AN OVERVIEW OF GREEN ENERGY SOURCES, ENHANCING THE ENVIRONMENTAL AND ECONOMIC ELEMENTS OF THE WORLD'S SUSTAINABILITY

Yalini R.[1], Ramesh K.[2], Subbarayan M R.[3] and Sivakumar A[4*]

[1]Department of Electrical and Electronics Engineering, Jayam College of Engineering and Technology, Dharmapuri, Tamilnadu, India. yalinik9603@gmail.com

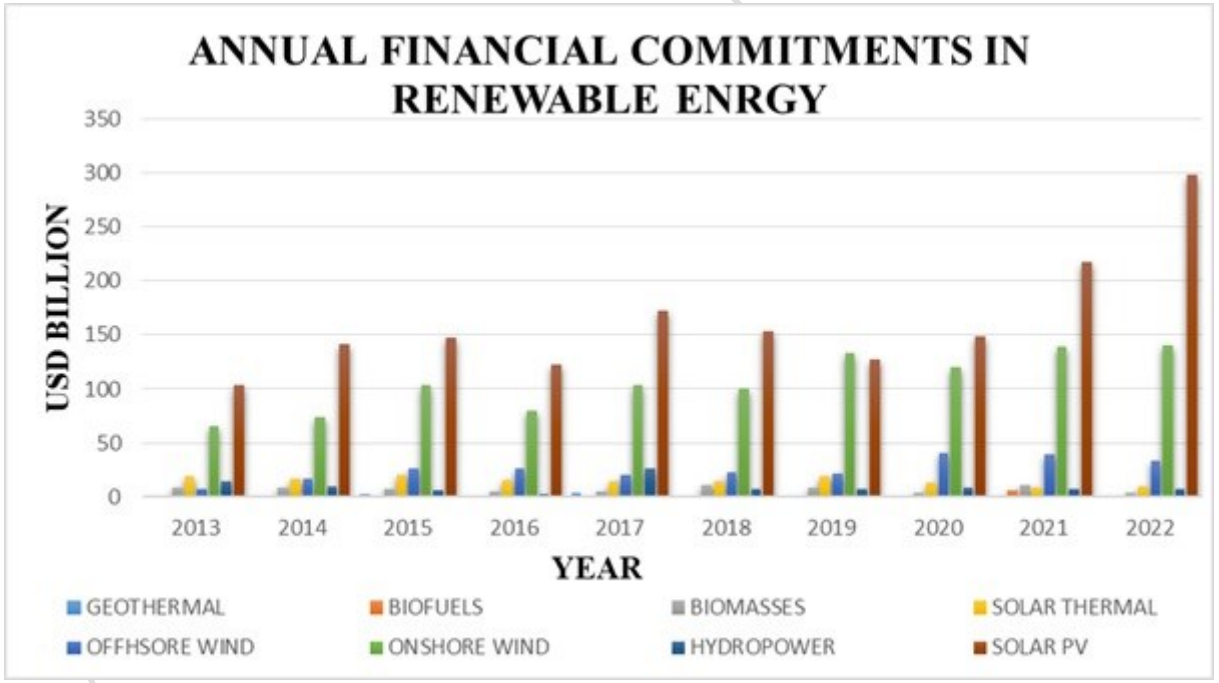
[2]Department of Electrical and Electronics Engineering, Jayam College of Engineering and Technology, Dharmapuri, Tamilnadu, India. ramesh120376@gmail.com

[3]Department of Mechanical Engineering, Jayam College of Engineering and Technology, Dharmapuri, Tamilnadu, India. subbarayan7779@gmail.com

[4]Department of Mechanical Engineering, Varuvan Vadivelan Institute of Technology, Dharmapuri, Tamilnadu, India. sirarira@gmail.com

*to whom all correspondence should be addressed: e-mail: sirarira@gmail.com

GRAPHICAL ABSTRACT



ABSTRACT

In a transitional world, where countries strive for the achievement of better environmental quality through setting up various goals, there is a need for the substitution of fossil fuels and non-renewable resources which deteriorates the environment, with renewable energy resources which alleviates the problems of scarcity, depletion and degradation of natural resources. This

article focuses on improving the economic welfare of the countries through the consumption of renewable energy resources, which focuses on the environmental benefits and the economic improvement in the nation's life. It is evidence showing the contrast between differences in electricity generation and the capacity of different types of renewable energy resources in the world, which is solved by focusing on renewable energy consumption.

Keywords: Renewable energy resources, Electricity generation and Capacity, Technologies, Economic Welfare

INTRODUCTION:

"The World has enough for everyone's need, but for anyone's greed" quoted by M.K.Gandhi, depicts the reality of the growing human needs which influence the consumption of non-renewable resources, those which take longer time to replenish, and when consumed given by-products like greenhouse gases, chlorofluorocarbons, which are hazardous to the nature and the environment as it deteriorates the quality of the resources available and depletes the stock that is not extracted. To meet the growing demand, there is a derived demand for renewable energy resources which are available in abundance and can easily be replenished, enabling countries to meet their demands more efficiently with least waste-generating technologies, thereby bringing in energy security ((Zhao, 2018), (Menegaki, 2018)) in the countries, aiming to have energy interdependence rather than focusing on independence, that is substituting energy imports can be replaced with the joint actions by the country to cope with the demands of renewable energy in the world to meet the global demand.

OBJECTIVES:

This article explores the economic advantages derived from renewable energy consumption. The major focus is on the electricity generated and the capacity of electricity from different renewable energy sources, the sharp contrast between them and the reasons for such differences. This article also talks about the recent technologies used in the consumption of certain renewable sources, and the predominant prevalence of certain energy resources on which most countries target to achieve the environmental objectives. This will not only lead to improvement in the environmental domain but also bring in the economic welfare of the country, by improving employment opportunities, which nurtures the living standards of people through infrastructural investments which are endowed with investments in global renewable energy, thereby increasing the per capita income of individuals contributing to the

larger GDP of the nation. The data in the article referred to is from the International Renewable Energy Agency (IRENA) and International Energy Agency (IEA) and a qualitative analysis of the bar diagram is used to demonstrate the findings from the reports released by the international organizations.

LITERATURE REVIEW:

The usage of renewable energy sources, the scientific advancements to elevate their usage, their upcoming potentials and their plan of execution were discussed (Ellabban, O et al., 2014).Also, the impact of various power electronics and smart grid technologies for optimal use of renewable energy sources was represented.

The significance of diffusing renewable energy technologies (RETs) (Kishore et al.,2010) was stated and only 20-25% of the total capacity of renewable resources has been realized in order to meet the growing derived demand, renewable energy technologies must be used more efficiently through techno-economic, learning and experience curve approach.

The need to replace fossil fuel energy resources with renewable energy resources through microgrids, which are single controllable grids which interconnect the energy generated and distribute it was explored(Abu-El et al.,2019).

The impact of renewable energy resources consumption on the Chinese economy, working on the Cobb-Douglas function in the Impact of Renewable Energy Consumption to Economic Growth: a Panel Data Application (Inglesi-Lotz, 2016) was studied empirically.

The transmission from energy independence to energy interdependence (Hongtu zoha et al.,2019), energy security and the growing need for efficient utilization of resources, and energy security is not focused on the fall of imports but on the interdependence between countries to jointly cope with risks and challenges.

