Studies on Nonconventional Energy Sources for Electricity Generation

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Abstract

Renewable energy is energy generated from natural resources and includes wind power, solar radiation as well as energy from other naturally and constantly replenished sources (sunlight, rain, wave, tides, geothermal heat, etc.). Renewable energy sector has one very big advantage over fossil fuels, the fact that it is highly ecologically acceptable compared to fossil fuels, because renewable energy sources release very little CO_2 emissions into atmosphere compared to fossil fuels as the convincingly biggest pollutants. The findings of this research work is that the use of renewable energy will be available after finishing the traditional sources of energy like oil, gas and coal. This work may be the guide line for future use of renewable energy instead of nonrenewable energy in the world. This work also shows that the renewable energy is capable to face the energy crisis in the world in near future.

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Keywords: *Renewable Energy Sources, Solar Energy, Wind Energy, Geothermal Energy, Applications*

INTRODUCTION

Renewable or non-conventional energy resources can be classified as below: Solar Energy, Wind Energy, Geothermal Energy, Bio-Mass Energy, Bio-Gas Energy, Hydropower, Wave Energy, Tidal Energy, OTEC etc. The Earth receives 174 Petawatts (PW) of incoming solar radiation (insolation) at the upper atmosphere. Approximately 30% is reflected back to space while the rest is absorbed by clouds, oceans and land masses. The total solar energy absorbed by Earth's atmosphere, oceans and land masses is approximately 3,850,000 exajoules (EJ) per year. In 2002, this was more energy in one hour than the world used in one year[5].Sun is ours closest star and the source of almost all available energy on Earth. Sun's energy originates from nuclear fusion in its core, where temperature reaches 15 millions °C. Nuclear fusion is process of joining two light atoms into one heavier atom. Sum of all masses before reaction is larger than sum of all masses after reaction - difference is transformed into energy by famous Einstein's Equation,

$E = mc^2$, Where, E = Energy, m = Mass and c = Speed of light on Sun, light atoms are hydrogen atoms (input) and resulting atom is helium atom (output). Thanks to nuclear fusion on Sun, every second about 600 million tons of hydrogen is transformed into helium, having 4 million tons of hydrogen transformed into energy as side effect. This energy in form of light and heat spreads itself into the universe with one small part of that energy reaching the Earth. Under optimal conditions, on earth's surface can be gained 1 kW/m^2, and real value depends upon location, season, day time, weather conditions, etc

II. Methodology

A. Solar Energy

Solar Energy conversion is divided into two parts. Firstly Solar Thermal(ST) Conversion and Secondly Solar Photovoltaic(SPV) Conversion. One of the Applications of Solar Thermal Conversion is given in the following:

Figure 1: The 19.9 MW Gemasolar solar plant in Spain[5]

Solar Photovoltaic (SPV) are semi-conductor elements which are directly transforming solar energy to an electrical energy. Cheaper units with formless silicon have efficiency of 10%, up to a 25% for more expensive units. Photovoltaic can be used as independent energy sources or as supplementary energy sources. As independent energy source it is used on satellites, traffic signs, calculators and distant objects that are demanding long-lasting energy source. Sun's radiation power is much stronger in space because Earth's atmosphere absorbs large proportion of radiation resulting in larger gained energy.

Figure 2: Solar Photovoltaic cover the roofs of an increasing number of homes.

Figure 3: Solar Photovoltaic System.

B. Wind Energy

The terms "wind energy" or "wind power" describe the process by which the wind is used to generate mechanical power or electricity. Winds are caused by the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and rotation of the earth. Wind turbines convert the kinetic energy in the wind into mechanical power. This mechanical power can be used to run a generator and thus generator converts this mechanical power into electricity. Figure 3.5 shows a view of wind firm in California, USA.

Figure 4: A wind firm in California, USA.

Worldwide there are now over two hundred thousand wind turbines operating, with a total nameplate capacity of 282 GW as of end 2012[7]. The European Union alone passed some 100,000 MW nameplate capacity in September 2012, while the United States surpassed 50,000 MW in August 2012 and China passed 50,000 MW the same month. Table 3.1 shows the a list of top ten countries by nameplate wind power capacity.

