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# RENEWABLE SOURCES OF ENERGY AS AN ALTERNATIVE IN PLACE OF CONVENTIONAL SOURCES OF ENERGY FOR POWER GENERATION

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## ABSTRACT

*The sources of energy which are inexhaustible and being produced continuously in nature are called Renewable or Non- conventional sources of energy. Some of these sources include solar energy, wind energy, and tidal energy. The conventional Energy sources are basically based on fossil fuels which have finite reserves in nature and hence would extinct in future. Since the development and progress of mankind are closely related to energy sources, many countries throughout the world have engaged themselves in searching and developing renewable energy sources that would be very essential to sustain the life cycle of human being. Our country, India has also taken certain initiatives in this view. In this paper, a review based study has been presented regarding various renewable energy sources and their country status in India and the rest of the World.*

***KEYWORDS;*** *Hydro power, solar energy, wind energy, biomass energy, energy from the sea*

## 1. INTRODUCTION

We have started showing renewed interest in exploring and using the alternative source of energy due to two reasons

- Because the fossil fuels and nuclear fuels in the earth are limited which may last for long, and
- Because of the undesirable effects of pollution and environmental consequences both from the use of fossil fuels and from the radioactive wastes of nuclear power plants.

So it is compulsory to produce electricity from alternative sources which can replace partly or fully the conventional sources of energy for generating electricity to save them as they are limited as well as to save their adverse effects on environment. Although many research work are being conducted on worldwide to use some alternative sources of energy which can sustain in future. Fossil fuels are non- renewable sources. So some countries like USA, CHINA, JAPAN, NEW-ZEALAND researched and are being in search of using alternative sources of energy for power generation.

The fossil fuels were exploited as surface deposits of asphalt, peat and coal, oil from surface seepage, and gas venting from underground reservoirs. The use of energy got enhanced with the invention of electricity and development of electric energy generating stations, consuming either fossil fuels or potential energy of water. Now world is taking step to set up an economy which is non-conventional resources as the major sources as compared to conventional sources. Alternative sources are less costly but their installation is little bit expensive which is compensated by their operating cost, have no adverse effect on environment, renewable and efficient.

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## 2. Advantages of Renewable sources of Energy over conventional sources of Energy in power generation.

- In comparison, renewable energy systems do little impact on natural habitat and environment as it is user friendly compatible with the environment.
- Renewable sources of electric energy which never get exhausted.
- Non- conventional sources of electric energy are economical to use.
- These are efficient sources of electric energy.
- Reduction in CO2 emissions.

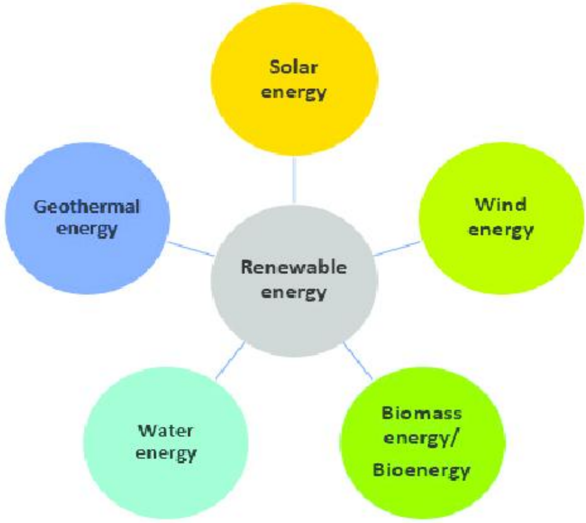


**Fig.2.1:** Renewable Sources of Energy

### 3.1 Hydro Power

India has endowed with a vast and viable hydro potential for power generation of which only 15% has been harnessed so far. The share of hydro power in the country's total generated units has steadily decreased and it presently stands at 21.53%. It is assessed that exploitable potential at 69% load factor is 84000 MW.

At 60% load factor, this translates into 84000 MW.

Present installed capacity 38106.4 MW as on 30.06.2011.

21.53% share of installed capacity for electricity.

The total hydropower capacity is forecasted to increase from 1,607 GW in 2011 to 1,680 GW in 2035 (IEA, 2012e). According to the World Economic Outlook (WEO) 2012 report, China is expected to double its capacity by 2035, an amount of 420 GW. To put this in perspective, 420 GW is close to the entire capacity of OECD countries in 2011. The IEA has also estimated that the capacity will also significantly increase in India and Brazil. It is forecasted that the capacity will grow from 42 GW to 115 GW in India and from 89 GW to 130 GW in Brazil (IEA, 2012e). Other regions, such as Europe and North America where the hydropower sector has already matured, will modernize their current plants and improve storage capacity instead of developing new facilities (Martinot and Sawin, 2012). Based on the IEA survey, issues such as the availability of funding, political and market risks, and local environmental concerns are considered to be barriers to the develop of hydropower capacity in Africa. Figure (2) shows the sources of primary energy consumption on a worldwide scale for the year 2011, based on BP statistics (2012). The energy technology differs among the OECD and non-

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OECD countries with respect to coal, nuclear and hydro sources. The difference is attributed to their technological capabilities.

### 3.1.1Small hydro power scenario:

The concept of small hydro power plants or micro hydel systems is much more promising in a country like India. Many of the problems associated with large hydel plants such as large capital, long gestation period etc. could be avoided and they could offer cheap power locally even at remote areas.

- Hydro power based generation based on plants of capacity 25 MW or less.
- More socially, environmentally and economically viable.
- Estimates of MNES place the potential at 15000 MW.
- Beneficial for rural electrification, as most of the potential sites are in rural areas.
- MNES has identified about 4500 such sites in India.
- Cost of small hydro plant half that of a thermal plant.

➢ **Sector-wise Energy Consumption in the world:**

Sector-wise energy consumption is shown in Fig.3.1. It could be seen from the figure that the biggest consumer of energy is our industry. Industrial **sector** has been dominating as the highest primary **energy consumption** by **World** since 1980 to 2010

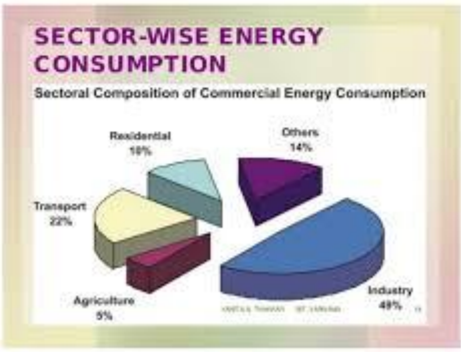


**Fig.3.1:** Sector-wiseenergy consumption of the world

### 3.1.2 Hydroelectric Power Potential

India is endowed with an enormous hydropower potential energy, which is assessed by Central Electricity Authority as 148700 MW. In February 2010, Minister of state of energy reiterated the commitment to raise the hydro capacity from current 26% to 40% of national power production. Hydropower is environmental friendly and meet the peak power requirements which stabilizes the power system. It involves no fuel cost and can provide energy security by saving costly fossil fuel.

