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The solution to the global energy crisis with new materials, and sustainability

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Abstract

Earth harbors a variety of energy resources and us humans have made use of these resources for the benefit of our civilization. It is high time, where we need to understand that these resources are going to deplete soon as the world will enter an era of the global energy crisis. We humans have proved that we can sustain in almost every crisis that earth bestows upon us as we move on to deal with problems related to the non-renewable energy source. Due to the excellent heat storage capacity and environmental friendliness of Phase Change Materials (PCMs), the application of PCMs for heat dissipation and storage has attracted much attention in recent years. Phase change materials can absorb or release much heat in time of the phase transition process. We develop an understanding of various renewable sources of energy which will help us to understand their sources and their usage by different nations of the globe. A further focus was given to find a new materials-based solution to the renewable energy most suitable for us and help us by analyzing the different sources of renewable energy sources and storage to understand the path of renewable energy the world is choosing to sustain in the battle of sustainability.

Keywords: Phase Change Materials, Energy, Sustainability, Non-renewable Energy, Renewable Energy, Nature

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Public Interest Statement

While many of the advances in materials science have been driven by breakthroughs in material design and fabrication, understanding the changes that occur in a material during its utilization or operation in devices is of immense importance for its successful integration. Considering these aspects and the continued growth in materials research, there is a clear need for new topical journals which can serve researchers to understand the phase transitions and exploit the phenomena to current, state-of-the-art research in the field of materials science, moreover with full accessibility.

1. Introduction

Mother earth has gifted us with sources of energy. Some of those energy sources are never-ending and are called the renewable source of energy, while some of these energy sources are limited. The energy sources which are not unlimited are depleting at a mammoth rate as the Earth cries to do proper usage and management of the energy sources. The whole of human civilization is fighting hard to develop themselves daily but at the same time, they are facing the trouble of energy depletion. It has been studied that the energy requirement of us would increase rapidly as the fall of the supply of natural resources will occur. Without changing Considering the present scenario we cannot stand strong by using the traditional non-renewable energy sources as our only source of energy. As we become more civilized and look forward to developing our self. Mother nature has shown us that whenever the balance between technology and policy is disturbed often destruction is followed. Factors like climate change, huge population, and excessive demand for resources and continuous dependence on fossil fuel for our energy are the factors that are the main cause of this serious trouble that we are facing. We are in a situation where the problem is common and known to everybody but at the same time, we are not ready to address this issue and take serious step to do something that will help us to sustain more in the lap of mother earth before we come to point of standstill. The use of fossil fuel for our energy sources has not only depleted the total energy resources, we have but has also increased the total amount of greenhouse gasses drastically than it was ever in the past. [1]. The emission that is coming out from burning of these fossil fuels are mainly Carbon-di-oxide, it is estimated that burning of fossil fuel is emitting nearly 37billion tons of Carbon-di-oxide. (2) A deeper insight into the study of Energy usage suggests that by 2030, the global energy supply will be 742EJ showing an increase of 55% from 2007. Though we are looking at other modes to fulfill our energy demand studies show that the demand will stay the same on fossil fuel, which is 80% of the primary energy supply. The only way to get rid of this crisis and sustain is to use energy efficiency and by doing so we will also reduce the emission and will prevent climate change mainly by stopping global warming, a major factor for climate change occurring. [3] It is also estimated that from 38 Gt Carbon dioxide per year the amount would increase to 75 Gt Carbon-di-oxide by the year 2035. Studies have also suggested that 77.8% of the primary energy consumption has been from fossil fuels. Therefore, the utilization of the energy storage effect of PCMs can achieve delayed overheating and temperature regulation in the fields of electronics thermal management, solar-thermal energy storage, industrial waste heat recovery and off-peak electricity storage systems. Development of phase change materials for energy storage is an indivisible part of resolving the energy crisis problem in the future.

