Renewable Energy: Resources and Effective Coherent Technology

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Abstract: **Renewable energy is a clean form of energy that does not contribute to environmental pollution. The main objective for disseminating renewable energy systems and technology is to fulfill the energy demand globally in a sustainable, reliable, and affordable way. The significant challenges of the 21st century are climate change, depleting fossil fuel resources, and reducing greenhouse gases emissions. Renewable energy resources, namely solar energy, wind energy, geothermal energy, Ocean energy, and biomass energy, have the potential to overcome these challenges and fulfill energy demand economically and sustainably. In contrast, energy-rich non-renewable resources, namely oil, natural gas, coal, and nuclear energy, are not sustainable and limited in supply that cannot fulfill the energy demand in the future. The issue of climate change and CO2 emissions can be resolved by substituting fossil fuels with renewable energy resources and improving Energy Efficiency. Renewable resources are environmentally friendly and available locally, a better substitute for non-renewable energy. However, the construction and operation of renewable energy systems and integration with present systems are critical, and upcoming technologies will overcome these barriers.**
In this paper, renewable energy resources and alternative technologies for efficient energy use are discussed.

Keywords: **Renewable Energy, Energy Efficiency, Clean Energy, Sustainability, Greenhouse gases.**

I. INTRODUCTION

The critical challenges of the 21st century are depleting fossil fuels, climate change, and emissions of greenhouse gases. The leading cause of carbon emission is excessive use of non-renewable sources, polluting our environment. The non-renewable energy sources are coal, oil, natural gas, and nuclear energy. These resources are limited in nature, and the regeneration process of fossil fuels takes millions of years under the earth's crust. The main advantage of conventional energy resources is that they are easy to use, but they are limited and will expire in the future. Also, they are non-environmental friendly.

To fulfill the energy demand in the future, the reliable and sustainable source of energy is renewable energy, green energy. Renewable energy resources include solar, hydro, wind, tidal, geothermal, and biomass energy. At the same time, renewable energy resources are available in abundant amounts globally and cleanest form of energy in the world. Many countries have started replacing and integrating non-renewable energy sources with renewable energy sources. Implementing and integrating renewable energy with conventional energy is a complex task due to cost disadvantages and the subsidization of fossil fuels.

The main significant advantage of green energy is that it eliminates the harmful effects of fossil fuels on the environment as renewable energy resources are more environmentally friendly. Furthermore, green energy emits negligible or no greenhouse gases, which are better for humans and animals' health.Green energy resources are available naturally in abundant amounts, and they can provide stable prices as they are not affected by transmission and transportation costs. Also, there will be no effect of the geopolitical disputes and crises on energy prices. The availability of renewable energy resources locally, such as solar and wind, will make more independent on centralized sources and lead to flexible energy infrastructure. Green energy represents an economical solution of energy that will improve the accessibility of electricity in developing and underdeveloped countries as solar and wind is available globally and suitable for all Geographic locations. Without compromising reliability, our world is just a few years away from renewable energy systems infrastructure.

In the first section, the significant resources of green energy - wind, solar, geothermal, hydro energy as well as other sources of renewable energy such as biomass, ocean energy and vibration energy are explained, which plays a vital role in reducing carbon emissions and improving environmental conditions. Furthermore, renewable energy supply resources and energy coherent technology are two main clean energy concepts. These concepts can help to generate clean form of energy which leads to sustainable environment. The effective coherent technologies that improve energy utilization efficiency (e.g., Electric vehicles - EV, combined heat and power - CHP, and virtual power plant - VPP) are discussed in the second portion. These present coherent technologies have the potential to reduce greenhouse gas emissions. The conclusion is explained in the last part.

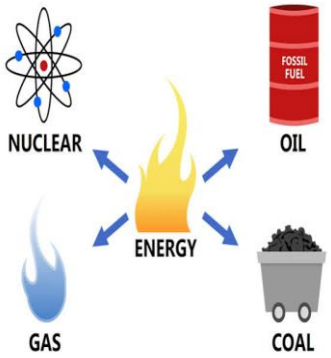

Fig.1 Non-renewable Energy Resources

Fig.2 Renewable Energy Resources

II. RENEWABLE ENERGY SUPPLY RESOURCES

Renewable energy supply resources include solar and wind, the most important and easily available resources with geothermal, hydropower, ocean, and biomass energy. In recent years, a large amount of investment has been made by many countries to produce renewable energy more effectively and efficiently to increase the power supply. Currently, renewable energy resources are not comparable with non-renewable energy sources due to the cost of power generation. In contrast, renewable energy generation is sustainable. Also, it reduces transmission and distribution costs. The renewable energy resources and their current facts of development are discussed below:

i. Wind Energy

Wind energy is a sustainable form of energy, generated by wind turbines, a better substitute for fossil fuels. Winds are formed by the rotation of the earth, irregularities of the earth's surface, atmospheric heat, and pressure differences in the environment. Wind turbine uses the kinetic energy of wind and convert it into mechanical energy first and then to electrical energy using variable speed generators. The wind energy generation process is entirely non-polluting using these natural factors and wind turbines. Also, no any kinds of greenhouse or harmful gases are released during wind energy generation. Therefore, wind energy is one of the green forms of energy.