Table 1: Top ten countries by nameplate Wind Power capacity (2012 year-end)[7].

Sl. No.	Country	Wind Power Capacity (MW)	World Total (%)
1	China	75,564	26.8
2	United States of America	60,007	21.2
3	Germany	31,332	11.1
4	Spain	22,796	8.1
5	India	18,421	6.5
6	United Kingdom	8,845	3.0
7	Italy	8,144	2.9
8	France	7,196	2.5
9	Canada	6,200	2.2
10	Portugal	4,525	1.6

A graphical representation of top ten wind power electricity generated country is shown below in figure 5.

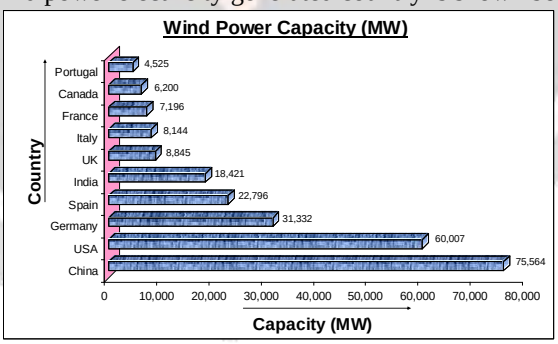

Figure 5: Top ten wind power electricity generated country.

A graphical representation of wing power generation in the world is shown in figure 6.

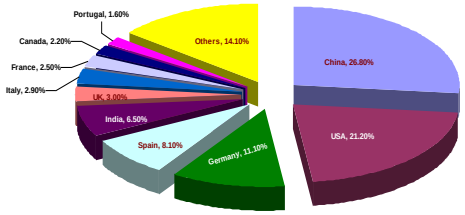

Figure 6: Wing power generation in the world.

C. Bio-Energy

Biomass is renewable energy source that consists of many animal and plant products. It can be directly transformed by combustion in energy and produce water steam for industry and household's heating and to gain energy in smaller thermal power plants. So far the most advanced chemical conversion of biomass is fermentation to alcohol. Biogas as the result of fermentation without presence of oxygen consists of methane and carbon and can be used as fuel, and other modern procedures of energy biomass include pyrolysis, gasification and getting hydrogen. Main biomass advantage relating to fossil fuels is less damaging gases emission as well as less waste waters.

Biomass: Wood's Energy

European Union has 58% of primary energy gained from renewable energy sources that are coming from wood. That large part is traditional exploit of forest's potentials. France produces most primary energy from wood. In year 2000 France had 9.8 Mtoe of energy gained on this way. Sweden (8.3 Mtoe) and Finland (7.5 Mtoe) are also representing significant use of wood's energy. Although thermal consumption (heating households, heating water) represents main part of energy's consumption, small part of wood's energy transform itself in to an electrical energy as well.

Biogas Energy

Biomass is biological material derived from living, or recently living organisms. In the context of biomass for energy this is often used to mean plant based material, but biomass can equally apply to both animal and vegetable derived material. Biomass is carbon based and is composed of a mixture of organic molecules containing hydrogen, usually including atoms of oxygen, often nitrogen and also small quantities of other atoms, including alkali, alkaline earth and heavy metals.The carbon used to construct biomass is absorbed from the atmosphere as carbon dioxide (CO2) by plant life, using energy from the sun. Plants may subsequently be eaten by animals and thus converted into animal biomass. However the primary absorption is performed by plants.
The estimated biomass production in the world is 146 billion tons a year, consisting of mostly wild plant growth. Biomass can be converted to other usable forms of energy like methane gas or transportation fuels like ethanol and biodiesel. Rotting garbage, and agricultural and human waste, all release methane gas and is called "landfill gas" or "biogas." Crops, such as corn and sugar cane, can be fermented to produce the transportation fuel, ethanol. Biodiesel, another transportation fuel, can be produced from left-over food products like vegetable oils and animal fats. Between 1990 and 2000 number of bio-gas power plants constantly increased. Today is about 3000 power plant in Europe, with also 450 garbage disposals which are valorizing biogas. Year production of those installments is about 2304 ktoe, and that is about 5% totally manufactured Europe's biomass energy. Biogas is the result of anaerobic transformation of organic materials (biocomposable waste, energy substances) with the help of anaerobic organisms, and when produced it contains methane and carbon dioxide. Biogas can be used as the source of electricity and to heat buildings and water. As the fuel its primary use is in engine with internal combustion. Figure 7 shows a typical Gober Gas plant.

