Renewable Resources in Zero Energy Buildings with Economical and Environmental Aspects: A Case Study in Odisha

ArchanaPatnaik[1], Md Asif Akbari[1], Dr. P.C Saha[2]

Abstract: A net zero energy building can be defined as a building which generates as much energy through renewable sources as much as it consumes from the Grid. To achieve this purpose, Renewable Energy Sources like Solar Energy, Wind Energy, Biogas Energy and Geo thermal energy have to be harnessed properly so that the energy borrowed from the Grid can be replenished by these sources. In this paper, an attempt has been made to compare the economic and environmental aspects of energy generated from these resources in Od-isha and to tell us which of the above mentioned non-renewable energy resource is the best suited based on the parameters of economic and environmental feasibility. As Odisha is developing at a good rate, it becomes absolutely essential to look for renewable energy resources which will serve as the backbone for ZEB. Our study shows us that Solar, Bio-gas and Wind energy will be the major contributor of renewable energy for ZEB's owing to their widespread availability.

Keywords: *Zero Energy Buildings, Solar Energy, Wind Energy, Geo-thermal Energy, Bio-gas Energy.*

Introduction

A net zero energy building can be defined as a building which generates as much energy through renewable sources as much as it consumes from the Grid. Though the definition of Zero Energy Buildings (ZEB's) is still debatable, one may assume the above mentioned definition to simplify the problems and to focus more on how to make a building self-energy sufficient through renewable sources [1]. The emission of greenhouse gases in harnessing of non-renewable energy adds to the problem of global warming, thus making it all the more important to renew our focus on alternative energy sources such as renew-able sources because

these forms of energy don't contribute to pollution . Buildings constitute a major chunk in producing Green House Gases directly or indirectly and hence the need of Net Zero En-ergy Building becomes a vital importance. With this comes the importance of advocating the use of Renewable Energy. During the last 20 years more than 200 reputable projects claiming net zero energy balance have been realized all over the world which extensively utilise the non-renewable energy sources to earn the tag of ZEB [2].With the increase in availability of efficient technical solutions, bigger and more energy intensive building ty-pologies have been built as Net ZEBs since 1998. The Sun Carrier Omega Net Zero En-ergy Building (NZEB), located in the central part of India, in the city of Bhopal, the capital of Madhya Pradesh is an example of ZEB in which the major source of energy is solar and wind energy. The focus has been due to threatening resource shortage, climate protection as well as the avoidance of rising energy costs [3]. The plan of the Odisha Government to convert Jagannath temple, Konark temple, State secretariat and High Court as zero energy buildings is a step in the right direction to exploit renewable energy resources and only advocates the need to undertake studies related to utilization of non-conventional energy resources in ZEB.

I Objective of the study

In this paper, an attempt has been made to compare the economic and environmental as-pects of energy generated from these resources in the state of Odisha.

II Components of Zero Energy Buildings

Paying close attention to the building's orientation on the site, and window and door placement can help in achieving proper ventilation. Roof vents help prevent the built-up of moisture and heat. Trees help the performance by providing an obstacle from the incoming cold wind and by providing shade in the summer. Thus the performance of passive housing design depends upon proper orientation of buildings with respect to trees as they can block the incoming solar radiation required to heat the house.

A logical solution to create more comfortable air temperatures inside and outside of build-ings is to add green plants to façades and roofs, t hereby using the natural processes of the plants to create comfort.

Figure 1: Green wall **[4]**

Glazing can be used as an outer covering of the wall to provide the greenhouse effect. The concept of super-insulation can be done by adding multiple high performance insula-

tions by panelized or site casted wall systems to make a building air-tight, to eliminate thermal bridging and offering sound structural performance.

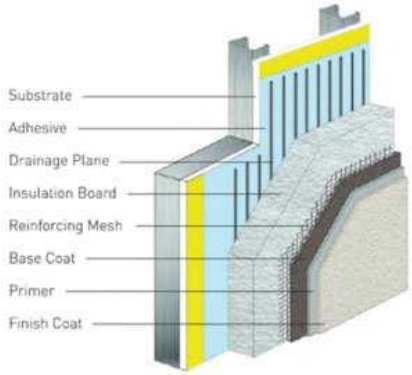

Figure 2: Exterior Insulation Finishing Systems [5]

Roofs can be improved by adding thermal insulation and using light coloured roof paint. It was determined that the lighter coloured surfaces such as white, off-white, brown and green yielded 9.3%, 8.8%, 2.5% and 1.3% reduction in cooling loads compared to an black-painted LASRS surface[6].