A huge market that has a value of 1.5 trillion dollars is energy and the leading player in this industry is a fossil fuel. The demand for these energy sources is high and at the same time, we need to understand that anyhow we need to survive without these sources of energy. Studies suggest that such high demand for fossil as it is now will only make these energy sources available till 2030. An increase of 500 quadrillion Btu to 701.6 quadrillions Btu of energy consumption will occur by 2030, this means that an average

increase of 1.1% yearly increase will occur. [4]

2. Materials and Method

Energy is a form that is used in various forms by us to run our lives using technology, the fact is that is we need to find a proper source of energy which will help us to sustain in our environment as we focus on Renewable source of energy. Renewable source of energy is among those sources which are the available source of energy for the future generation. We critically analyze each source of such energy and focus on the best renewable source of energy that will be available to us and is also safe to use (Fig 1). The figure 1 depicts the usage of total fossil fuels that is done from 77.8 percent of the primary energy consumption from fossil fuel.

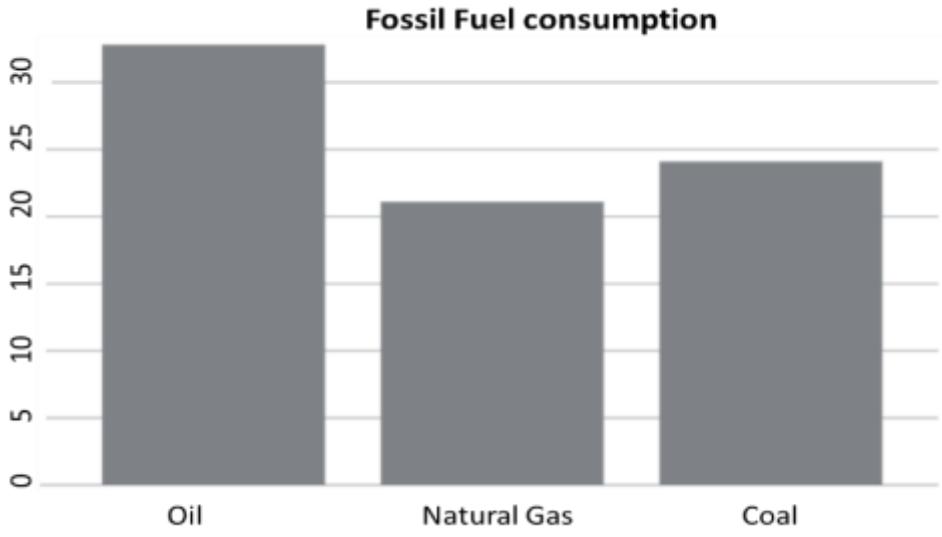

Figure 1: Consumption of various natural energy resources

A study conducted also highlighted that the total energy that was released every day by humankind is almost equivalent to the amount of heat released by the burning of 100 large oil tankers. The above discussion possess a threat and an alarm for the requirement of research and development of energy which will allow us to sustain. This paper will highlight the different methods that will provide a solution to the different methods and technologies that have come up to replace the non-renewable sources of energy as we will also go in detail and will conclude the most efficient source to replace the non-renewable source of energy with the application of Phase Change Materials.

2.1. Total Non- Renewable Energy Resource of the Earth

A huge market that has a value of 1.5 trillion dollars is energy and the leading player in this industry is a fossil fuel. The demand for these energy sources is high and at the same time, we need to understand that anyhow we need to survive without these sources of energy. Studies suggest that such high demand for fossil as it is now will only make these energy sources available till 2030. An increase of 500 quadrillions Btu to 701.6 quadrillions Btu of energy consumption will occur by 2030, this means that an average increase of 1.1% yearly increase will occur as seen in figure 2.