Figure 7: A typical Gober gas plant.

In many countries including the developed country are using the biogas for various purposes. Figure 3.9 shows Biogas production near Sevelten, Germany.

Figure 8: Biogas production near Sevelten, Germany.

Figure 3.10 shows the world's largest carbon neutral fuel cell power plant - a 2.8 megawatt stationary fuel cell power plant installation at a water treatment facility in California. The plant's unique on-site fuel cell application converts biogas into electricity[8].

Figure 9: World's Largest Biogas Fuel Cell Power Plant, California, USA.

D. Bio-Fuels

Bio-fuels are liquid fuels which have been derived from other materials such as waste plant and animal matter. There are two main types of bio-fuels: Bio-ethanol and
Bio-diesel.

Manufacturing of Bio-Fuels

Bio-fuels or bio-diesels are manufactured from vegetable oils, waste cooking oils, animal fats or tall oil (a by-product of the pulp and paper industry). These oils undergo a process called transesterification whereby they are subjected to a reaction with an alcohol (usually methanol or ethanol) using a catalyst such as sodium hydroxide. The resulting chemical reaction produces an ester called bio-diesel and a by-product called glycerin.

Pure bio-diesel fuel is significantly less flammable than petroleum diesel which burns at 50 degrees Celsius. Bio-diesel's flashpoint is about 150 degrees Celsius. Pure bio-diesel tends to lose its viscosity or to gel at lower temperatures when compared to petroleum. This can be a concern for its use in colder climates. Bio-diesels are often used in combination with petroleum diesel and are referred to as bio-diesel blends. These blends will have a flashpoint and a gel point somewhere between the two pure fuels depending on the mixture.

Use of Bio-Fuels

Bio-diesel can be blended with diesel in any concentration but that which is used in Canada at the present time is usually a 5% or a 20% blend. In France, however, where bio-diesels are more commonly used, even for heating fuels, blends of up to 50% are employed. France is currently the world's largest producer of biodiesel[10].

Table 2: A list of world's top ten bio-fuel producer in 2010.

Sl. No.	Country	Production (toe)
1	USA	25,351,000
2	Brazil	15,573,000
3	Germany	2,930,000
4	France	2,312,000

5	Argentina	1,687,000
6	China	1,399,000
7	Spain	1,179,000
8	Canada	996,000
9	Italy	670,000
10	Thailand	647,000

(toe = tons of oil equivalent, 1 toe = 11.63 MWh)

A graphical representation of top ten Bio-fuel producer in the world is shown in figure 10.

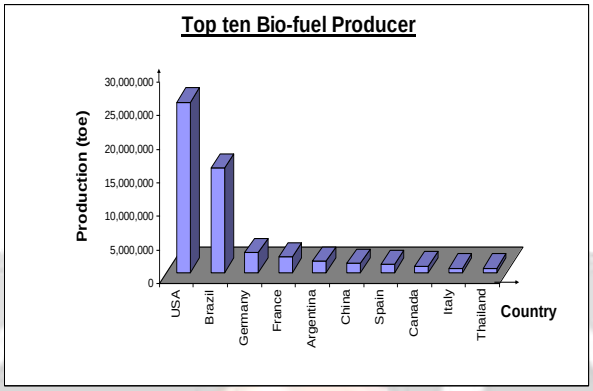

Figure 10: Top ten Bio-fuel producer in the world.

Bio-Ethanol

Bio-ethanol is used as a replacement for gasoline and bio-diesel is used as a replacement for diesel. Bio-fuels have an important role to play in displacing the types of fuels the world has used in the past[9].