India has a big potential (15,000 MW) For a large number of micro (up to 100Kw), Mini (101-1000 Kw) and small (1MW to 25MW) hydel plants in hilly states of Himachal, Jammu and Kashmir, Uttarkhand, Haryana, Sikkim, west Bengal and Arunachal Pradesh. These projects can be set up on rivers, canals or at small dams where generated power can be supplied to nearby villages situated far away from the grid power. The installed capacity of such projects was 2953 MW at the end of Jan. 2011.

At present 56 pumped storage projects are operating in the country with installed capacity of 94000 MW.A pump storage plant keeps the frequency of the power system within limits (48.5 Hz-51.5 Hz) and saves it

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from power collapse. Another advantage is the improvement in the supply voltage by operating in synchronous condenser mode, when it generates reactive power for VAR compensation of the power network.

A power grid dominated by thermal power generation, hydropower and pump storage schemes the peaks and covers the troughs of the daily demand curve.

### 3.2 Solar Energy

The basic source of energy produced by the sun is through nuclear fusion. In this reaction, two atoms of deuterium (heavy hydrogen) combines to form one atom of helium and during the process it releases large quantum of energy which reaches the earth's surface through electromagnetic radiation.

Thus, the sun releases the enormous amount of energy due to continuous fusion reaction taking place in the sun. The sun sends out the energy in the form of radiations at the rate of 3.7× 10 raise to power 20 MW. However, the energy intercepted by the earth is about 1.85 × 10 raise to power11 MW. This energy available is several times more than all the energy produced and consumed in the world today.

- **Solar Energy Collectors**

Solar collector is an equipment in which solar energy is collected by absorbing radiation in an absorber and then transferring to a fluid.

- Flat plate collector:- It has no optical concentrator. Here, the collector area and the absorber area numerically the same, the efficiency is low, and temperatures of the working fluid can be raised only up to 100 degree Celsius.

  Flat plate collectors are used for low temperature applications like solar water heating, space heating and cooling, drying, low temperature power generation etc.

- Concentrating type collector:- Here the area receiving the solar radiation is several times greater than the absorber area and the efficiency is high. Mirrors and Lenses are used to concentrate the sun rays on the absorber, and the fluid temperature can be raised up to 500 degree Celsius. For better performance, the collector is mounted on tracking equipment to face the sun always with its changing position.

  These collectors are used for vapour engines and turbines, process heating Industry, refrigeration, cooking etc. These are also suitable for thermo-electric generation.

### 3.2.1 Solar Energy Devices

The devices which work by using solar energy are: solar cell, solar cooker, solar water heater.

- Solar cell: A Solar cell converts solar optical energy directly into electrical energy. A Solar cell is essentially a semiconductor device fabricated in a manner which

Generates a voltage when solar radiation falls on it. The method of producing electricity using solar cells is known as photovoltaic power generation.

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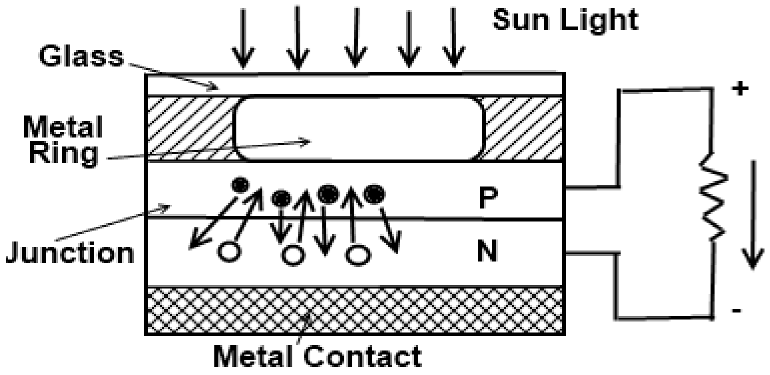


**Fig.3.2.** Solar cell

- Solar cooker: The solar cooker is a device which is used to cook food by utilizing the heat energy radiated by the sun.

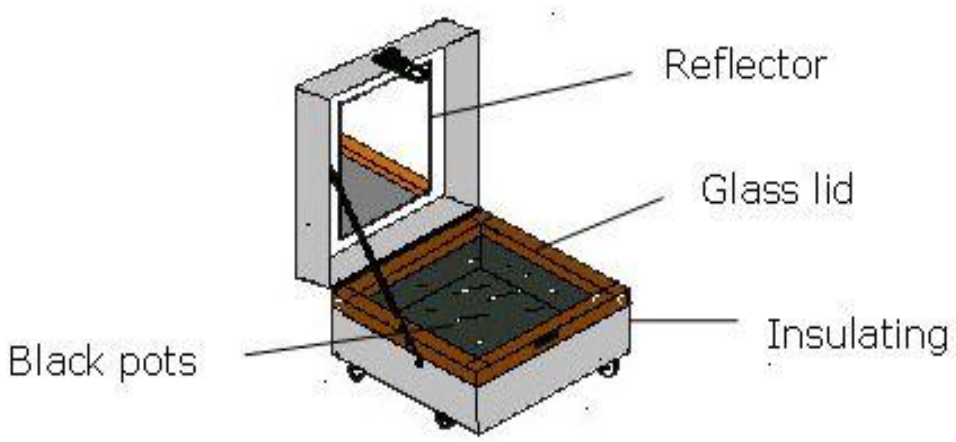


**Fig.3.3:** Domestic solar cooker

### 3.2.2 Typical Solar Power Plant

The figure of typical solar power plant is shown below:

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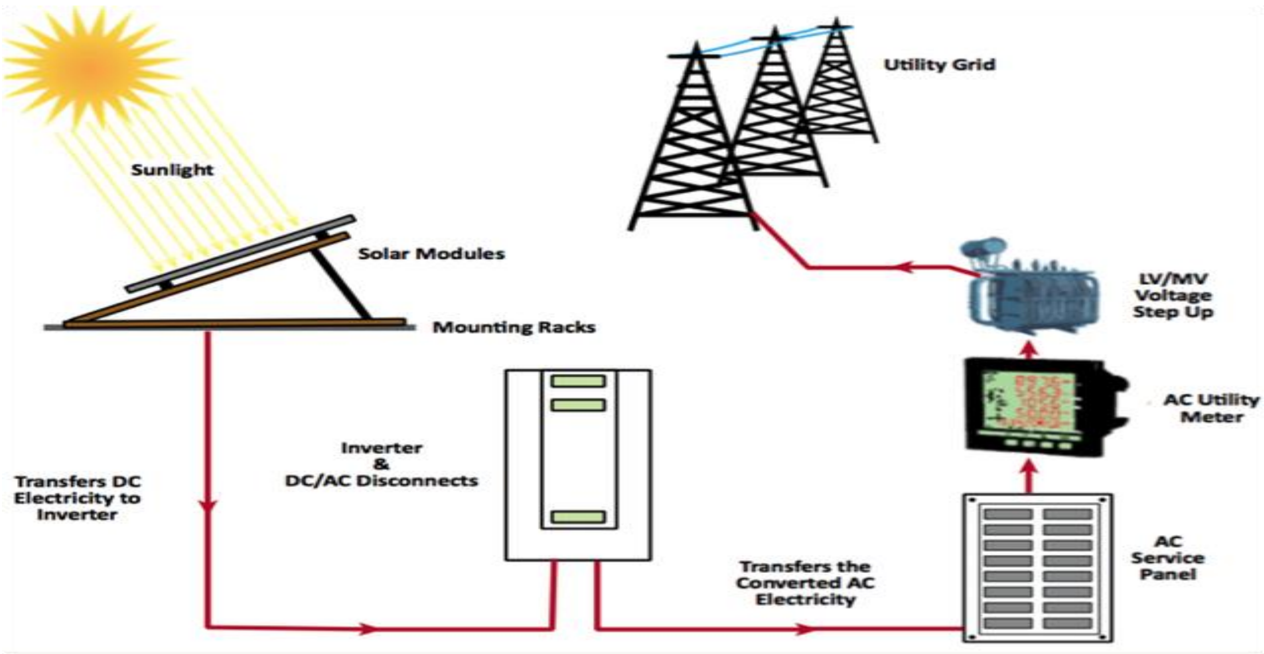


