of CNG converted vehicles is 150249. In addition to that 42549 CNG vehicles was imported. Total number of CNG vehicles is 192798 as of May, 2010. Average CNG usage (approx.) is 102 MMCF per day.

Liquefied Petroleum Gas (LPG): To reduce the dependency on imported oil and thus to save foreign currency, the use of LPG has to be popularized. Currently the supply of LPG of the country is 95,500 Metric Ton.

Renewable Energy: The major sources of renewable energy in Bangladesh are Solar Energy, Hydro, Power and Biogas.

Hydro Power: There are one large hydro facility in the country at kaptai, installed in the 1960s and producing 1000GWh per year.

Nuclear Energy: Steps are being taken to setup nuclear plants to meet up the emerging demand of energy in future.

Biogas: Biogas is the most promising renewable resource for Bangladesh. Presently there are 10000 of households and village-level biogas plants in place throughout the country.

Solar Photovoltaic: Solar photovoltaic are in use throughout the country with over 2,00,000 household level installations comprising around 12MW total capacity.

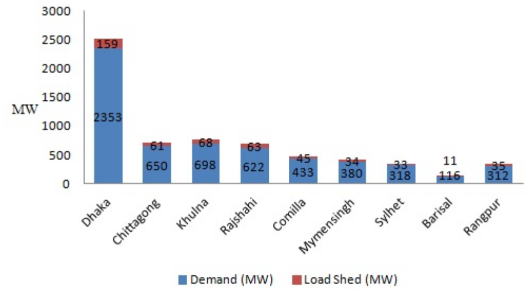
Power Sector Scenario: Planned and appropriate use of power is one of the pre-conditions for economic development of Bangladesh. During FY 2011-12, a total of 35,118 million-kilowatt hour (MkWh) net energy (14,673 MkWh in public sector and 16,682 MkWh in private sector including SPP under REB) was generated [6]. Of the total generation, the public sector power plants generated 53 percent while private sector generated 47 percent. The share of gas, hydro, coal and oil based energy generation was 79.15 percent, 2.21 percent, 2.52 percent and 16.12 percent respectively. Net energy generation by fuel type is shown in Fig. 2.

Table 3: Some Major Power Generation Projects up to 2016
Source: Power Division [7]

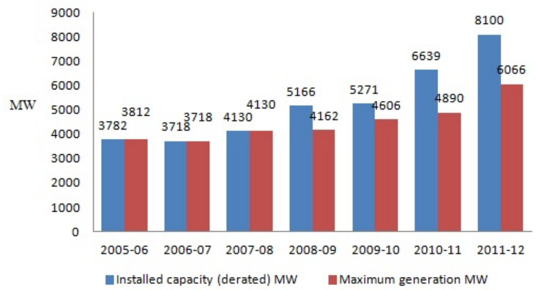
Sl. No.	Name of the Power Plant	Capacity (MW)	Owner	Expected Commissioning Date
Under Construction				
01	Raujan	25	RPCL	Oct 2012
02	Katakhali 50 MW Peaking Power Plant	50	BPDB	Nov 2012
03	Khulna 150 MW GT	150	NWPGC	May 2013
04	Haripur 360 MW CCPP GT	273	EGCB	Feb 2013
05	Meghnaghat 300-450 MW CCPP (2nd Unit) Duel Fuel: SC GT Unit	220	IPP	Oct 2013
06	Chittagong 150-300 MW Coal Fired Power Project	283	IPP	June 2015
07	Maowa Munshiganj 300-650 MW Coal Project	522	IPP	Feb 2016
Under Process				
08	Regional Power	500	IPP	Aug 2013
09	Bibiana #3 CCPP: SC GT Unit	300	BPDB	Sept 2014
10	Ghorashal, Narshingdi 100 MW PP	108	IPP	Oct 2013
11	Khulna 1300 MW Large Coal	1300	PPP/IPP	June 2016
Solar & Wind Power Projects				
12	Hatia Solar Wind Diesel Hybrid	7.5	BPDB	2013
13	Kaptai Solar	5	BPDB	Sept 2014
14	Solar	7	IPP (BPDB)	Jan 2015
15	Wind	100	IPP (BPDB)	Mar 2015

Future Prospects: Several programmes have already been taken up to implement short, medium and long term plans for the balanced development of power sector to scale up electricity generation. There is a plan to connect new power plants with the capacity of 16,000 MW from both public and private sectors during the period from 2012 to 2016. Some major power generation projects are shown in Table 3.

Demand and Supply Gap: In spite of large production capability there remains a small amount of load shed. And this load shedding is being reduced day by day. Demand and load shed in different regions of Bangladesh on date 1st October 2013 is shown in Fig. 3(a). And year-wise installed capacity and maximum generation since FY 2005-06 is given in Fig. 3(b).



(a)



(b)

Fig.3: (a) Demand and Load Shed in different Regions of Bangladesh (on 01-10-2013) [8]
(b) Installed Capacity and Maximum Power Generation [2, 3]

3. SUMMARY

The energy sector in the world is evolving remarkably. Planned and appropriate use of power can play an important role for the socio-economic development of Bangladesh. The present energy crisis can be solved by establishing LNG terminal, strengthening of BAPEX and reducing extreme dependence on natural gas. Private sector can play a key role to meet the challenge of huge amount of financing requirement. Proper use of renewable energy resources such as solar, biomass, hydro and wind power can ensure the energy security to a large scale. And continuous efficiency improvement is also a key for sustainable development. To conclude, concentrated efforts from all quarters can ensure affordable and quality power supply to the people of Bangladesh.

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IMPROVEMENT OF CONVENTIONAL ELECTRIC HEATER TO REDUCE ENERGY LOSS AND ITS PERFORMANCE TEST

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ABSTRACT: With rapid growth of population and urbanization, the energy demand is increasing day by day. Electrical energy is an important component for developing economy. Only 40% of our population has access to electricity. Due to shortage in supply, it becomes important to conserve electricity. Although there is restriction to use electric heaters, still it is being used in small scale in halls, hostels, messes etc. Conventional electric heater losses heat by radiation through bottom and by conduction through the mortar. Heating is not very effective, if the air gap between the utensils' bottom and coil plate is not optimized. A comprehensive study has been conducted to improve the conventional electric heater to reduce energy loss. Heat loss through the bottom and mortar is reduced by putting thermal insulation and a reflective coating. Three test specimens were used to carry out the test with an improved heater and a conventional heater. The results reveal that energy can be saved by 35%, 30% and 17% for boiling water, cooking rice and red lentil respectively. Also, aluminum sheet is used instead of white cement and thermal insulation to make the construction simpler and the performance test was carried out. It is found that when glass woolwith white cement is used, save in energy is around 30% whereas the same is around 28% when only aluminum sheet is used. Thus, by providing thermal insulation and reflective coating the heat losses from an electric heater can be reduced significantly.

Keywords: Electric heater, Thermal Insulation, Reflective coating, Cooking time, Energy conservation.

1. INTRODUCTION

Modern world depending upon coal, oil and natural gas for a majority of its energy needs and the prediction that the world will need nearly double its energy resources within several decades; therefore it is important to conserve energy. There are two kinds of energy sources on which we depend – renewable and nonrenewable. Renewable energy sources are those that are continuously replenished such as water, wind and solar. Non-renewable energy sources, on the other hand, like gas, coal, and oil cannot be replaced within a shorter duration [1].Therefore, consumption of these sources needs to be controlled to ensure that the limited supply we have will be available to future generations.

Like the rest of the countries of the world, the demand for energy is increasing day by day in Bangladesh. Electricity is the major source of power for most of the country's economic activities. According to PDB records, the demand of electricity varies between 5500 - 6000 MW daily but it goes up to a maximum of 6700-6800 MW during the peak summer [2].The installed capacity is 8525 MW in 2013 but the highest generation was so far 6350 MW recorded on 04-08-2012. Only 40% of the population has access to electricity grid with a per capita consumption of 136 kW-hr per annum. Overall, the country's generation plants have been unable to meet the demand over the past decade [3, 4]. Also, there are several areas like Khulna, Rajshahi, and Barisal where natural gas supply is not available. In those areas, liquefied petroleum gas (LPG) is most commonly used for cooking purposes. Besides, sometimes electric heaters are used. Although, PDB has banned the use of such electric heaters, still it is used for cooking purposes in small scale in hostels, halls, messes etc. But the people are not aware of the energy loss it causes.

The structure of a conventional electric heater is such that appreciable amount of heat is wasted during cooking. A greater portion of the bottom area of the heater is open to the atmosphere which causes heat loss by radiation. Again through the inside wall of the heater which is mainly mortar, appreciable amount of heat is lost by conduction. Moreover, the height of the heater body is not to any standard and there is air gap in between utensil's bottom and the coil plate. This causes less heat to receive by the utensil as air acts as thermal insulator which ultimately is a loss of energy. Due to these losses, the heater is needed to keep on to complete the cooking operation for a longer period and hence consumes more electrical energy. So, if this heat loss can be reduced, then electrical energy will be saved. The aim of this work is to conserve energy by means of improving the conventional electric heaters by reducing the energy loss and thus the cooking time.

It is obvious that thermal insulation can reduce heat losses in a conventional electric heater [5]. Among various thermal insulators, glass wool may be considered suitable because of its very low thermal conductivity and temperature resistance [6, 7]. Moreover, it is readily available and low cost comparing to other type of insulators. Again heat loss through the mortar can be reduced by providing a reflective coating. Considering this a light color material (say white cement) is chosen as reflective material[8].On the other hand, the reflectivity of aluminum sheet is around 84% to 98% [9, 10, 11]. Since it provides high reflectivity and use of it makes the construction easier, so it may also be chosen as alternative of white cement coating. In this work both materials were used and tested.

2. CONSTRUCTION

(i) Construction of an Insulated Electric Heater by Using Glass Wool and White Cement:

At first a box is made using MS sheet, which provides the necessary structure to hold the glass wool insulation surrounding the electric heater base. Both the bottom and surrounding of the heater is insulated by glass wool. On inside wall of the base, a mixture of white cement, chalk powder and water is brushed so that the mixture acts as a reflective coating. Figure 1 illustrates the thermal insulation and reflective coating.

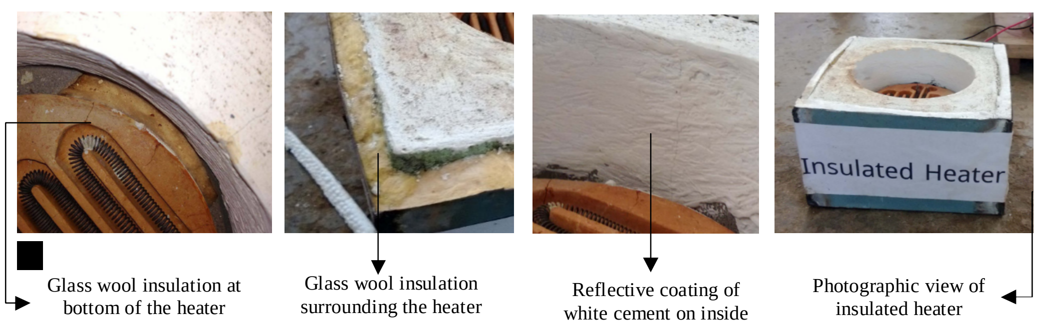

Fig.1: Detail photographic view of Insulated Electric heater using glass wool, white cement

(ii) Construction of an Improved Electric Heater using Aluminum Sheet:

A piece of aluminum sheet is bend and is placed inside the wall of an electric heater to form the coating as shown in Figure 2. Again the open bottom area of the heater is covered by another piece of aluminum sheet as shown in figure. Using aluminum sheet instead of glass wool and white cement helps reducing the complexity of the previous construction.

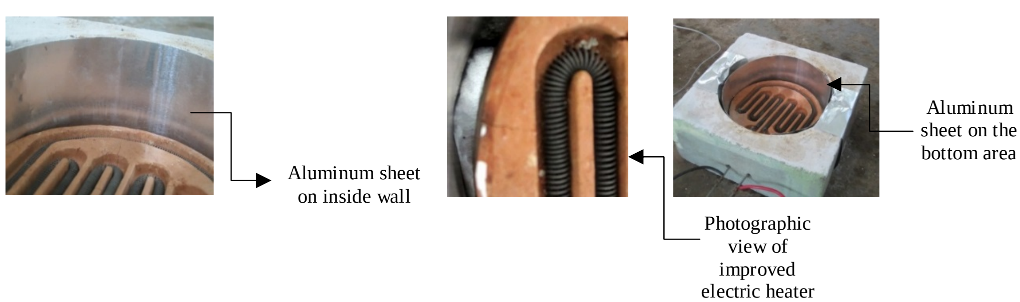

Fig.2: Photographic view of an Improved electric heater using aluminum sheet and coated areas

3. EXPERIMENTAL SETUP

(i) Experimental Setup for Temperature Profile along Radial and Vertical Direction:

To obtain the optimum height between the coil surface and the utensil, temperature profile for both insulated and bare electric heaters are determined along radial and vertical direction from coil plate surface to a height of 4.5 cm. For this, three thermocouples and three temperature recorders are used. A wooden frame is constructed and used to hold the thermocouples along the radial direction and to move the thermocouples vertically easily at different heights. Along radial direction at 0 cm (centre of the coil plate), 5.75 cm and 11.5 cm, three thermocouples are placed to record the temperature. Again along vertical direction, temperature is determined at six heights from coil plate to the utensils bottom surface. These set-ups are shown in Figure 3 and Figure 4.

Fig.3: Experimental setup for temperature profile of insulated heater along radial and vertical direction

Fig.4: Experimental setup for temperature profile of bare heater along radial and vertical direction

(ii) Experimental Setup for Performance Tests:

Three different specimens - Water, Minicate Rice and Red Lentil were used for performance tests for both insulated heater and bare heater. In these tests, cooking time, initial water temperature, final water temperature and energy consumption were measured for both the heaters with the help of stopwatch, thermocouple, temperature recorder and energy meter (as shown in Figure 5). Hence, the percent energy save is achieved. The variation in percent energy save with amount of cooking and hence maximum percentage of energy save is also determined.


Fig.5: Experimental setup for performance tests using glass wool insulation and white cement


Fig.6: Experimental setup for performance tests using coating of aluminum sheet

(iii) Experimental Setup for Performance Tests using Aluminum Sheet:

Instead of glass wool and white cement only reflective coating of aluminum sheet is used afterwards. Then the variation in percent energy save with amount of cooking and hence maximum percentage of energy save is determined. After that, the comparison between the improved insulated electric heater using glass wool and white cement and the improved heater using only aluminum sheet has been brought into picture. This set-up is represented in Figure 6.

4. RESULTS

(i) Result for Optimum Height Condition:

The temperature profiles along radial direction at three different points are shown in Figure 7for both the bare and insulated electric heaters. The three points were at 0 cm (centre of plate), 5.75 cm and 11.5 cm along the radial direction. It is evident from the figure that the temperature at various points inside an insulated heater is more than that of the bare heater at the same point. This is because heat loss was recovered by providing thermal insulation. Figure 7 also represents that temperature at the mid-point is always higher than that at the sides. This might be because of coil density is moreat the middle. Figure 8 shows the temperature distribution along the height from the coil plate to the utensils' bottom. At points closer to the coil plate, the temperature is significantly more than that at distances points . This is due to the air gap. As thermal conductivity of atmospheric air is low as 0.024 W/m.K, it acts as an insulator in between utensils and coil plate. Observing these temperature profiles, it can be concluded that, if an electric heater is insulated and coated then heat energy and electrical energy can be saved. Also, if the distance between utensils' bottom surface and coil plate is reduced, then the utensils will receive more heat because the air gap will be minimized appreciably.So, cooking time will be less and energy will be saved. But care should be taken so that the utensils' bottom mustnot touch the coil surface to avoid accident.

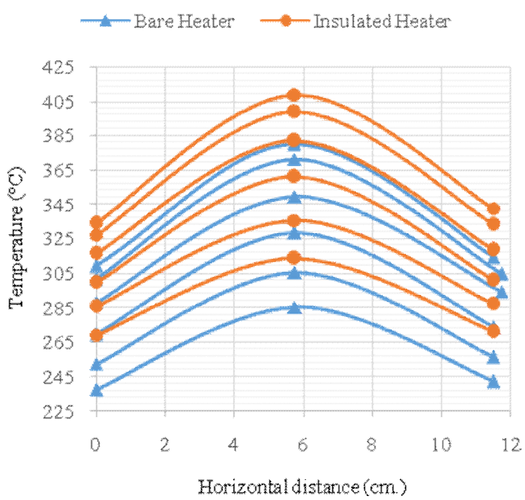

Fig.7: Temperature Profile along Radial Direction for both Bare and Insulated Heater

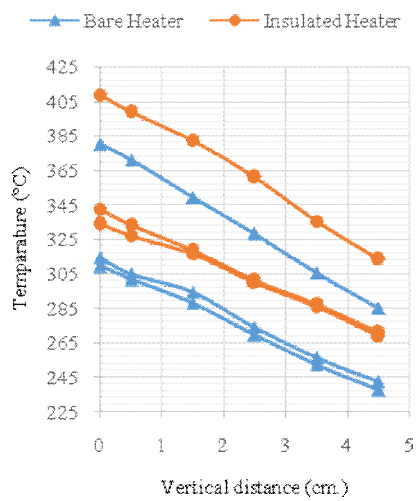

Fig.8: Temperature Profile along Vertical Height for both Bare and Insulated Heater

(ii) Result for Performance Tests of Insulated Electric Heater:

With the three test specimens - Water, Minicate Rice and Red Lentil the performance tests were carried with bare and insulated heaters as described earlier for several days. In each case, the percentage energy save was calculated from the observed information during each cooking. In case of water, it was observed that the insulated heater performs better compared to the bare heater for raising the temperature of water to its boiling point. For each observation, 800 ml water was used as sample. By determining the energy consumption by both heaters, the percent energy save was calculated.