Encyclopedia of Biodiversity empirically depicts the transition from fossil fuels to renewable energy resources and enhances energy security by harnessing biomass and biofuels, and heavily investing in its research, development, and production. The demand for bioenergy is growing and there is still a long way to go to decide whether it will help or harm the ecosystem depending upon the production process of bioenergy. (*Encyclopedia of Biodiversity*, 2013).

RENEWABLE ENERGY RESOURCES:

Renewable energy sources are the sources which do not deplete when extracted and are

available in abundance. The extraction of such resources is unlimited and perpetual, as the needs grow, the derived demand for the renewable resources grows instantaneously. Human wants and needs are unlimited, such wants can also be met by various other resources which are non-renewable or exhaustible, which are resources which deplete with extraction and consumption. Since, with nurturing concerns over environmental stability and sustainability, the extraction of such non-renewable resources is in downfall. Renewable energy includes solar, wind, hydro, biogas, etc. They are in-exhaustible and can be used multiple times because the time for their regeneration is much less or regeneration is needless. Whereas the regenerative capacity of non-renewable or exhaustible resources like fossil fuels is much slower and might take thousands of years to replenish to meet global human needs. When the rate of extraction exceeds the rate of natural growth or the regenerative capacity, then arises the problem of resource depletion and degradation, which is unlikely to occur with the renewable resources whose regenerative capacity exceeds the extraction rate. The International Energy Agency has set up a NET ZERO SCENARIO 2050 (NZE), is a normative step taken by this organization that shows the pathway of achieving Net zero carbon emissions by 2050 by the world countries, using renewable energy resources as a great means of achieving this target. It involves use of better technologies in the extraction and consumption of the resources. This target also focuses on achieving the United Nations Sustainable Development Goals and aims to limit the rise of global temperature 1.5 degrees Celsius and prevent further overshooting of temperature.

WIND ENERGY:

The wind is the result of the heating and cooling of the atmosphere, it is described as the motion of air from a high-pressure area to a low-pressure area and is also caused by the rotational movement of Earth and other topographical factors (IEA). This energy is used for producing electricity by converting the kinetic energy of air into electricity using turbines which rotate and converts the kinetic energy into rotational energy using a shaft. Wind energy is extracted using windmills which are set up in expanse locations with high wind flows and small wind turbines are also used by farmers in extracting wind energy. This extraction and consumption of wind energy is also hindered by the cost of installation, the intermittent monsoon changes, the availability of land resources and the loss of aesthetic scenery which people demand in the recent era.

Wind energy includes both onshore and offshore activities. This field has gained significance in having an edge in ameliorating resource depletion, environmental degradation and further global conflicts. Wind energy has improved rapidly since the early 2000s, there were many supportive policies and agreements in support of wind energy thereby reducing the other costs incurred both economically and environmentally. There were many innovations from the 1830s-1890s, in manufacturing the turbines, as the size of the turbine and the length of the blades determine the electricity that can be harvested from wind. Modern wind power is considered to be built in Denmark in 1891, later the modern wind power sector emerged in the 1980s. Wind technology innovation is focused on manufacturing of high towers and long blades which are sometimes restricted due to public acceptance and environmental reasons.

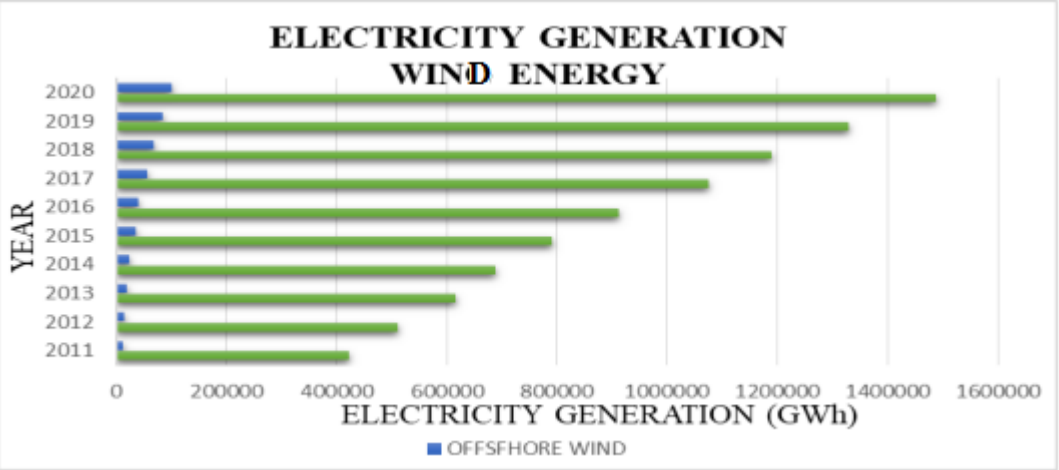


Fig.1 Electricity Generation-Wind Energy

From Fig.1, it is evident that the electricity generation from wind energy has increased significantly in both modes by a factor of 98 in the past two decades. According to the International Energy Agency, in 2022 the total wind capacity was 900GW of which 93% was in onshore wind and the remaining 7% from the offshore wind fields (IEA).