**Fig.3.4.**solar Power plant.

### 3.2.3 Solar Energy Scenario

- 300 clear sunny days every year in India
- A potential for 30 MW per sq. km in India.
- Solar photovoltaic (SPV) contribute 2.5% of power generation from renewable energy.
- SPVs with aggregate capacity of 47 MW have been deployed for various applications.
- 21 grid interactive SPV projects aggregating 1.615 MW for providing voltage support implemented by MNES.
- Target of 1000 MW by 2013 with target of 20000 MW of solar power by 2020 of MNES.
- Conventional PV cells have low efficiency, and extremely high upfront costs, which has reduced its viability.
- Total installed capacity of renewable energy source is 18454.5 MW as on 30.06.2011.

### 3.3Wind Energy

Wind energy is an indirect form of solar energy since wind is introduced chiefly by thee uneven heating of the earth’s crust by the sun. The conversion of this wind energy into electric power can reduce the power deficit to a large extent.

- **Wind Generator**

The kinetic energy of the wind can be utilized to produce shaft power which is turn into electrical power by means of an electric generator.

Horizontal axis wind turbine (HAWT) generators are being used all over the world successfully.

The main components of a propeller type wind generator is shown by a schematic diagram in Fig.3.5.

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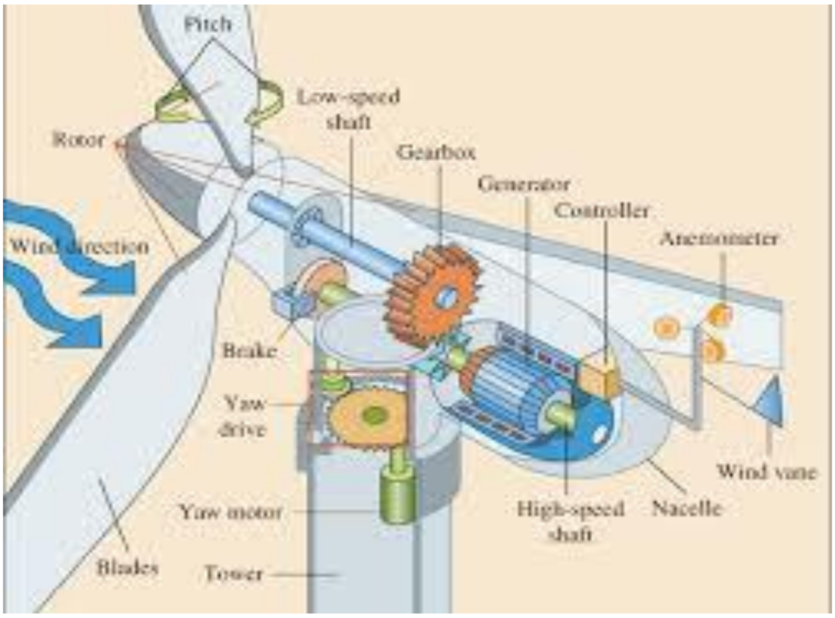


**Fig.3.5:** Wind Generator

### 3.3.1 Wind energy scenario

- India is the fifth largest wind power producer in the world with a capacity of 12009 MW as on 30 June 2011.
- Estimated that 6000 MW additional capacity of wind power will be installed by 2012.
- Gross wind energy potential: 65000 MW.
- Technical potential: 45000 MW.
- States with high potential: Tamil Nadu, Gujarat, Andhra Pradesh, Karnataka, Kerala, Maharashtra.
- Capital cost of wind power projects ranges from Rs. 4.5-5.5crore/MW and the cost of generation is estimated to be Rs. 2.25-2.75/kWh.

- **Global scenario**

As per Global Wind Energy Council (GWEC) the international wind markets grew by 36% in 2008. Total wind power installed capacity of the world stood at 138459 MW by September 2009. Over 80 countries now have commercial wind power installations. In US and Europe it is planned to carry power from wind resources to load centre through EHV lines.

### 3.3.2 Wind Power Potential and Achievements in India

India's wind power potential has been assessed at 48561 M, as detailed in Fig.1.4. However, the potential for grid-interactive wind power is less, i.e., around 15000 MW (sites having wind power density in excess of 300 W/m2 at 50 m hub height are considered).

India now ranks fifth in the world after USA, China, Germany and S pain with an installed capacity of 11807 MW son 31-03-2010. Wind power installed by leading countries as stood on 31-12-2009 is:

USA = 35159 MW; China = 26010 MW

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Germany = 25770 MW; Spain = 19149 MW

The wind power potential in India is given in table.1.

**Table-1.**Wind power energy

| State | Potential in MW |
|---|---|
| Andhra Pradesh | 2200 |
| Gujarat | 3100 |
| Karnataka | 4120 |
| Kerala | 1380 |
| Madhya Pradesh | 1920 |
| Orissa | 840 |
| Rajasthan | 1210 |
| Tamil Nadu | 1900 |
| West Bengal | 1180 |
| Other state | 2150 |
| Total | 20000 |

### 3.4 Biomass Energy

Biomass refers to solid carbonaceous material derived from plants and animals. These include residues of agriculture and forestry, animal waste and discarded material from food processing plants. Biomass can be considered a form of solar energy as it is used indirectly to grow these plants by photosynthesis. It is renewable source of energy because the organic matter is generated around the year.

### 3.4.1 Power Generation from landfill gas

Recycling of city garbage and MSW poses a serious problem due to its enormous quantity. Its sanitary disposal through landfill is a successful method even in UK and USA. A large pit at the outskirt is prepared and a pipe system for gas collection is laid down before the waste is filled. MSW is buried, eventually the gas produced does not escape into the atmosphere. After 2-3 months, depending on the climate, landfill gas can be extracted by inserting perforated pipes into the landfill (Figure 3.6).