Bio-Diesel

Bio-diesel is the first bio-fuel that became known to wider audience and is the mostly used bio-fuel in Europe. It is manufactured from oil or fats with the process of transesterification and its chemical structure is very similar to mineral diesel. Table 3 shows the top ten European Countries consumption of Bio-diesel in 2010.

Table 3: Bio-diesel consumption by European Countries.

Sl. No.	Country	Production (GWh)
1	Germany	25,993
2	France	23,532
3	Italy	15,088
4	Spain	13,803
5	U. K	9,616
6	Poland	9,179
7	Austria	4,749
8	Portugal	3,783
9	Belgium	3,223
10	Sweden	2,035

(1 toe = 11.63 MWh, 1MWh = 10^3 GWh))

A graphical representative of bio-diesel production of top ten countries in the world is shown in figure 3.12.

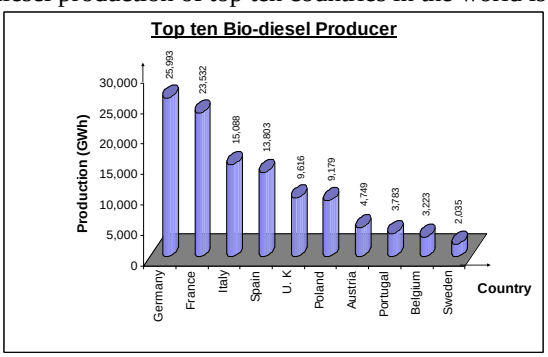

Figure 11: Bio-diesel production of top ten countries in the world

Bio-diesel is using in the United States of America besides the conventional diesel and petrol. Even they are available in fuel station at convenient way. Figure 12shows a photograph of Bio-diesel station at California, USA.

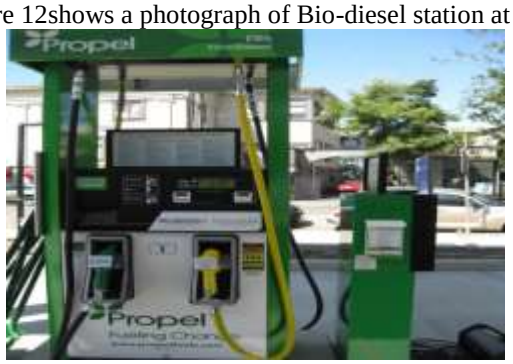

Figure 12: A bio-diesel station at California, USA.

Benefits of Bio-diesel

The major benefits of Bio-diesel are listed below[9]:

1. The major reduction in greenhouse gas emission. The manufacturing of pure bio-fuel produces 60 to 100 percent fewer greenhouse gas emissions compared with that of petroleum diesel.
2. Many food and animal waste products that now end up in our landfill sites decompose naturally to produce methane gas which also contributes negatively to climate change. By diverting these products into bio-diesel instead, we can further impact the environment in a positive way.
3. Bio-diesel is composed of 11 percent of oxygen by mass which when added to petroleum diesel, allows it to burn more efficiently.
4. Bio-diesel has mild solvent properties and is thus considered to be a clean fuel. These factors allow bio-diesel to help reduce the emissions of fine particulates and unburned hydrocarbons into the air, some of which have been associated with cancer causing properties.

E. Hydropower, Hydroelectric power

The term Hydroelectricity is referred to electricity generated by hydropower. Hydropower is the production of electrical power through the use of the gravitational force of falling water. It is the most widely used form of renewable energy, accounting for 16% of global electricity generation in 2010 and is expected to increase about 3.1% each year for the next 25 years[11]. Hydropower is produced in 150 countries, with the Asia-Pacific region generating 32% of global hydropower in 2010. China is the largest hydroelectricity producer, with 721 terawatt-hours of production in 2010, representing around 17% of domestic electricity use[11].

Calculating the Amount of Available Power

A hydropower resource can be evaluated by its available power. The power available from falling water can be calculated from the flow rate and density of water, the height of fall, and the local acceleration due to gravity.