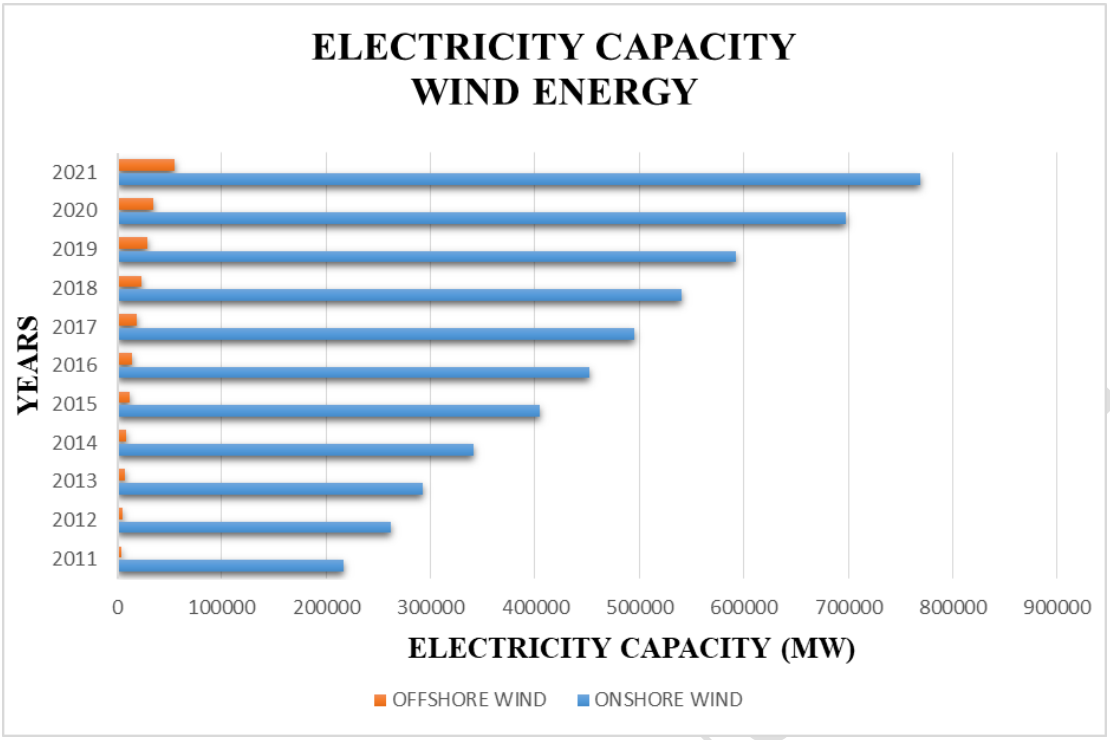


Fig.2 Wind Energy Capacity

It is evident from Fig.2 that the proportion of offshore winds increased proportionately compared to onshore winds in recent years. In 2011, the electricity capacity of onshore wind fields was 216345 MW whereas the electricity generated from onshore fields was 48187 MW which is 22% of the total capacity. The electricity capacity of offshore wind fields during the same time period was 3776 MW whereas the generated electricity was only 1329 MW which constitutes only 35% of the total capacity. In 2020, the electricity capacity of onshore winds is 697266 MW and the electricity generated is only 24% of the total capacity, which is 169916MW. The electricity generated from offshore winds is 11428 MW which constitutes 33% of the total capacity of 34358 MW. China is expected to share 60%-80% of the global capacity of wind power, becoming the hub of manufacturing of wind energy. With improvements in technology and innovations, the Global Weighted-Average Levelized Cost of Electricity (LCOE) of onshore wind fell by 56% and offshore winds fell by 48%.

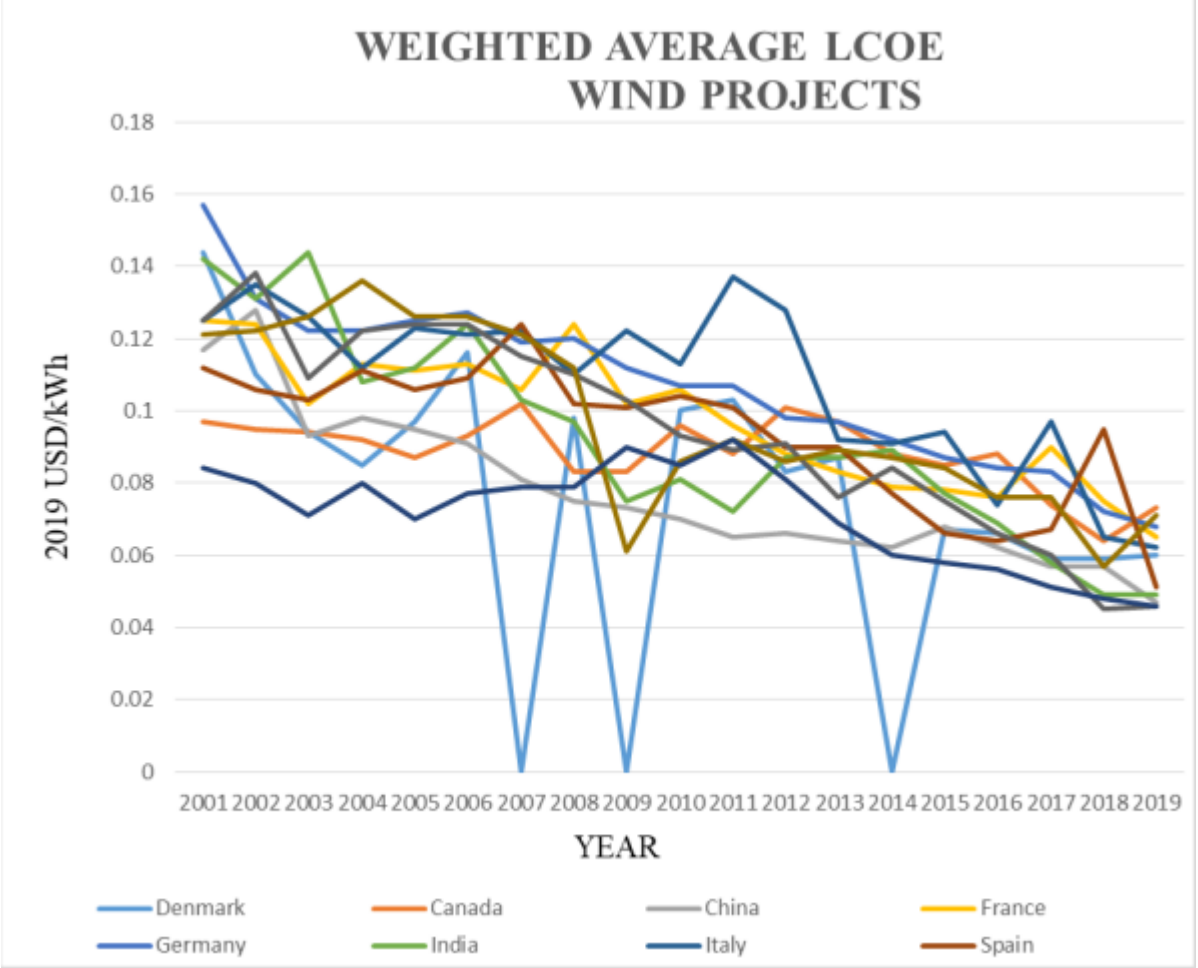


Fig.3 Weighted Average LCOE wind Projects

The chart shown in Fig.3 depicts the downfall of the economic cost incurred in onshore wind fields which are predominant, in generating electricity. The demand for more renewable resources, electricity through wind energy creates a pathway for better economic growth triggering various economic indicators contributing to the nation's wealth and development.

SOLAR ENERGY:

Solar Energy, the energy extracted from sunlight which is an abundant source, helps in producing electricity. The sunlight is extracted through the photovoltaic (PV) cells and systems which absorb the sunlight rays and stores them in batteries or converts them into electricity. This system includes the solar power grid, solar panels etc. This extraction also has pressing

limits such as intermittent seasonal changes, high cost of installation, and the need for investments in technologies for efficient extraction. This solar energy extracted through various photovoltaic systems produces electricity in smaller domains like households and bigger industries which are majorly dependent upon solar energy like iron and steel industries and chemical industries. China is again leading in the electricity capacity of solar energy because there have been many solar power projects which are subsidised by the Chinese government, boosting the production of solar energy through solar power grids and photovoltaic systems.

Concentrated Solar Power (CSP) is a technology which uses mirrors to concentrate solar rays that heat fluid which generates steam, which in turn runs the turbine and generates electricity. This technology is used in large power plants and projects, at the end of 2020 the total global capacity of Concentrated Solar Power reached 7 GW. The greatest advantage of CSP is it enables the heat to be stored in molten salts, which allows the electricity to be stored and generated even after Sunset. There are various methods for concentrating solar rays like point concentration, linear concentration, etc. Linear concentration is also known as the parabolic trough collector which is a curve-shaped system that concentrates sun rays at one location, point concentration is done through solar towers or power towers. “Necessity is the mother of Invention” rightly says the importance of innovations in extracting solar power. There was an invention of windows which are transparent and act like solar panels, they have a standard solar coating and are easily added to any normal window while being made, and this coating contains a mixture of organic salts which absorbs the non-visible solar spectrum of rays. This solar window also does the normal function of a window, like letting the light pass through the room, and this is developed by Ubiquitous Energy, which says that this energy will transform the solar capacity worldwide by turning every window into solar panels and skyscrapers into solar powerhouses, which in reality was done by Michigan University. This will also enable the generation of electricity to the whole building, also when this coating is done on laptops, and mobile phones to power these devices, and then we will be able to achieve our climate goals, in which solar power with wind power will contribute more than 70% of global energy by 2050. There’s another technology where green roofs are set up on the rooftop, which moderates the temperature thus increasing the efficiency of solar panels. A study conducted in Australia has majorly found that bio-solar roofs can increase solar generation by 107% during peak seasons.