The insulated heater reduced heat losses, saved cooking time and for this appreciable amount of energy was saved. Hence, from Table 1, it is observed that maximum energy save is 43.9% while the minimum save is 15%. From Table 1, it can be concluded that around 35% energy is saved in boiling 800 ml water. Similarly, performance tests were also conducted for cooking 60 gm Minicate rice along with 500 ml water. From Table 2, it is seen that maximum save is 32% and minimum save is 25% by using glass wool insulation with white cement coating. It can be concluded that around 27% to 30% energy was saved in cooking 60 gm Minicate rice along with 500 ml water.

Again for cooking 50 gmred lentil along with 375 ml water, from Table 3, it is seen that maximum energy save was 23.08% and minimum was 16%. It can be concluded that around 17% energy was saved by the insulated heater in this case.

Table 1: Results for energy save (%) by Insulated heater in boiling 800 ml water

Obs. No.	Energy consumed with Insulated heater (kWhr)	Energy consumed with Bare heater (kWhr)	Energy Save %
14.07.2013 (Sunday)			
1.	0.23	0.33	30.30
2.	0.24	0.29	17.24
3.	0.23	0.35	34.30
15.07.2013 (Monday)			
1.	0.23	0.41	43.90
2.	0.24	0.38	36.84
3.	0.26	0.41	36.59
16.07.2013 (Tuesday)			
1.	0.25	0.39	35.89
2.	0.25	0.37	32.43
3.	0.23	0.27	15.00

Table 2: Results for energy save (%) by Insulated heater in cooking 60 gm rice along with 500 ml water

Obs. No.	Energy consumed with Insulated heater(kWhr)	Energy consumed with Bare heater (kWhr)	Energy save %
18.08.2013 (Sunday)			
1.	0.31	0.45	31.11
2.	0.32	0.47	32.00
3.	0.31	0.44	29.55
19.08.2013 (Monday)			
1.	0.33	0.44	25.00
2.	0.32	0.43	25.58
3.	0.32	0.44	27.27
20.08.2013 (Tuesday)			
1.	0.30	0.43	30.23
2.	0.33	0.45	26.70
3.	0.32	0.45	28.90

Table 3: Results for Energy save (%) by Insulated Heater in Cooking 50 gm Red Lentil along with 375 ml Water

Obs. No.	Energy consumed with Insulated heater(kWhr)	Energy Consumed with Bare Heater(kWhr)	Energy Save %
18.08.2013 (Sunday)			
1.	0.21	0.25	16.00
2.	0.18	0.23	21.74
3.	0.20	0.26	23.08
19.08.2013 (Monday)			
1.	0.22	0.27	18.52
2.	0.20	0.24	16.67
3.	0.21	0.25	16.00
20.08.2013 (Tuesday)			
1.	0.21	0.25	16.00

2.	0.20	0.24	16.67
3.	0.23	0.28	17.86

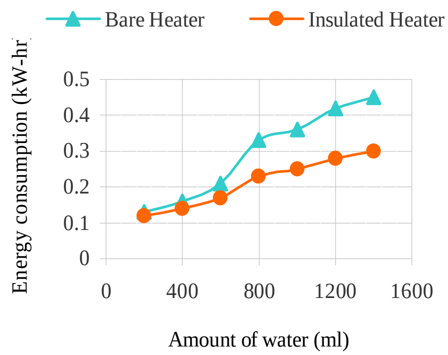

Fig.9: Energy consumption (kW-hr) with varying amount of boiling water (ml)

(iii) Variation in Energy Save (%) with Cooking-time in case of Insulated Electric Heater:

It has been seen that with the change in amount of cooking i.e. cooking time, the percentage in energy save also changes. In Figure 9, these results are shown graphically. It is evident from the figure, that when amount of water is less, the difference in energy consumption with bare and insulated heater is less. With the increase in amount of cooking i.e. amount of water (ml), this difference increases. As a result, when the amount of cooking is less, save in energy (%) is also less; when the amount increases, percent energy save also increases. This is due to the fact that when cooking amount is less, then less cooking time is needed. As a result, heat entrapment inside the insulated electric heater is less for small period and hence save in energy (%) is not so significant. But when amount of cooking increases, the time period also increases. As a result, heat entrapment occurs inside the heater for longer time and hence significant portion of energy is saved.

(iv) Variation in Energy Save (%) with Cooking-time in case of Coating of Aluminium Sheet:

As aluminum sheet is appreciably reflective, this was chosen and applied instead of thermal insulation and white cement coating. This reduced the complexity of construction. With various amount of cooking, the variation in energy save (%) in this case was also observed which is illustrated in Figure 10.It shows the energy consumption with both heaters at various amount of boiling water (ml).

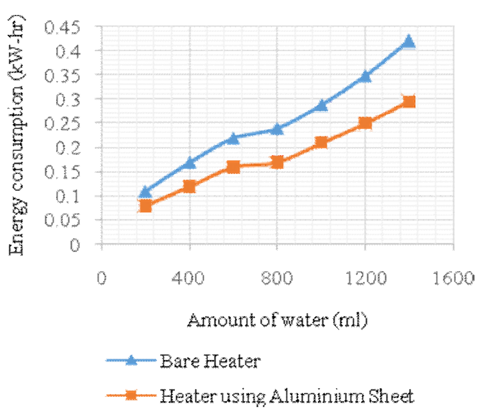

Fig.10: Energy consumption with varying amount of boiling water (ml) when aluminum sheet is used

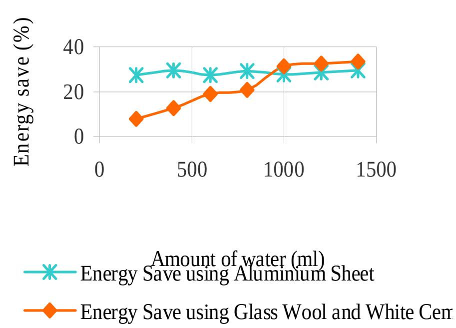

Fig.11: Comparison in Energy save(%) between aluminum sheet coating and glass wool insulation with white cement coating

Figure 10 reveals that whenaluminum sheet is used as reflective surface on both bottom and inside wall of an electric heater, then the difference between energy consumption with the improved heater and bare heater almost remains same though the amount of cooing material. As a result percent energy save remains almost same in all cases.

(v) Comparison of Energy Save withAluminum Sheet vs Thermal Insulation with White Cement Coating:

Figure 11 illustrates that when heat lost was recovered by using thermal insulation of glass wool with white cementcoating, save in energy (%) varied from 7.69% to 33.33% for various amount of cooking i.e. amount of boiling water (ml). But when only aluminum sheet was used, save in energy varied from 27.27% to 29.52% for same amounts of cooking. So, the application of aluminum sheet provides more stable output than application of glass wool with white cement. Moreover, it makes the construction simpler than before.

5. CONCLUSION

Energy conservation has become a crying need now a days. As our countryis densely populated, the sources of energy are getting limited day by day, it is ought to focus on energy conservation for prosperous future and future generations. For this reason, we should always think of such alternatives which will provide us the same output or almost similar output but consume less energy. It has been seen through this projectthat heat losses as well as energy losses in an electric heater can be reduced significantly providing similar output with less energy. Around 30% save in energy is possible if thermal insulation of glass wool with reflective coating of white cement is used whereas around 28% save is possible if reflective coating of simply aluminum sheet is used. So, anyone can use either one of this to reduce energy loss in a heater. It should be kept in mind that if around 30% energy loss could be recovered every day in each kitchen in those areas where electric heaters are used for cooking purpose then life will change drastically. The government should take initiatives to produce improved electric heaters reducing the height from coil plate and applying reflective coating.

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THERMAL PERFORMANCE OF FLAT PLATE SOLAR WATER HEATER COLLECTOR WITH MODIFIED CIRCULATING PIPE ABSORBER

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ABSTRACT: An investigation is reported of the thermal performance of a flat plate solar water heater with a circulating absorber pipe surface. The thermal performance of the two-side parallel serpentine flow solar water heater depends significantly on the heat transfer rate between the absorber surface and the water, and on the amount of solar radiation incident on the absorber surface. The modified pipe arrangement has a higher characteristic length for convective heat transfer from the absorber to the water, in addition to having more surface area exposed to solar radiation. It means during the operation of water heater, more solar energy is converted into useful heat. However, this modification has reduced the efficiency of the system marginally.

Keywords: Solar water heater, Thermal performance, Solar radiation, Modified pipe arrangement, Conversion heat transfer

1. INTRODUCTION

The solar water heater is a well-developed technology for water heating in many countries, including Malaysia. Numerous solar water heater designs are available in the market, reflecting the needs of different locations and applications [1]. Some designs are simple and others complicated. These systems are expensive and have pay back periods of up to 5 years. Natural convection or thermosyphon solar water heaters are popular in many developing countries due to their simple designs and grid power in dependence [2].

Another version of a solar water heater, the integrated solar water heater or BIS, has been proposed and tested by several researchers [1, 3-6]. The simple design of this type solar water heater has a good potential for numerous developing countries. The integrated solar water heater provides a simple and economic application of water heating via solar energy. This collector/storage system is integrated, as the collection of solar energy and storage of hot water occurs in a single unit. The long term performance of a built-in-storage solar water heater was studied by Garg [7].

The thermal storage ability of the solar water heater is important, as it dictates to a large extent the duration of time the collected thermal energy can be retained and consequently the applicability of the device. Thermal energy storage has been examined in great detail by Dincer and Rosen [8].

In the present study, a modification to the pipe shape of the absorber surface is suggested and analyzed. A parallel serpentine instead of flat plane absorber surface is considered. The modified surface has a higher characteristic length, which affects the convective heat transfer coefficient from the absorber surface to water, in addition to having more surface area exposed to solar radiation. The performance of the modified 2-side parallel serpentine system is compared with the non-modified version, in terms of design and operational parameters. It is observed that the proposed solar water heater converts more solar energy into useful heat than the BIS system [9].

2. DESIGN DETAILS

In present study, the shape of (2-side parallel) flat plate glazes solar water heater and the area of the absorber surface is calculated for different parameters of serpentine (Fig.1). The volume of water in the tank is fixed at 180 liters. All the surfaces of the storage tank are made of black color 3 cm thick plastic sheet. There are a 3.81 cm air gaps between each pipe and a 7.62 cm gaps between the collector and the body. The glaze thickness is 5 mm. The system performance has been evaluated based on two different configurations and compared efficiency with previous flat plat solar water heater system: such as, direct flow, oscillatory flow, spiral flow, serpentine flow, parallel-serpentine flow, web flow, modified serpentine-Parallel, prototype of v-trough [10, 11]. Fig. 1 shows side A and B of the collector absorber and it can be observed that the two sides are not attached together.

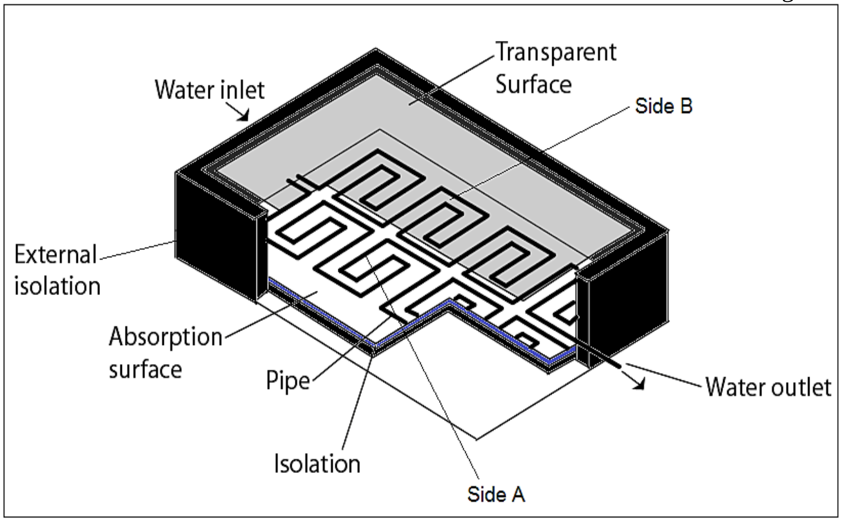

Fig.1: Cross-sectional schematic of a flat plat solar water heater with 2-side serpentine pipe absorber surface.

The practicality of the design is that faults appearing on one side can be easily fixed. The inside air gap is important as when the sunlight hits the glass plate, the indoor air is heated like the inside of a greenhouse. Nevertheless, water flowing inside the copper pipe takes time to reach the outlet and during this time. The water flowing inside the absorber tubes is heated as a result of which hot water from the collector outlet is obtained. The absorber surface absorbs most part of incident radiation. The angle of inclination of the absorber surface is taken to be equal to the latitude of the location to maximize the amount of incident solar radiation. This angle also impacts natural convection heat transfer. The system is south facing.

3. ANALYSIS

The authors developed a transient model to analyze the thermal performance of the solar water heater with a parallel serpentine absorber surface. The input climatic variables are hourly values of solar radiation and ambient temperature for a typical day of Kuala Lumpur. The hourly values of solar radiation and wind speed data collected by using the RETScreen and Pyranometer and from various correlations in Hottel-Whillier-Bliss [12-14]. Energy balance equations for a flat plat modified design are developed for the absorbing surface and the water [15]. We invoke several assumptions in the analysis:

1) As the distance between the collector glass plat and the absorber pipe is 4cm, it is considered the same as a plane surface for determining the incident solar radiation into useful energy gain, thermal losses and optical losses.
2) All thermo-physical properties were considered the same as a constant within the operating temperature range of the water heater.
3) There are no lateral gradients in the temperature of the absorber surface and water in the storage tank.
4) All the components of the water heater at the beginning of the heating cycle (morning) are taken to be at ambient temperature.
5) The inlet water temperature during constant flow withdrawal is considered same as the constant ambient temperature.

The efficiency parameters were based on the Hottel-Whillier equation [14].

$$Q_a = (\alpha \times \tau) \times E = A_0 \times E \quad (1)$$

The thermal energy loss from the collector to the surroundings can be represented as the product of a heat transfer coefficient Q_a times the difference between the mean absorber plate temperature Tm and the ambient temperature T_{a1}. A_0 is the gross area of the collector (total area occupied by a collector). The first term is the absorbed solar energy and the second term represents the heat loss from the collector. The solar radiation E absorbed by a collector per unit area of absorber q_t can be calculated using the optical properties of covers and a plate.

$$q_t = k \times (T_m - T_{a1}) \tag{2}$$

An energy balance can be expressed for the absorber surface as follows:

$$Q_u = A_0 \times E - k \times (T_m - T_{a1}) \tag{3}$$

The useful energy gain (Q_u) from the collector is defined as the difference between the absorbed solar radiation and the thermal loss or the useful energy output of a collector.

$$\eta = \frac{Q_u}{E} \tag{4}$$

On the other hand, the heat absorbed by Q is equal to the $\dot{m}$ (mass flow) multiplied by c. The temperature gradient between the thermal factor temperature at the collector exit and the point of entry (T_e-T_i) shown in Fig 2. Since the heat absorbed by the thermal factor equals the solar collector's use heat the equation can be rewritten as follows:

$$\dot{m} = \frac{Q_u}{c \times \Delta T} \tag{5}$$

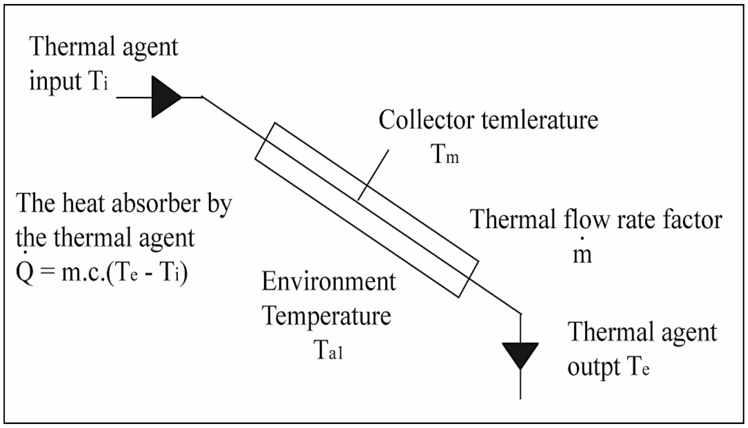

Fig. 2. Schematic diagram of the various absorber parts.