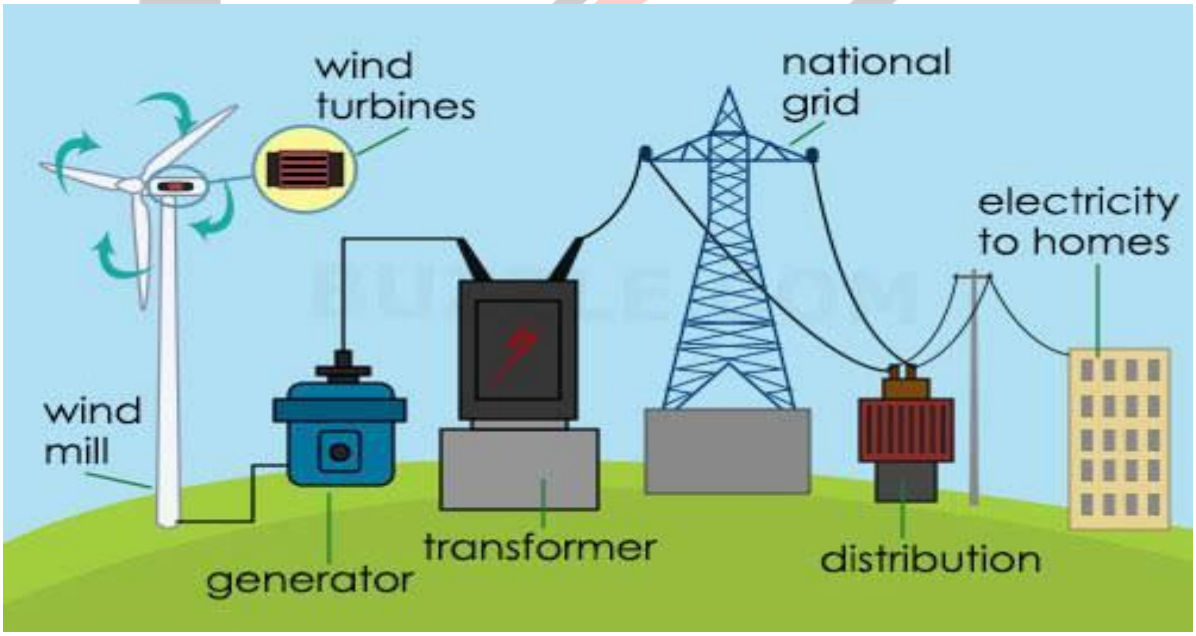

Fig.3 Wind Energy Generation System

The vital source of renewable energy is a wind farm, an array of large wind turbines. All turbines are interconnected with each other by a medium voltage power collection system and communication network in the wind farm. Nowadays, wind turbines are designed in such a way that they can generate electricity even if the wind speed is low. To minimize dependency on fossil fuels and reduce carbon emissions, many countries have started using this technology.

The main barrier in wind energy sources is transmission cost. The installation of wind turbines depends on the windy sites where population density is low, but it increases the cost of power transmission to residential areas. In some windy sites where fewer land resources are available, offshore wind turbines are an effective solution for land-based turbines. Similarly, in the case of residential areas, offshore turbines can be installed to save transmission costs. The largest offshore wind farm, located in Denmark, includes 80 turbines that produce 2 MW of power. According to (2009), Ngô and Natowitz, Denmark export the majority of power it generates from wind turbines because the domestic demand is substantially less than the power produced.

Another limitation in wind energy systems infrastructure is cost. The total cost of wind energy systems includes both installation and operation expenses, where revenue is dependent on wind turbines' performance and the quantity of energy generation. Taxes can achieve these financial targets, but national energy policy also plays a vital role. Power generation using wind turbines can be successful when there is a market or government policy for generated power, in which some local or residents can sell a part of the power generated by their wind turbines back to a local utility.

Haack (1981) calculated the net energy of a small wind conversion system in the US and compared it to other fossil fuel-based electricity generation sources. He estimated the energy production through a simulation model taking into account wind speeds, residential electricity demands, and parameters from the generator, inverter, and storage components. The results showed that net energy obtained by the wind system is better than other systems. Haack argued that additional steps used in the process of obtaining fuels by new technologies increase the efficiency of conversion.

