Angat – Pampanga River – Manila Bay Ecosystem Renewable Energy and Fuel Cell Research and Development Project

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ABSTRACT

The main objective of this research and development project is to utilize anything that has kinetic energy or state variance in the ecosystem for the generation of electricity. We have been largely dependent on fossil fuel for our energy needs in the form of electricity and fuel for our homes and industry. It's utilization for energy generation has resulted in atmospheric emissions which have contributed largely to global warming and climate change. Bulacan State University (Bustos Campus) is located a few hundred meters from the banks of the Angat river. Upstream, the river primarily provides water for Metro Manila and hydro electricity. After it is used for irrigation at the Bustos dam area, it simply drains idly to Manila Bay. The Angat-Pampanga River is the country's second largest river system. An integration system that combines wind. bio mechanical forces or solar energy may be set up to make a community mini power grid to serve the needs of people living along the river or sea coast. Each community is envisioned to have a degree of self reliance in energy. This paper also presented a prototype of the custom built biome reactor, a generator, which is to be deployed to generate electricity from the river systems ecosystem renewable sources.

<u>Expected Results</u>

- Research in the area of the design and fabrication of indigenous generators/alternators for harnessing water, wind, solar and bio-mechanical forces in the ecosystem
- Low cost electricity from water, wind, solar and bio-mechanical sources to augment the power needs of river side communities
- Hydrogen fuel cells for home and industrial applications
- Computer profiling and databasing of physical, chemical and biological properties of water and other natural resources along the water ways.
- Ecological balance in the watershed, riverside and seaside communities through environmental protection policy recommendations
- Human resource development plan through technology and ecology education among the communities which will participate in the project

Keywords: renewable energy, hydroelectricity,hydrogen fuel cell, biome reactor

REVIEW OF LITERATURE

There is growing interest world wide in the development of renewable energy sources for electricity and fuel. The following are the reviews in the Philippines, Venezuela, Norway and the US. The US, Venezuela and Norway are considered important due to the fact that they are oil producing nations, yet they make considerable investment in renewable energy research and development.

The Philippine Setting

The Philippine Renewable Energy Act of 2008 was signed into law December 16, 2008. It is an act promoting and enhancing the development, utilization and commercialization of renewable energy resources. The harnessing and utilization of renewable energy (RE) comprises a critical component of the government's strategy to provide energy supply for the country. There is considerable resistance to the further development of large hydropower projects due to the potential for upstream flooding, destruction of agricultural areas and animal habitat and disruption of communities in the affected areas. The logical next step would be to focus on smaller, more manageable run-of-river projects. However, such a shift will not come without considerable challenges such as a decrease in new capacity given the smaller scale of the projects, intermittent supply of power and considerable decrease in power generation during the summer months. here is also a need to develop and commercialize suitable micro-hydro technology in the Philippines even as hydropower technology for large and small projects is proven and mature. The Philippines remains to be **dependent** on imported electro-mechanical equipment for micro-hydro projects. The costs of these equipment vary based on kilowatt capacity. For instance, a 5-kW equipment with controls and metering devices cost US$11,000 while a 100-kW equipment costs US$64,500 (DOE : 2010).