Small temperature differences between the entry and the exit temperatures of the collector imply a high flow-rate factor in the collector. A low flow-rate factor causes a high difference in temperature between the collector entry and exit points as showed in Fig 2.

This experiment used water as the fluid medium and the circulation pipe is made of copper. Hence, from the material transmittance chart the ordinary glass transmittance (□) is 0.80, and from the absorption surface charts, the short waves radiation (α) is 0.35; global losses factor (k) is 3 W/m^2 and the thermal capacity of water is (c) 4185.5 J/kg/degree Celsius. This experimental setup is developed on the roof of the Engineering Tower on the 4th floor of Block L, University of Malaya, Malaysia which is geographically located at latitude 3.11° North and longitude 101.65° East [12]. The collector slop is determined by Cooper's equation [16]. The slope of the collector, (β) angle of inclination δ and day of year (n_1) is calculated from the equation:

$$\delta = 23.45 \sin[0.9863(284 + \mathrm{n}_1)] \tag{6}$$

$$\beta = (Q_1 - \delta) \tag{7}$$

In the complete modified design of the solar water heater collector, the average slope is setup with a 22° angle on the roof surface. This is the average value of 2 months with the slope of the collector. From the Pyranometer, two months (June to July, 2012) daily analysis the solar radiation and the daily analysis on the temperature is shows in Fig 3.

Analysis on the temperature from the collector water inlet and main absorber plat by using heat sensor, K-type thermocouple and data logger is shows in Fig 4. Survey the Malaysian market and calculated the total cost of constructing a 2-side parallel serpentine flow solar water heater system is RM 1726.6 (U$549.87). Economic and maintenance analysis, of this experiment via one standard method, i.e., the Annual-worth method [17].

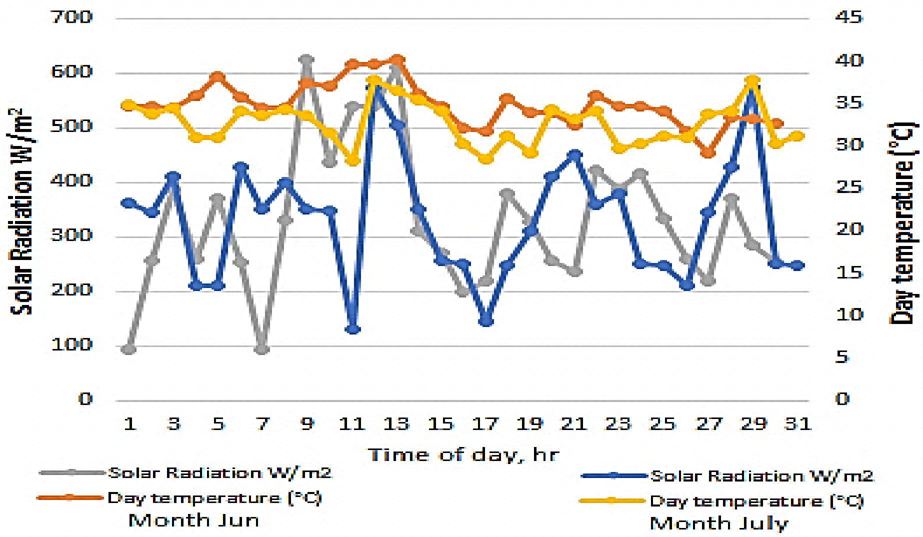

Fig. 3. Solar radiation and daily temperature from June to July.

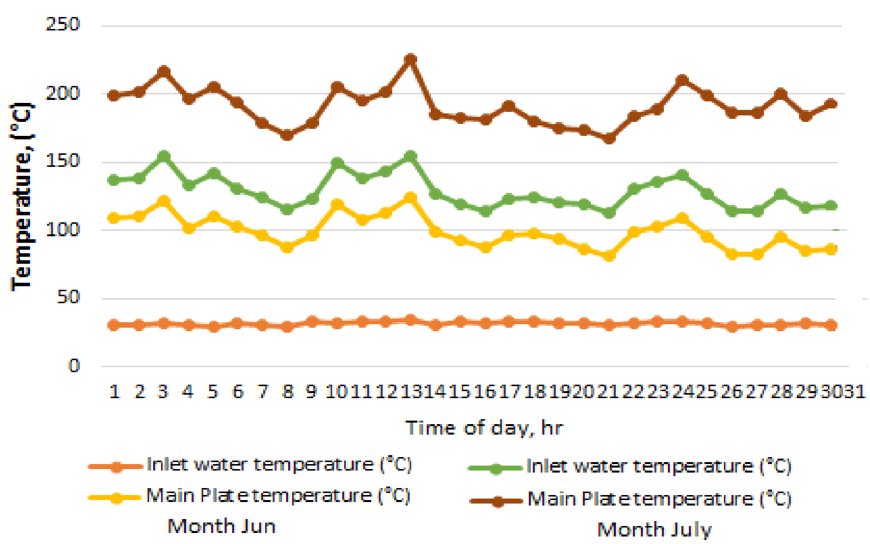

Fig. 4. Water temperature inlet and the main plate of the absorber.

4. RESULTS AND DISCUSSIONS

Calculations for a typical day are made under the climatic conditions of Kuala Lumpur. The month thought are June and July in order to permit examination of the period when the maximum heat is obtained from the solar water heater. The variations of solar radiation and ambient temperature for local conditions are plotted in Fig. 3.

The thickness of copper pipe is 1mm and the diameter is 22.86mm. The absorber pipe air gap is around 3.81cm. The copper pipe distance from both side lengths of the polystone sheet is around 10.62cm, while the width of the inlet side to pipe is approximately 12.70cm and to the outlet side is 10.16cm. The collector has one inlet and one outlet channel joined together with a solid pipe. The flow of water can be about 30,000 millilitres (30 litres) per hour. If the absolute pump running period is around 6 hours, the flow of water is then approximately 180 litres (47gallons). The water pump is capable of supplying 7.9 gallons of water per running hour.

Fig. 4 is the temperature of the collector inlet water and the absorber plate. The water inlet temperature is normal weather temperature around 28°C to 35°C and the main absorber temperature can rise up to 117°C. This heat can be absorbed to the copper pipe and increased the outlet water temperature. Figs. 5 and 6 show the temperature difference of the water inlet and outlet. It is found that the average value of the inlet and the outlet water temperature difference is around 16°C. However, the temperature difference between the outlet water and the main plate is around 18°C even though, the main plate temperature is approximately double that of the outlet water temperature. The modified design of the absorber flat plate collector should achieve a temperature of 117°C on the main plate and the temperature at the outflow water is 94°C which is almost a boiling temperature. The inlet water temperature is sometimes increased from 37°C to 40°C because there is some detached air temperature inside the pipe.

In Fig. 7 the efficient calculation of modified flat plat collector from June and July. Solar thermal collector efficiency at the inlet and the outlet water temperature depends on the solar radiation. The average efficiency is 75.50%. It is observed that the collector maximum efficiency occurred for 1 hour from 1pm to 2pm.

In Fig 8. Shows efficiency improvement on the modified design of the flat plate solar water heater collectors as compared to the previous design of the solar water heater. The modified design can achieve 75% efficiency. However, the direct, oscillatory, serpentine and web flow design of the SWH has a very low efficiency. On the other hand, the modified design of the spiral, parallel-serpentine and prototype V-trough flow, the SWH thermal efficiency is close to 5%.

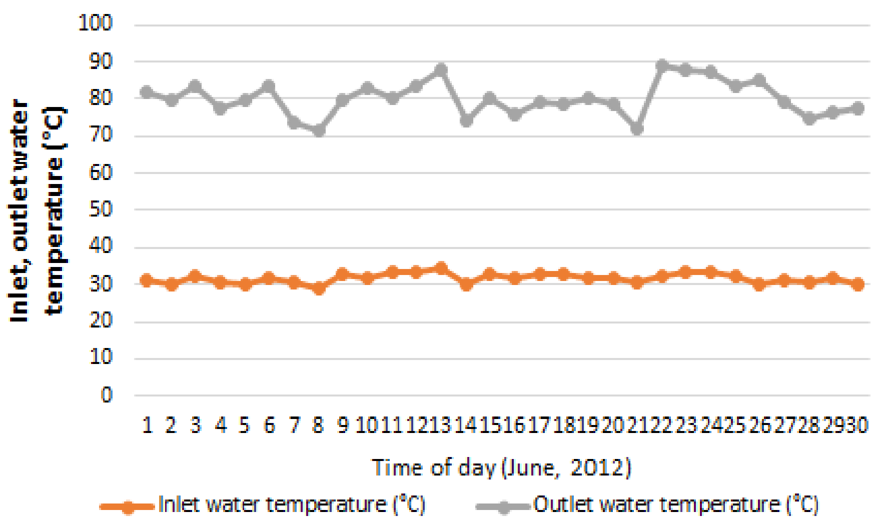

Fig. 5. The temperature of the water inlet and outlet on June.

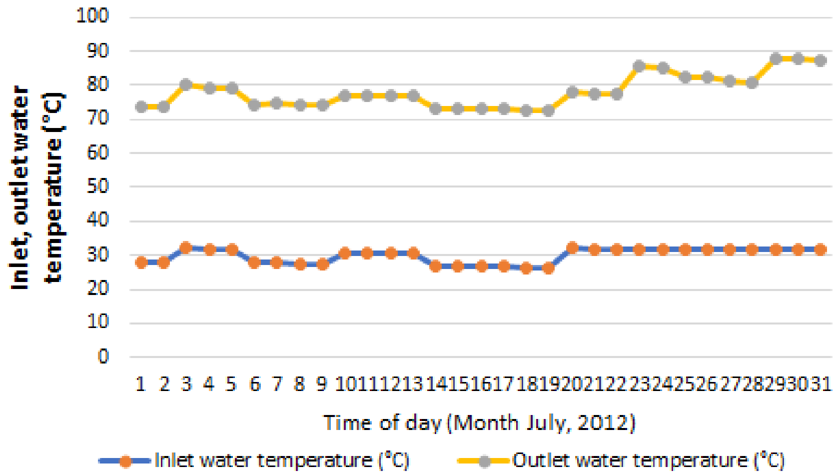

Fig. 6. The temperature of the water inlet and outlet in July.

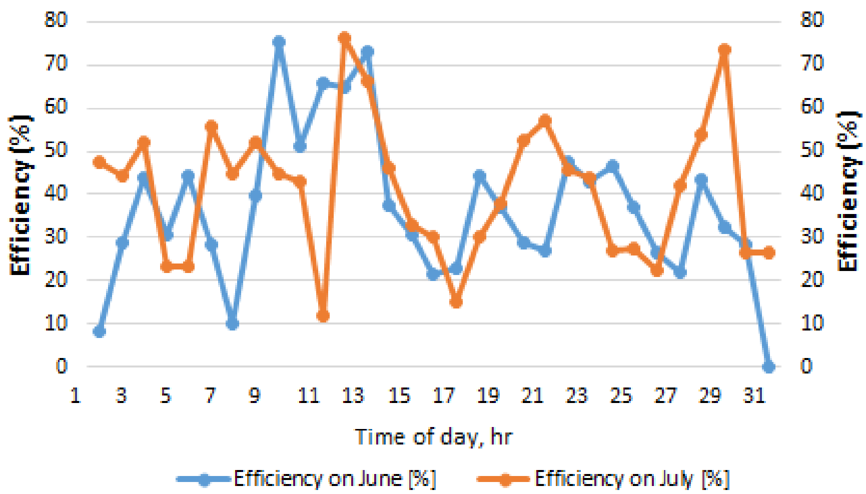

Fig. 7. The efficiency of the modified flat plat collector.

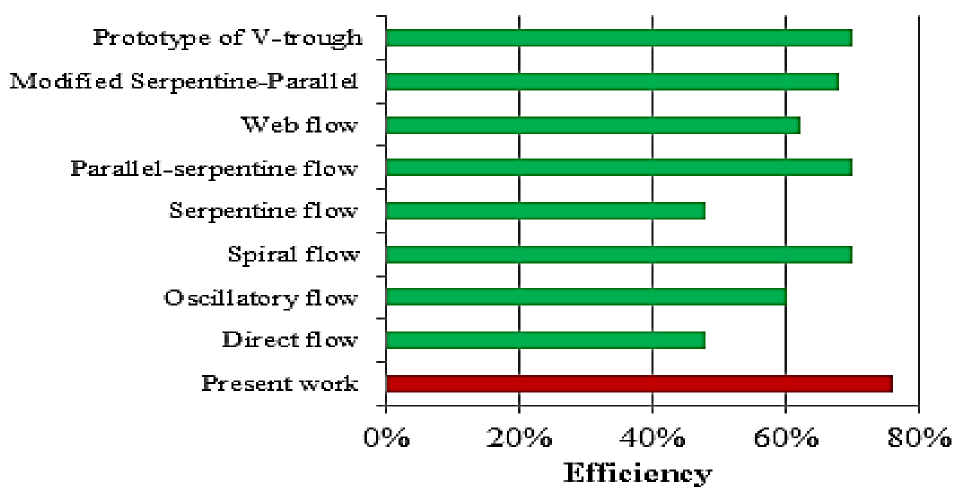

Fig. 8. Comparison of efficiency between the modified solar thermal collectors and the previous SHW solar thermal collectors.

Heat losses calculated from June to July. The bottom heat losses for the polystone sheet were the same, i.e., 3W/m2K, but the top heat losses were a little bit more, i.e., around 5W/m^2K. The bottom heat losses depended on the ‘emissivity’ of the materials which was why the resultant value was the same while the top heat losses were mainly based on the mean ambient temperatures of the collector. It is observed that the total daily heat losses were around 8W/m^2K from June to July of 2012. The results of calculations on cost analysis. The solar water heater system is more economical and becomes more attractive than the electrical water heater in the long run. It is advantageous for the family to use the solar water heater after a usage period of at least 5 years.

5. CONCLUSION

The 2-side parallel serpentine solar water heater with the modified design of absorber has proposed improving the thermal efficiency of the inclusive system. The new proposal advantages are that easy to be fabricated, less cost and superior thermal efficiency. The experiment data has shown that this flat plate collector has achieved the average efficiency for two months of 75.50% and the temperature of 98°C. This study has proven that the experimental work performed can be possibly improve the thermal efficiency of the solar water heat collector. Especially; in Malaysia where sunshine is plentifully available in most part of the country for harnessing of renewable solar energy.

ACKNOWLEDGMENT

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NOMENCLATURE

A_0	collector area (m^2)
c	thermal capacity (J/kg °C)
E	radiation intensity
k	global losses factor (W/m^2 °C)
Q_a	heat derived from the absorption surface (W/m^2)
Q_u	useful energy gain (W)
SWH	solar water heater
T	temperature
T_{a1}	average temperature of the environment (°C)
T_m	average temperature of the absorption surface (°C)
	mass flow (kg/m^2)
Greek symbols	
α	absorption factor
β	collector slope (degree)
Δ	gradient
δ	inclination angle (degree)
τ	transmission factor
η	efficiency
Subscripts	
e	output
*electrica*l	
i	input

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PERFORMANCE STUDY OF SOLAR PV CELL IN BANGLADESH CONTEXT

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ABSTRACT*:* In Bangladesh huge amounts of solar energy are being wasted which have the ability to meet the demand of existing power crisis in Bangladesh. Among different solar technology Solar PV cells are being used in a wide extent. The performance analysis of this Solar PV cell in the condition of Bangladesh has been focused in this paper along with environmental and economic analysis. It has been found that this technology has a promising future in Bangladesh from different perspective.

***Keywords**:* Solar PV cell, Bangladesh, Performance study, Month wise study, Solar energy

1. INTRODUCTION

Bangladesh is a developing country of 1,47,570 square km and a huge population.[1] This huge amount of people produces an extensive power demand for their daily. But the reality is the government cannot meet this increasing demand of energy. At present limited fossil fuels and biomass sources are used for energy requirement in Bangladesh so, for an alternative energy source Solar PV is a very good option. Although solar energy is exhausted and pollution free, it has too many advantages. First, it comes in a very dilute form and secondly the intensity of solar radiation varies depending upon the time of the day, season of the year and condition of the sky.[2] It has been seen that, there have been many solar products used in Bangladesh like ESL-SL-301,ESL-1061 and HSL 309.[3]Among RRE solar products there are solar water heater, solar emergency lanterns, Yard lighting etc. Now-a-days- as we know, global warming due to greenhouse gas emission and energy scarcity worldwide are promoting almost all the country in the world to look for alternative sources of energy like nuclear energy, solar energy which do not emit carbon.[4]Now developed countries can go through the nuclear energy but Bangladesh cannot have this option and so the best option for Bangladesh is solar energy. The average bright sunshine duration in Bangladesh is 7.6 hours in a day and for monsoon it is about 4.7 hours.SO, in this paper mainly efficiency of solar cell with respect to time, places and seasons will be discussed here Again the life cycle cost of a solar panel will also be discussed here

The purpose of this paper is to analysis the performance of Solar PV in Bangladesh on the basis of payback period analysis and it can be proved that Solar PV is now a mandatory energy source for developing country like Bangladesh. Here the technological limitations will be shown and besides this, the importance of getting rid of the limitations will also be discussed in this paper.