It is found that the best environmental solution for conventional sources of energy is wind power generation if three conditions are satisfied:

1. Use of high efficient turbines on a proper site (windy site)
2. Consume less energy in the transportation stage
3. Performing the recycling process correctly.

ii. Solar Energy

The sun is a huge source of solar energy. Solar energy is a clean and green form of energy that does not contribute to the emission of greenhouse gases and provides sunlight to all living beings on the earth. Solar energy is the most suitable renewable energy as it is available quickly and inexhaustible. Solar energy can be converted directly into electrical energy using technologies such as solar photovoltaic cells (PV) and solar thermal systems.

Solar photovoltaic technology (PV) is a technology in which electric energy is generated directly using photovoltaic cells. In this technique, energy is generated through the photoelectric effect. The arrangement of solar photovoltaic is in such a way that they can capture maximum sunlight. Using these photovoltaic modules, electric energy generated is in the form of direct current (DC), which is then converted into alternate current (AC) using inverters.

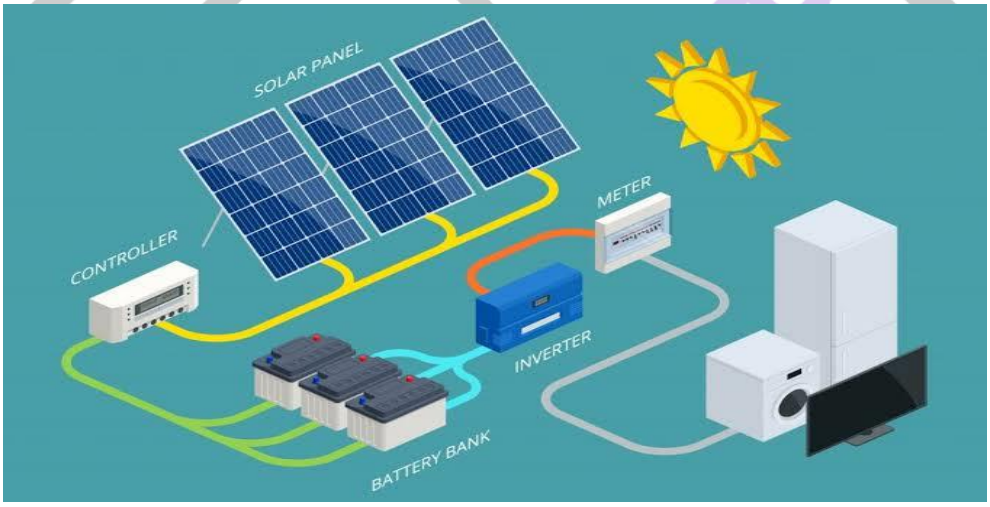

Fig.4 Solar Energy Generation System

Furthermore, in the solar thermal power plants technique, solar radiations are concentrated on a small portion to get the high temperature as output. This high temperature is used to produce steam which is used to rotate turbines. With the help of a turbine-generator system, electrical energy is produced. Solar thermal power systems consist of Parabolic Trough Systems, Solar tower Systems, and Stirling systems.

Considering the energy demand for residential, commercial, and industrial use, solar energy is the best alternative for non-renewable resources. In the 1990s, Japan started large-scale electricity generation using photovoltaic (PV), and afterward, Germany started solar electricity generation power plants for sustainable power generation. Taking advantage of government subsidies and cheap cost labour availability, China has developed a vast solar power generation infrastructure with a low cost of power generation. Many technologies are used to establish solar radiation, including thermal solar energy concentrated solar power plants (CSP), solar towers, and photovoltaic systems.

Photovoltaic technology allows the integration of PV collectors into the building and can turn external walls, windows, and roofs into PV collectors. However, some environmental and health concerns can arise from the use of materials in the PV systems. There is a need for innovations and technological improvements to overcome material challenges. The production of photovoltaic

cells is one of the fastest-growing industries. This type of industry requires research on low cost and high efficient materials, devices, and system design to improve performance and good political support for returns on investments. Solar home systems, remote houses, communities, and industries have a good solar PV power generation market.

In contrast, there are also adverse effects of solar technologies, such as land use, impacts on buildings' appearance, etc. Solar power generation is affected by weather conditions. Due to cloudy weather or because of pollution and dust problems, the efficiency of solar power generation decreases. Comparing wind and solar power generation, solar power has time restrictions. Therefore, solar power generation is affected by weather, geographic conditions, and location. Solar energy is a sustainable substitute for fossil fuels if some minor barriers are overcome with upcoming future technologies for reliable and efficient power generation to fulfill energy demand.

iii. Geothermal Energy

Geothermal energy is a cleaner and more sustainable form of renewable energy. The process of radioactive decay of uranium and potassium produces magma (heat source) inside the Earth's crust which generates a tremendous amount of heat energy. Geothermal energy is energy generated from heat which generates from the radioactive decay of materials inside the Earth. Geothermal is a type of thermal energy generated by the radioactive decay process with a temperature of approximately 4,000˚C at the Earth's core and stored within the Earth. The first geothermal power generation plant was built in Larderello. There are a total of 24 countries currently using geothermal power plants.