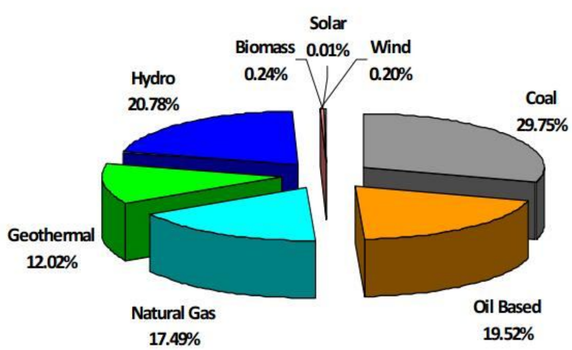


Figure 1. Philippine Energy Profile

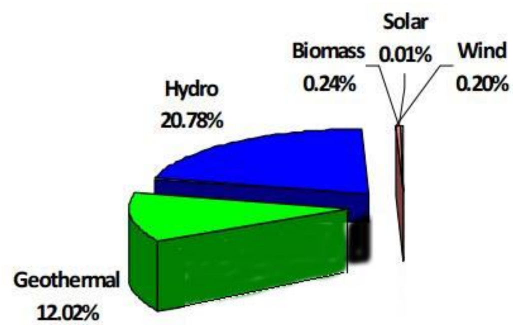


Figure 2. Possible profile in 50 years

The above shows that the Philippines is 66.76 % dependent on non renewable resources such as coal, oil and natural gas for the generation of power. (DOE: 2011). We import most of our coal and oil to power our electric plants. We do not import natural gas now. We have current reserves estimated at 3.9 trillion cubic ft.. Domestic consumption on the other hand is 102 billion cu. ft. per year. Unless new natural gas reserves are found, at the current rate of consumption, natural gas will last 38.23 years.

If no new natural gas reserves are found and if oil and coal becomes unavailable, the Philippines will be forced to look for alternative sources of energy to compensate for the loss in the other fuel sectors.. We need to tap renewable energy sources like geothermal, hydro, biomass, solar and wind to compensate for the possible loss of supply or uncontrolled increase in the prices of fossil based fuels.

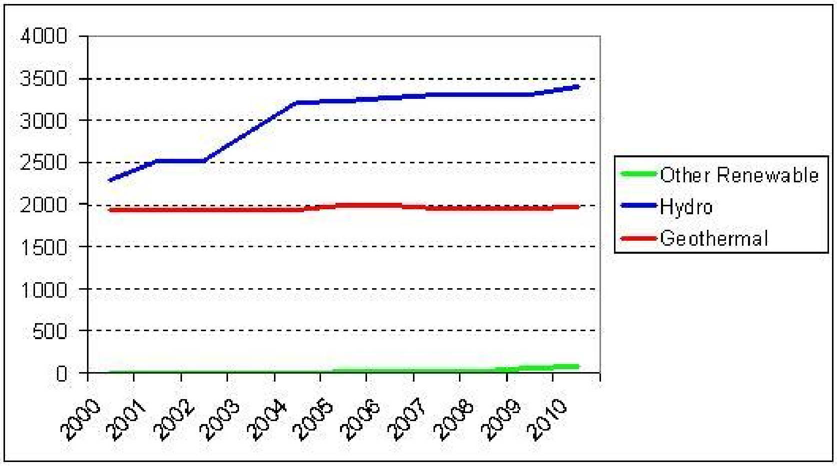


Figure 3. Philippine Renewable Energy Sources (33.24%)

The challenge facing the Philippines now is to generate more power from these sources. The rate of increase of utilization and percentage share must increase dramatically and agressively in the next years. Figure 3 shows that in the past decade there is no significant increase or development in these sectors.