2. SOLAR PV CELL: BANGLADESH SCENARIO

There has been ample scope for solar PV technology in Bangladesh. As Bangladesh is a highly populated country, there has been high shortage of energy in this country. And the combination of abundant sunshine and this shortage of energy have created Bangladesh an ideal place for establishing solar PV technology.
In 2002, about 7000 Bangladeshi households were using solar panels in their houses. In 2010, more than 1.4 million rural households get access to electricity supplied by solar panel.[1] About half of Bangladesh's 160 million people still don't have access to reliable electricity, but with the low prices for solar PV panels, among other factors, installations under the Bank-supported project have

doubled in the past two years to 40,000 a month. In the remote areas of Bangladesh the national grid power are still not available thus only solution for the power crisis is solar panel for this region.

The IDCOL (Infrastructure Development Company Limited) is working on the mission of ensuring basic electricity in the rural areas of Bangladesh. Achieving 100 percent electrification is difficult because Bangladesh is a country crisscrossed by hundreds of rivers. According to the Rural Electrification Board (REB) estimates, it will require a total cost of US$ 13 billion dollar for extending grid to the marginal service area. Because of the high cost for extending grid to the marginal areas, the idea of growth of off grid solar electricity will offer a less expensive way of ensuring electricity all over the country. So for refinancing, IDCOL offers grids to lower cost off grid to Solar home system(SHS) and build institutional capacity of the partner's organization(PO's).The names of 16 PO's:Grameen Shakti,Brac Foundation,Coast Trust,TMSS,SRIZONY Bangladesh,CMES,IDF,Shubashati,UBOMUS,DORP,BRIDGE,PMUK,RSF,PDBF,Mukti,Hilful Fizul have agreed with Participation Agreement(PA) with the solar program in our country.Operational flow diagram of IDCOL's solar home project is described by the figure 1.

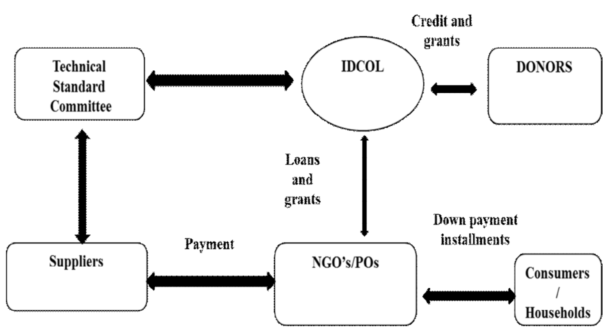

Fig.1:Operational flow diagram of IDCOL's solar Home Project.

From one PO's perspective like Brac Foundation we get to know that Brac Foundation has installed capacity 36621KW solar home system (may 18,2008) stand alone solar home system to provide electricity in Rural grid off areas

Table 1: Brac Solar Energy Program[1]

Particulars	Comulative
No. Of region Covered	55
No. of area Covered	260
No. of PO Working	345
No. of Sales Promotion	29
Sales	49000 unit

3. PERFORMANCE OF SOLAR CELL

III. PERFORMANCE OF SOLAR CELL

Efficiency of a solar cell is the proportion of the electrical output of a solar cell to the incident energy in the appearance of sunlight. The energy conversion efficiency (η) of a solar cell is the percentage of the solar energy which is exposed in the cell and convert it into electrical energy can be described by the following equation.

$$\eta = \frac{P_m}{E \times A_r} \qquad (1)$$

As mentioned before, A is the total area, Pm is the maximum power and E is the irradiance of the standard spectrum normalized to some total irradiance.

Normally the Total irradiance is 1000mW/cm^2.For a meaningful measurement of η, the irradiance is considered with a reference cell whose short circuit current is calibrated with respect to a standard field. By convention, the performance of solar energy is measured under test conditions unless stated

otherwise.STC includes a temperature of about 25 degree celcius and an irradiance of 1000 W/m^2 with an air mass of 1.5 spectrum.
Various factors affect solar conversion efficiency very deeply. They are described below:

A. Wavelength of Light

When the surface of a solar cell is struck by light, some photons are reflected and do not enter the cell. Other photons pass through the material. Of these, some are absorbed but only they can only generate heat whereas some possess necessary energy to separate electrons from their atomic bonds to produce charge carriers, negative electrons and positive holes. Band gap is the least amount of energy which is needed to liberate an electron from its bond and this energy varies among many semiconductor materials. The PV cell is not perfectly 100% efficient and the reason working behind it is because they cannot respond to the entire field of sunlight. Photons having energy less than the bandgap of the material are not absorbed, which causes wastage of about 25% of incoming energy. The energy content of photons above the bandgap is wasted surplus—re-emitted as heat or light—and causes for an additional loss of about 30%.

B. Recombination and Natural resistance

Charge carriers which are electrons and holes in a solar cell may recombine before they make it into the electrical circuit. This direct recombination is a major problem for many materials. The natural resistance flowing in cell decreases solar cell efficiency. These losses occur in places like the thin top layer typical of many devices, the bulk of prime solar material and the interface between the cell and electrical contacts leading to an external circuit.

C. Other Parameters

Solar cell works best at low temperature determined by their material properties. In case of temperature rise, loss of efficiency occurs. As most of the energy striking on the cell converts into heat , it is important to cool the cell repeatedly. The efficiency of a cell can be reflected by reducing the amount of reflection of light. Untreated silicon reflects more than 30% of the incident light. To reduce the amount of reflection of light, a special type of coating is used.
Larger electrical contacts can minimize electrical resistance but covering a cell with large opaque metallic contact blocks too much incident light. So, a trade off must be made between loss due to resistance and loss due to shading effects.

D. Determining Conversion Efficiency

The performance of a photovoltaic cell device can be calculated to assume the amount of power produced by it. Current-voltage (I-V) relationships, calculating the electrical characteristics of PV devices, are shown by I-V curves. These I-V curves are found by exposing the cell to a constant level of light and maintaining a contain cell temperature, differentiating the resistance of the load, and measuring the current that is produced. On an I-V curve, the vertical axis indicates current, and voltage is indicated by the horizontal axis. There are 2 important points on the I-V curve through which the curve passes through:

- The short circuit current where positive and negative terminal of the cell is short circuited and the voltage between the terminals is zero.
- The open-circuit voltage (V_{oc}) is the voltage across the positive and negative terminals under open-circuit conditions when the current is zero, which corresponds to a infinite load resistence. I-V Curve of a solar cell is discussed below:

By varying the load resistance from zero (a short circuit) to infinity (an open circuit), highest efficiency can be indicated at the point at which maximum power is delivered by the power. Power is the product of voltage and current. Therefore, on the I-V curve, the maximum-power point (P_m) occurs where the product of current and voltage is maximum

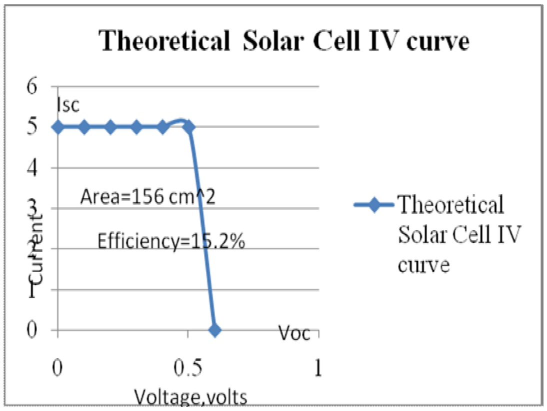

Fig.2: I-V curve of a solar cell.

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4. EFFECT OF DIFFERENT PARAMETERS ON BANGLADESH CONDITION

As it is found that with the increase of temperature, the efficiency of solar cell decreases .For example, a temperature increasing of about 40 degree Celsius above its ambient temperature causes a power loss of 2%.So, in Bangladesh in summer the efficiency of a solar cell decreases to a specified extent. In other seasons except winter the efficiency remains normal. In winter the efficiency increases a bit than its normal efficiency.From various experiments and research a decision has been taken that the effect of dust on a solar cell is noticeable in case of low irradiation condition. For a low irradiation condition it is found that in presence of high amount of dust the reduction of power caused is found to be high. It should also be mentioned that the reduction of power in case of high irradiance condition is not negligible. So, from the perspective of Bangladesh it can be said that because of presence of high amount of dust, the power for high irradiance will be reduced to a great extent. Thus it is necessary to keep the solar cell clean to avoid reducing the peak power.

Many brands of PV solar panels do not tolerate shading, even from the branch of a leafless tree. Shading obstructions may be from “soft” or “hard” sources. Shading obstructions are considered “hard” when objects are in direct contact with the glass, completely blocking the sun’s rays. Bird droppings, broken tree branches and wayward Frisbees are examples of hard shading that can affect a panel’s performance. Partial hard shading of one cell in a photovoltaic panel can create a power drop as much as 50%. Because all the cells in a panel are connected in a series string, all the cells will be affected, ultimately reducing the panel output by about the same percentage.

A. Month wise performance

It is a clear concept that in summer solar radiation should be higher than in winter. Now from the view of tilt angle, we get to know that if the solar rays fall perpendicularly on the amount of direct rays will be higher paving the way to a better result.Some collected surveys are shown below:

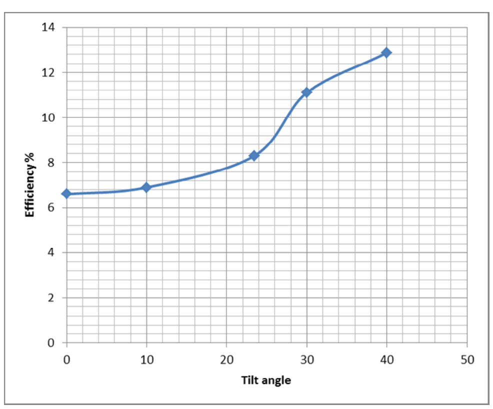

Fig.4: Variation of efficiency with tilt angles in summer(June 2006)

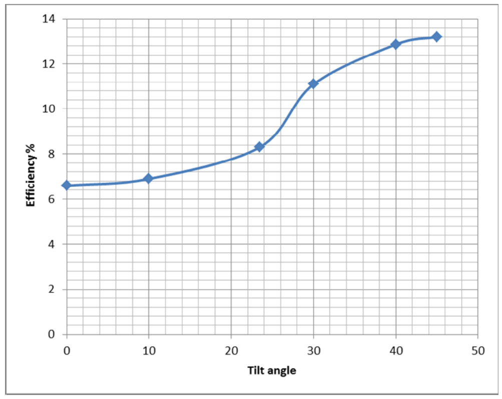

Fig.5: Variation of efficiency with tilt angles in winter (December 2006)

So from the statistics it has been shown that during the month of June the zenith angle becomes almost zero at noon. The efficiencies are fluctuating between 5.89% to 4.22%. Again total insolation received per day is 2.47 KWh/m^2 to 5.06 KWh/m^2. This difference is caused because of the cloudiness of different days. The low values in summer are done because of high ambient temperature and high solar temperature.

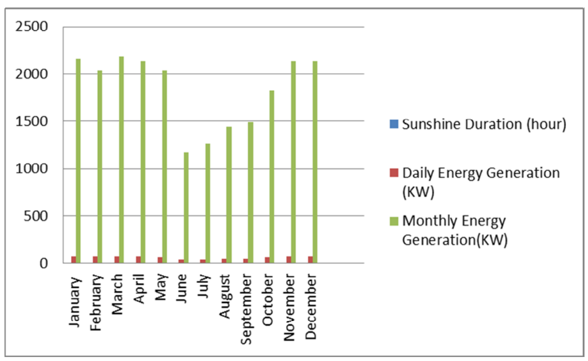

Fig.6: Month wise study on power generation

From figure 4 and 5, it is to be known that the impact of difference of tilt angle is not too much significant in this time. As increase of tilt angle increases the average distance from surface and it leads to lower temperature compensating the high value of tilt angle. Confirmation can be ensured by further study. Winter results are not same as that of summer. In this period of time the sun is in the winter solistic about 46 degree south of Dhaka. It is clear that efficiency in winter is much higher than efficiency in summer. Since the temperature is lower in winter than that in summer even with tilt angles of 0 degree. The efficiency (6.66%) is higher than the highest value in 5.89%.Thus high panel temperature decreases high panel efficiency. A details analysis of performance on the basis of power generation on different month in Bangladesh is presented in figure 6.From the analysis it is evident that power generation is maximum in winter where the sunshine is low. The maximum power generation can be achieved in March.

5. ECONOMICS ANALYSIS

Solar PV cell are not so cheap in recent days. But researchers all around the world are working in this perspective. But this technology shows a good payback period. For which this technology is feasible from the economic perspective. The style cycle cost of a solar PV cell can be expressed as

LCC=Co+ OMpv+ Rpv……………………. (2)

Life cycle cost of a solar PV system consists of initial capital investment (Co), the present value of maintenance and operation cost (OMpv) and the present value of battery replacement cost (Rpv).Here Co is expressing the sum of the investments of different parts of the PV system, PV array, DC/AC converter, Storage batteries, electronic control and battery charger, packaging, transportation and installation..

Operational and maintenance cost includes various costs like taxes, recurring costs, maintenance, insurance etc. It is specified and defined as the percentage of the initial capital cost. If escalating rate is eo and discount rate is d the life time maintenance for N years is:

$$OM_{pv} = OM_o \left\{ \left(\frac{1+e_o}{d-e_o} \right) \left(1 - \left(\frac{1-e}{1+d} \right) \right) \right\}^N \quad if\ d \neq e_o \quad \ldots\ldots\ldots\ldots\ldots\ldots\ (3)$$

OMpv=OMoN× if d=eo…………………………… .(4)

Battery replacement cost is defined as a function of number of battery replacements over a life time. The cost annuity method aims to convert all the net cash-flow life cycle costs with an investment project into a series of annual payment of equal amounts. Components cost estimated(collected data) in Bangladesh are given below:

Table 1: Cost components for solar based recharging stations

Component	**Description**	**Quantity**	**Cost in taka**
PV modules (15 KW)	Local Market	150 Module (100 Wp) (estimated)	14,25,000
Combiner Box	Midnite Solar MNPV [3]	8 (estimated)	44,000
Charge Controller	Local Market	1	2000
Wiring	Approximate		5000
Control Circuit, Maintenance, installment and others	Approximate		50000
Total			15,26,000

The payback period normally indicates the amount of time for recovering the cost of the investment and cost benefit analysis of our system.[6]From a analysis it has been found that the payback period fot this system is about 9 years for 1KW-hr=8 taka,7 years for 1KW-hr=10 taka and 6 years for 1 KW-hr=12 taka.[6]. Thus it clearly indicates that the PV powered system is the lowest cost option at a daily energy demand up to 15kWh even under unfavorable economic conditions .It can also be decided that the life cycle cost of diesel generator is higher than PV lighting system. So, the PV system is economically feasible in remote areas and rural areas of Bangladesh

6. CONCLUSION

This paper presents the use of solar PV in the remote and rural areas of Bangladesh. It also covers the performance characteristics and economic analysis of a standalone PV system. It is found that PV array can supply power and it is more profitable than diesel generated power system within a specified range. Again, Solar PV works more efficiently in winter than summer. Although there are some technological limitations regarding this, it is hoped that we shall get rid of the limitations in the near future.

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Feasibility study of the wave of the Bay of Bangle for the power generation to meet up the power demand as a renewable energy source

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ABSTRACT: This paper presents the results of a study addressing the feasibility of generating electrical power from waves in the Bay of Bangle and describes the wave resource assessment, presents a description of the types of wave energy conversion devices and the devices that have advanced to the stage of sea trials. Economic considerations and the estimated cost of power generation are also presented. The development of the new WEC (wave energy conversion) devices is at an early, but extremely dynamic, stage. More than 100 concepts have been proposed worldwide; and because of the interest in marine renewable, the number of concepts grows every month. By using ocean wave, Bangladesh can mitigate the power demand. From this study it is found that the ocean wave of the Bay of Bangle can be used as a renewable energy for the generation of electrical power to solve the power crisis in Bangladesh.

Keywords: Renewable Energy, Ocean Wave, Feasibility Study, Bay of Bangle, Wave Energy.

1. INTRODUCTION

Ocean energy conversion has been of interest for many years. Recent developments such as concern over global warming have renewed interest in the topic. Electricity is the basic necessity and the most important thing of any country. In according to the circumstance of Bangladesh, most of the populations are deprived from such facilities for the crisis of electricity. However, a few power plants are generating power by using conventional system and renewable energy. Such as- Gas power plant, steam power plant, Hydro-electric power plant. Wind mill, Solar system. Now a days power generation from renewable sources are most popular all over the world. Every country has effort to generate power from renewable energy on account of its availability.