From the following graph of electricity generation and capacity of the world countries fig.4, we see that, in 2011 the solar photovoltaic cells had a capacity of 72216 MW but the electricity

generated was only 7214 MW which is 9.8% of the total capacity.

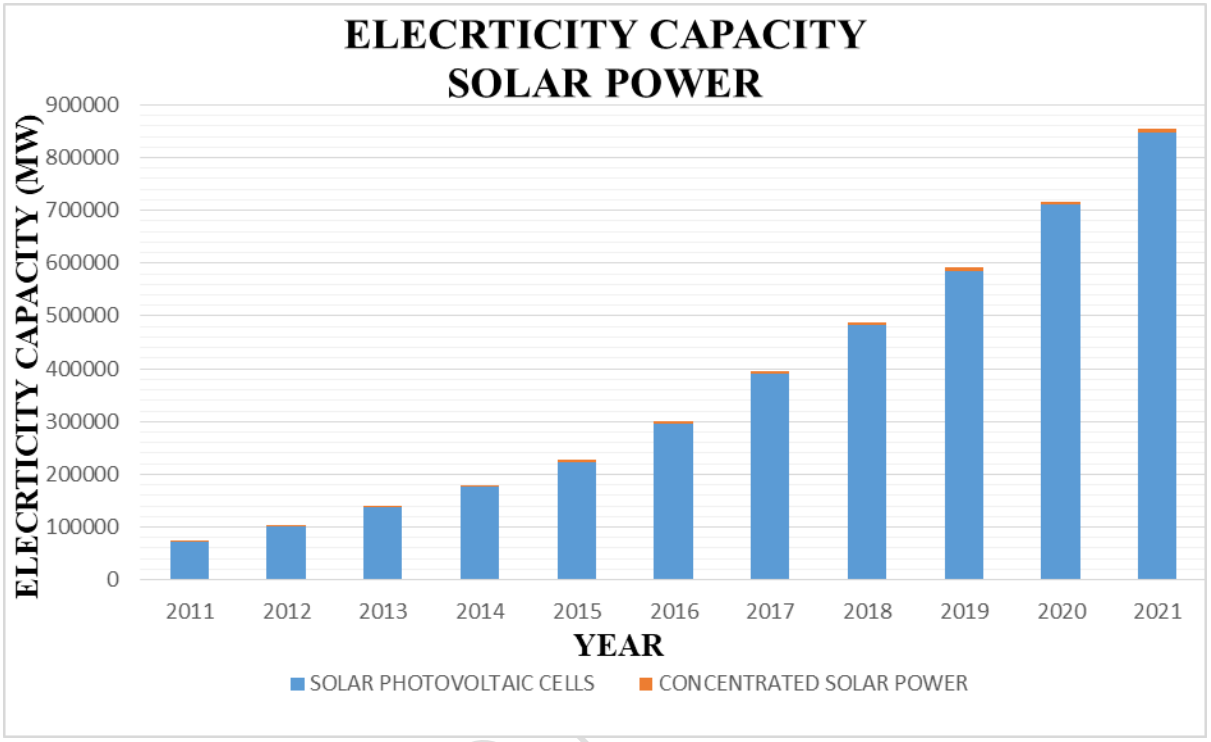


Fig.4 Solar Power Capacity

Whereas of concentrated solar power, the capacity was 2567 MW but the electricity generated was only 368.74 MW which is only 14% of the total capacity. In 2020, solar photovoltaic cells had a capacity of 710700 MW whereas the electricity generated was only 77190 MW which is 10.8% of the total capacity. Although the proportion of concentrated solar electricity capacity and generation has increased, in 2020 the capacity was 6511 MW and the electricity generated was 1612.1 MW which is 24% of the total capacity.

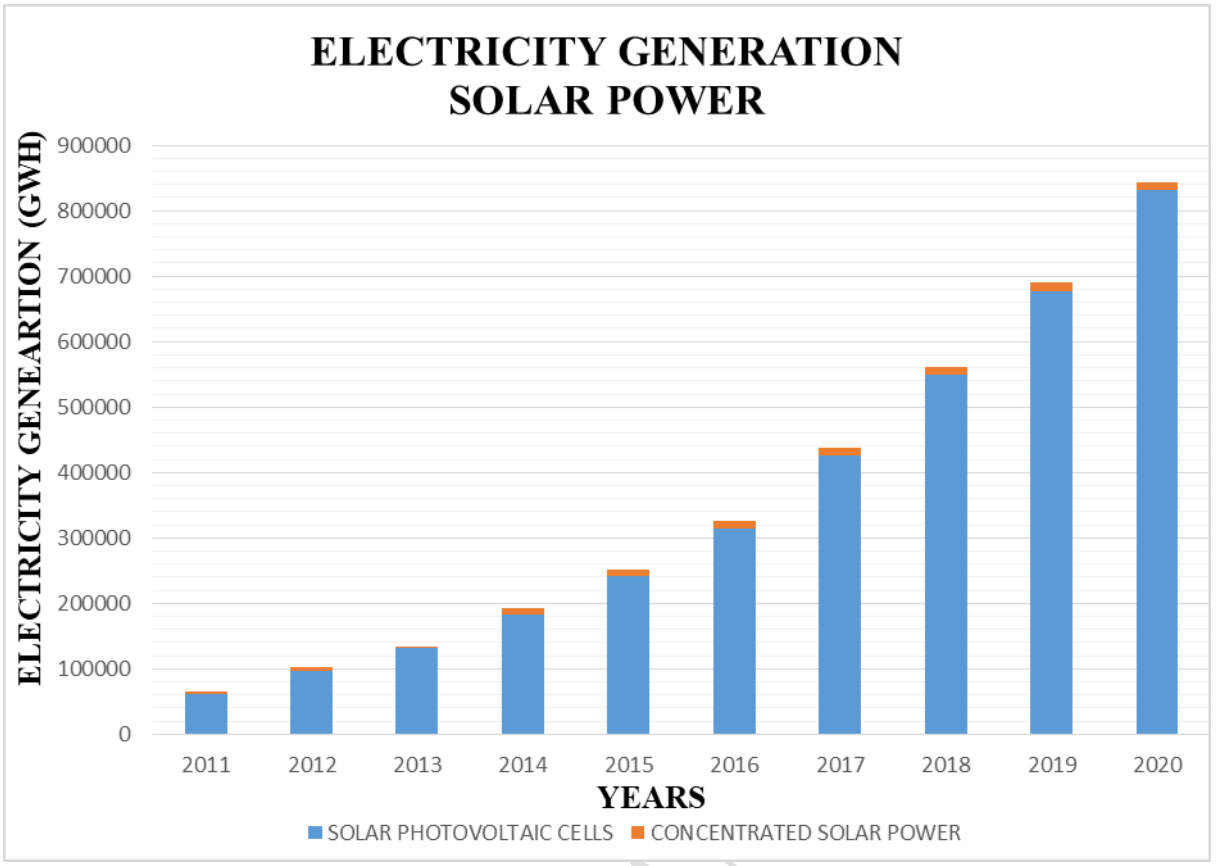


Fig.5 Solar Power Generation

As solar power cannot be produced throughout the day and throughout the year, the maximum capacity of solar power is not achieved to the fullest and the climate and seasonal changes influence this disproportion. The total installed capacity of solar photovoltaic cells at the end of 2020 has reached 710 GW, and during which additional 125 GW was added to the endowment. Solar power panels include systems which can be handy like a home kit in rooftops having capacity of 3-20 KW or even used in large scale industries with capacity of GWs. The improvement in the technology has led to the reduced cost in the generation of electricity from solar power panels. The Global Weighted – Average Levelized Cost of Electricity has been reduced by 85%.