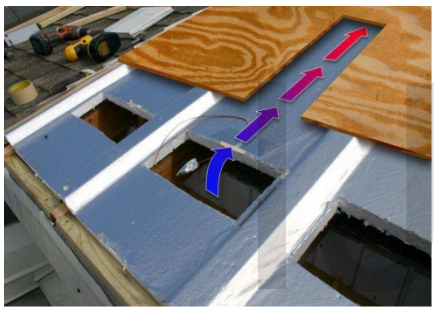

Figure 3: Naturally Ventilated Sloped Roofs.

A building roof that is either fully or partly covered with a layer consisting of a water-proofing membrane, growing medium and the vegetation layer may also be a good source of passive cooling.

Building should effectively allow daylight to penetrate deep into highly occupied spaces, and employ a high-tech sensory lighting system that adjusts artificial lighting output based on the amount of daylight present by using occupancy sensors. HVAC equipment, natural ventilation, evaporative cooling etc. can be used to make 30%-40% more EE.

III Sources of Renewable Energy

As green building practices become more common in the global construction industry, the goal of designing zero energy buildings has emerged as the next frontier. Its impact in reducing Green House Gases and thereby Global Warming is going to be second to none. Today, research scientists, architects and owners observe that a program that is oriented to sustainable development from the outset may enable us to discover techniques that will bring environmental and social benefits without additional costs. For example, by simply orienting a building to exploit its windows and capture passive solar heat as much as pos-sible, promoters and architects can create their designs with a mind to consume less en-ergy, increase the sustainable development aspects and improve daylight penetration. Apart from these natural resources we can make the zero energy building by utilising the following various forms of renewable energy:

A. Solar Energy

Homes employ solar thermal and solar photovoltaic (PV) technologies to produce the re-quired amount of energy which can be utilized for a year. Several design guidelines exist that help designers to determine the orientation of buildings along with the best blend of thermal mass and windows. In addition, numerous components are necessary to achieve the net zero energy target, including solar thermal collectors, PV, and efficient HVAC sys-tems.

(i) Photovoltaic

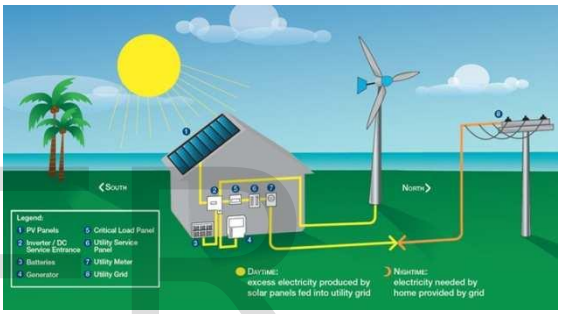

Figure 4: Use of PV panels on the roof

The photovoltaic convert the light energy directly into electric energy by photoelectric effect at the atomic level. The photons of light energy are converted into electrons and thus electricity is harnessed. In the past two decades, research and development have improved the efficiency and reliability of photovoltaic and have reduced the cost of photovoltaic electricity. India, due to its geo-physical location, receives solar energy equivalent to nearly 5,000 trillion kWh/year which is equivalent to 600 GW among which alone OD-ISHA is having is gross solar capacity of 40000 MW. The estimated annual solar power capacity of different districts of ODISHA is shown below.

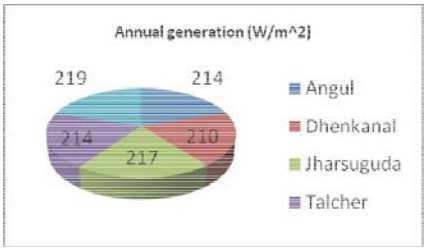

Figure 5: Annual solar power generation from 1MW power project in different districts of ODISHA.

Based on the studies conducted by different agencies the following upcoming projects are considered which are shown in the below chart.

Figure 6: Upcoming solar projects in ODISHA.