There are mainly four types of geothermal resources are hydrothermal, geo-pressured, hot dry rock and magma. From these all resources currently, only hydrothermal resources are in use commercially, whereas other technologies are still needed improvements for practical use. Geothermal energy can be used to produce electrical energy or directly in space heating, water heating, greenhouse heating, aquaculture, laundries, and industrial processes.

To determine the accessibility of geothermal energy, the geothermal gradient and permeability of rocks are used. Geothermal energy is available worldwide, and an essential factor in geothermal energy is called the geothermal gradient. Geothermal gradient indicates and helps to decide whether the geographic location is suitable for a geothermal plant or not. Geothermal gradient measures the rate at which the temperature increases as the depth of the Earth increases. For instance, the average geothermal gradient in France is 4˚C/100m with a range of 10˚C/100m. Whereas in the Alsace region to 2˚C/100m in the Pyrenees Mountains. In Iceland and the volcanic regions, the gradient can reach as high as 30˚C/100m (Ngô and Natowitz, 2009). By using the permeability of rocks, the heat flow rate is calculated. The heat flow rate to the surface is considered another important factor in determining the availability of geothermal energy.

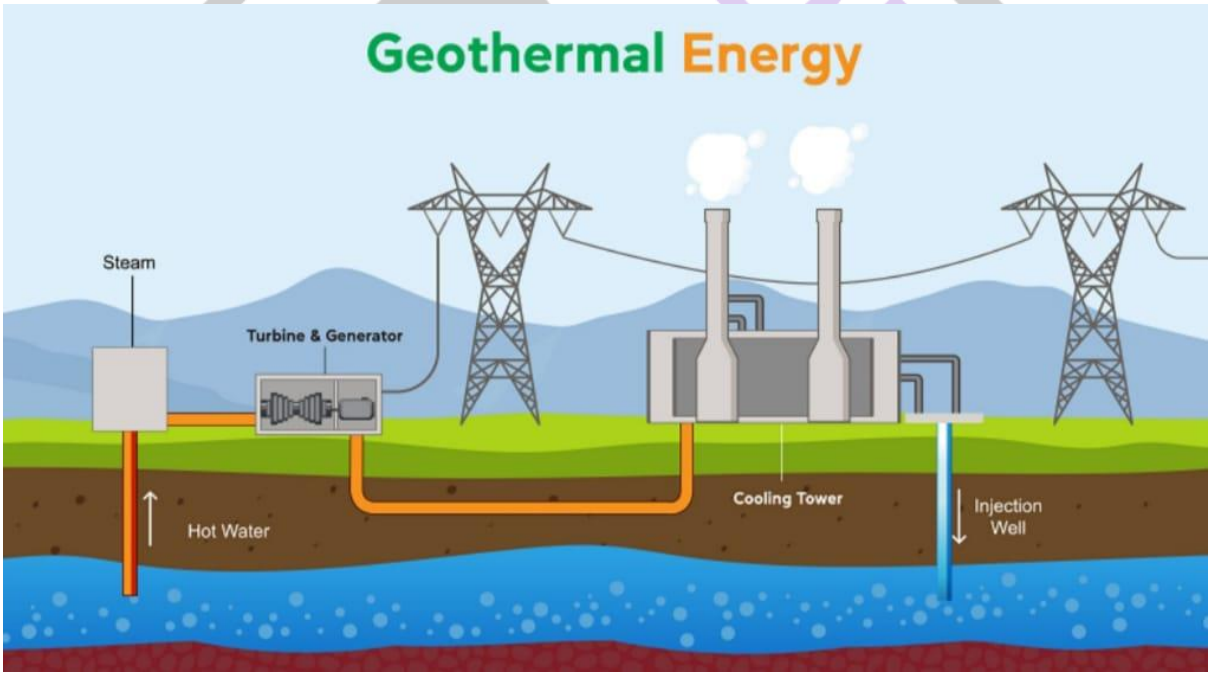

Fig. 5 Geothermal Power Plant

Geothermal energy has a significant advantage compared to wind, and solar energy resources are that, it is available for 24 hours a day throughout the year. Geothermal energy is independent of weather conditions and storage capabilities. Also, it can be used for both base and peak load power plants. To balance geothermal energy production costs and to increase the feasibility of power generation, fiscal policy must be used, including a carbon tax. The materials and energy inputs determine the geothermal power plant's lifecycle. Even less convenient geothermal heat and power generation also contribute to an energy system and improve sustainability.