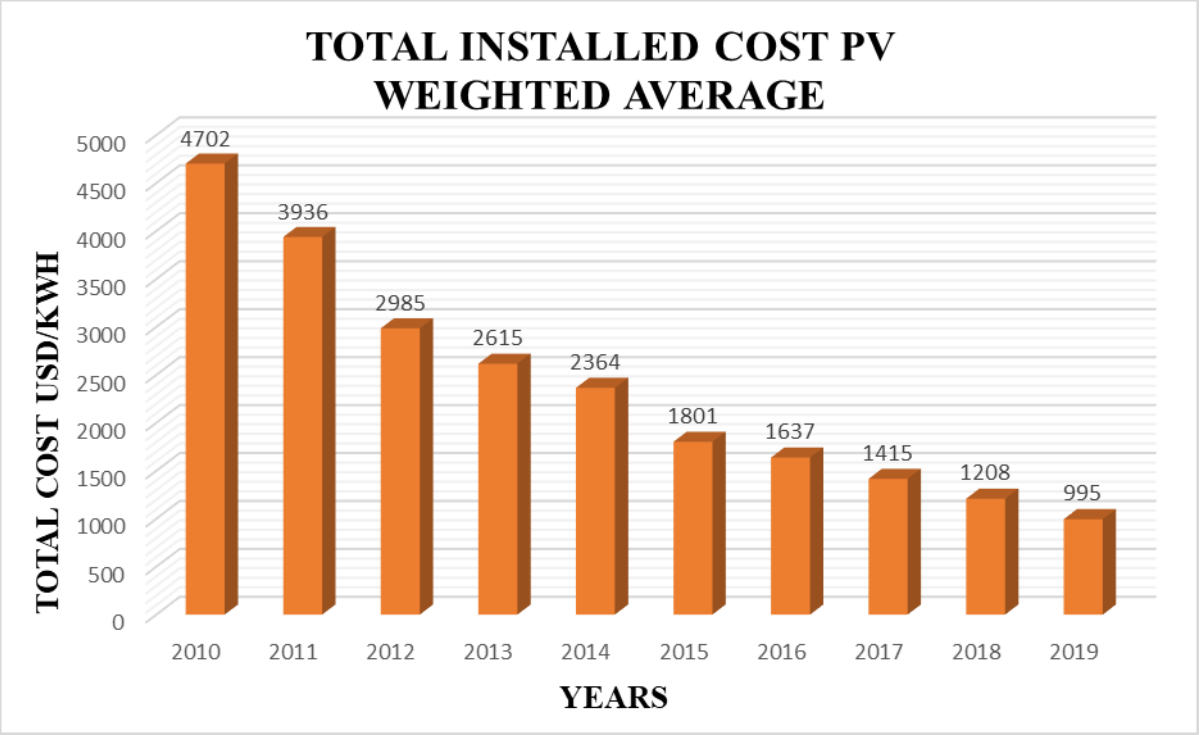


Fig.6 Total Installed Cost PV Weighted Average

HYDROPOWER:

Hydropower is extracted from the kinetic energy of flowing rivers and water systems is converted into electricity, which is stored and utilized by households and industries. This energy is extracted through turbines set in water flow, the faster the flow, speeder will be the turbine runs, and more electricity will be generated. Ocean energy is another type of energy which is extracted from oceans. The extraction of hydropower might cause hindrances the lives of aquatic animals, and the diaspora is dependent on the water resources. Hydropower is expected to become the world's largest source of renewable electricity in the 2030s (IEA) and is now contributing more significantly to electricity generation. It is expected to overtake wind and solar power and the pumped storage of hydropower brings in clean energy transmission. However, the growing conflicts of climate change causes extreme vagaries in the rainfall in various parts of the world, which hinders the generation of electricity from water.

According to the International Energy Agency, Global hydropower is expected to increase by 17% or 230 GW by 2030 (IEA). This resource produces 80-100 TWh per year of electricity

which is adequate for providing electricity to 70-80 million households. Hydropower is generated through two major means: dams or reservoirs or without them. Hydropower dams are large reservoirs where water is stored and is used to generate electricity during peak demands, and seasonal changes etc., hydropower without dams or reservoirs is used on a small scale and meets low demands and operates a turbine in a flowing river, which is why this is considered to be an eco-friendly measure as it doesn't interrupt the flow of river.

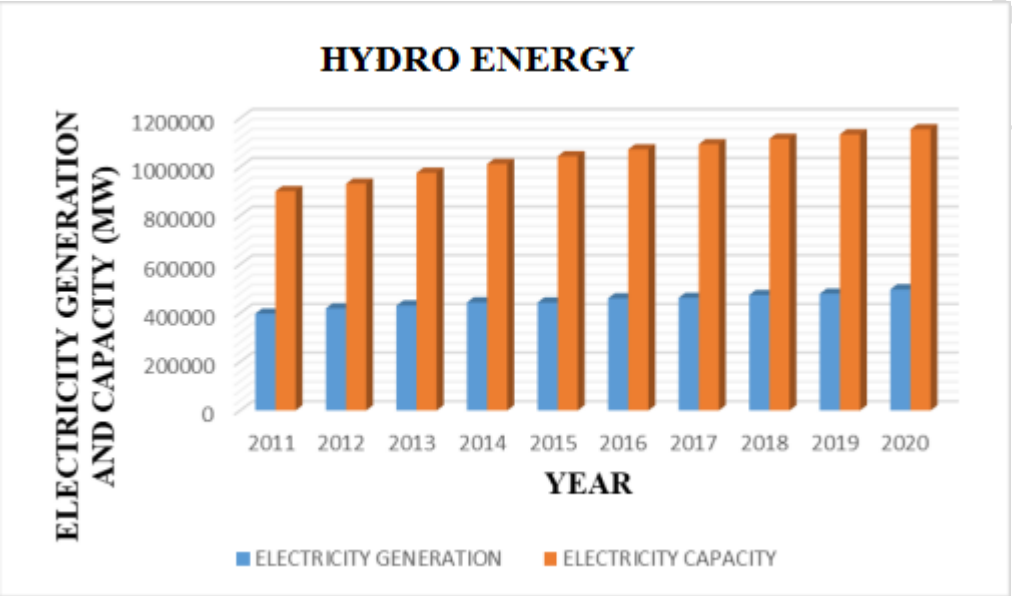


Fig.7 Hydroelectric Energy Generation and Capacity

Given, from the above Fig.7 we infer the electricity capacity and generation by the world countries. Initially in 2011, the electricity generated was 397685.4 MW as against the capacity of 900822 MW, which constitutes nearly 44.5% of the capacity. In 2020, the capacity is 1154757 MW but the generated electricity is only 497239.72 MW which is only 43% of its capacity. The electricity generated is only 40-50% of the electricity capacity of the world, which depicts the scarcity of the resource. With unrestricted extraction of electricity from the hydropower plants and with deteriorating climatic conditions, water is now becoming a scarce resource, also the diminishing environmental quality makes it even worse.