The gas flows through pipes under natural pressure. As the gas has calorific value of about 4500kcal/m3 it can be used either for direct heating/cooking applications or to generate power through IC engines. One of the largest landfill gas plants in the world is a 46 MWe plant in California.

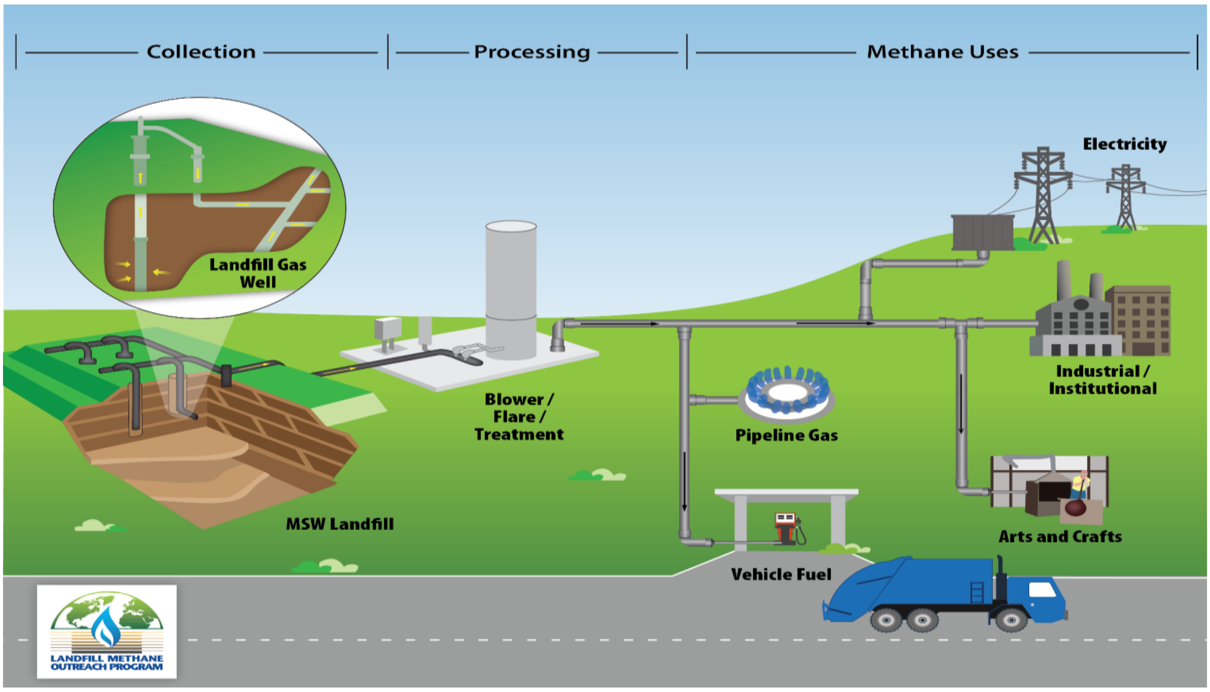


**Fig.3.6:** Landfill gas for power generation

### 3.4.2 Biomass resource development in India

The energy scenario in India indicates that ‘biomass’ is a promising form of renewable energy matching with the agricultural base in rural areas and industrial development in urban set-ups. The estimated potential and physical achievement of bio-power are given in Table 2

**Table -2.** Potential vis-a-vis achievement in the field of bio-power

| Resource | Estimated potential (MW) | Achievements up to Jan. 2009 (in MW) |
|---|---|---|
| Bio-power (woody biomass) | 52000 | 683 |
| Waste to energy | | |
| (i) Grid- interactive power | 5000 | 34.95 |
| (ii) Distributed power | 50000 | 11.03 |
| Rural-30,000 MW (Captive generation-industrial 20000 MW) | | |
| Biomass Gasifiers | - | 87 |
| Co-generation (bagasse) | 5000 | 1034 |
| Family type biogas plants | 120 lakhs | 39.8 lakhs |

➢ **Future of Biomass energy in India**

Use of biomass is growing globally. Modern biomass has potential to penetrate in four

- Process heat applications in industries generating biomass waste.
- Cooking energy in domestic and commercial sectors (through charcoal and briquetts).
- Electricity generation and
- Transportation sector with liquid fuels.

Future of biomass energy lies in its use with modern technologies.

### 3.4.3 Global scene

In US 45 Billions KWh of electricity is from Biomass and 4 billion gallon of ethanol is used in vehicles. Biomass supports 66000 jobs in the US. In Sweden, biomass and peat contribute 12% of total energy while in Austria this figures is 13%. Worldwide biomass contribute 14% of total energy and its 38% in developing countries especially in rural sector.

### 3.5 Energy from the Sea

The Energy from the sea can be obtained mainly in three forms:

- Tidal energy,
- Wave energy, and
- Ocean thermal energy.

### 3.5.1 Tidal Energy

Tidal energy is renewable source of energy of hydro energy which is available due to rise and fall of tides which occurs twice a day. The tides are caused due to the gravitational attraction of moon and sun up on the rotating earth.

- **Tidal Power Plants**

The tidal range of 5m and above available in particular location can be utilised to operate a hydraulic turbine. The mechanical power of the turbine can be used to run a generator to produce electrical power. The first tidal power plant was commissioned by General De Gaulle at La France in 1966.

Tidal power plants can be broadly classified into the following four categories:

- Single-basin single-effect plant.
- Single-basin double-effect plant.
- Double-basin with linked-basin operation.
- Double-basin with paired-basin operation.

- **Tidal power development in India**

India has a long coastline of 6000km and there are promising sites for setting up tidal power plants in West Bengal and Gujarat. A feasibility report on tidal power prospect of Durgaduani Creek in Sunderbans area of West Bengal was carried out in 1995 jointly by National Institute of Ocean Technology Chennai and IIT Madras at the behest of the West Bengal Renewable Energy Development Agency. The mean tidal range is 3.54m with a basin area of 1.07 sq.km. On the basis of the report, there is a proposal to install a 3 MW capacity tidal power plant in Durgaduani. In Sunderban area there is a potential of 50 MW of tidal power.

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### Global Scenario of Tidal Energy

The tidal power plants in operation are detailed in Table.3.

**Table -3.** Details of tidal power in the world

| Location | Year | Total capacity | No. of units | Tidal range(m) |
|---|---|---|---|---|
| La Rance Brittany,France | 1966 | 240 MW | 24 | 8.5 |
| Kislaya Guba, Russia | 1968 | 400 kW | 1 | 3 |
| Annapolis NOVA Scotia, Canada | 1984 | 17.8 MW | 1 | 5.5 |
| China | | | | |
| I. BAISHAKOU | 1978 | 960 kW | 6×160 kW | 3.5 to 7.8 |
| II. JIANGXIA | 1980 | 3.0 MW | 6×500 kW | 5 |

### 3.5.2 Wave Energy

The movement of large quantities of water up and down can in principal be harnessed to convert into usable forms of energy such as electricity or mechanical power. Waves are formed on the surface of water by the frictional action of the winds resulting in the radial depression of the blowing winds in all directions.