A. Wind Energy

Wind power is a clean energy source that can be relied on for the long-term future. A wind turbine creates reliable, cost-effective, pollution free energy. It is affordable, clean and sustainable. One wind turbine can be sufficient to generate energy for a household. Be-cause wind is a source

B. Wind Turbines

Wind turbines are mounted on a tower to capture the most energy. At 100 feet (30 meters) or more aboveground, they can take advantage of the faster and less turbulent wind. Tur-bines catch the wind's energy with their propeller-like blades. Usually, two or three blades are mounted on a shaft to form a rotor. When the wind blows, a pocket of low air pressure gets formed on the downward side of the blade. The low-pressure air pocket then pulls the blade towards it, causing the rotor to turn. This is called lift. The force of the lift is actually much stronger than the wind's force against the front side of the blade, which is called drag. The combination of lift and drag causes the rotor to spin like a propeller, and the turning shaft spins a generator to make electricity. This electricity is then used for our household purposes in Zero Energy Buildings. In windy countries like India, economic factor kept aside, wind turbines produce more energy than the solar panels and this can be used at night also.

In the state of ODISHA the three major companies Suzlon, Regan and C-wet have con-ducted various surveys regarding scope of wind power generation in ODISHA and given a clearance for the following sites.

Figure 7: Proposed wind energy sites in ODISHA.

Among which Suzlon Energy, a wind power major in the country has been given clearance to set up 99 MW projects in Koraput and NabarangpurDistricts [7].

A. Biogas energy

Biogas typically refers to a gas produced by the biological breakdown of organic matter in the absence of oxygen. Bio-gas originates from biogenic material and is a type of bio fuel.

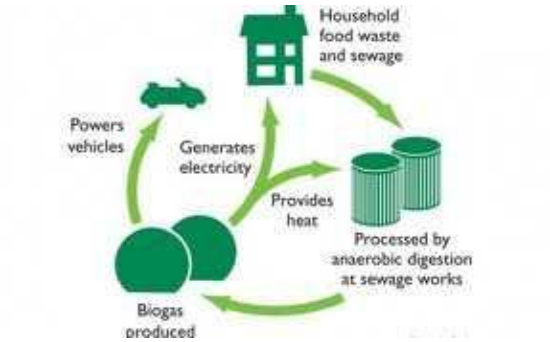

Figure 8: Cycle of biogas energy

i) Scope of Bio-Gas Plants in Odisha

The basic feed material for, bio-gas plants in India has been considered to be cattle dung which is available in plenty. The estimated cattle population of 238 million in the country has the potential to produce about 1000 million tonnes of dung every year. According to an estimate (1977) of Khadi and Village Industries Commission (KVlC), bio-gas plants of average family size may provide energy equivalent to 5432 million liters of kerosene which in terms of current prices may cost well over Rs. 1000 crore per annum. The scope for bio-gas plants in India, therefore, is substantial if the benefits accruable from such plants are exploited by people living in rural areas. The state has a large livestock popula-tion. According to the latest livestock census the total livestock population of Orissa was over 23 million. Cattle are the primary livestock assets, followed by goats, as they account for nearly 60 per cent of the total livestock population. The population density of livestock in Orissa is about the same as in the rest of the country and hence there is no dearth of cat-tle dung as well. Biogas technology is feasible in principle in most climatic zones under all climatic conditions, where temperature or precipitation is not too low. As it is Odisha re-ceives high intensity of sunlight and good amount of rain throughout the year which makes it all the more favorable for Biogas production. The gross potential of Biogas in Odisha is estimated to be 1700 MW whereas its Feasible Potential is 750 MW. Also, the state has to mandatorily implement Renewable Purchase obligations (RPO) for which the figure lies at 117 MW for Biomass. This means that the state will try its best to exploit biomass and aid in production of biogas to achieve its RPO. The huge potential of the state in the produc-tion of biogas is also a good sign for clean and green energy.

Figure 9: Boxes in green signify the Upcoming Biomass Power Projects in Odisha.

According to National Biogas and Manure Management Programme (NBMMP), State-wise estimated potential of Biogas for installation of family type Biogas plants for Odisha is 605000 units. The state's Cumulative Physical Achievements as on 31-3-2011 lies at 245868 units and still a lot of work remains to be done. This only shows that utiliza-tion of biogas for production of energy is fast becoming a trend in Odisha and can be tapped upon for ZEB as well.