Geothermal resources emit 55g/kWh CO_2; this rate can be decreased to 0 if geothermal fluids are injected back into the ground. However, again, the response of a geothermal reservoir depends on the geothermal system. Also, there are minor problems such as releasing steam, gases, and hot water into the river, which advanced technologies can remove. Some developing countries with geothermal energy resources face difficulties in geothermal power generation with present technologies due to insufficient finances

and infrastructure knowledge. The main disadvantage of geothermal energy is high investment costs and the risk of insufficient heat of geothermal technology.

In a recent study, Chamorro et al. (2012) reviewed the status of geothermal energy (worldwide) and found that high-temperature technologies (flash and dry steam) are the most developed geothermal power generation technologies. They defined four plant models, including 1FMP (single flash), 2FMP (double flash), 3FMP (triple flash), and DSMP (dry steam), to analyze various geothermal systems. The results showed that the DSMP model has the highest NPV amount (1,013.6 million dollars) and IRR factor (22.8%). Also, the cost of electricity is estimated to be 29.38 $/MWh for the DSMP model, the minimum among the different models.

iv. Hydro Energy

Hydro energy is clean energy as it is generated from flowing water. Hydroelectric power plants use the potential energy of stored water in the dam for power generation. The continuous and fast-flowing water converts potential energy to kinetic energy, and then using generators, electricity is produced. There are mainly three types of hydropower generation plants globally:

(i) Run-of-river- The power is generated by the flow of river water directly. E.g., Small scale hydropower stations

(ii) Reservoir- The power is generated by releasing stored water from dams.

(iii) Pumped storage- The stored water is backed up into the reservoir to be pumped again.

In the world, nowadays hydropower is generated from large-scale power plants produce hundreds of megawatts of power and involves the construction of massive dams, which tends to have ecological impacts. Whereas small-scale dams generate less power than large-scale dams and have less impact on the environment. Microscale hydropower generation plants are sufficient for small villages and individual residential houses as they can produce power in kilowatt with low environmental disturbance.

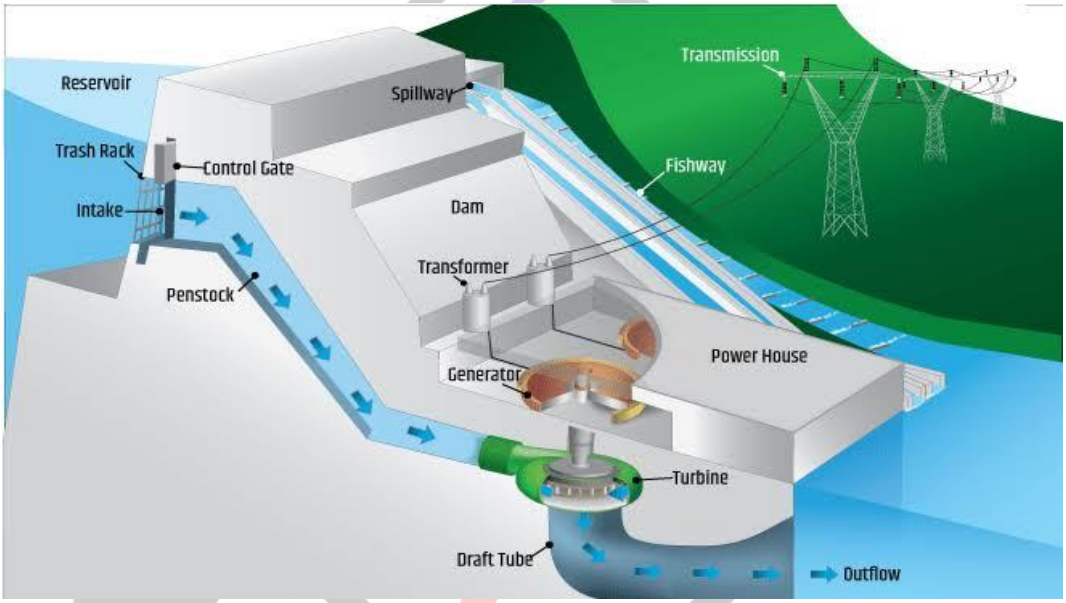

Fig.6 Hydro-electric Power Plant

Hydropower is the largest resource of renewable energy for power generation globally. Currently, approximately 19% energy demand of the world is fulfilled by hydroelectric power plants. In 1950, hydroelectric power generation was 340 TWh (terawatt-hour) worldwide, covering one-third of energy demand globally, which increased drastically to 2994 TWh (terawatt-hour) in 2005. This shows that hydropower generation has fast growth in the world. Itaipu Dam is the largest capacity hydropower plant in the world installed on the Paraná River and developed by Brazil and Paraguay together. Initially, the capacity was 12.6 GW in 1984, and it was increased to 14 GW in 2006.