The availability of this wave energy depends upon the height and frequency of waves. It is estimated that about 10 Kw of energy is available for 1 m of wave front and its potential in India is estimated to 40000 MW. The power developed can be estimated by the formula.

Power, P = 0.55 H sq. × t

Where, H = Wave height, t = time period in seconds, P = Power in Kw

In India, 150 Kw system utilizing wave energy has been installed at Thiruvananthapuram.

### 3.5.3 Ocean Thermal Energy

The temperature gradient across the depth of sea can be used to generate electrical power. It is called **ocean thermal energy conversion (OTEC).** Since the temperature differential is very low, the efficiency of energy conversion in such plants is very low coupled with high capital cost. The plants using temperature differential of sea water are called **ocean thermal energy conversion (OTEC) plants.**

There are two basic types of OTEC systems which are:

(i) Open cycle system or Claude Cycle System
(ii) Closed cycle system or Anderson Cycle System.

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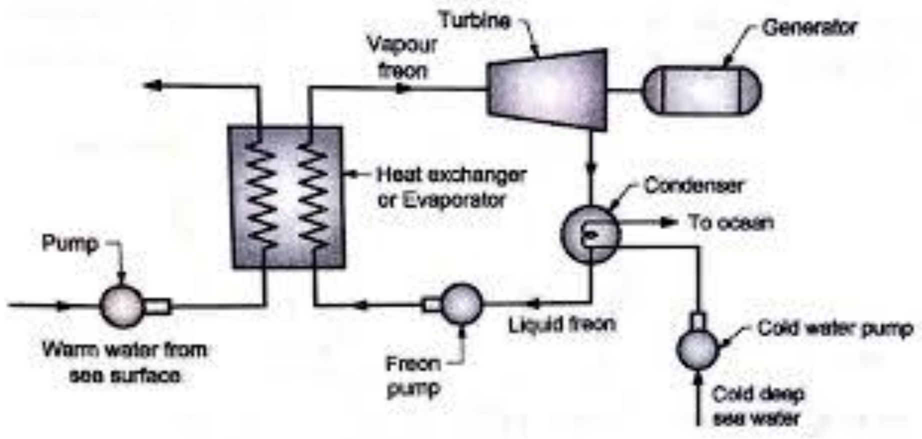


**Fig.3.7:** Open cycle OTEC system

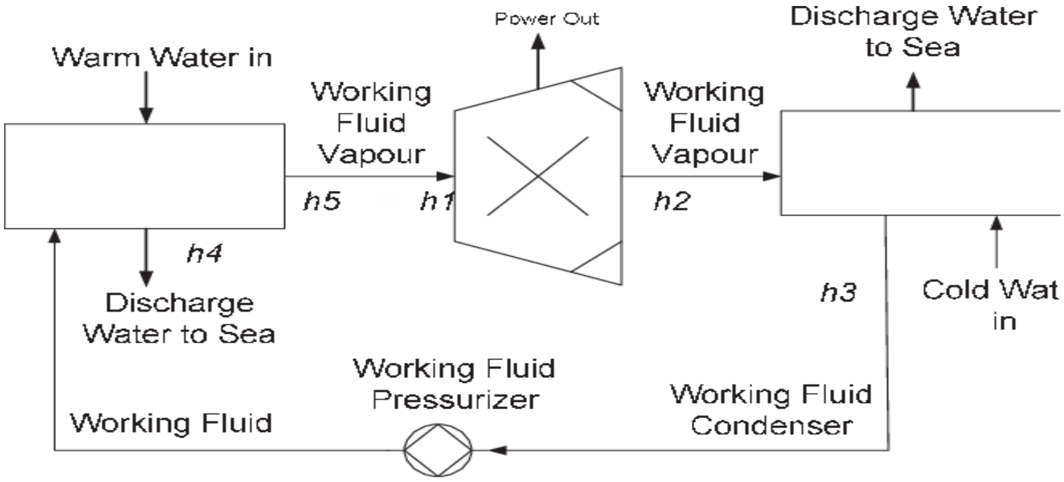


**Fig3.8:** Closed Cycle OTEC system

## ➢ Development of OTEC in India

As a tropical country with a long coastline, India has tremendous ocean thermal energy potential. India is fortunate to have in its Exclusive Economic Zone (EEZ) and continental shelf an ocean area comparable to its land area. The National Institute of Ocean Technology is implementing the world's first 1MW floating OTEC technology demonstration project off the Tuticorin coast in Tamil Nadu.

India's OTEC resource potential is estimated at around 180000 MW. For the mainland, the cost of power generation for a plant upwards of 25 MW is expected to be comparable to fossil fuels units. But for islands, an OTEC power plant of any size is cheaper than the conventional generation units.

## ➢ Global Development of OTEC Plants

The first OTEC power plant was developed in 1979 in the Hawaii state of the USA. It was a prototype 50 Kw floating plant operated on closed Rankine cycle principle with ammonia as the working fluid. The plant was designed with the ocean water temperature difference of 21 deg. cel. The available net power was only 15 Kw,

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as 35kw was used in pumping the warm and cold water. Its successful operation established that power generation through an OTEC system is technically viable.

Another plant was installed in Nauru (Japan) in the Central Pacific Ocean during 1981. The net power output was 31.5 KW. The turbine used was axial flow type with 3000 rpm, the generator was directly coupled and supplied power at 415 V, 50 Hz.

### 3.6. Geothermal Energy

Geothermal energy in the form of thermal energy is a form of renewable source of energy having energy density. It is renewable since the earth's interior will continue to provide energy continuously in the process of cooling of earth's interior. It is inexhaustible like solar or wind energy. The geothermal energy in the form of heat energy can be utilized economically and efficiently for generation and other applications with the existing available technologies.

➢ **Applications of Geothermal Energy**

- Space heating and cooling
- Generation of electric power
- Industrial process heat.

Other applications include desalination of water, heavy water production, extraction of minerals from geothermal fluids, timber seasoning etc. However, the geothermal energy is presently utilized mainly for power generation and space heating purposes only.

### 3.6.1 Scope for Geothermal Energy in India:

In India we have about 150 known geothermal sites which can produce geothermal fluids upto 160 deg. Cel. Either in the form of hot springs (upto 90 deg. Cel.) and shallow water reservoirs (upto 160 deg. Cel.). However, the main locations of geo-thrermal fields are:

(i) Puga valley in j and k
(ii) Manikaran in Himachal Pradesh
(iii) Sohana near Delhi
(iv) Unai and Jalgaon in Maharashtra
(v) Tuwa in Gujarat
(vi) Tattapani in Chhatisgarh
(vii) Bakreswar in Bihar
(viii) In the belt of Godavari and Mahanadi basin

A 5 kW Pilot geothermal power plant has been installed at Manikaran by the GSI and National Aeronautical Laboratory (NAL), Banglore.

### 3.6.2 Global Scene

The geothermal-based electrical generation capacity in the world stands at approximately 10715 MWe. A global-level study of renewables in the year 2000 showed that geothermal energy ranked third after small hydro and biomass. There are several countries where geothermal energy is dominant.