In SI units, the power is: $P = \eta\rho Qgh$, Where, P = Power in watts, η = The dimensionless efficiency of the turbine, ρ =The density of water in kilograms per cubic metre, ~1000 kg/m^3 , Q = The flow in cubic metres per second,
g = The acceleration due to gravity, 9.8 m/s^2, h = The height difference between inlet and outlet

Hydroelectric Power at a Glance

The cost of hydroelectricity is relatively low, making it a competitive source of renewable electricity. Hydro is also a flexible source of electricity since plants can be ramped up and down very quickly to adapt to changing energy demands. However, damming interrupts the flow of rivers and can harm local ecosystems, and building large dams and reservoirs often involves displacing people and wildlife[11]. Once a hydroelectric complex is constructed, the project produces no direct waste, and has a considerably lower output level of the greenhouse gas carbon dioxide (CO_2) than fossil fuel powered energy plants. Table 4 shows ten of the largest hydroelectric power station in the world [9].

Table 4: Top ten largest hydroelectric stations.

Rank	Name of the Dam	Country	Name of the River	Installed Capacity (MW)
1	Three Gorges Dam	People's Republic of China	Yangtze	22,500
2	Itaipu Dam	Brazil Paraguay	Parana	14,000
3	Guri	Venezuela	Caroní	10,200

4	Tucurui	Brazil	Tocantins	8,370
5	Grand Coulee	United States of America	Columbia	6,809
6	Longtan Dam	People's Republic of China	Hongshui	6,426
7	Krasnoyarskaya	Russia	Yenisei	6,000
8	Robert-Bourassa	Canada	La Grande	5,616
9	Churchill Falls	Canada	Churchill	5,428
10	Bratskaya	Russia	Angara	4,500

From the table it is seen that The Three Gorges Dam is the world's largest hydroelectric Dam which is located in the heart of the Yangtze River. More than a mile wide and over 600 feet long, the dam is the most extensive and most expensive engineering project in the world. It meets up the 3% of China's total energy needs. Three Gorges Dam is also intended to control flooding of the Yangtze River Basin and enable more efficient navigation along the river to increase trade along the port cities.A graphical representation of the top ten Hydraulic Power Plants with their installed capacity is shown in the figure 13.

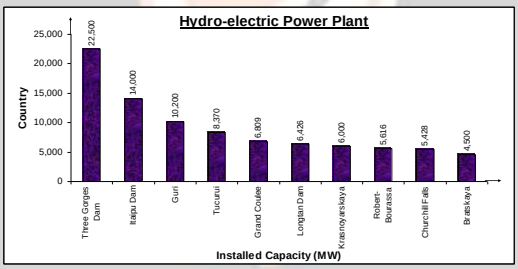

Figure 13: Top ten Hydroelectric Power Plants in the world.

The project has used a world record of 16 million cubic meters of concrete, flooded 100,000 acres of farm land, and relocated more than 1 million people from the Yangtze River Basin. Despite the economic benefits, the Three Gorges Dam has been referred to as "The most environmentally and socially destructive project in the world" (Dai Qing). Now, China's government has finally acknowledged the vast environmental destruction associated with the dam, and has started to develop extensive plans to address these problems[12]. Figure 14 shows an aerial view of Three Gorges Dam.

Figure 14: Aerial view of Three Gorges Dam.

In the last thirty years or so, production of energy in water power plants has tripled, but hydro energy's share was only increased for 50 % (from 2.2% to 3.3%). That is because of the restrictions that hydro energy has. It can't be used in all areas because it needs abundance of fast flowing water, and also is very desirable to have it enough throughout all year, because electricity can't be cheaply stored. To negate effect of water-levels' oscillations, water gates as well as accumulation lakes are being built. That significantly increases the whole power plant's expenditures, and also raises the level of underground waters near the accumulation. Underground water level has large influence on flora and fauna, so hydro energy isn't completely harmless for environment.