The ocean holds a tremendous amount of untapped energy. Although the oil crisis of the 1970s increased interest in ocean energy, relatively few people have heard of it as a viable energy alternative. In fact, hydroelectric dams are the only well known, mass producing water-based energy, but the ocean is also a highly exploitable water-based energy source. Ocean energy comes in a variety of forms such as geothermal vents, and ocean currents and waves. The most commercially viable resources studied so far are ocean currents and waves which have both undergone limited commercial development. Estimates conclude that marine and tidal currents combined contain about 5 TW [19] of energy, on the scale of the world's total power consumption. There is approximately 8,000-80,000 TWh/yr or 1-10 TW of wave energy in the entire ocean [19] and wave energy provides "15-20 times more available energy per square meter than either wind or solar" [20]. There is a large number of concepts for wave energy conversion; over 1000 wave energy conversion techniques have been patented in Japan, North America, and Europe [21].

1.1OCEAN WAVE CHARACTERISTICS

Ocean waves develop in deep water as the result of energy transfer from sustained winds during storm events. Waves are usually described by height and period, with height measured as the difference between trough and crest, and period as the time between successive crests. Wave energy is proportional to the square of wave height, which means 2-meter and 10-meter waves have, respectively, four times and 100 times the energy of a 1-meter wave. Because wave heights occur over a wide range or spectra, wave heights are defined for engineering purposes by the significant wave height (HS), which is the average height of the largest one-third of the waves in a wave field. Individual wave heights can be greater than 1.6 times the significant wave height [18].

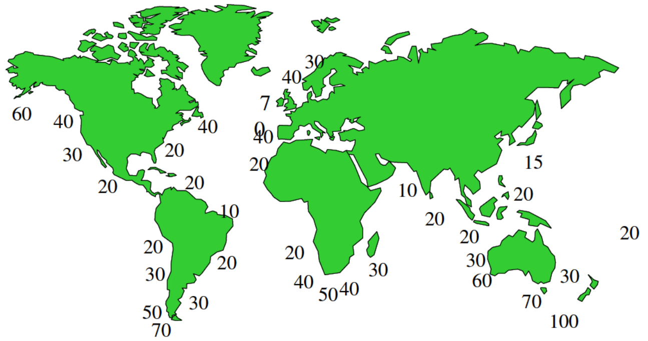

Fig. 1: The scenario of world map with ocean area

Fig.1 shows the ocean area in the world map where the ocean and marginal seas are about 71% of total area of the world [1].

2. TYPES OF WAVE ENERGY CONVERSION SYSTEMS

There are several types of energy conversion system already available in the world are presented here as follows [5]:

- 2.1. Oscillating Water Column
- 2.2. Tapered Channel Systems (TAPCHAN)
- 2.3. Floating Devices
- 2.4. Off-Shore vs. On-Shore Devices
    - 2.4.1 On-Shore Devices
    - 2.4.2 Off-Shore Devices
- 2.5. Hybrid System.

Although many wave energy conversion systems (WECS) have been invented, only a small proportion has been tested and evaluated. Furthermore, only a few have been tested at sea, in ocean waves, rather than in artificial wave tanks [7].

2.1. OSCILLATING WATER COLUMNS (OWC): These devices generate electricity from the wave-driven rise and fall of water in a cylindrical shaft. The rising and falling water column drives air into and out of the top of the shaft, powering an air-driven turbine. Fig. 2 Shows the construction of the energy conversion system of Oscillating water column.

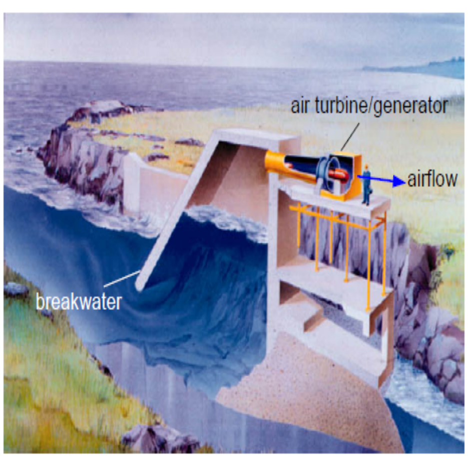

Fig. 2: Oscillating water column [15]

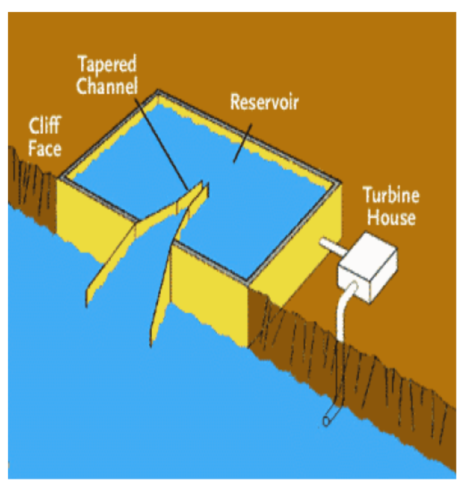

Fig. 3: Tapered Channel Systems [16]

2.2. TAPERED CHANNEL SYSTEMS (TAPCHAN): These shoreline devices, also called "tapered channel" or "TAPCHAN" systems, rely on a shore-mounted structure to channel and concentrate the waves, driving them into an elevated reservoir. Water flow out of this reservoir is used to generate electricity, using standard hydropower technologies. Fig. 3 Shows the construction of the energy conversion system of Tapered Channel Systems.

2.3. FLOATS OR PITCHING DEVICES: These devices generate electricity from the bobbing or pitching action of a floating object. The object can be mounted to a floating raft or to a device fixed on the ocean floor. Fig. 4 Shows the construction of the energy conversion system of Floats or Pitching Devices.

Fig. 4: Floats or Pitching Devices [17]

2.4. OFF-SHORE VS. ON-SHORE DEVICES: Although wave energy applications are still in the early phase of development, a variety of conversion devices have been constructed and tested. These devices can be classified in two groups:

On-shore systems including a variety of fixed oscillating water column (OWC) devices. The construction of the energy conversion system of On-Shore Devices as shown in Fig. 5. Off-shore systems such as oscillating water column (OWC) devices, heaving buoys and rafts Fig. 6 Shows the construction of the energy conversion system of Off-Shore Devices.

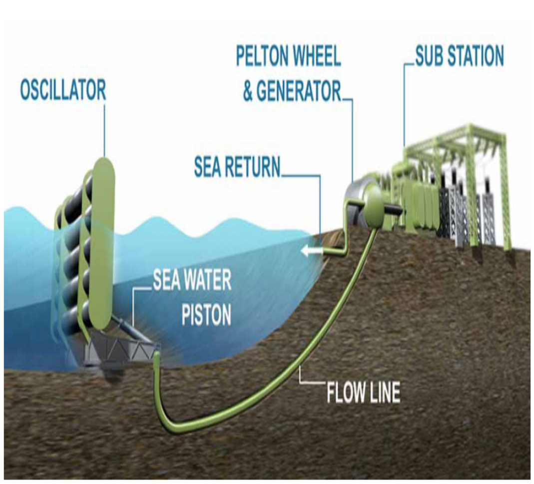

Fig. 5: Off-Shore On-Shore Devices [14]

Fig. 6: Off-Shore On-Shore Devices [14]

2.5 HYBRID SYSTEMS: Hybrid systems combine the available power for more than one source. These include the: (1) Monitor (hybrid wind, tide, and wave) and (2) Wind and Ocean Swell Power (WOSP). Combining two, or more, sources of renewable energy into one system may improve the cost effectiveness and available power from these systems.

3. ALTERNATIVE ENERGY SOURCES OF BANGLADESH (A COMPARISON AMONG ENERGY TYPE, ENERGY DENSITY, PREDICTABILITY, AVAILABILITY, POTENTIAL SITES)

The total power of waves breaking on the world's coastlines is estimated at 2 to 3 million megawatts. In favorable locations, wave energy density can average 65 megawatts per mile of coastline. Long Island wave energy density is estimated at between 17 and 20 MW/mile (11kW/m). Alternative energy sources according to availability of density are shown in Table 1.

Table 1: Alternative energy sources according to availability of density

Energy Type	Energy Density	Predictability	Availability	Potential Sites
Wave Energy	Low to Moderate	Predictable in most sites	80-90%	Extensive but can become Limited
Combustible Fuels	Very High	Predictable	80-90%	Extensive
Wind	Low	Unpredictable except in limited number of sites	30-45%	Limited
Solar	Low	Unpredictable except in limited number of sites	20-30%	Limited

Table 2: Represent Wave energy Comparisons to other Renewable energy

Table 2.Wave energy Comparison to other renewable

	OPT Wave power	Solar	Wind
Energy density and predictability	High	Low	Low
Availability	90%	20%-30%	20%-30%
Potential Sites	Virtually Unlimited	Limited	Very Limited
Average power Output per Plant	Scale able to 100+MW	Scale able to 5MW	Scale able to 30MW
Environmental issues	None	Visual Pollution	Noise and Visual Pollution
Fuel	None	None	None
Power Station Cost/kW		$10,000	$3,000
Secondary	$6,200	$4,500	$1,000
Primary	$2,300		
Energy Cost/kW			
Secondary	$7-10	$25-50	$10
Primary	$3-4	$10-15	$5-6

4. COSTING FOR THE POWER GENERATION FROM THE OBTAINED WAVE ENERGY

These cost estimates are for a small scale project in Alaska collected from [3] and presented in Table 3.

Table 3: Costing for the power generation from the obtained wave energy

	1 Unit		2 Units		4 Units		8 Units	
	K$ USD	**$/MW**	**K$ USD**	**$/MW**	**K$ USD**	**$/MW**	**K$ USD**	**$/MW**
Capital Cost	$8,890	$13.7	$15,097	$11.6	$26,237	$10.1	$48,370	$8.9
Annualized	$330	$0.51	$510	$0.39	$810	$0.31	$1,400	$0.27
Rated Power	650	kW	1,300	kW	2,600	kW	5.200	kW
Capacity Factor	48	%	48	%	48	%	48	%
Availability	95	%	95	%	95	%	95	%
Annual Energy Output	2596	MWh	5193	MWh	10,386	MWh	20,772	MWh
Cost of Electricity (2010 $)	45.1	c/kWh	38.0	c/kWh	32.3	c/kWh	28.4	c/kWh

These cost estimates are for a small scale project in Alaska and not representative of future costs

5. ADVANTAGES OF WAVE ENERGY CONVERSION

Wave energy systems have many advantages. Among these are:
• Renewable and sustainable resource
• The resource is relatively well-characterized
• Abundant
• Reduces dependence on fossil fuels
• Pollution-free
• More concentrated
• Dissipates wave energy/protects shoreline;
• Present no difficulty to migrating aquatic animals;
• Local economic development; and

- RENEWABLE AND SUSTAINABLE RESOURCE: Wave energy is a renewable and sustainable energy resource. Waves are generated by the wind, which is in turn generated by the uneven heating of the atmosphere by the sun. As such, wave energy is a virtually inexhaustible resource. The energy is free (although the cost of conversion is not).
- THE RESOURCE IS RELATIVELY WELL-CHARACTERIZED: There is a ready supply of wave energy data collected from wave monitoring buoys. These data are very thorough and go back many years. These data are important as a guide to the likely economics and the best locations for sitting wave plants. Estimating the potential resource is much easier than with wind, an important factor in attracting project lenders [13].
- ABUNDANT: Wave energy is abundant. Although variable from place-to-place and season-to-season, some estimates show that wave energy could amount to nearly 16 percent of the world's current total electricity output. That would be nearly 2,000 terawatt-hours (TWh) annually, or as much as the world's large-scale hydroelectric plants produce [14].
- REDUCES DEPENDENCE ON FOSSIL FUELS: As is true with all renewable energy resources, use of wave energy has the potential to significantly reduce the use of fossil fuels for electricity production and other applications. Wave energy consumes no fossil fuels during operation, and will displace their use. Hawaii currently depends on imported fossil fuels for more than 90% of its energy requirements.
- POLLUTION-FREE: No serious environmental impacts have been attributed to WECS, except of course during construction. Construction impacts occur with all energy conversion systems construction. And, construction impacts can be minimized by various mitigation measures. Wave energy generates little or no pollution. On the other hand, non-renewable energy resources such as fossil fuels produce air pollution, water pollution and thermal pollution and nuclear energy produces thermal pollution and highly radioactive nuclear waste.

- MORE CONCENTRATED: Wave energy contains roughly 1,000 times the kinetic energy of wind, allowing much smaller and less conspicuous devices to produce the same amount of power in a fraction of the space. Wave energy varies as the square of wave height, whereas wind energy varies with the cube of air speed. This results in much higher average power production from waves per unit of time [13].
- DISSIPATES WAVE ENERGY/PROTECTS SHORELINE: Wave energy systems can shelter the coast, and are therefore useful in harbor areas or coastal erosion zones. WECS can be incorporated into breakwaters, thus reducing the cost of such systems, and providing for dual use. Construction of large-scale offshore devices results in new areas of sheltered water, attractive for fish, sea birds, seals and seaweed. Offshore wave power plants can be spaced sufficiently far apart that wave energy passing between the plants will diffract into the calmer waters immediately behind the plants. The environmental impact at the coast would be a broad, diffuse lowering of wave energy levels. A 5 to 10% withdrawal of wave energy offshore would correspond roughly to a 3 to 5% reduction in wave heights at the coast [12].
- PRESENTS NO DIFFICULTY TO MIGRATING AQUATIC ANIMALS: While migrating aquatic animals (e.g., fish, whales, and dolphins) may encounter WECS, they can easily avoid them. WECS can be designed to minimize entrapment.
- LOCAL ECONOMIC DEVELOPMENT: Use of wave energy allows the generation of electricity in the local area using a free, indigenous, renewable energy resource. This will reduce the export of scarce local capital that may have been used to purchase imported fossil fuels. Renewable energy systems are also generally more labor intensive than fossil fuel or nuclear energy systems. Increased job creation and retaining capital at home will assist in local economic development.

6. CHALLENGES FOR WAVE ENERGY CONVERSION

Wave energy systems also face many challenges that must be overcome before they are widely used. Among these challenges are:
• Visual impact
• Disturbance or destruction of marine life
• Coastal erosion
• Threat to navigation
• Location-dependent
• Sited in marine environment
• Maintenance requirements
• Variable resource
• Efficiency

- VISUAL IMPACT: The visual impact of a wave energy conversion facility depends on the type of device as well as its distance from shore (it should be noted, however, that many of these do not apply to offshore systems). In general, a floating buoy system or an offshore platform placed many kilometers from land is not likely to have much visual impact (nor will a submerged system) [7].
- DISTURBANCE OR DESTRUCTION OF MARINE LIFE: Wave energy devices may have a variety of effects on the wave climate. This could influence the shore and shallow sub-tidal areas and the communities of plants and animals they support [5]. However, ecological impacts relating to the alteration of waves are not fully understood and need to be studied further [8].
- COASTAL EROSION: Some wave energy conversion devices concentrate wave energy into a tapered area before conversion (e.g., TAPCHAN). These focusing surge devices are sizable barriers that channel large waves to increase wave height for redirection into elevated reservoirs. The water then passes through hydroelectric turbines on the way back to sea level thus generating electricity. Continuous arrays of such onshore or shore based wave-energy devices could physically alter coastlines. These array types may result in increased coastal erosion where the waves are concentrated and more sedimentation in adjacent areas [10].
- THREAT TO NAVIGATION: Once in place, wave energy conversion devices could be a dangerous obstacle to any navigational craft that cannot see or detect them by radar [11], or by direct sighting. For most devices this could be overcome by conventional techniques (e.g., painting, radar reflectors, lights, education regarding location, etc.) [5]. In long arrays of WECS there would be a need for navigational channels between them [9].

- LOCATION DEPENDENT: As is true with all forms of renewable energy, the application of wave energy conversion devices is location dependent. Such devices must be sited where the wave resource is greatest.
- SITED IN MARINE ENVIRONMENT: Designing a mechanical device to capture wave energy poses challenging engineering problems. The device must be capable of gathering useful energy from a relatively calm sea with wave heights of a few feet (~1 meter). It must also be able to survive sea conditions where wave heights can exceed 50 feet (15 meters). Components used will have to be "robust" and corrosion resistant [6].
- MAINTENANCE REQUIREMENTS: The effects of sitting in the marine environment (exposure to variable, and sometimes extreme, wave forces; marine corrosion and biofouling; and in some cases, limited accessibility), could significantly increase the amount and cost of maintenance required.
- VARIABLE RESOURCE: Wave energy is a variable resource. Waves come in intervals. Wave energy changes with regard to wave lengths, periods and wave heights. Wave energy will not produce electricity at a steady rate and thus not necessarily at times of peak demand. The variable nature of wave energy can be mitigated to some extent by various energy storage technologies, but at an increased cost.
- EFFICIENCY: While the projected conversion efficiencies of WECS under certain circumstances (e.g., design wave height) are greater than those for wind, solar, or even conventional fossil fuel or nuclear power plants, the output of such devices is significantly less under small waves. And, wave energy devices will not be able to utilize all of the energy available under storm conditions.