A.Geo Thermal energy

B. Heat from the earth can be used as an energy source in many ways, from large and complex power stations to small and relatively simple pumping systems. This heat energy is known as geothermal energy. Below the Earth's crust, there is a layer of hot and molten rock called magma. Heat is continually produced there, mostly from the decay of naturally radioactive materials such as uranium and potassium. It is considered as a clean, renewable energy resource because the heat emanating from the interior of the Earth is essentially limitless. It is estimated that just 1 per-cent of the heat contained in the first 10 kilometers depth from of the earth's crust is equivalent to 500 times the energy contained in all of the earth's oil and gas re-sources[12].

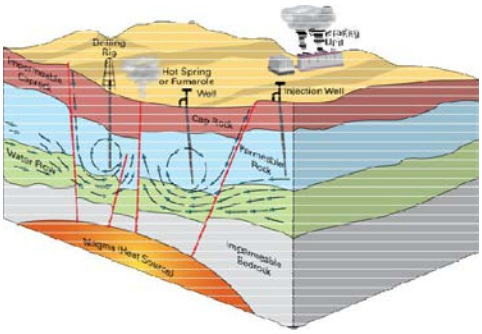

Figure 10: Geothermal energy concept

Because geothermal power does not rely on variable sources of energy, unlike, for exam-ple, wind or solar, its capacity factor can be quite large – up to 96% has been demon-strated. . It is currently estimated that the geothermal potential of the world for electricity production is 12,000 TWh/year. The geothermal belt of Bakreswar Province (north), Go-davari province (south), Sonata province(west) in the state of ODISHA display heat flow values between 104 to 280 MW/m2 with a thermal gradient of about 60 to 90 °C/km which is sufficient for the geothermal power generation.

I Comparison among the renewable energy sources

While it may appear that all the renewable energy solutions have advantages along with quite a few disadvantages, it's important to consider a few global trends. The cost of renewable energy resources is steadily decreasing as technology improves the performance per rupees ratio and greater demand lowers production costs. In an effort to assess the real viability of alternative energy solutions on a large-scale, it is useful to compare the cost per kilowatt-hour (kWh) for each of the five most common types of renewable energy resources particularly available in ODISHA region. The cost in rupees per unit includes ini-tial capital costs (amortized), maintenance, fuel and waste disposal costs. Tax incentives are built into the calculations.

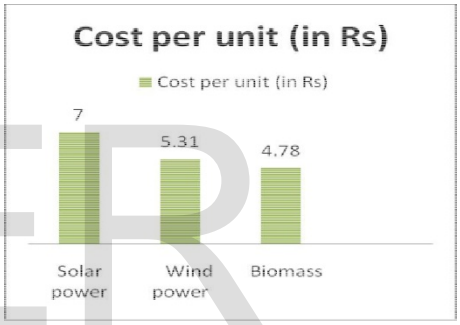

Figure 11: Cost per unit of different renewable energy sources in ODISHA.

As Orissa contributes 25% of Eastern India's installed power capacity by established cap-tive power plants of companies like Vedanta and NALCO but still just 5% of total energy comes from renewable sources upto 12.6 GW of power[13][14].Among those energy sources due to the hot climatic condition in ODISHA the state is having gross solar energy potential of about 40000 MW. The rest renewable sources capacities are shown below.

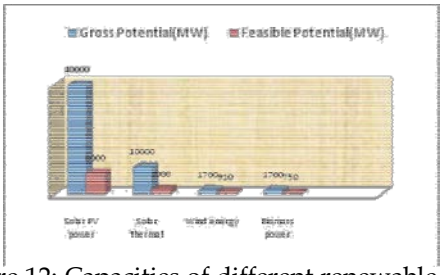

Figure 12: Capacities of different renewable energies in ODISHA.