The United States of America started late in geothermal energy extraction and installed 420 MWe near the Geysers field on the West coast. Many towns in the USA, namely California, San Bernardino, Colorado and Oregon use geothermal energy

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## 4. Present uses of Renewable Energy

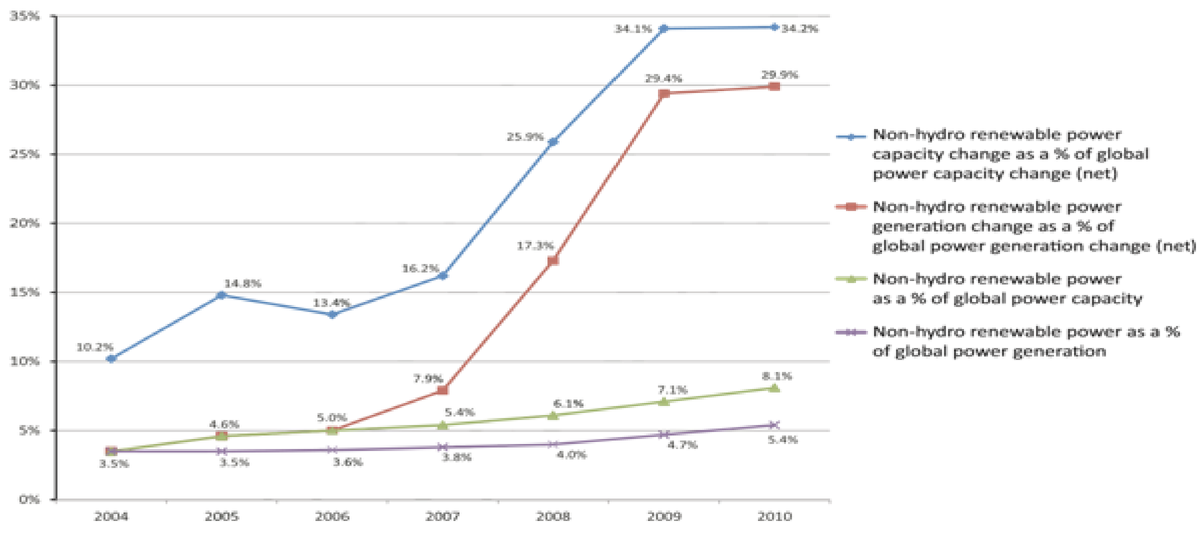
Since 1990 the energy provided from renewable sources worldwide has risen at an average rate of nearly 2% a year, but in recent years this rate has increased to about 5% annually. As a result, the global contribution of renewables has increased from about 74 EJ in 2005 to about 89 EJ in 2009 and represents now 17% of global primary energy supply (528 EJ), (see Figure 3.2 ). Most of this renewable energy comes from the traditional use of biomass (about 39 EJ) and larger-scale hydropower (about 30 EJ), while other renewable technologies provided about 20 EJ.

Many renewable technologies have experienced high annual growth rates – some (biofuels, wind, solar electricity, solar thermal, and geothermal heat) even experiencing double-digit growth rates globally over the past five years – and now represent an economy with more than US $_{2005}$ \$230 billion of investment annually. With cumulative installed contributions to the power, fuel, and thermal heat markets growing rapidly, turnkey costs reflect not only the capital intensity and most often zero or low fuel costs of these solutions, but also the technology and scale advancements of the past decades. The levelized costs of energy, particularly for the more mature renewable technologies, offer competitively priced solutions in some markets but are still comparatively expensive in others under current economic pricing schemes.

In 2009, the contribution of renewable energy technologies to the world's electricity generation was roughly 3800 TWh, equivalent to about 19% of global electricity consumption. Renewable power capacity additions now represent more than one-third of all global power capacity additions.

In the figure presented in Table 5, the contribution of renewables to the primary energy supply based on the substitution calculation method is presented. Using this method, non-traditional renewables contributed 50 EJ in 2009. Following other calculation methods and Table 4– the total result for 2009 would be different: 28.5 EJ when using the physical content calculation method and 26 EJ when using the direct equivalent calculation method.

### 4.1 Potential and obstacles for renewable energy technologies




The potential of renewables to provide all the energy services needed is huge, and in the Further developing and exploiting renewable energy sources using modern conversion technologies would enhance the world's energy

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security, reduce the long-term price of fuels from conventional sources, and conserve reserves of fossil fuels, saving them for other applications and for future generations. It would also reduce pollution and avoid safety risks from conventional sources, while offering an opportunity to reduce greenhouse gas emissions to levels that will stabilize greenhouse gases in the atmosphere, as agreed upon globally. It could also reduce dependence on imported fuels, minimize conflicts related to the mining

**Figure 4.1** |The generating power and capacity of non-hydropower renewable energy sources as a proportion of global power generation and capacity in the period 2004–2010. Source: UNEP and BNEF 2011.

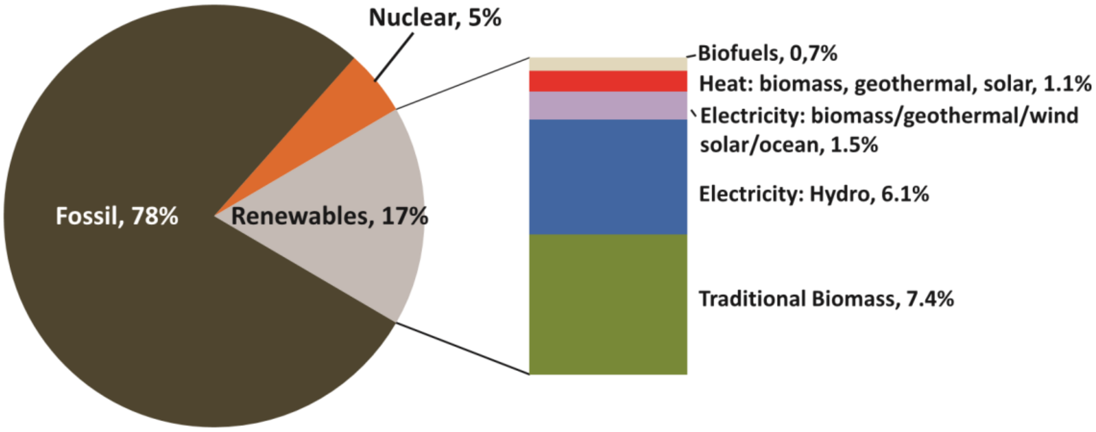


**Figure 4.1** | Renewable share of primary energy supply in 2009 (528 EJ). Source: fossil and nuclear fuel use: IEA 2011;

renewables and use of limited available natural resources, and spur economic development, creating new jobs and regional employment. But using energy from renewable sources also faces a number of challenges because of their often low spatial energy intensity (J/m²) or energy density (J/m $^3$) compared with most fossil fuel and nuclear energy sources, their generally capital intensive installation costs, their sometimes higher-than-desirable operational costs, and a variety of environmental and