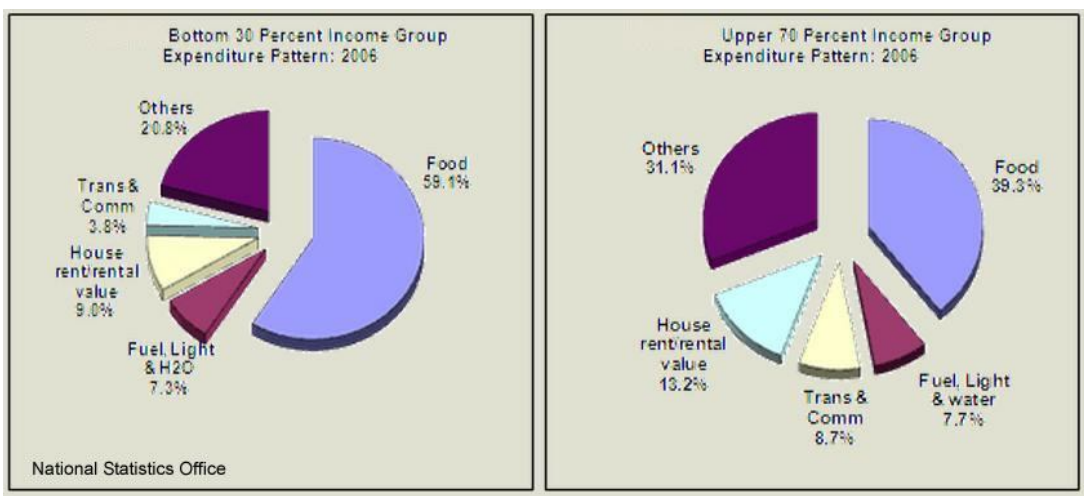


Figure 4. Filipino Family Expenditure Pattern

The Philippines now has a population of 101.8 million (ranked 12th) with a growth rate of 1.903%. Our per capita GDP is $ 3,500 (ranked 162th). The per capita GNI $ 3,950 (ranked 118th. Those living below poverty line :is 32.9% or 33.5 million. In the U.N. HDI we are ranked 112th. Comparatively, the U.S. per capita GDP is $ 47,200, Japan per capita GDP is $ 34,000 and Norway per capita GDP is $ 54,600 (CIA: 2011).

An energy crisis if not prepared for now by the Philippines will worsen the current economic situation in the country with the lower 30% of the population taking the hardest hit.

The Latin America / Venezuelan Setting

In Latin America, R&D programmes on hydrogen energy are scarce, with Brazil the leader in research on H2 energy pro-duction from renewable sources, in particular hydroelectricity. Venezuela itself has been, historically, a large-scale pro-ducer and exporter of fossil fuels. However, there is a large sector of the rural population that has no permanent energy supply, as it is both difficult and costly to supply them from the traditional energy system. In this context, it is particu-larly important to develop a solar-hydrogen energy system in Venezuela. The introduction of such a system would enable these isolated and underprivileged rural areas to gain autonomy in terms of energy, improving quality of life and stimulating the local economy because it is labour-intensive, and promoting sustainable development (Contreras: 2007).

The US Hydrogen Fuel Cell Research Project

Hydrogen is an energy carrier, not an energy source, meaning that it stores and delivers energy in a usable form. Using hydrogen as a form of energy can not only reduce the dependence on imported oil, but also benefit the environment by reducing emissions of greenhouse gases and criteria pollutants that affect our air quality.

The US President's Hydrogen Fuel Initiative accelerates the research and development of fuel cells and hydrogen production, storage, and delivery infrastructure technologies needed to support hydrogen fuel cells for use in transportation and electricity generation. Under the President's Hydrogen Fuel Initiative, the DOE Hydrogen Program works with industry, academia, national laboratories, and other federal and international agencies to overcome critical technology barriers, address safety issues and facilitate the development of model codes and standards, validate hydrogen fuel cell technologies in real world conditions, and educate key stakeholders who can facilitate the use of hydrogen and fuel cell technology (US DOE: 2010).

Norway

The electricity sector in Norway relies predominantly on hydroelectricity. A significant share of the total electrical production is consumed by national industry. The share of renewable energy in the electricity sector is 98%, comparatively the share of fossil fuel is 1% (Norway Statistics: 2011)

METHODOLOGY OF THE STUDY

This study focuses on community based power generation and distribution. An assessment of the families living in these target communities was done. One hundred people representing families living in communities along the river were interviewed. This gave the researcher a statistical measure of the demographics and characteristics of the communities which are the primary participants and beneficiaries of the present study. SPSS regression and descriptive statistics were used in the analysis of the data coming from the communities.

Research was also done on the technological aspect of generating electricity and energy from the river, wind and biomechanical sources. The physical and chemical properties of such sources were also studied. Then methods of how that electricity can be utilized for an electrolyzer for the hydrolysis of water to produce hydrogen for possible fuel cell production. Research was also done on how excess electricity not used for hydrolysis may be used to supply power to homes in the communities. Utilizing the inputs from the community and technology research, design and fabrication were done to create the system prototypes. Empricial tests were then used to assess the feasibility of the project.

ANALYSIS, INTERPRETATION, PRESENTATION OF THE RESULTS OF THE STUDY

The following analysis becomes relevant in the light of the intent of the project to encourage community based power generation and distribution among riverside and coastal communities.

Family Profile of Respondents

Table 1
Family Profile of Respondents

	Mean	Interpretation
Family Members	5.27	Size of family
Income	2.41	5,000 to 10,000 pesos /month
With Work	2.28	43% employed
No Work	3.02	57% unemployed
Source of Income	2.91	Fishing or Employed

The average family size of the respondents is five, which means that families has an average of three children. Income earned on a monthly basis is 5,000 to 10,000 pesos. The primary source of income is either fishing or employment in a nearby office or business establishment. This figures would indicate that there is a probable need for additional sources of income for the family, as shown in the table, at least three members of the family which are able to work are unemployed.