7. STUDY THE WAVE OF BAY OF BANGLE

7.1 CAUSES OF WAVE GENERATION

Waves are generated at sea by the wind. Small ripples form on the water as the wind blows across the ocean's surface. The size of waves depends on three things:

1. The duration of the wind;
2. The strength of the wind, and;
3. The *fetch*, or the distance over water across which the wind blows.

The longer the wind blows the bigger the waves; stronger winds mean higher waves; and the greater the fetch, the bigger the waves. Thus the biggest waves of all occur in the storms that last the longest with the most energetic winds with hundreds of miles between the storm at sea and the beach.

Waves do not actually consist of water traveling from where the wind is blowing all the way to the beach. Instead of moving water, waves are moving energy that was transferred from the wind to the water. This energy propagates, or moves, through the ocean to the beach in the form of a wave. But the water itself is not moving forward as in a current. Instead, the energy rolls through the water in a circular motion called a *wave orbital*. The *crest* of a wave is the top of a wave orbital, and the *trough* of a wave is the bottom of a wave orbital. When the waves reach the shore they expend their energy by breaking and then moving sand and shaping the beach.

7.2 MEASURING WAVES

The dimensions of a wave are measured both by crest height and the distance between crests. *Wave height*s the vertical distance from the crest (highest part of the wave) to the trough (the lowest part of the wave). Most untrained observers at sea tend to greatly overestimate wave height, which is quite understandable because they do not have any stationary reference points. And then there is the terror factor. A person holding on for dear life on a rolling, bounding vessel is easily convinced of the giant size of the waves.

Standing on a beach, a good way to estimate wave height is to assume that the surfer out there is 6 feet tall! In many cases, the amplitude is also used as a measurement of the wave's size; *wave amplitude* is one-half of the wave height. The *wavelength* is the distance from one crest to the next crest, or from one trough to the next.

Waves travel at different speeds, and the speed is typically measured as the wave *period* or wave *frequency*. Wave period is the number of seconds it takes two successive wave crests to pass a given point. Wave frequency is the inverse of the period, or the number of waves that pass a given point during a given time period. As the length of a wave increases, so does its speed. In a general way, the higher the wave period the greater the wave height. Big storms in North Carolina may produce waves with 12 to 15 second periods, while calm weather wave periods are more likely to be 3 to 5 seconds.

7.3 SIGNIFICANT WAVE HEIGHT

Commonly Referred To As Seas In The Marine Forecast
This is the average of the highest one-third (33%) of waves (measured from trough to crest) that occur in a given period. This is measured because the larger waves are usually more significant than the smaller waves. For instance, the larger waves in a storm cause the most beach erosion, or the larger waves can cause navigation problems for mariners. Since the Significant Wave Height (Seas) is an average of the largest waves, it should be aware that many individual waves will probably be higher.

If we take a sample forecast of Seas beyond the Reef of 2 to 4 feet, this implies that the average of the highest one-third waves will have a Significant Wave Height of 2 to 4 feet. But mariners need to keep in mind that roughly one of every ten waves will be greater than 4 feet; one in every one hundred waves will be greater than 5 feet; and one in every 1000 waves will be greater than 6 feet.

As a general rule, the largest individual wave one may encounter is approximately twice as high as the Significant Wave Height (or Seas).

Note: Seas can refer to the combination or interaction of wind waves and swells (combined seas) in which the separate components are not distinguished. This includes the case when swells are negligible or are not considered in describing sea state.

8. GRAPHICAL REPRESENTATION OF SINIFICANT WAVE HEIGHT OF BAY OF BANGLE

The graphs shown below are the significant wave height (m) of Bay of Bangle at different months in the year of 2012. The data of wave height is an average value for every day. The data is collected at Longitude 92 East and Latitude at 21 North. The data collection time starts from 717points which is gradually increases by adding one minute after every point.

VARIABLE: Significant Wave height (m)
DATA SET: Significant Wave height Map - Based on NRT merged data
FILENAME: dataset-nrt-global-merged-mswh-latlon-switched
FILEPATH: http://atoll-aviso.vlandata.cls.fr:41080/thredds/dodsC/
SUBSET : **717 points (TIME)**
LONGITUDE: **92E**
LATITUDE: **21N**

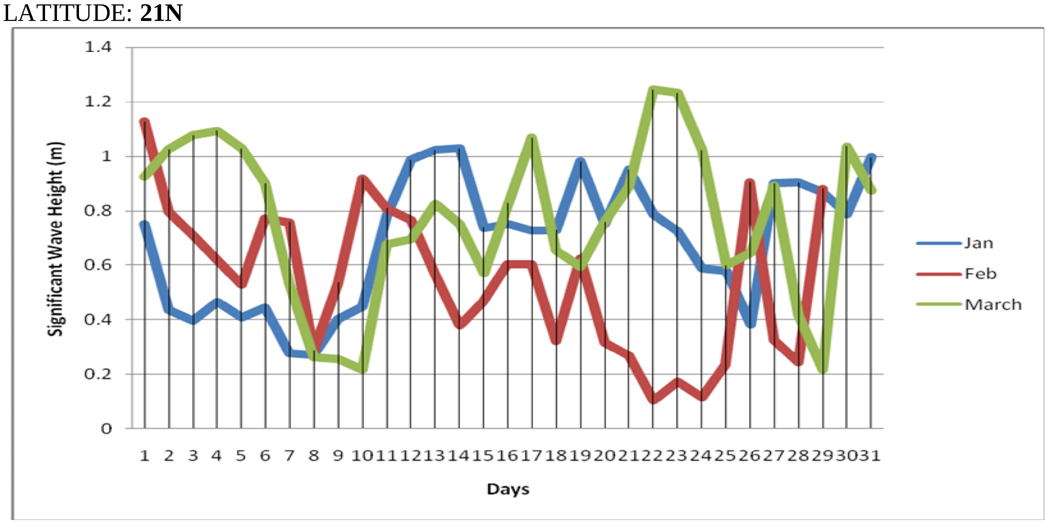

Fig. 8.1: Significant wave height merged (m) in January February and March.

Fig.8.1 provides information about the significant wave height of the bay of Bangle over the first three months in the year of 2012.

At the month of January the wave heights are fluctuated between0.78m to 1.00m wildly, but the trend was upward. The maximum wave height is observed at 14th January. At the month of February the wave heights are fluctuated between o.5m to 1.17m abruptly, but the trend was upward. . The maximum wave height is observed at 1st February. It is shown from the graph that was denoted for the month of March the wave heights are fluctuated between o.95m to 1.25m wildly, but the trend was downward. The maximum wave height is observed at 21st March.

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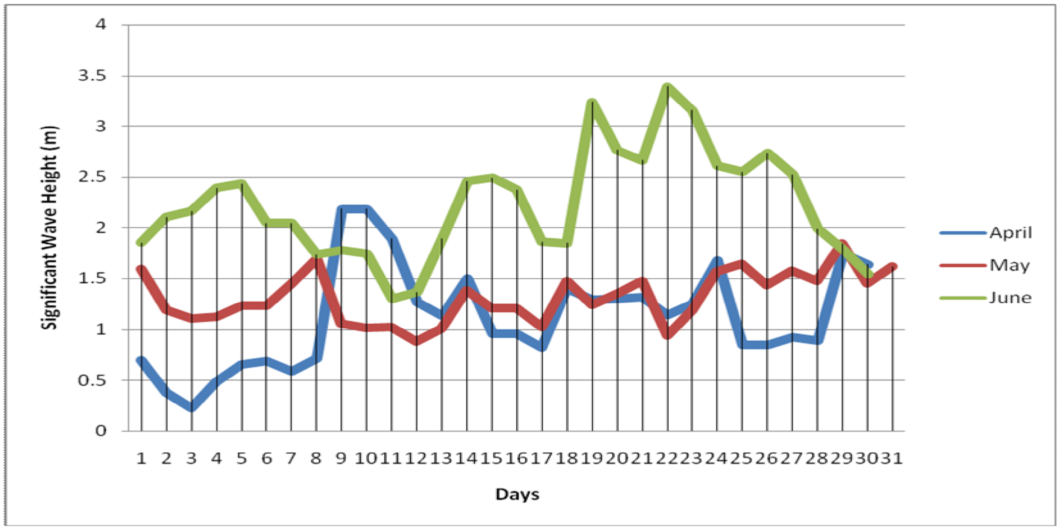

Fig. 8.2: Significant wave height merged (m) in April, May and June.

Fig. 8.2: present the information about the significant wave height of the bay of Bangle over the three months that means April, May and June in the year of 2012.

At the month of April the wave heights are fluctuated between 0.54m to 1.52m wildly, but the trend was upward. . The maximum wave height is observed at 9th April. At the month of May the wave heights are fluctuated between 1.52m to 1.56m gently, but the trend was upward. The maximum wave height is observed at 8th February. It is shown from the graph that was denoted for the month of June the wave heights are fluctuated between 1.5m to 3.48m wildly, but the trend was downward. The maximum wave height is observed at 22nd June.

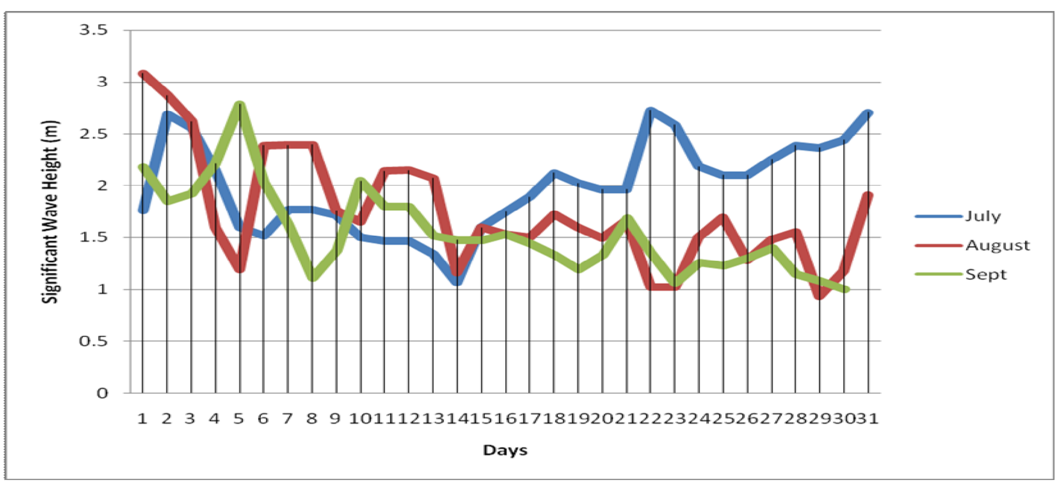

Fig. 8.3: Significant wave height merged (m) in July, August and September.

Fig. 8.3 shows the information about the significant wave height of the bay of Bangle over the three months that means July, August & September in the year of 2012.

At the month of July the wave heights are fluctuated between 1.56m to 2.55m wildly, but the trend was upward. The maximum wave height is observed at 22nd July. At the month of August the wave heights are fluctuated between 1.8m to 3.2m gently, but the trend was upward. The maximum wave height is observed at 1staugust. It is shown from the graph that was denoted for the month of the wave heights are fluctuated between 1.5m to 3.48m wildly, but the trend was downward. The maximum wave height is observed at 22nd June.

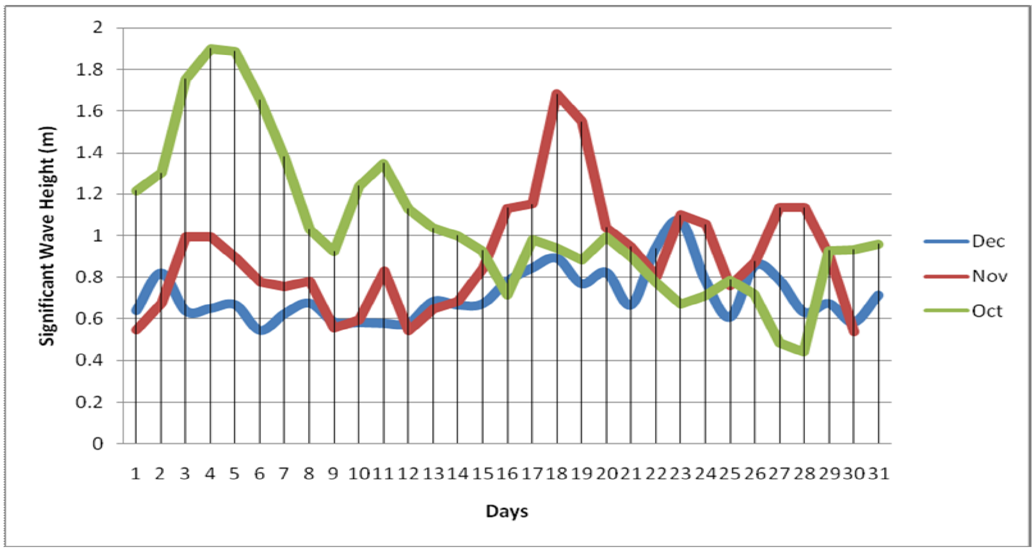

Fig. 8.4: Significant wave height merged (m) in October, November and December.

Fig. 8.4 provides information about the significant wave height of the bay of bangle over the three months that means October, November & December in the year of 2012.

At the month of October the wave heights are fluctuated between 0.98m to 1.9m wildly, but the trend was upward. The maximum wave height is observed at 4th October. At the month of November the wave heights are fluctuated between 0.47m to 1.7m wildly, but the trend was downward. The maximum wave height is observed at 18th November. It is shown from the graph that was denoted for the month of December the wave heights are fluctuated between 0.64m to 0. 20m wildly, but the trend was downward. The maximum wave height is observed at 23rd December.

9. RESULT

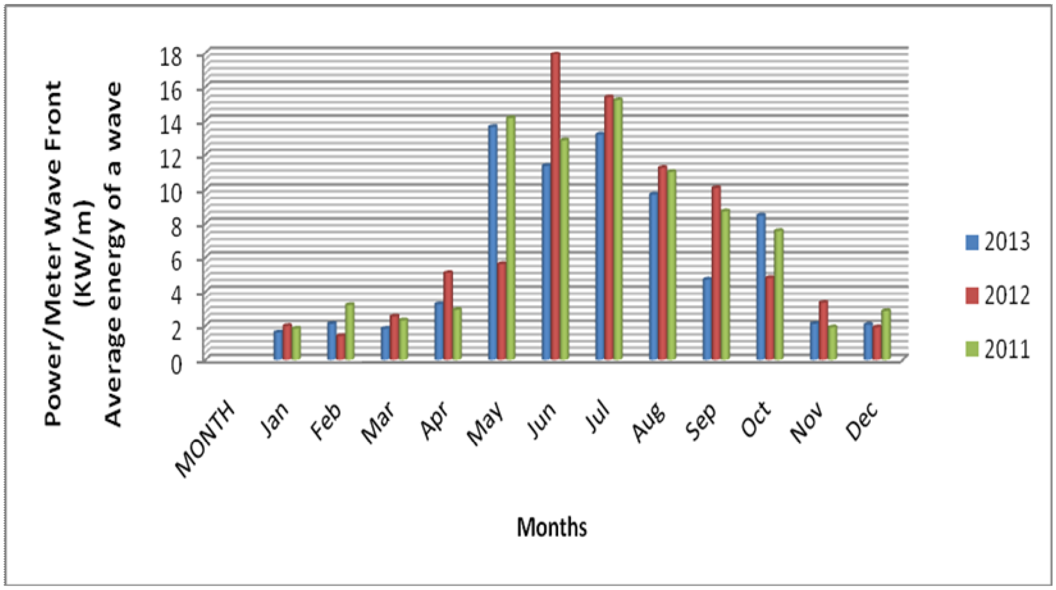

Fig. 9: A comparison of wave power at different months among the year of 2013, 2012 and 2011.

The graph provides information about the average energy of wave of the Bay of Bangle over the year 2011, 2012 &2013. As regards the first four months that means January to April of these years have no significant change of wave energy. From May to August significant wave energy is observed, whereas at the month of July of these years have good average wave energy. The wave energy of September and October of those years is too much better than November and December. It is also seen that the wave energy level are almost same for every year.