GEOTHERMAL ENERGY:

Geothermal energy is derived from the heat of the Earth either produced at the utmost top layers or the deep layers of magma. This energy is harnessed to produce electricity which is used by various industries at large rather than households. 'Geo' means Earth and 'Thermal' means Heat, which means energy extracted from the Earth's heat. Various geothermal plants are set up at potential locations where the heat is extracted through various means. These plants are more focused in the areas where there are tectonically active plates thereby producing more heat, hence it can be harnessed for generating electricity by heating and cooling. The greatest merit of this energy is it can be set up at low cost and is present throughout the year as there are movements in the Earth due to the presence of mantle between crust and core.

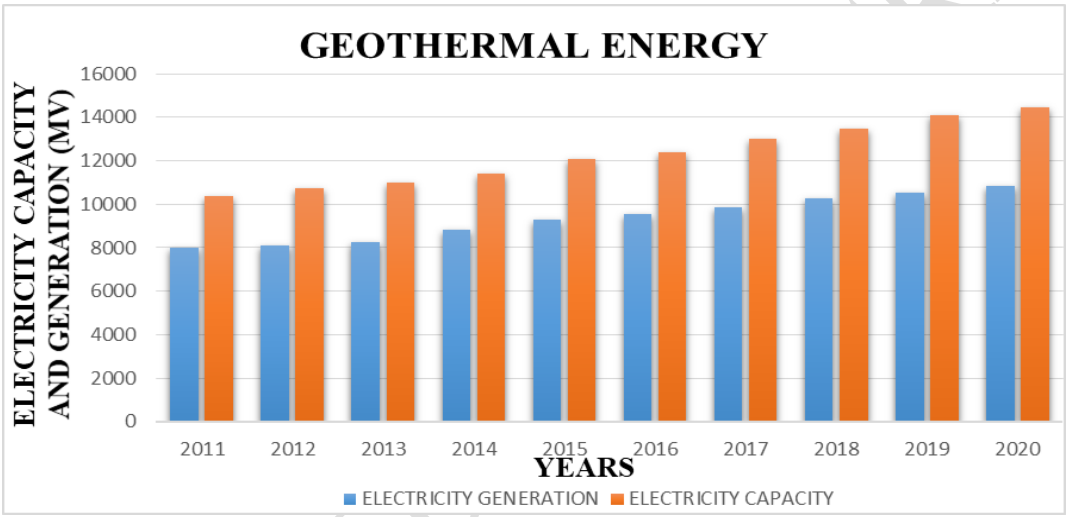


Fig.8 Geothermal Energy Generation and Capacity

International Renewable Energy Agency (IRENA) has cooperated with Global Geothermal Alliance which is a platform for enhancing the sharing of coordinated actions to harness geothermal energy and provide electricity and heat worldwide. Many power plants now harness more than 180 degrees Celsius which are dry or flash plants which use medium temperature fields to generate electricity. In 2021, the USA was the largest user of geothermal energy of 3794 MW followed by Indonesia with 2,356 MW and the Philippines.

Fig.8 depicts the electricity capacity and generation from geothermal energy, in 2011 the electricity capacity was 10376 MW and the electricity generation was 7974.43 MW which is 76% of the total capacity, and in 2020 the electricity generated was 10838.92 MW which is 75% of the total capacity of 14438 MW. It is also evident that the generation of

electricity has increased in magnitude, whereas the proportion of it against the capacity has had a marginal decrease. Compared to other renewable energy sources, this source has the highest percentage of electricity generation in proportion to the total capacity of geothermal energy.

BIOENERGY:

The rapidly developing industry consists of two major aspects: biofuel and biomass. Bioenergy is now replacing fossil fuels as it is a renewable resource, it is an energy extracted from biomass – which are plant and animal-based substances and are renewable like cow dung, grasses, wood etc. Biofuels are the feedstock i.e., the raw materials of biomass and are classified into First-generation, Second-generation and third-generation fuels. First-generation fuels include corn, sugarcane, maize etc. Second-generation biofuels include cotton, wood, grasses, plants which contain cellulose and the third-generation biofuel is derived from algae. This energy is considered to be the father of renewable extrication as it started with human civilization 1.5 million years ago. This is considered to be most useful as it makes use of waste materials to generate electricity and energy and replaces fossil fuels thus ameliorating the problem of environmental degradation and deterioration of resources.

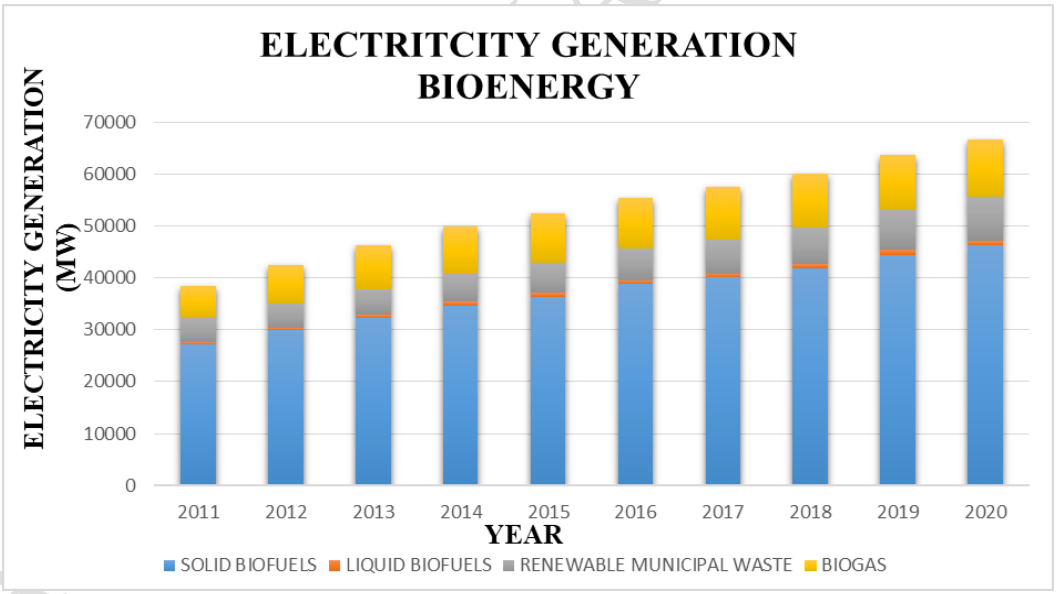


Fig.9 Bioenergy Generation

Bioenergy being the most efficient renewable source of energy, has grown significantly in the past decade. In 2011, the electricity generation of bioenergy as solid fuels was 27167 MW, as renewable waste 4636.75 MW, and as biogas it was 6175.34 MW and the least was liquid fuels, whereas the electricity capacity during the same period from solid fossil fuels was

51563 MW, as renewable municipal waste it was 6899 MW, and as biogas, it was 11463 MW. The electricity generated was nearly 50% of the total capacity. The electricity capacity in 2020 was 92773 MW of which only 50% was generated for electricity, which shows that the proportion has remained the same.