Solar power is most available energy source in the state but it is costlier than other sources. The high cost of solar energy is largely due to the high price of silicon crystals. Silicon prices continue to rise as their widespread production applications are leading to supply shortages. However, newly developed

alternative materials could bring the cost down below3.07/kWh in the near future. High- Renewable scenario variant showed that PV and STE together could provide up to 25% of global electricity by 2050[15].But the fact is that the solar energy conversion efficiency of plants is low, in practice less than 1 percent. Consequently relatively large land surfaces are required to produce a substantially amount of energy. According to the Ministry of New and Renewable Energy (MNER) India's po-tential wind power is estimated at 45195 MW among which ODISHA shares just 1700 MW. Wind energy is substantially more mature and developed than solar (especially me-dium to large scale solar). A typical (750 kW) wind turbine provides enough power for 328 typical (non-electric heating) homes. The initial investment for the machines and in-stallation is quite high, and maintenance, when required, can also be costly[16]. However, various studies have concluded that over the life of its usage, a wind turbine costs are ap-proximately the same as coal, natural gas, and nuclear-based electricity and lower capital costs and continued increases in wind turbine productivity will drive down the cost level of wind energy. Wind power can reduce pollution generated by fossil fuels such as coal, oil, and gas.

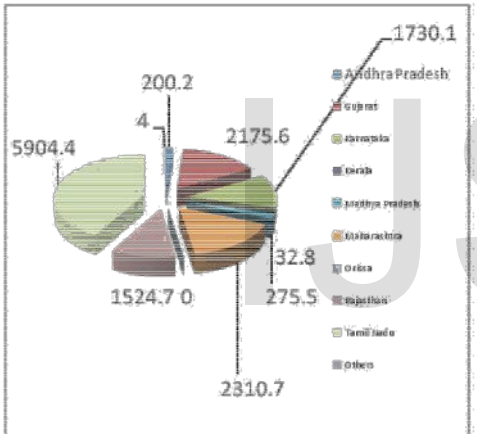

Figure 13: Trends in wind energy capacity state wise[17]

[18]. ODISHA is having a feasible biogas potential of 750 MW with the Current installed capacity being 1.48MW. Also, family biogas plants are being installed at a massive scale in Odisha which only goes on to say that biogas production is only going to get cheaper in the coming days. Economically, biogas systems have been shown to be cost-effective and environmental friendly as the generation cost of biogas is similar to that of wind [19]. Presently the cost of electricity produced due to biogas lies at Rs. 4.78 per KWh which is the most economical of all the renewable energy resources.

In case of Geothermal energy, ODISHA is having a gross capacity of 400 MW yet the state is not having a single working geothermal power plant. A Geothermal power plant can power entire cities while a smaller power plant can supply a rural village. Geothermal energy does not require as much land to produce its power as do other clean energies. A geothermal power plant only requires roughly 10 percent of the amount of land needed by a solar farm to produce the same amount of energy(EIA). An analysis shows that geother-mal and wind energy could actually become more economic than coal in the next 15 years[20].

IV Conclusions

The comparison of various forms of renewable energy resources show us that all forms of energy sources are sufficient to produce energy for our daily needs; the difference being the amount of energy that each source can produce under limited costs. Solar energy is the most widely used form of renewable energy presently but it is costly as well. The cost in volved in generating wind energy is high initially but the amount of energy it generates in short span of time is commendable and can be developed as a source of energy which can overtake solar energy in being the most popular and widely used. Also, it can be exploited to generate more energy as compared to solar energy. Biogas can also be used for our en-ergy needs but its only constraint is that it needs huge quantity of waste and it is also not feasible everywhere. Geothermal energy is an upcoming form of energy having great po-tential to generate electricity but a lot of research still has to be done to tap into its full po-tential. Thus, after comparing all forms of renewable sources of energy, it can be safely concluded that solar, wind and biogas energy lead the pack in their contribution towards realisation of ZEB. In the context of Odisha, this assumes significance as all these forms of energy is available in abundance and can be easily exploited.

References:-

[1] Anna Joanna Marszal and Per Heiselberg, A literature review of Zero Energy Buildings (ZEB) definitions.

[2] Goetzberger, A, et. al. (1994), The Self-Sufficient Solar House Freiburg, Advances in Solar Energy, vol. 9-].

[3] EikeMusall, Tobias Weiss, Karsten Voss, Aurélie Lenoir,Michael Donn,Shaan Cory,François Garde], Net Zero Energy Solar Buildin gs: An Overview and Analy-sis on Worldwide Building Projects.