**Table 4.**Present status of Renewable Energy technologies as of 2009

| Technology | Installed capacity increase in past five years (percent per year) | Operating capacity end 2009 | Capacity factor (percent) | Secondary energy supply in 2009 | Primary energy supply in 2009 (EJ/yr) based on the substitution calculation method | Turnkey investment costs ($/kW of output) | Current energy cost of new systems | Potential future energy cost |
|---|---|---|---|---|---|---|---|---|
| Biomass energy | | | | | | | | |
| Electricity | 6 | 54 $GW_e$ | 51[a] | ~ 240 $TWh_e$ | 3.3 | 430–6200 | 2–22¢/$kWh_e$ | 2–22¢/$kWh_e$ |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Bioethanol | 20 | 95 bln liter | 80[a] | ~ 76 bln liter | 2.7 | 200–660 | 11–45 $/GJ | 6 –30 $/GJ |
| Biodiesel | 50 | 24 bln liter | 71[a] | ~ 17 bln liter | 0.9 | 170–325 | 10–27 $/GJ | 12 –25 $/GJ |
| Heat / CHP | ~ 3 | ~ 270 $GW_{th}$ | 25–80 | ~ 4.2 EJ | 5.2 | 170–1000 | 6–12¢/$kWh_{th}$ | 6–12¢/$kWh_{th}$ |
| Hydroelectricity | | | | | | | | |
| Total capacity | 3 | ~ 950 $GW_e$ | 30–80 | ~ 3100 $TWh_e$ | 32 | 1000–3000 | 1½-12¢/$kWh_e$ | 1½-10¢/$kWh_e$ |
| Smaller scale plants (<10 MW ) | ~ 9 | ~ 60 $GW_e$ | 30–80 | ~ 210 $TWh_e$ | 2.2 | 1300–5000 | 1½-20¢/$kWh_e$ | 1½-20¢/$kWh_e$ |
| Geothermal energy | | | | | | | | |
| Electricity | 4 | ~ 10 $GW_e$ | 70–90 | ~ 67 $TWh_e$ | 0.7 | 2000–4000 | 3–9¢/$kWh_e$ | 3–9¢/$kWh_e$ |
| Direct-use of heat | 12 | ~ 49 $GW_{th}$ | 20–50 | ~ 120 $TWh_{th}$ | 0.5 | 500–4200 | 2–19¢/$kWh_{th}$ | 2–19¢/$kWh_{th}$ |
| Wind electricity | | | | | | | | |
| Onshore | 27 | ~ 160 $GW_e$ | 20–35 | ~ 350 $TWh_e$ | 3.6 | 1200–2100 | 4–15¢/$kWh_e$ | 3–15¢/$kWh_e$ |
| Offshore | 28 | ~ 2 $GW_e$ | 35–45 | ~ 7 $TWh_e$ | 0.07 | 3000–6000 | 7–25¢/$kWh_e$ | 5–15¢/$kWh_e$ |
| Solar Photo-Voltaics | | | | | | | | |
| Electricity | 45 | ~ 24 $GW_e$ | 9–27 | ~ 32 $TWh_e$ | 0.33 | 3500–5000 | 15–70¢/$kWh_e$ | 3–13¢/$kWh_e$ |
| Solar thermal electricity (CSP) | | | | | | | | |
| Without heat storage | 15 | 0.8 $GW_e$ | 30–40 | ~ 2 $TWh_e$ | 0.02 | 4500–7000 | 10–30¢/$kWh_e$ | 5–15¢/$kWh_e$ |
| With 12h heat storage | - | - | 50–65 | - | - | 8000–10,000 | 11–26¢/$kWh_e$ | 5–15¢/$kWh_e$ |
| Low- temperature solar thermal energy | | | | | | | | |
| Low-temperature heat | 19 | ~ 180 $GW_{th}$ | 5–12 | ~ 120 $TWh_{th}$ | 0.55 | 150–2200 | 3–60¢/$kWh_{th}$ | 3–30¢/$kWh_{th}$ |
| Ocean energy | | | | | | | | |
| Tidal head energy | 0 | ~ 0.3 $GW_e$ | 25–30 | ~ 0.5 $TWh_e$ | 0.005 | 4000–6000 | 10–31¢/$kWh_e$ | 9–30¢/$kWh_e$ |
| Current energy | - | exp. Phase | 40–70 | negligible | - | 5000– | 9– | 5– |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 14,000 | 38¢/kWh$_e$ | 20¢/kWh$_e$ |
| Wave energy | - | exp. Phase | 25 | negligible | - | 6000–16,000 | 15–85¢/kWh$_e$ | 8–30¢/kWh$_e$ |
| OTEC | - | exp. Phase | 70 | negligible | - | 6000–12,000 | 8–23¢/kWh$_e$ | 6–20¢/kWh$_e$ |
| Salinity gradient energy | - | R&D phase | 80–90 | - | - | - | - | - |

[a] industry-wide average figure; on plant level the CF may vary considerably.

Social concerns related to their development. An additional important issue is the intermittent character of wind, solar, and several ocean energy, requiring backup system investments or other innovations to secure a reliable energy supply.

### 4.2 System integration of renewable energy technologies

System integration studies show no intrinsic ceiling to the share of renewables in local, regional, or global energy supplies, depending on the resource base and energy demand. Intelligent control systems, supported by appropriate

**Table 5 |** Contribution of modern renewables to primary energy supply in 2009 using three calculation methods: the substitution method (with GEA conversion efficiencies), the physical content method, and the direct equivalent method.

| **Technology** | **Primary energy supply in 2009 (EJ/yr) using the substitution method** | **Primary energy supply in 2009 (EJ/yr) using the physical content method** | **Primary energy supply in 2009 (EJ/yr) using the direct equivalent method** |
|---|---|---|---|
| Biomass energy | 12.1 | 12.1 | 12.1 |
| Hydroelectricity | | | |
| Total hydropower capacity | 3 2 | 1 1.2 | 1 1.2 |
| Smaller scale plants (<10 MW) | *2 .2* | *0 .76* | *0 .76* |
| Geothermal energy | 1.2 | 3.3 | 0.67 |
| Wind electricity | 3.7 | 1.3 | 1.3 |
| Solar PV electricity | 0.33 | 0.12 | 0.12 |
| Solar thermal electricity (CSP) | 0.02 | 0.05 | 0.007 |
| L ow-temperature solar thermal energy | 0.5 | 0.43 | 0.43 |
| Ocean energy | 0.005 | 0.002 | 0.002 |
| **Total supply** | *49.9* | *28.5* | *25.9* |

Energy storage systems and energy transport infrastructure, will help renewable energy meet the energy demands of different sectors. However, the variability of wind, solar, and several ocean energy resources can create technical or cost barriers to their integration with the power grid at high levels of penetration (20% or above).