This includes various conversion methods like pyrolysis which heats the raw materials to 400-500 degrees Celsius, hydrothermal treatment which produces bio-oil, and gasification heats the raw materials to 800-900 degrees Celsius and includes free steam. This also includes transesterification and fermentation which converts into renewable energy forms. In 2020 USA's primary energy consumption was contributed by bioenergy to the extent of 4% and mostly contributed by wood-based products. This energy can be used directly as heat or electricity or indirectly like biofuels etc. Bioenergy contributes to three-quarters of the world's renewable energy. This energy has traditional uses like wood, and cow dung, and modern uses like liquid biofuels from bagasse, biogas and biomass. Brazil is the leading country in liquid biofuels and has a large number of flexible-fuel vehicles which run through ethanol extracted from the fermentation of carbohydrates.

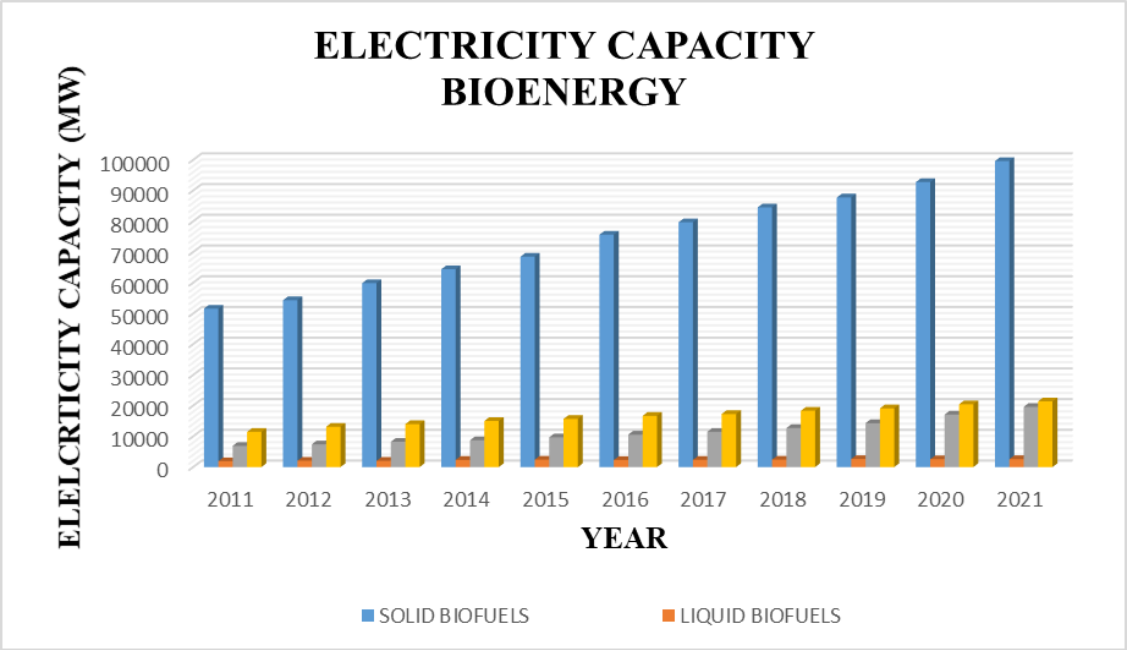


Fig.10 Bioenergy Capacity

ECONOMIC PERQUISITES:

Renewable energy resources not only impact the environment positively and significantly, but also the economy of various countries both in terms of standard of living and also the growth and development of the country in monetary terms, thus bringing in a holistic development.

INVESTMENTS:

Renewable energy resources are gaining importance all over the world, which is a cause for luring investments in this sector, as most of the developed as well as developing countries focus on the major environmental goals set by international organizations like the United Nations Sustainable Development Goals (UN SDG), United Nations Framework on Climate Change (UNFCCC), Intergovernmental Panel on Conflicts of Climate Change (IPCCC), who have set targets like Net Zero Emission by 2050 and reducing the carbon emissions by 30% by 2030, reducing the global temperature below 1.5 degree Celsius. Thus, many countries focus on the importance of renewable resources and realize the need to substitute fossil fuels thus reducing carbon emissions.

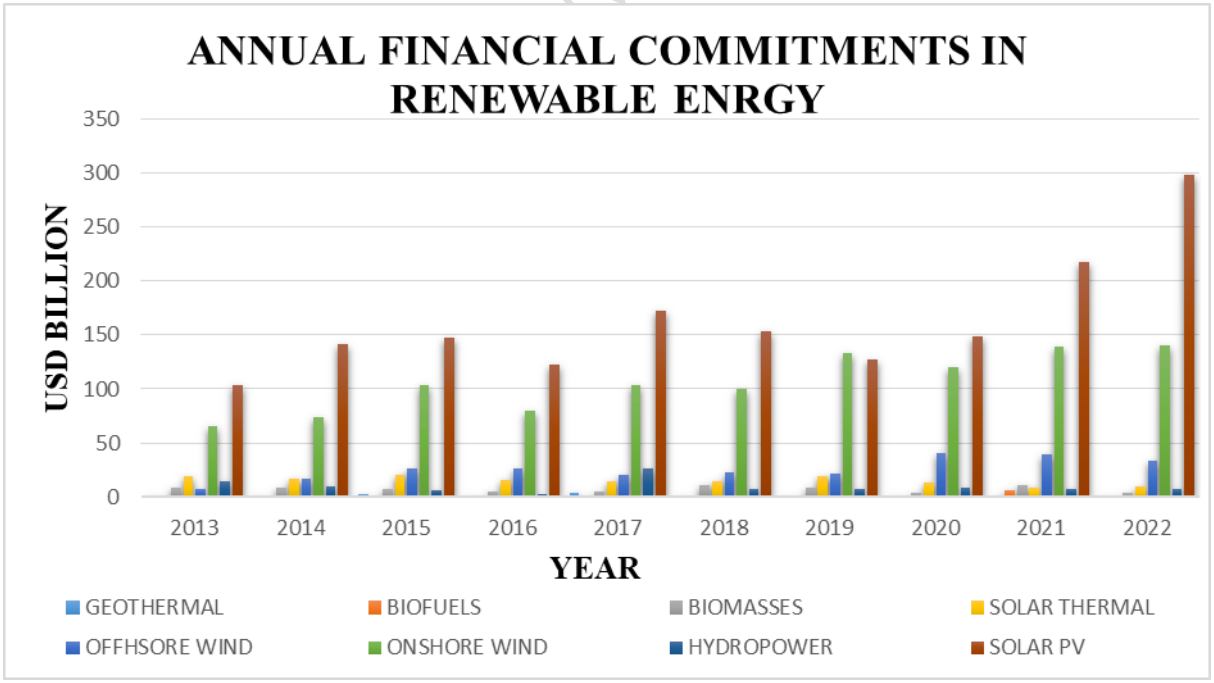


Fig.11 Annual Financial Commitments in Renewable Energy

The above Fig.11 represents the nurturing investments in various renewable energy resources from 2013-2022. The onshore wind and solar PV continued to dominate and received 32% and