F. Geothermal Energy

The term Geothermal originates from two Geek words 'GEO' and 'THERM'. The word ‘GEO’ means the earth and the word ‘THERM’ means heat from the earth. Geothermal energy is energy derived from the heat of the earth. The earth’s centre is a distance of approximately 4000 miles and is so hot that it is molten. Temperatures are understood to be at least 5000 degrees centigrade. Heat from the centre of the earth conducts outwards and heats up the outer layers of rock called the mantle. When this type of rock melts and becomes molten it is called magma. Magma can reach just below the earth’s surface.

Inner Earth's heat is the result of forming planets from dust and gases that happened more than 4 billions years ago, and since radioactive decompose of elements in rocks continuously regenerates this heat, geothermal energy is renewable energy resource. Basic medium that is transferring heat from inner to surface is water or steam, and this component is renewing itself on a way in which water from rains is bursting deep on fissures heating itself and circulates back to surface where it appears in shapes of geysers and hot springs.

Figure 15: Temperatures in the Earth.

Geothermal energy has huge potential because its quantity is 50000 times bigger from all energy that can be gained from oil and coal across the world. Geothermal resources are located from shallow surface all the way to couple of kilometers deep reservoirs of hot water and steam which could be brought to surface and there exploited. In nature geothermal energy is mostly in the form of volcanoes, hot water springs or wells and geysers. However, progress in science didn't stop only in exploring healing effects of geothermal energy and has pushed use of geothermal energy in many different ways of which two take special place, namely its use in producing the electricity and its use in heating the households and industrial installments. Uses of geothermal energy for central heating of the buildings and for generating electricity are the main ways of its exploration, but not the only ones. Geothermal energy can be also used in many other ways and it's used for pasteurizing milk, paper manufacturing, in swimming pools, drying timber and wool, animal husbandry etc.

Main disadvantage when exploiting geothermal energy is the fact that there aren't many places on the Earth highly suitable for exploit. Best areas are on the edges of the tectonic plates, namely areas of high volcanic and tectonic activity. The International Geothermal Association (IGA) has reported that in 2010, 10,715 megawatts (MW) of geothermal power in 24 countries is online and it represents a 20% increase in online capacity since 2005. IGA projects growth to be 18,500 MW by 2015. In 2010, the United States led the world in geothermal electricity production with 3,086 MW of installed capacity from 77 power plants. The largest group of geothermal power plants in the world is located at The Geysers, a geothermal field in California. The Philippines is the second highest producer, with 1,904 MW of capacity online. Geothermal power makes up approximately 27% of Philippine electricity generation.

Table 5: shows the installed geothermal electric capacity of top ten countries.

Sl. No.	Country	Capacity (MW in 2010)	Percentage of National Production.
1	United States of America	3086	0.3%
2	Philippine	1904	27%
3	Indonesia	1197	3.7%
4	Mexico	958	3%
5	Italy	843	1.5%
6	New Zealand	628	10%
7	Iceland	575	30%
8	Japan	536	0.1%
9	Iran	250	5%
10	El Salvador	204	25%

A graphical representation of the top ten Geo-thermal power producer with percentage of national production is shown in the figure 16.

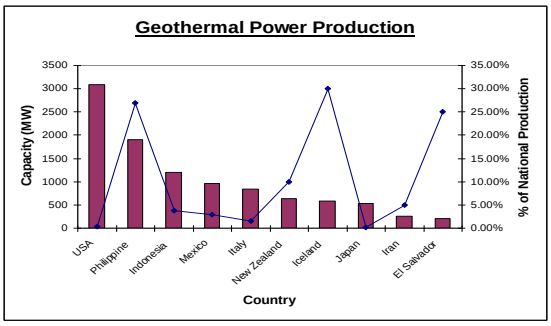

Figure 16: Top ten Geo-thermal power producer with percentage of nation production.

Figure 17: One of 21 power plants at the Geysers, California, the largest geothermal development in the world.