Consumption Pattern of Respondent Families

The consumption pattern as indicated in the next table shows how the families are utilizing their income. Priority is given to education, food / water, house rent and electricity. The following table shows the consumption patterns of riverside families.

Table 2
Family Consumption Pattern

Rank	Expenditures	Mean
1	Education	3.05
2	Food	4.33
3	House Rent	4.56
4	Electricity	4.68
5	Clothing	5.03
6	Health	5.49
7	Cellphone	7.57
8	Water	7.86

The respondents ranked the eight consumption activities from 1 to 8 with 1 as the most important and 8 as least important. The mean of their answers were obtained the get their ranked consumption pattern. Clothing, health services, cellphone/telecommuncations and water for drinking were the next group in the order of their importance. Electricity consumption ranked number 4 shows the importance of the use of energy in the household.

Proximity to River

Table 3
Proximity to the Angat River

Proximity to River	Home Location
0.5 kms	24.20%
1 km	20.20%
> 1.0 km	55.60%

Twenty four percent of the respondents live very near the river. 20% lives within one kilometer of the river and the rest lives beyond the one kilometer mark away from the river. This is important in the assessment of the benefits derived from the river and river resources utilization, particularly for power generation.

River Resource Utilization

Table 4
River Resource Utilization

ACTIVITY	USAGE
Farming/Agriculture	29%
Drinking	22%
Laundry	21%
Food Source	19%
Income/Fishing	4%
Gravel/Sand	3%
Fish Pond	1%
Waste Dump	1%

The previous table, would seem to indicate that farming and agricultural use is the major mode of utilization, then drinking, laundry and as a source of food. Drinking as an answer were clarified by the researcher by going back and talking to the respondents asking them if they were really drinking water from the river. The answer given was, they thought that the water from local water utilities or mineral water refilling station were coming from the river. It was their perception that the water they are drinking somehow came from the river.

Respondents General Perception on River

Table 5
Perception on River Resources

Perception	Mean	Values Range	Interpretation
Benefits	1.74	1-Very Beneficial 2-Beneficial 3 - None	Beneficial
Dangers	1.64	1-No Danger 2-Dangerous 3-Very Dangerous	Slight Danger
Water Quality	2.66	1-Very Clean 2- Clean 3- Slightly Clean 4- Dirty 5- Very Dirty	Slightly Clean

The respondents in the study indicated that the river is beneficial. It has a mean average of 1.74 interpreted as beneficial. The respondents also viewed the river as slightly dangerous with a mean of 1.64. Those who live near the river are aware that sometimes the river overflows its banks during rainy season, when the upper river dams reach their spilling level. The slight danger indicates that the respondents have learned to adjust to the dangers posed by living near a large body of running water. In terms of water quality, the respondents viewed the river as slightly clean or less polluted with a mean of 2.66. This would indicate that the water from the river is still safe for domestic usage.

Ecosystem Energy Sources Profile for Angat River

Table 6
Renewable Energy Source Profile

Potential Sources of Renewable Energy	**Values**	**Interpretation**
River	60 cu.meter per second 3.91 m/s	Micro Hydro Projects
Wind	5.8 to 10.4 km/hr (1.61 m/s to 2.88 m/s)	Not suitable for power generation

According to NREL (Natioal Renewable Energy Lab), rural power applications are usually viable at lower wind speeds (5 to 6 m/s), and in some cases, at wind speeds as low as 4.5 m/s. These are the main sources of energy which may be tapped for the generation of electricity for the community.