46% of global renewable energy investments respectively. Other renewable energies like hydropower, geothermal, biomasses, and biofuels attracted investments of 9% of the total

investments, which were dominated by the investment in hydropower energy. Solar thermal attracted an investment of 8% and offshore wind attracted an investment of 5%. In 2022, 95% of the investments were predominantly made in wind and solar energy technologies, which will have a triple-down effect on the economies of the countries endowed with either or both of these resources. In the World Investment Report released by the International Energy Agency (IEA), China is the leading country with more than 170 billion USD investment in renewable energy, which is followed by the European Union with more than 140 billion USD, followed by Japan and India. India nearing 20 billion USD, which depicts that there are only few countries which have higher investments in renewable energy. To achieve the environmental goals set by countries like Net Zero Emission by 2050, reducing the temperature to 1.5 degrees Celsius, we must ameliorate the problem of imbalances in technologies used or available to various countries.

EMPLOYMENT:

As the triple-down effect flows, with better investments in global energy resources, the country's development kick starts its journey towards growth and development both economically and socially. When countries focus on environmental objectives, it is a step towards a clean nation, better and healthier lifestyle, availability of scarce resources and meeting the growing demand of the growing population. The focus on renewable resources also impacts nurturing the GDP of any country, employment opportunities, and per capita income of the individuals, when employment opportunities increase the living standard of the people will also increase, and the social evils will gradually reduce, which allows them to contribute significantly to the country's GDP. This will also lead to increased investments in infrastructural development of the country, the healthcare sector, and education sector, gain importance, and there will be a sectoral shift towards the service sector, paving the way for the promotion to the status of a developed nation.

As said earlier, wind and solar energy dominate renewable energy resources, they provide employment opportunities to 7.8 million people globally, whereas in 2019 it was only a Million people are employed, creating a transmission from fossil fuel jobs to clean energy jobs. Vehicle manufacturing units on par with oil supply manufacture 13.6 million people thereby devoting 10% of the workforce to the automobile companies. Energy resources account for 2% of global employment according to the World Economic Forum.

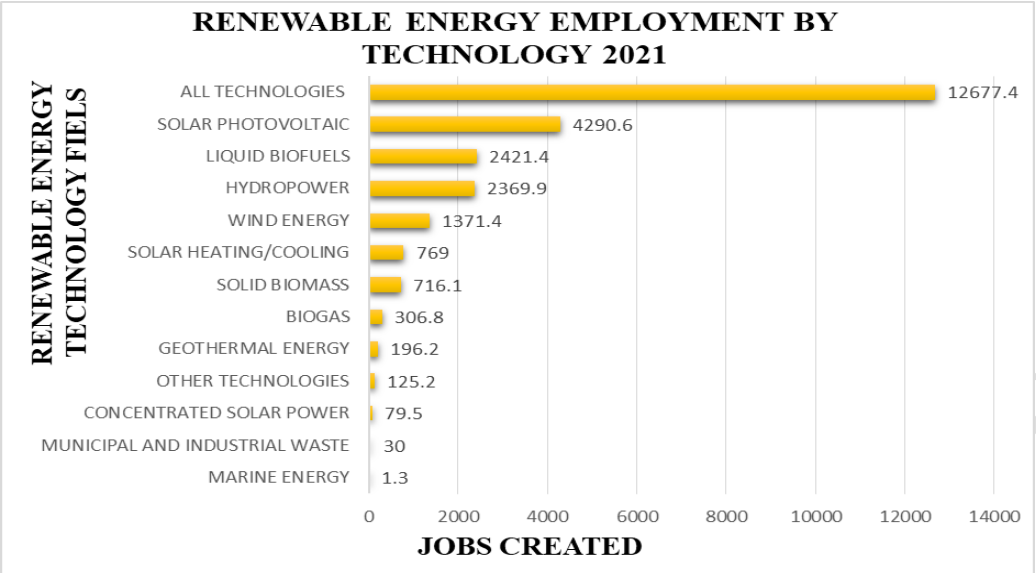


Fig.11 Renewable Energy Employment by Technology

This sector has a highly skilled workforce, with 45% of the population playing major high-skilled roles. When countries strive to achieve environmental objectives like achieving Net Zero Emissions, will create 14 million plus new jobs by 2030 while 16 million energy workers will shift to clean energy and this transition should also take place in the nation to clean energy, according to IEA. Thus creating such employment opportunities will endow any nation with a better standard of living and per capita income, incentivized by the infrastructural development will lead to increased GDP of the country.

COUNTRY	FASTEST 5-YEAR PERIOD OF GROWTH	INCREASE OVER 5-YEAR PERIOD	AVERAGE ANNUAL GROWTH [% Points]	PREDOMINANT SOURCE
URUGUAY	2013-2018	1% - 35%	7	Wind
DENMARK	2010-2015	20% - 51%	6	Wind
LITHUANIA	2012-2017	13% - 43%	6	Wind
NAMIBIA	2014-2019	2% - 27%	5	Solar
NETHERLANDS	2017-2022	11% - 32%	4	Both
PALESTINE	2015-2020	2% - 23%	4	Solar
JORDAN	2015-2020	1% - 21%	4	Both
CHILE	2017-2022	10% - 28%	4	Both
GLOBAL (What's needed)	2022-2030	12% - 41%	3.6	Both
GLOBAL (History)	2017-2022	7% - 12%	1.1	Both
G20 COUNTRIES	2017-2022	7% - 13%	1.2	Both

Table.1 Investment in Renewable Energy (Source: World Resources Institute)

The above table is derived from the World Resource Institute which depicts the annual average growth increase in the countries in the last few years by investing in renewable energy resources. Increasing solar and wind generation between 12% to 41% by 2030 requires a rapid pace of change, however, Denmark, Lithuania, Netherlands, Palestine, Jordan and the other three countries have all grown solar and wind energy proving it's possible (WRI). This data

only pertains to wind and solar energy as they are predominant in the recent era of energy transition.

CONCLUSION:

Renewable energy resources play a significant role in improving the environmental and economic aspects of the world, by achieving environmental objectives like climate and temperature control and economic welfare concerning energy security (*Encyclopedia of Energy, Natural Resource, and Environmental Economics*, 2013) and energy independence of any country. This article explores the magnitude of electricity generated and the capacity of various renewable resources, the vast differences in brimming the scope of these capacities and the reasons behind them. Renewable energy is the greatest means in this era to meet the derived demand of the growing population without degrading the environment and depleting the resources and ensuring a better life for the future generations. It is an incentive to achieve environmental goals like reducing the global temperature, Net Zero emissions, more efficient and the economic development through better employment opportunities, better standard of living, per capita income and in the end speeding the GDP of the country. In recent times, the G-20 summit with India's presidency has introduced the Global Biofuel Alliance to meet the quest for clean energy and sustainability. The countries have decided to bring an investment of 5.8-5.9 trillion USD, for developing countries and 4 trillion USD per year for developed countries for clean energy technologies and to achieve the Net Zero target.

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