G.Ocean Energy

Ocean energy is a term used to describe all forms of renewable energy derived from the sea including wave energy, tidal energy, river current, ocean current energy, offshore wind, salinity gradient energy and ocean thermal gradient energy. Oceans cover more than 70% of Earth's surface and they therefore present interesting energy source that may with time provide us with energy to power our households and industrial facilities. At this moment ocean energy is renewable energy source very rarely used as there are only few ocean energy power plants and most of these power plants are also very small so energy gained form oceans is literally negligible on global scale. But future should put more attention to this renewable energy source and there should be significant increase in produced energy, especially with more attention to renewable energy sector. There are three basic types that allow us to use ocean for its energy. We can use the waves (wave energy, wave power), ocean tidal power (ocean high and low tides), and we can even use temperature differences in the water to create an energy (Ocean Thermal Energy Conversion, OTEC).

Wave Energy

Wave energy is the transport of energy by ocean surface waves, and the capture of that energy to do useful work such as electricity generation, water desalination, or the pumping of water etc. Ocean wave energy is the form of the kinetic energy that exists in the moving waves of the ocean since waves are caused by blowing winds over the surface of the ocean. This energy can be used to power a turbine and there are many areas in the world where wind blows with sufficient consistency to provide continues waves. There is tremendous energy in wave power which gives this energy source gigantic energy potential. Majority of wave energy technologies are still oriented to installations at or near the water surface, and the main difference between these technologies is their orientation to the waves with which they are interacting with and in their working principle in which they convert the energy of the waves into desired energy forms. Among most popular wave energy technologies are terminator devices, point absorbers, attenuators, and overtopping devices.

The main problem of wave energy is the fact that this energy source isn't the same in all parts of the world. It varies significantly from place to place. This is the reason why wave energy can't be exploited in all parts of the world but there are many researches that work on solutions of how to solve this variability problem.

Tidal Energy (Tidal Power)

Tidal energy is another type of ocean energy In this case when tides comes into the shore, they can be trapped in reservoirs behind dams. Tidal power is actually a form of hydropower that exploits the movement of water caused by tidal currents or the rise and fall in sea levels. Tidal energy is produced thanks to the use of tidal energy generators which are large underwater turbines placed in areas with high tidal movements, and designed to capture the kinetic motion of the ebbing and surging of ocean tides in order to produce electricity. Tidal power has enormous potential for future electricity generation because of the massive size of the oceans. The potential of tidal power has been recognized for very long time (small dams were built along oceans since 11th century). However, compared to river dams, tidal-power projects are much more expensive, since massive structures must be built in a difficult saltwater environment. Cost effectiveness is actually a main reason why tidal power hasn't yet found its place among top used renewable energy sources despite its huge potential.Tidal energy has many advantages. It is renewable energy source since tides will continue to ebb and flow and it produces no greenhouse gases or any waste, it needs no fuel in order to work, since

tides are totally predictable it can produce electricity reliably and once built it's not expensive to maintain, but there are also some negative sides as well. Cost effectiveness is still very serious issue since building one of these power plants requires a very wide area and this also brings some environmental problems since it completely changes environment in this area and affects life of many ecosystems, especially for birds that rely on the tide uncovering the mud flats so that they can found food. There is also the already mentioned fact of limited working time of only about 10 hours, when tide is actually moving.

Ocean Thermal Energy Conversion (OTEC)

Ocean Thermal Energy Conversion is a method for generating electricity that uses the temperature difference that exists between deep and shallow waters since the water gets colder the deeper you go. If there is bigger temperature difference, there is the greater efficiency of this method, and minimum temperature difference must be at least 38 degrees Fahrenheit between the warmer surface water and the colder deep ocean water in order for this method to be efficient. This method has very long history that dates from the very beginning of the 19th century and some energy experts believe that if it could become cost-competitive with conventional power technologies, OTEC could produce gig watts of electrical power.

IV. Conclusion

Now a day besides the conventional sources non conventional sources becoming popular. World trend is now on the use of non conventional sources of energy. There are lots of non conventional sources of energy. All these sources are using by many countries. China, USA and Germany produce are producing a substantial part of its total power generation using wind power. USA, Brazil, Germany, France are the top energy producer using bio-fuel. China has the world biggest hydro power plant. This trend of using non conventional energy sources is increasing day by day.

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