Multiple Regression Analysis

Table 7
Multiple Regression of the Benefits
Derived from Angat River Resources

Predictors/Independent V.	**Beta**	**Sig. t**
INCOME	-0.007	0.948
PROXIMITY TO RIVER	-0.239	0.010 **
PERCEIVED DANGER	0.064	0.525
PERCEIVED WATER QUALITY	0.090	0.373
** p < .01 level of significance		
Adj. R Square = 0.029	F = 1.739	

Multiple regression analysis shows the benefits derived from the river may be affected or influenced by the level of family income, proximity to the river, perceived danger and perceived water quality. The model shows that the adjusted R square is 0.029 which means that 2.9% of any change in the perceived benefits come from the factors used in our study, the rest of any variance come from factors outside our model. One predictor or independent variable has a highly significant effect on the benefits acquired from the river, proximity to the river has sig. T of 0..010 interpreted as highly significant. The beta of -0.239 means that any change in proximity to the river has an inverse effect of - 23.9% on the benefits acquired from the river. Statistically this would mean that the relationship is inversely proportional. As the respondents live away from the river the perception of its usefulness diminishes.

Analysis of the Findings of the Study

The results would indicate that the respondents view the river as a potential source of benefits for their families. Those who live near the river are aware of its dangers but more so the potentials of the river. The respondents view the river as a potential economic ally not an adversary which will threaten their lives. The study also revealed the economic and financial difficulties the families are in. They are still using the river as a potential source of food and income. Fishing and agriculture are still viewed as a primary economic activity supported by the river. This would seem to indicate that the respondents are open and positive to any usage of the river which will help them economically or financially. Their perception of the river as slightly clean indicates that they would be adverse to pollution of the river. When they indicated that they thought drinking water comes from the river and that they are doing laundry in the river, indicate that they would prefer to maintain a certain level of ecological balance in the river.

These findings have significant influence in the product development stage of the study.

- Any renewable project to be based on the river must maintain ecological balance and not pollute the river
- There is an indication that people will participate as long as it will help them economically either through job creation or reduction of the cost of electricity used for their homes
- Any project should also consider the danger imposed by variances in the level of water in the river, when they indicated that it is slightly dangerous, it means that there is unpredictability in the level and speed of the current all year round and it must be considered in project design
- The slightly clean water quality would indicate that the water in the river is a potential source of water as raw material which may be used for the generation of hydrogen for fuel cell research and production.
- The research reinforced the idea that the four key elements for the project is present in the community and the river ecosystem for the generation of renewable energy

    1. KINETIC ENERGY - running water from the river
    2. WIND ENERGY - along the river river banks
    3. BIOMECHANICAL ENERGY – from the communities
    4. SOLAR - from sunlight

The results of the research on the people living near the Angat river system showed to indications of resistance or any negative factors that would prevent successful research and development of renewable energy resources from the river.

Initial set of data from the ecosystem would indicate that the run of the river is good for micro hydro applications. Wind data is not encouraging since the low density and velocity of the wind in Bulacan area is not suitable for wind farms to generate electricity.

This necessitates fabrication of new generator set models which may be used to harvest energy from the Bulacan area ecosystem. No water or wind turbine design will be suitable to harness energy from our area. That is if we will be using imported generator systems. Hence, the heart of this project is a new generation of generator designs for our particular needs in the area. Thus, this has given birth to the BIOME REACTOR.

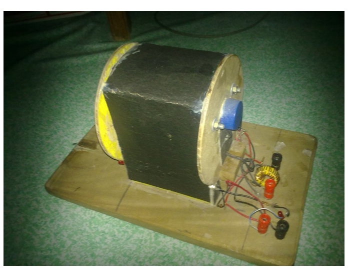
Power Generation Unit – "THE BIOME REACTOR"

The power generation unit, a.k.a. **BIOME REACTOR**, is the heart ot the system. This is one of the seven modules or units of the entire production design. It integrates and converts water, wind energy and biomechanical kinetic energy to electricity which may be used for water hydrolysis and domestic consumption.

Custom built Power Generation Unit

Input : kinetic energy from water, wind or biomechanical sources
Output: scalable AC / DC voltages

Product/Prototype Specifications



- magnet wire & permanent magnets design
- **0.001133** horsepower input to power the machine (river, wave, wind or biomechanical energy sources) approx. equal to the power needed to move 65 grams a distance 2 centimeters per second.
- less than 200 – 300 rpm for full electrical generation capacity
- fractional movement power generation capability
- 2.62 watts output (with load), 3.22 watts (no load)
- maximum of 28.5 volts, 0.092 amperes output
- upward and downward scalability of design
- multi terrain and multi mode site installation

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