[4](Tournesol Site works LLC.), http://continuingeducation.construction.com/crs.php?L=260&C=808.

[5] EIFS, EIMA: EIFS Industry Members Association, http://www.durabilityanddesign.com/news/?fuseaction=view&id=8237

[6] Han J, Lu L, Yang H (2009), "Investigation on the thermal performance of different lightweight roofing structures and its effect on space cooling load", Applied Ther-mal Engineering; Volume 29,Issue 11–12, pp.2491–9.

[7] Sudeshna Ghosh Banerjee, Krishnan Raghunathan, RuchiSoni, Unleashing the Po-tential of Renewable Energy in India, report of OREDA.

[8] NABARD (2012) Model Bankable Projects - Agricultural Engineering – Biogas. Available at http://www.nabard.org/modelbankprojects/biogas.asp.

[9] Pramodini Pradhan Vinod Ahuja P. Venkatramaiah Edited by SanneChipeta Da-nish, Livestock Services and the Poor A Global Initiative Livestock Services and the Poor in Orissa A Case Study March 2003 Agricultural Advisory Centre.

[10] NABARD, 2012; Kossmann, Poenits and Habermehl, 1997a.

[11] Renewable Energy Potentials and Opportunities in Odisha: A.K Choudhury Dy. Director (Projects) OREDA.

[12] Antonia V. Herzog, Timothy E. Lipman, Daniel M. Kammen, RENEW-ABLE ENERGY SOURCES, Energy and Resources Group, Renewable and Ap-propriate Energy Laboratory (RAEL), University of California, Berkeley, USA.

[13] The Ministry of New and Renewable Energy, (MNRE), India in its Report of 2008.

[14] Clean Energy Regulation and Civil Society in India: Need and challenges to effective participation, October 2010 under Prayas(Energy Group), Pune, India.

[15] "Solar Energy Perspectives: Executive Summary". International Energy Agency. 2011.

[16] Liam Byrnesa, b, Corresponding author contact information, E-mail the cor-responding author, Colin Browna, John Fosterb, Liam D. Wagnerb, Australian re-newable energy policy: Barriers and challenges, Volume 60, December 2013, Pages 711–721.

[17] Source:-Indian wind energy association (http://www.inwea.org/aboutwindenergy.htm)

[18] RENEWABLE ENERGY SOURCES Renewable and Appropriate Energy Laboratory (RAEL), University of California, Berkeley, USA.

[19] Nag, KN, Mathur, AN, Ali, NM, (1985): Energy from biomass: An eco-nomic analysis. In: Behl, HM, Vimal, OP, (Eds.) (1985): Procs. National Seminar Cum Workshop: Bio Energy Education. Ajmer, pp31-42.

[20] U.S. National Renewable Energy Laboratory (NREL)

Authors Profile

ArchanaPatnaik is pursuing her B.Techin civil engineering from KIIT University, Bhuba-neswar. She is a resident of the Bhubaneswar, Odisha.She has a keen interest in the con-cept of Zero Energy Building which is a part of Green Building. She has previously pub-lished two papers on the components of Zero Energy Building.

MD ASIF AKBARI an Aligarh Muslim University alumnusis currently pursuing his B.Tech from the School of Civil Enginnering, KIIT University and selected for the prestigious National Research Fellowship- 2013 (NIT, Silchar) & Shortlisted for Research fellowship programme-2013 under INDIAN INSTITUTE OF TECHNOLOGY, BOMBAY. He is a resident of Teghra(Begusarai), Bihar. He is a student member of ACI(American Concrete Institute) and ASCE (American Society of Civil Engineers). He has previously published two papers on Zero Energy Building. His areas of interest are zero energy building and energy sustainability. He may be contacted at akbariasif12@gmail.com

Dr. Purnachandra Saha got his PhD Degree from IIT Bombay. The area of specialization is earthquake engineering and structural control. The title of the thesis is "Seismic Control of Benchmark Cable Stayed bridge".He is member of ASCE , Earthquake Engineering Re-search Institute (EERI), and Institution of Engineers (India). He has published 15 international papers.Dr. Saha has worked in Multinational company (mainly design of power plant and petrochemical structure before completing his doctoral degree.