To reduce or overcome these barriers, the main approaches in the electricity sector involve: drawing power from geographically larger areas to better balance electricity demands and supplies; improving network infrastructures; increasing the transmission capacity, including the creation of so-called super grids for long-distance power transmission; developing the Smart Grid further; applying enhanced techniques to forecast intermittent energy supplies hours and days ahead with high accuracy; increasing the flexibility of conventional generation units (including dispatchable renewables) to respond to load changes; using demand-side measures to shift loads; curtailing instantaneous renewable supplies when necessary to guarantee the reliability of power supplies; and further developing and implementing energy storage techniques.

### 4.3. Policy instruments and measures

A key issue is how to accelerate the deployment of renewables so that deep penetration of these technologies into the energy system can be achieved quickly. Renewable energy technologies face a number of factors that make it harder for them to compete based solely on costs: their capital intensity, scale, and resource risk; their discounted value to traditional utility operators; their real or perceived technology risk; the absence of full-cost accounting for environmental impacts on a level playing field; generous subsidies to the use of conventional energy sources; and a lack of recognition of their long-term value for reducing utilities' exposure to variable fuel costs.

A wide range of regulatory, fiscal, and voluntary policies have been introduced globally to promote renewable energy – whether renewable electricity, renewable heat, or renewable fuels. These serve a range of technology-specific objectives, including innovation, early-stage development and commercialization, manufacturing, and market deployment, as well as wider political goals such as creating new manufacturing bases for a technology, local and global environmental stewardship, and economic prosperity. These policies all help to reduce risk and encourage renewable energy development, and they are generally used in combination. Integrating renewable energy into the conventional energy system will require a portfolio approach that addresses key issues such as comprehensive and comparable cost-benefit analysis of all energy options, provision of stable and predictable policy environments, and removal of market barriers and competing subsidies for fossil fuels, thus increasing the probability for successful innovation and commercialization, provided that the policies complement one another.

Of the market pull policies, two are most common. Feed-in tariffs (FITs) ensure that renewable energy systems can connect and supply their power to the grid and offer a set price for renewable energy supplies. Policies known as quota or obligation mechanisms (also referred to as Renewable Portfolio Standards, Renewable Electricity Standards, or Renewable Fuel Standards) set an obligation to buy but not necessarily an obligation on price. So far, FITs have been used for electricity only, although some countries are now considering how to provide them for heat. Quotas have so far been used for electricity, heat, and transport. Biofuel mandates are now common globally.

The rapid expansion in renewables, which has largely taken place in only a few countries, has usually been supported by incentives or driven by quota requirements. The FITs used in the majority of European Union countries, China, and elsewhere have been exceptionally successful. The number of states, provinces, and countries that have introduced policies to promote renewable energy doubled in the period 2004–2009.

### 4.3 Future contribution of renewable energy

Many studies have been done on the potential of renewable energy in the remainder of the twenty-first century. Most of them indicate that the contribution of these sources, excluding traditional and non-commercial uses, could increase from today's 10% of world energy supply to 15–30% in 2030, to 20–75% in 2050, and to 30–95% in 2100, depending on assumptions made about economic growth, the volume of investments in energy efficiency and energy technology development, policies and measures to stimulate the deployment of different technologies, and public acceptance of these technologies. Some studies suggest that by 2050, renewable sources could provide 75–95% of the world's energy, or even all of it, if there is enough societal and political

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will to choose a path of clean energy development that focuses mainly on renewable sources; on new energy transmission, distribution, and storage systems; and on strong improvements in energy efficiency. There is, however, no consensus on whether such a deep penetration of renewables can be achieved in practice within the indicated time frames because of physical limits on the rate at which new technologies can be deployed, the need to design targeted policies to accelerate the deployment of specific, and the difficulty of curtailing energy use through actions on the demand side.

### 4.4 Steps for the better and efficient use of renewable energy technologies

-Setting up biomass/solar/wind power generation systems and energy saving in every government office to encourage and inspire people.

-Strenous exaltation of renewable energy by government agencies, public sector, corporate, academic institutions etc.

-Foundation of national-level body to increase awareness of renewable energy at comprehensive level.

-Research and development of renewable energy technologies get provided the financial support and sponsorship.

-Development of technically trained man-power for renewable energy sectors.

-Establishing aspiring goals and targets for power generation renewable sources.
-Making it compulsory to install solar water heating systems for all urban residential and commercial establishments.

-Imperative renewable energy systems provision for new residential, commercial and industrial buildings.

-Restricting use of large battery energy storage systems and promoting use of bio fuels in vehicles.

-Abrogating duties/taxes on import of small-scale renewable energy generating equipment and providing manageable loans for setting up renewable energy enterprises.

-Handsome incentives and subsides for installation and successful operation of renewable energy equipment and additional incentives for buyers and manufactures of renewable energy equipment in rural areas.

-Cultivation of energy crops on marginal and degraded land.

## CONCLUSION

Renewable energy technologies could reduce carbon dioxide emissions by replacing fossil fuels in the power generation industry and the transportation sector. Due to negative and irreversible externalities in conventional energy production, it is necessary to develop and promote renewable energy supply technologies. Power generation using renewable energy sources should be increased in order to decrease the unit cost of energy and to make them compatible with a competitive alternative to the conventional energy sources. Two main solutions may be implemented to reduce $CO_2$ emissions and to overcome the problem of climate change: replacing fossil fuels with renewable energy sources as much as possible and enhancing energy efficiency regardless of type. In this review, we considered hydro, wind, solar and geothermal sources, because of their significant contribution to power generated by renewable sources.
Renewable energy production and supply is continuously increasing on the global level.

Following the drastic increase in oil price and its impacts on both coal and gas prices, a large amount of investment has been made over recent years in renewable energy. These advancements in technology have enabled countries to produce renewable energy in larger quantities and more cost effectively. Hydro power is the largest renewable energy source for power generation around the world. Despite its large energy generation contribution, its development is difficult due to a high initial fixed investment cost and environmental and population relocation costs.

Hydro power is attractive due to a combined supply of water for agriculture, household, recreation and industrial-use.

Improved energy efficiency is an important way to reduce energy use, and thereby $CO_2$ emissions, and to overcome the climate change problem. We discussed state of the art methods for the technical and economic feasibility in the implementation of renewable energy sources, as well as the possibility of their combined use and substitution in the first part of this review. In the latter part wediscussed energy efficiency technologies. This review of renewable energy generation and efficiency technologies has provided detailed and useful information that can be used in the decision making of different stakeholders in the rapidly developing market. Each technology has both advantages and disadvantages that vary by location, availability, the technological capability of producers, financial limitations and environmental considerations. Each municipality, region or country has different initial conditions that determine the energy mix that can be produced at the lowest cost while minimizing the harm done to the environment. Thus, there is no single solution to every energy need and problem, but rather an optimal location specific solution among a set of possible renewable solutions.

Concerning the finite and limited reserves of conventional energy sources and their impact on environment, a great emphases should be given to the development of renewable energy sectors and their proper utilisation for the benefit and betterment of mankind. Such initiatives would also be helpful to create many employment opportunities at all levels, especially in rural areas. Thus, mainstreaming of renewable energy technologies is becoming very essential for the developing countries.

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