Hydroelectric power generation is attractive as it is a clean source of energy and store water as well as energy. The stored water is useful for agricultural, industrial, and household purposes. Also, the stored energy can be used for applications such as base-load and peak time power generation. Hydropower is a better substitute for fossil fuels. Hydropower plants' greenhouse gas emissions factor is 15g CO2 equivalent/kWh, which is approximately 30 to 60 times less than that of non-renewable energy power generation plants. The main advantages of hydroelectric power generation plants are a more concentrated energy resource than solar and wind, available on-demand, long-lasting technology, limited maintenance, no fuel needed for power generation.

The development of hydroelectric power plants is totally dependent on geographic location and monsoon conditions. Currently, the development of hydropower plants is complex due to some financial, technical, and environmental problems. Hydropower plant installation includes huge initial fixed investment as well as affects the environment a lot. Hydropower plant construction causesecological disturbance due to land acquisition and lots of engineering works. Furthermore, the problem of relocation is associated with the local residential population as well as the construction of dams is permanent with a sunk cost of utilities which cannot be removed.

In Europe and North America, where the hydropower sector is already developed, improving storage capacity instead of developing new hydropower plants considering environmental impacts. Lehner et al. (2005) applied a model to analyze possible impacts of climate change on Europe's hydropower generation, and it is indicated that hydropower potential will decrease

significantly by 25% or more in south-eastern European countries. It is predicted that the overall hydropower potential of Europe will decrease about 6% by 2070 due to climate change. Ehnberg and Bollen (2005) investigated the availability of hybrid power plants using hydropower plants with the following power combinations: solar power, solar power and storage, solar and hydropower, solar and hydropower with storage. This will result in improvement in efficiency and contribute to fulfilling energy demand.

v. Other renewable sources

Solar, wind, hydro, and geothermal energy are major energy resources that contribute to renewable energy generation. Biomass, ocean waves and, tides, vibrations are also other types of renewable energy resources from which clean energy can be generated. Biomass is consists of organic waste produced by plants, humans, animals, and marine life. The significant advantage of biomass is that it is readily available locally in all places. Biomass can be used to produce electricity as well as the heat source for cooking. Biomass is also used as chemical feedstock as biomass has low sulphur content than coal, contributing less carbon emission. In early 2000, the United States had an installed capacity of 11 GW from biomass including the forest product and agricultural industry, municipal and solid waste industry, and other sources (Ngô and Natowitz, 2009).

Ocean energy is energy generated from ocean sources. Due to the massive availability of ocean sources, extracting energy from the ocean is considered an interesting renewable energy option. There are mainly six different ocean energy resources are available: offshore wind energy, wave power, marine current energy, ocean thermal energy conversion, tidal power, and osmotic power. The Bayof Fundy has the largest tidal range in the world that enables it to support a power station with a capacity of 2 GW or more (Tester, 2005).

Everything present in the world vibrates at some frequency. Some at the low frequency, which are detectable, and some cannot be detected with high frequency. Vibration energy can be converted into electric energy using transducers. There are two types of transducers are available- piezoelectric materials and electromagnetic transducer. Piezoelectric materials are present in crystalline structures, which can produce electrical energy when mechanical stress is applied on them. Transducers are a device that converts different forms of energy into electrical energy. Vibrations produced by a large crowd, vehicles on roads, tall buildings, long bridges, and rails can be converted to electrical energy and can be used for small electronic appliances. Vibration energy can contribute to fulfilling small-scale energy demands in the coming years.

III. EFFECTIVE COHERENT TECHNOLOGIES IN RENEWABLE ENERGY

We discussed different renewable energy sources with their positive effects on the environment, current growth, and future scope to achieve sustainability. As mentioned earlier in this paper, there are mainly two ways to reduce CO2 emissions and to control climate change. The two main solutions are:

- replacing fossil fuels with renewable energy resources as maximum as possible
- by improving energy efficiency

For an electricity network, energy efficiency is considered in various stages: power generation, power transmission, power distribution, and power consumption. Currently available technologies are electric vehicles (EV), combined heat and power (CHP), and virtual power plant (VPP) discussed below:

i. Electric Vehicles (EV)

The primary source of carbon and greenhouse gas emissions is the transportation sector. Carbon emissions can be controlled to some extent by improving fuel efficiency for the short term. Electric vehicles (EVs), including batteries, fuel cells, and hybrid types, are considered sustainable options for electricity generation and storage to reduce carbon emissions. More use of electric vehicles will contribute to low CO2 emissions and a sustainable environment.

For the short term, all combinations of vehicle/battery are cost-effective power resources during peak time. If electric vehicles cover transportation networks, then demand for baseload power generation will decrease. Kempton and Tomic (2005) investigated the systems and procedures required to use energy in vehicles and the implementation of the vehicle to grid (V2G) technology. The significant role of vehicle to the grid (V2G) technology supports renewable energy through supply fluctuations and load management in the developing power markets.