10. CONCLUSION

The consumption of power increases day by day consequently reduces the source of fossil fuel. Bangladesh is a developing country where most of the power plants are dependent on natural gas around 63% of power are produce by gas. But the amount of reserved gas decreasing considerably and it will reduce to zero within a few years (short time). As a result it is necessary to reduce the dependency on fossil fuel which can be possible by utilization of renewable energy. Ocean wave is one of the kinds of renewable energy. There is limited resource of ocean wave power in Bay of Bangle at Cox's Bazar, Chittagong which is wave dominated power, which can be utilized by a recommended technology with a commercial consideration. Because, most of the wave power conversion system is based on wave and significant wave height produced. It is also known that Bangladesh has a very limited resources of wind power simultaneously there are significant amount of power in ocean wave (Bay of Bangle). So it is a most important energy source of renewable energy. By using this resource, Bangladesh can mitigate the power demand. From this study it can be concluded that the ocean wave of the Bay of Bangle can be used as a renewable energy for the generation of electrical power to solve the power crisis in Bangladesh.

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MODIFICATION OF THE IGNITION SYSTEM OF NATURAL GAS BURNER FOR CONSERVING PRIMARY ENERGY IN BANGLADESH

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ABSTRACT: Gas, as natural gas is the most abundant resource of fuel in our country. Gas stove is very popular for cooking among the people. But people use this natural gas as their wish and they seem not to be worried about the wastage of gas. They often forget to turn off the stove and left the stove burning after cooking. Here we have discussed the potential solution of natural gas wastage.

Index Terms: Primary energy, Energy consumption, Natural gas, Energy crisis

1. INTRODUCTION:

In Bangladesh, as in many other developing countries, poverty and lack of access to energy are closely linked. Although endowed with natural gas resources and some good quality coal deposits, Bangladesh continues to reel from widespread power shortages due to a lack of investment in power generation. Natural gas is the main natural resource of our country [1]. In recent years, several trillion cubic feet (TCF) of natural gas have been added to the confirmed 10.5 TCF [2] known as of 1996. Due to the fact that there has been comparatively little exploration to date, estimates of the total extractable natural gas resource in Bangladesh are uncertain and vary widely. An estimate of 20 TCF is gaining acceptance among experts, but some argue that experiences in comparable basins elsewhere in the world suggest that the ultimate recoverable resource could be as high as 50 TCF or even 100 TCF [3]. At the current rate of natural gas use in Bangladesh (1000 mmcfd) [4], the current estimated proven reserves would last 45 years. Even if the present rate of use increases at 10 per cent per year, these reserves would last about 17 years.

Currently, 10 percent of the natural gas is used by domestic and commercial users, according to Power Ministry [5]. In most houses housewives/housemaids generally keep the gas burner on indifferently to save the cost of match-box which leads to the misuse of a lot amount of gas [6]. Here the aim is to modify gas burner in such a way that it will sense the weight when the cooking pot is put on the burner. Then it will ignite automatically. The stove turns off automatically when the cooking pot is removed. Thus it can save gas. This automatic gas burner can be considered as an inexpensive means of alleviating the fuel wood crisis [7].

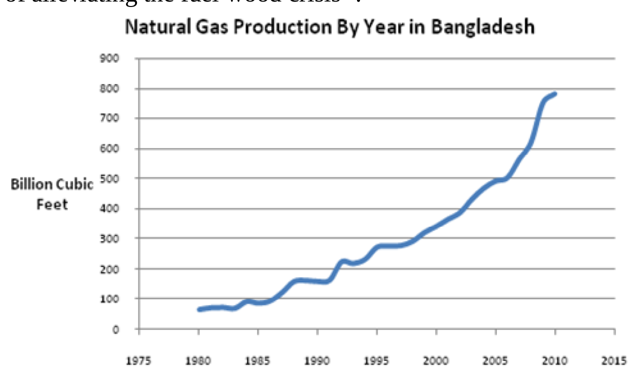


Fig 1. Natural Gas production By year in Bangladesh

2. IMPORTANCE OF ENERGY SAVING BURNER:

In developing countries, the big majority of the energy that is needed for cooking purposes comes from biomass (mainly wood and gas). In some countries it is easily up to 90%. In these countries, the burners that are used for cooking are usually very bad from energy saving point of view. In fact, the traditional burners in developing countries waste a lot of natural gas, mainly because of carelessness. Indeed, in urban areas, the local population prefers usually to use natural gas as cooking fuel because it is easier to use and produces nearly no smoke so that cooking inside is possible. There is a tendency in several countries to use liquid gas (LPG), which gives even a cleaner combustion. Because of growing population in developing countries and the inefficient use of natural gas become more and more crucial [8]. Other fuels such as petroleum or electricity are too expensive for the biggest part of household in developing countries [9]. Moreover, because of the price increase of such fuels on the international market, it is and will become more and more difficult to cook with theses fuels even for the wealthier part of the population. The massive introduction of energy saving burner is the only solution[10].

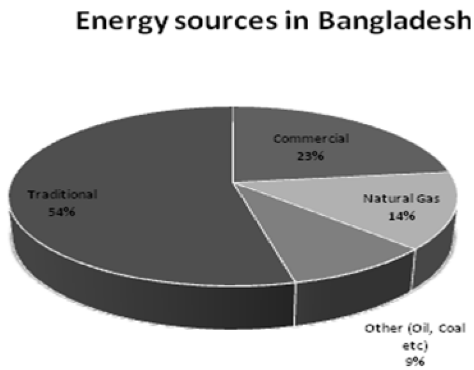


Fig 2. Sources of energy in Bangladesh

Application of energy saving burner in our daily life can save crores of taka every year in Bangladesh. A domestic single burner use approximately 12 cft gas per hour [11]. The average operational time for a gas burner is 8 hour. So, monthly consumption of a single gas burner will be (8 x 30 x 0.8 x 12) = 2304 cft. Which is approximately 65.24m^3 (1 m^3=35.31 cft) of gas . Price of 1 m^3 gas is Tk. 5.16. Total monthly cost for running a domestic single burner is about Tk. 338 (Tk. Three hundred and thirty eight). According to TIB report 19.2% of the natural gas are being misused [12].Which is about Tk. 65 (Tk. Sixty five) per month and Tk. 780 (Tk. seven hundred and eighty) per year. Approximately there are 7% users of natural gas burner in Bangladesh which is about 1,12,00,000 (one crore twelve lakh) in numbers. So, the misuse of gas is 442.368 cft (13 m^3) per month which costs (65 x 1,12,00,000) = 72,80,00,000/= (Tk. Seventy two crores and eighty lakhs) and 5308.416 cft (156 m^3) per year which costs 873,60,00,000/= (Tk. Eight hundreds seventy three crores and sixty lakhs) . This huge amount of money can be used in other productive sectors which can play vital role in the development of our country.

3. TYPES OF GAS BURNERS:

Gas stoves are classified mainly on the basis of their design, size and also the way the flame is lit [13]. In the earlier days few stoves had a standing pilot while others didn't have such a light, which distinguished one type from another. Today, there are different types available - the most common ones are explained here-

Non pilot system:
These stoves are predominantly used in the earlier times. They are lit manually using a match. The main disadvantage of this system was that, if the stove was accidently left open, gas would leak out and fill the room. Even with a small spark from a switch board could ignite the gas and cause fatal accidents.

Standing pilot system:
This stove has a continuous flame just under the cook top. As soon as the stove is on, the gas starts flowing from the burner. The main advantage is that these are very simple to use and total independent, as they are not dependent on any kind of outside power source.

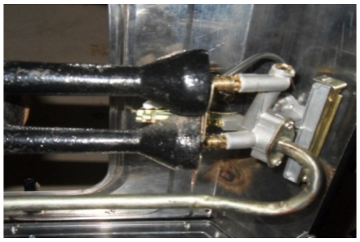
Modern Ignited stove:
This is common is most households, especially in case of student accommodations. These are popular since they make use electric sparks to ignite the burners. It usually has a very interesting

clicking sound, which is audible before the burner lights. The sparks are initiated by the turning on of the gas burner knob, which also helps in modulating the size of the flame.

Auto Ignition:
This is a welcome refinement in the stove, which makes work easy and quite simple. The knob can be just turned on as per the size of flame. These stoves are safe, easy to clean, and reduce the chances of accidents. Gas stoves are normally bought keeping in mind the number of members for whom cooking will be done and also as per the budget of the user.

4. MECHANICAL COMPONENTS:

Auto ignition:
High potential difference is used for auto ignition. Because of potential difference electron from low potential surfaces jumps to the higher potential surface and a spark is created which is used for switching the burner on. High potential difference is created by piezoelectric effect. In our ignition system when the knob starts to rotate, it pulls an internally set trigger. And when the trigger restores its position, it hits a piezoelectric material with high kinetic energy and gives spark to a gas jet that comes through a third gas pipe.



Ignition Process

Stepper motor:
A stepper motor is a brushless synchronous electric motor that can divide a full rotation into a large number of steps. We used a unipolar stepper motor.

Stepper motor

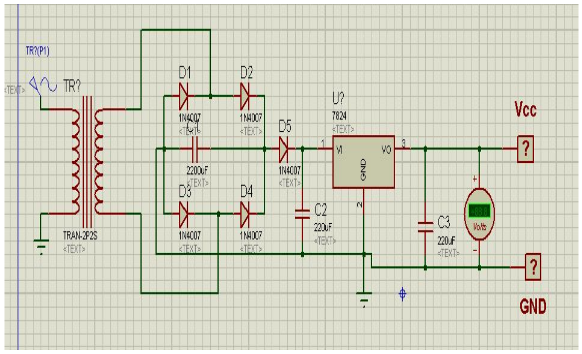
Gas Flow Control:
The gear is attached to the knob shaft to control the motion of the knob and hence to control gas flow rate. A stepper motor is used to rotate the knob. Four meshed gear mechanism is used to transmit the motion of motor to the knob.

5. ELECTRICAL COMPONENTS:

Transformer:
A step down transformer is used. It can convert the supply voltage into around 26V. Its current rating is 3 A.

Transformer

Power supply:



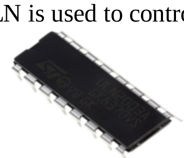
24 Volt DC Power Supply Circuit

LDR-LASER sensor:
LDR or light depending resistor may refer to a resistor whose resistance decreases with increasing incident light intensity (Photoconductivity).For our purpose; we used LDR to detect emission from LASER. When light incident from LASER associated with enough energy strikes the semi-conductor of LDR, then the electrons requiring the equivalent energy break the bonds will escape and as electricity is concerned with flow of electrons, therefore increasing current and decreasing resistance and vice-versa. Thus LDR makes the sense of weight with association of interruption of light from LASER.

Microcontroller:
A micro controller is an integrated chip that is often designed to execute only a specific task to control a single system, they are much smaller and simplified so that they can include all the functions required on a single chip. For our purpose we used this chip to control stepper motor.

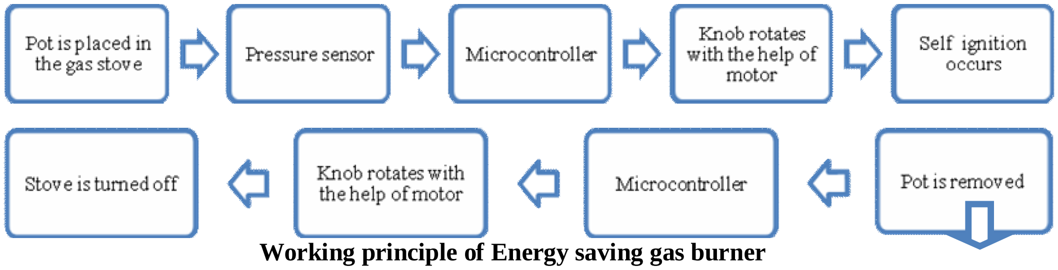

Microcontroller (ATmega8)

ULN 2003A:
ULN2003A is monolithic high voltage and high current Darlington transistor arrays. ULN2003A is a dedicated IC for driving high current. ULN is used to control stepper motor.


ULN 2003

6. WORKING PRINCIPLE:

When a loaded pot is placed on a gas burner it will sense the weight with the help of pressure sensor and ignite automatically with the help of automatic ignition system. And the system is controlled by a microcontroller. After cooking, when the pot is removed, the burner will turn off automatically. Besides this burner can be operated manually if anyone wishes. The working principle block diagram of energy saving domestic gas burner is given below:



Working principle of Energy saving gas burner

7. ADVANTAGES:

- As the igniting process is automatic, there is no risk of fire hazard during ignition.
- The burner can sense if there is any cooking pot on the stove and then it ignites automatically. So our automatic stove is more user friendly.
- Maximum users forget to turn off the stove after cooking and left the burner on. Our developed stove turns off automatically when the cooking pot is removed. Thus it can save gas. As maximum users do not turnoff the burner after cooking and leave the burner on, a lot of natural gas is wasted.
- The solution of this problem energy saving gas burner is self-sufficient for marketing purposes. This energy saving gas burner is believed to be profitable enough to ensure the better future.

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FUTURE OF MOTORIZED RICKSHAW: SOLAR ENERGY CONCEPT

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ABSTRACT*:* Motorized rickshaw has been very popular in recent times in Bangladesh although they demand a large amount of electrical power. In this paper solar panels are instrumented which eventually decreases the demand of power from the main grid to power up the batteries. The hydraulic disk brakes are introduced to the system to improve the safety features. It is also checked if the system shows the better mileage as before with the solar panels implemented. The dimensions of the body structures of rickshaw are discussed through CAD models with different isometric views. The outcome is delivered with proper electrics, system diagram and mileage graphs.

Keywords: Solar energy; Irradiance; Motorized rickshaw; CAD models.

1. INTRODUCTION

Rickshaw has turned out to be one of the most crucial transport medium in Bangladesh from last decade. After introducing rickshaw in 1938 to Dhaka from Calcutta, its demand has expanded in a large extent. Though these man powered pedal vehicle are seen as inefficient and inhumane, its popularity has increased because of its cheap availability. To reduce the physical labor, nowadays rickshaw pullers are heading towards the fact of driving motorized rickshaw instead of pedal driven ones. Motorized rickshaw allows better efficiency, mileage and less effort. The batteries that are usually used to drive the motor are rechargeable up to 12V mark. In most cases owners charge up the battery from the AC voltage mainstream which is illegal. Solar energy is possibly the best solution to it. Solar energy can solve this issue handsomely providing continuous source of energy that can charge up the batteries which will not affect the main grid. Again the scarcity of fossil fuel and the increasing price of this have led the world to think of such power source.

2. THEORETICAL BACKGROUND

2.1 SOLAR ENERGY

The sun is composed of Hydrogen (73.46% by mass) and Helium (24.85% by mass) which actually works as a huge fusion reactor. In this reactor immense amount of energy is produced. This energy radiates out in the space in the form of visible light (about 55%) and infrared radiation (heat).Only a small fraction of energy reaches the earth surface. Travelling at a speed of 186000 miles per second sunlight takes 8.3 minutes to make its 93 million miles journey to earth. Most PV modules capture the energy contained in the visible and lower end of the infrared portion of the spectrum.

2.2 SOLAR IRRADIANCE

Irradiance is defined as the amount of electromagnetic energy incident on a surface per unit time per unit area. Sometimes it is also called radiant flux density. It is measured in W/m^2. When integrating the irradiance over a certain time period it becomes solar irradiation. Irradiation is measured in either J/m^2 or Wh/m^2.

The irradiance on a horizontal surface on earth consists of the direct irradiance E_{dir} and diffuse irradiance E_{dif}. Another irradiance component which reflects from the tilted plane is known as E_{ref}. The average ground reflection is about 20% of the global irradiance. The irradiance E_{tilt} on a tilted plane consists of three components:

$$E_{tilt} = E_{dir} + E_{dif} + E_{ref} \quad (1)$$

2.3 BANGLADESH PERSPECTIVE OF SOLAR IRRADIANCE

Bangladesh is situated between 20°43' north and 26°38' north latitude .It is seen that Bangladesh is in a very efficient position to utilize the best possible amount of solar energy. It is observed that the annual amount of solar radiation ranges from 1840 to 1575 KWh/m^2 and this is 50-100% higher than in European countries. It is calculated that total annual solar radiation in Bangladesh is equivalent to 1.03 MJ. But total yearly consumption of energy is about 0.7 MJ. It can be understood that how efficiently solar radiation can fulfill the need of energy.

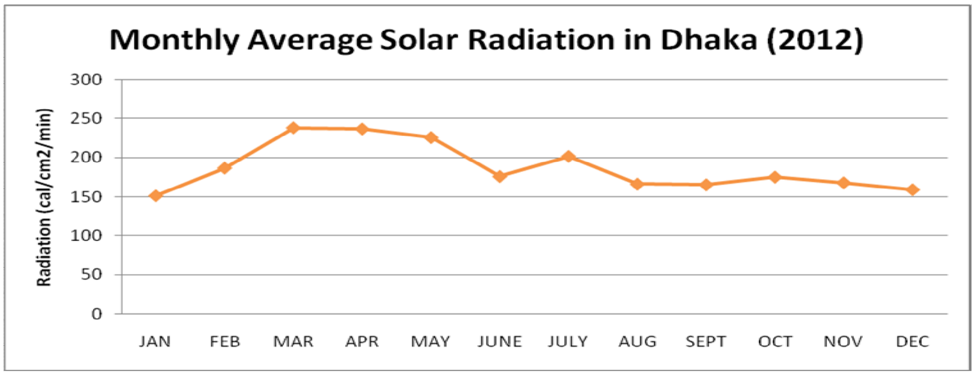

Fig1: Solar Radiation through a calendar year in Dhaka

3. SPECIFICATION OF SOLAR RICKSHAW

Measured values are taken under close observation from the workshops at Gazipur in Dhaka, Bangladesh. Following quantitative values of electric components are the rated values given by the manufacturers.

Serial Number	Features	Quantitative Value
1.	Power Source	Solar Energy and Pedal
2.	Electric Motor	500W-36V-10A
3.	Motor RPM	450
4.	Weight of Motor	2.5 kg
5.	Battery Voltage	12 V
6.	Battery Module Type	12V120Ah
7.	Weight of Battery	120 kg
8.	Total Weight of System	322.5 kg
9.	Dimension of Rickshaw	93 in X 40 in X 71 in
10.	Load	250 kg (Maximum)
11.	Power Transmission	Chain-Sprocket Movement
12.	Mean Speed of Rotor	20 mph

Table1: Specification of solar rickshaw

4. FUNCTION

Solar energy in the form of heat energy enters into solar panel. Thus it gets converted into electrical energy that travels through charge converter to charge up the batteries. Batteries are confined to work as DC voltage source. An inverter helps to convert the DC voltage to AC voltage which runs the AC compatible devices which is a motor in this case. Motor gives the power to the rear shaft of the rickshaw and thus two rear wheels make their ways on road. Motorized rickshaw has been very popular in recent times as it consumes less time to reach the destination. But the braking system has not yet been advanced according to it. Hydraulic disc brake is introduced to ensure the maximum safety of the passengers.

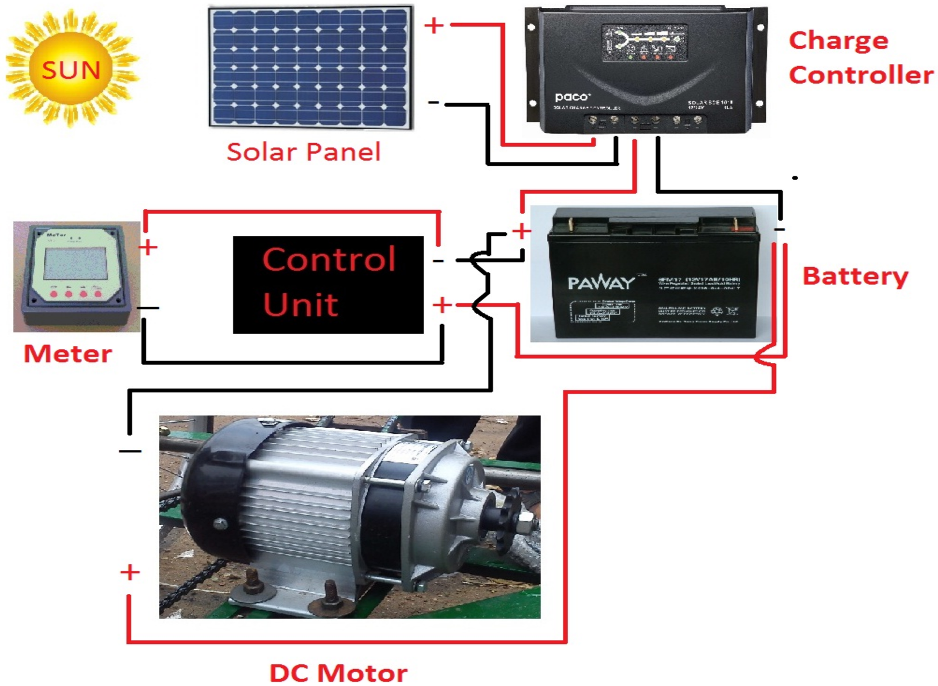

Fig.2: System Diagram

5. STRUCTURES WITH ELECTRICS

1. Solar Panel : 4 feet by 2 feet solar panel. Each of which will be 12 volt-127 W
2. Motor : A 36 volt DC motor. Current rating is 9-10 amperes.
3. Battery : Three 12 volts solar batteries.
4. Battery backup : 400 watt.
5. Running time : 4 hours.

6. BRAKING SYSTEM

Hydraulic disc brake is more essential than the mechanical one. The system operation of it makes it even more efficient in vehicle industries .When brake pedals are pressed down, pistons in the cylinder come into play by exerting some force .That causes flow of fluid from the reservoir to a pressure chamber through port. Thus an increment in pressure is occurred in the total hydraulic system. Caliper pistons then take responsibility to operate the brake pads. Brake pads operate upon the disc which makes minimum amount of friction to shut the whole movement down. Usual mechanical brakes take a minimum of three seconds to shut the rotor down from the top speed whereas hydraulic disc brakes take not more two seconds.

7. CAD MODELS

Solar panel is mounted over the hood supported by four curved cylindrical rod. This separates the hood completely from the panel which helps the puller or the passenger to operate the hood separately. Design needs to be very attractive to make it popular as a public transport. Designs signify two seated system one of which is for puller and the other is for passenger. It is seen that two rear wheels balance the whole system along with a wheel at the front. Rotor of the DC motor is connected to the rear shaft. Batteries rest under the passenger's seat. Having the batteries located over the driven wheels increases downward pressure, this is helpful for grip on loose surfaces. Electric wires from the solar panel, battery, control unit and charge controller snake through the chassis to the front. Puller unlocks the system and controls it by the meter placed at the front right corner of the rickshaw.

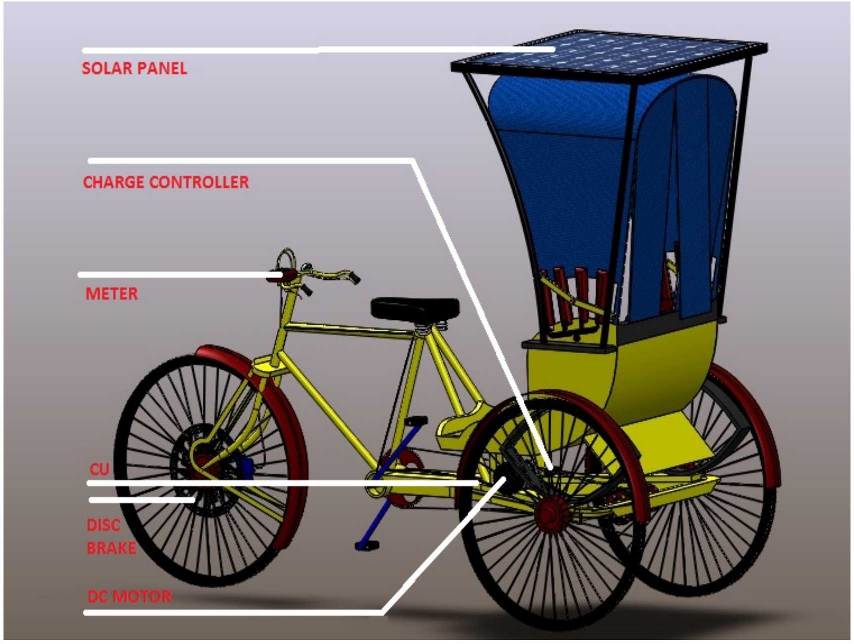

Fig3: SOLIDWORKS design of a solar powered motorized rickshaw (Isometric)

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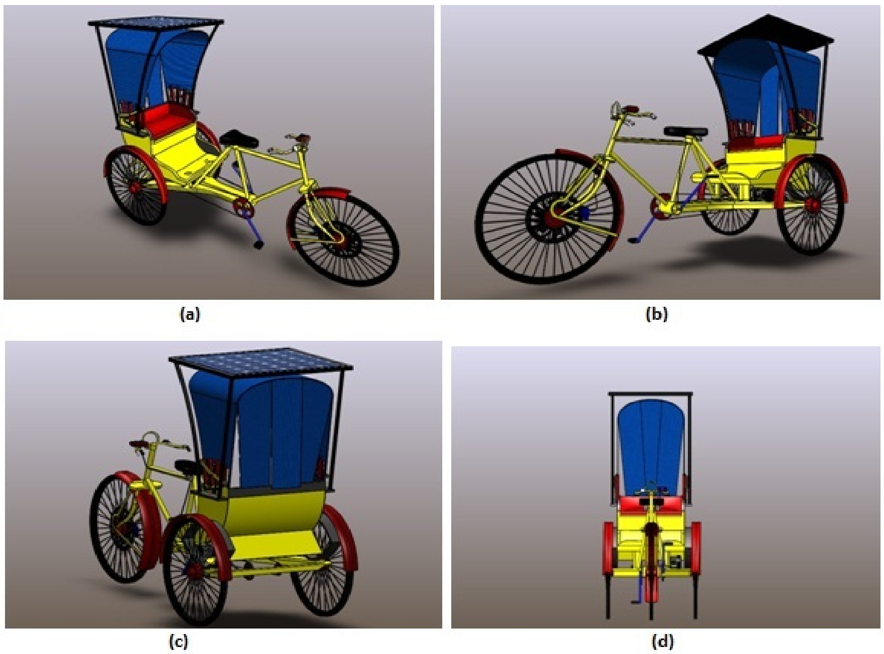

Fig4: (a) Isometric view (Right), (b) Isometric view (Left), (c) Isometric (Back), (d) Front view

Hydraulic disk brake is placed at the front wheel; this helps the puller to operate the system quite easily. Brake is chosen in such a way that ensures the most possible safety to the passengers sitting back.

8. MILEAGE

After switching the system on, the velocity starts to increase gradually. At the beginning the instantaneous acceleration was about 12960 mile/hour^2. Then it gradually lowers its acceleration till zero and gains the maximum velocity around 20mph. When the accelerator is released it takes 18 seconds to come to standstill through a gradual deceleration of 1800 mile/hour^2.

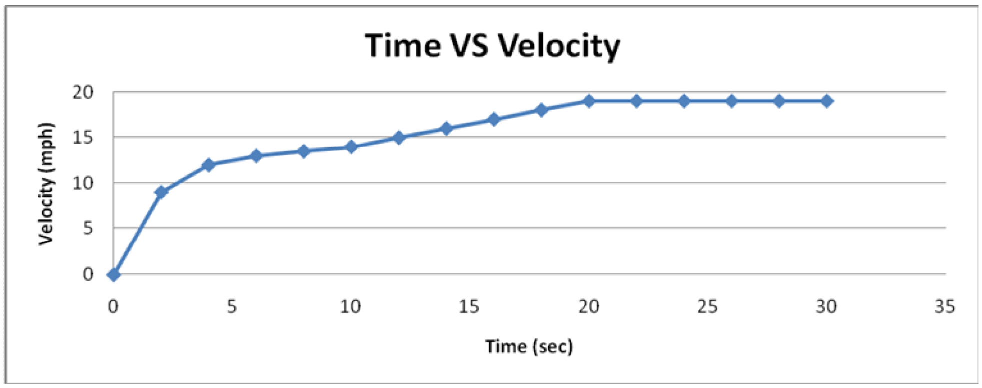

Fig5: Time VS Velocity graph (ascending)

When the brake is pressed it takes to stop with an deceleration of 1800 mile/hour^2.There is an instantaneous deceleration of 5mile/hour^2 at the the end. The deceleration in such small time interval shows the efficiency of the hydraulic brake. Friction is also responsible for the high value of instantaneous deceleration at the end.

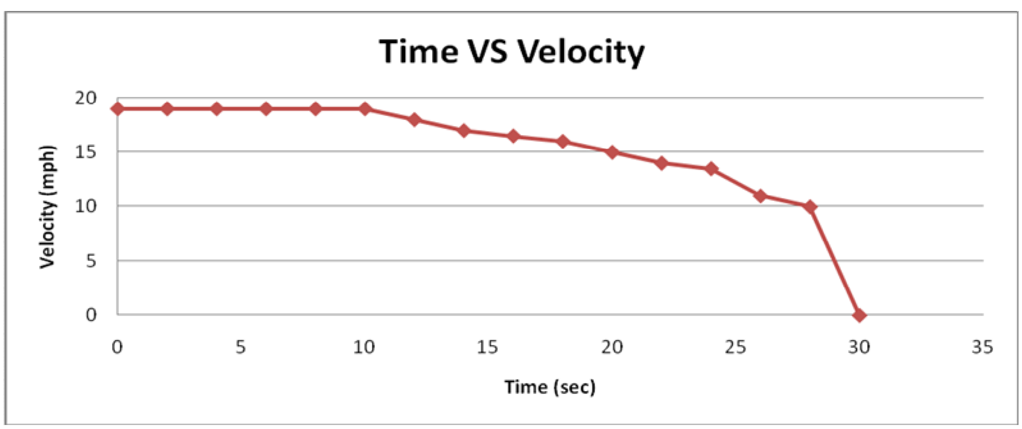

Fig6: Time VS Velocity graph (descending

9. PRECEDENCE
9.1 COMPARISONS

Solar paneled rickshaw will be advantageous in many ways. Firstly motor driven rickshaw is gaining popularity among the rickshaw pullers. It lessens their hard labor, helps them to earn more money in a way and they can have a large working hour if they want that results in a better income. But battery driven rickshaw needs a huge amount of power. It needs charging through all night and thus a great amount of power is consumed through the main grid. It costs a rickshaw puller a good deal of money each and every day. Solar power can be a remedy to it. Solar powered vehicles need no external energy source other than solar energy and storage cells. The difference between the rates of charging and discharging is manageable.

9.2 HEALTH ISSUES

As pedal driven rickshaws do not accept external forms of energy, pullers have to show a large amount of physical practice to make it run. Rickshaw pulling makes them vulnerable to diseases like Hernia which is the protrusion of abdominal contents through muscle weakness. Sometimes they become exposed to diseases like Tuberculosis. Pedal driven rickshaws need a handful of energy to operate. But malnutrition does not let them so. They get weaker quite quickly and cannot work through the day as well. At the end of the day they can hardly manage enough money to buy foods which are necessary to ensure the health of them including their family members. Solar powered motorized rickshaw utilizes the spontaneous energy from the sun. Thus pullers do not need to implement physical labor as before.

9.3 SOCIAL IMPRESSION

Pedal driven rickshaws do not permit the elderly people to drive as they are weaker and exposed to diseases. They become unproductive all of a sudden and cannot bear the needs of the family members. They become socially unaccepted. Due to this, the people living below the poverty line rises. Solar powered motorized rickshaw can make them fecund and earn their social potency back. Rickshaws are not available in the rural areas. Rural people migrate to towns to take up rickshaw pulling and attain some socio-economical mobility.

9.4 ENVIRONMENTAL IMPACT

Global warming is nowadays an alarming fact. The mean temperature has been rising due to increasing amount of carbon dioxide and other CFC gases which are hazardous to health and environment. Vehicles run by fuel emit carbon dioxide which adds temperature to the environment whereas solar powered motor driven rickshaw requires no fuel. Thus environment remains green and sound. Social awareness can be raised to promote this transportation if the people get the chance to know their responsibility over the environment.

10. ECONOMIC ANALYSIS

An analysis has been made in case of those rickshaw pullers who earn their subsistence by driving pedal driven rickshaw. A manually pedaled rickshaw can be hired for Tk 70 (US$ 0.91) for a single shift with a duration of 6-7 hours of a day. It is seen that monthly average income for such group of rickshaw pullers, taking into account all sources of income, is estimated at Tk 4,591(US$ 59.6) and the average monthly income for recent joiners is Tk 4,160 (US$ 54.03). The average monthly per capita income is estimated at Tk 1,073 (US$ 13.94). Existence of poverty within this group is nearly 18 per cent, with 3 per cent living in extreme poverty. A motorized rickshaw can be hired for Tk 350 (US$ 4.55) with duration of 5-6 hours. The amount is higher due to the cost of extensive amount of electricity usage which is necessary to charge up the batteries. But pullers can earn 3 times more than the ones who drive manual ones. A motorized rickshaw costs about Tk 62000 (US$ 805.2).Costs for solar panels for this purpose standalone varies from Tk 20000 (US$ 259.7) to Tk 30000 (US$ 389.69). Garage owners can start a business by investing money for such purpose. Banks can come forward by giving loans with less atrocious interest.

11. DISCUSSION

Scarcity of energy can be solved by renewable energy and solar energy. Solar energy is one of the best alternatives to fossil fuel energy. As we get this source of energy spontaneously, we should make the best use of it. Utilizing this power our transport system can be advanced for the sake of comfortable living. Being one of the most traditional transports solar powered motorized rickshaws has been introduced to lessen the manual labor and to solve the crisis of electricity throughout the country. The authority should take proper steps to make advancement at this very transport.

12. CONCLUSION

This paper generates a concept of utilizing solar power in an efficient way along with present transportation system. Through this paper researchers may come to know the advantages of it which eventually paves the way to its public acceptation. By further research, features of solar powered motorized rickshaw can be advanced with new mechanical designs and a system with better mileage. Thus this framework can be applied to the world of practice by quenching the thirst of energy.

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