Integration of renewable energy with transportation and electricity sectors using the vehicle to grid technology (V2G) reduces the significant CO2 emissions. For the development of a market that coordinates the production and consumption of renewable energy, Andersen et al. (2009) introduced an intelligent electric recharging grid operator (ERGO). ERGO model has the potential to overcome the problems of greenhouse gas emissions and power fluctuations. ERGO model can convert EVs to be distributed storage devices for electricity. Implementation of EVs can be influenced by carbon tax as well as by environmental and transportation policies. Plug-in hybrid electric vehicles (PHEVs) could be considered a cost-effective and reliable transportation solution as electricity costs at about $0.03/mile ($0.13/kWh), whereas gasoline costs $0.12/mile ($3/gallon). This shows that the use of EVs with renewable energy is cost-effective as well as leads to a sustainable environment.

Fig. 7 Electric Vehicles

ii. Combined heat and power (CHP)

Combined heat and power (CHP) is a technology in which heat and power are used together. Power distribution companies mostly supply only electricity and do not supply heat (hot water and stream). Globally, almost 30-40 % of the total energy load of countries is used for heating. CHP is efficient and useful as it uses waste heat energy for heating purposes, which is a waste by product. End users in the USA are able to purchase electricity as well as thermal energy from utility companies. It is estimated that the CHP capacity of the US will increase 20% by 2030. It will contribute to the reduction in CO2 to emissions by using CHP. Globally, the average efficiency of the power plant is 40%, while 60% of primary energy is converted to waste heat. Using CHP technology, the waste heat can be used for industrial processes, heating in residential and commercial buildings. This will help to improve the energy efficiency to approximately 85 %. Similarly, combined cooling heat and power (CCHP) able to provide a significant amount of primary energy with the reduction in CO2 emissions. Also, this technology can improve efficiency for CCHP in refrigeration. CHP units are the better option for making power systems more flexible in the term of the use of waste heat.

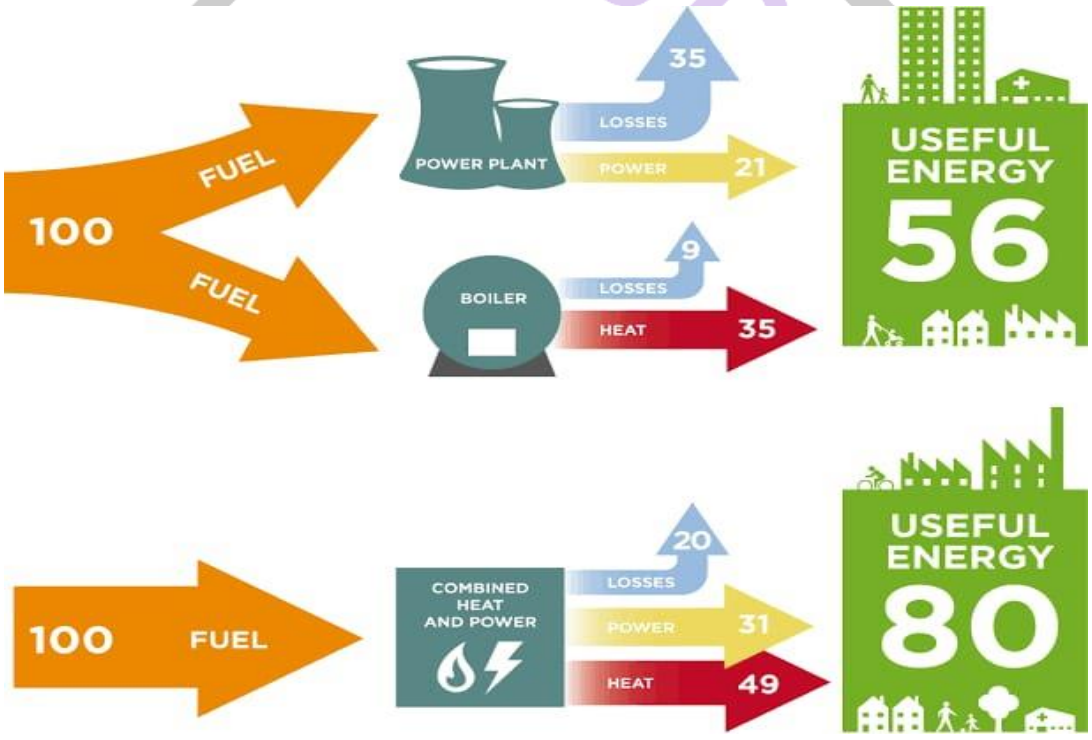

Fig. 8 Combined heat and power system

iii. Virtual power plant (VPP)

A virtual power plant comprises distributed energy resources including micro CHP (Combined heat and power), wind turbines, and solar photovoltaic panels. VPP is controlled and managed by the central control unit. A large amount of power loss occurs during power transmission to long distances. Distributed energy resources (DER) are introduced to overcome the energy loss problems. DER is generally located near to the distribution networks. The concept of VPP is used for DER integration.

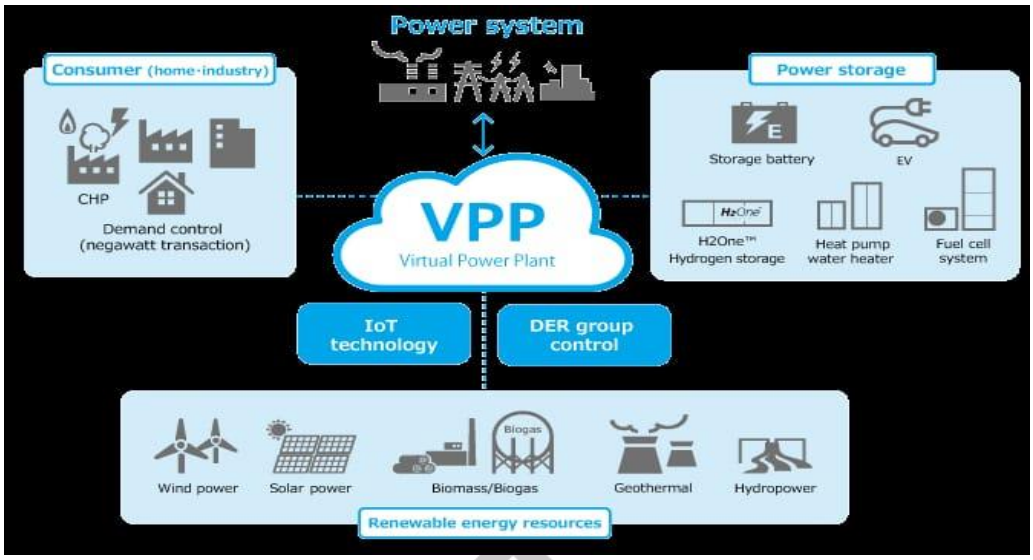

Fig.9 Virtual power plant

There are mainly two types of VPPs
1. Commercial VPP (CVPP)
2. Technical VPP (TVPP)

CVPP is the portfolio that DER can use to participate in electricity markets. CVPP can represent DER from any geographic place in the electricity network. Technical VPP allows operators to facilitate DER energy capacity and improve the power balance in the system at a low cost. Distributed energy resources DER can be part of both CVPP and TVPP simultaneously.

VPP is a new technology that can improve Energy Efficiency. Power generation using renewable energy resources such as wind and solar totally depends on weather conditions. It may cause an unstable power supply. It is essential to maintain a stable power supply. For stable use of renewable energy power, VPP is an important Technology. It is necessary to control power generation and storage stations which are situated at various locations as well as supply and demand of power. Accurate electricity supply and demand can be predicted, and balance between supply and demand can be maintained with the help of VPP technology. By using VPP Technology, stable use of renewable energy is possible.

IV. Conclusion

In this paper, it is concluded that renewable energy, which is non-polluting and current coherent technologies, needs more technical development to replace conventional energy resources. Renewable energy resources are available in abundant amounts with the potential to fulfill energy demand in the future. It will reduce the dependency on non-renewable energy resources. Power generation using solar panels to fulfill the energy need of residential houses is a good step towards sustainability. Our world is currently facing climate change issues, and renewable energy has the potential to overcome these problems in a sustainable way by replacing fossil fuels.

The prices of conventional energy resources are increasing, which results in a high cost of energy per unit. While, the use of renewable energy can reduce the cost of energy per unit. Hydro, wind, solar and geothermal energy are major sources of renewable energy. The main significant advantage of renewable energy is that power production does not contribute to CO2 emission and also reduce transmission and distribution cost. It helps to make the environment green. With current technologies in Electric Vehicles (EV), the pollution caused by the transportation sector is reduced. Combined Heat and Power (CHP) technologies prevent wastage of heat as it uses waste heat for heating purposes and improves fuel use fuel efficiency. Virtual power plant (VPP) technology helps to control and manage power demand and supply and reduce transmission expenses. By using renewable energy, stability in energy cost can be achieved as it does not affect by countries' geopolitical disputes or import costs, transmission and distribution costs.

Our world is currently facing climate change issues, and renewable energy has the potential to overcome these problems in a sustainable way by replacing fossil fuels. Renewable power generation is facing the problem of high equipment costs. Power generation using renewable energy resources is a complex task as operating and integrating with existing power systems need technical development for reliable operations. Considering the continuously increasing crude oil prices, there is a need for technical development in the renewable power sector. So it can fulfill energy demand with zero pollution.

Both renewable and non-renewable energy technologies have their own benefits and drawbacks varying with location, availability of resources and technology, financial and environmental limitations. To replace conventional energy resources with renewable energy completely, advanced technical development is required, and highly skilled experts are working on this to overcome the barriers in renewable energy production.

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