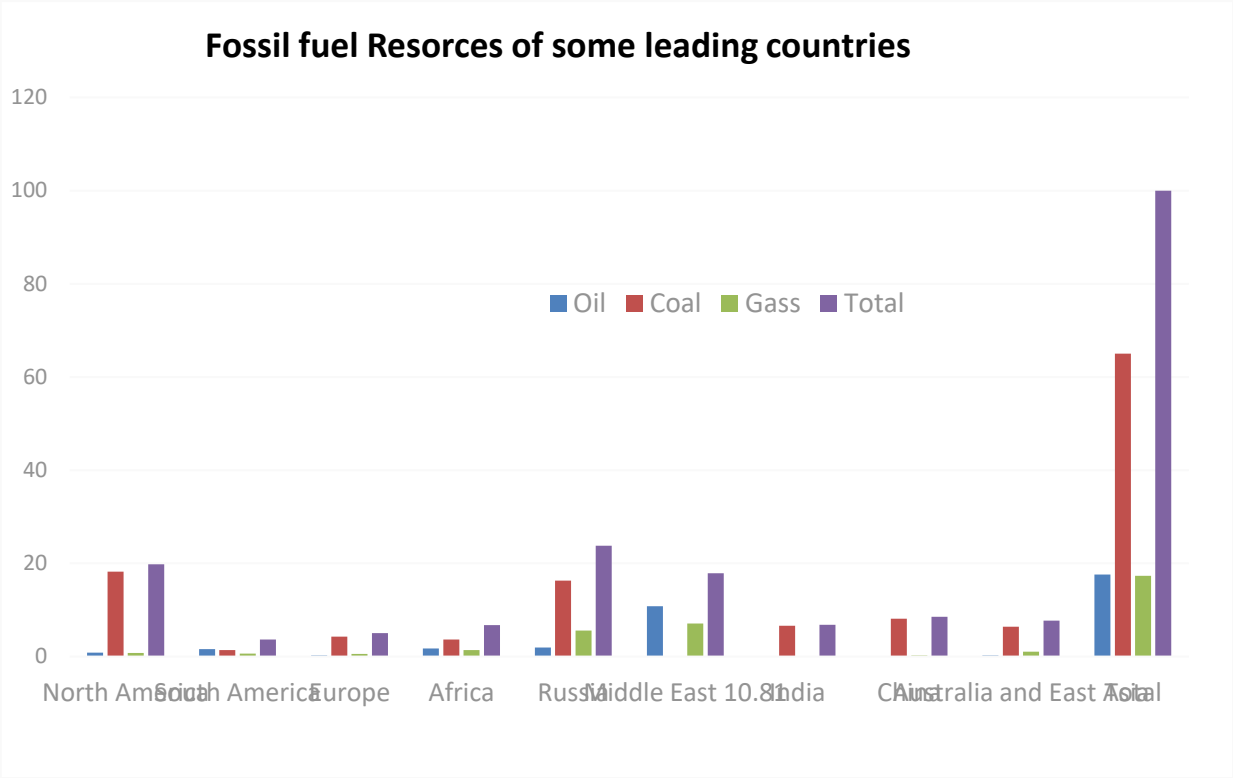

Figure 2: Fossil fuel Resources of some leading countries

3. Current Scenario of different renewable energy sources

3.1. Clean Energy Sources

As we move forward to develop various methods including materials to overcome the energy crisis, the demand for new process intensified technologies is in high seek. We look forward to Clean Energy sources in any way possible in a sustainable way. The solution will address the problem without showing any negative impact on our environment for a sustainable society with 3S approach (Source, System, and Service).

Understanding the 3S policy

- **Source**: The source should always be from a place that is clean and at the same time, the product should be available at a low cost in abundance.
- **System**: The efficiency of the system should always increase; the system should always be integrated with minimum waste production and proper waste management.
- **Service**: The service given by such policies should always be practical, clean, dependable, and efficient.

The 3S policy will help us to provide to create a clean energy system. The policy focuses on sustainability and hence helps us to create a better tomorrow [3]. Although clean energy services are making a strong impact in our battle of suitability there remains a challenge and need to deal with, to improve clean energy solution and address the critical target [4]

- Improved efficiency of the system
- Improved use of resources

- Coming up with solution's that possess zero threats to the environment
- To improve the design and improve the analysis and design
- To improve energy efficiency
- Need to use proper reusable materials to design such machines helping us to provide a clean energy solution.

3.2. Advantages and Disadvantages:

Thermal energy storage (TES) devices work using phase change material (PCM) which stores the energy and releases in the time of demand. Broadly, the PCM can be classified into two categories: organic and inorganic. Both the materials have different advantages and disadvantages as given in following table 1 though these are very much cost effective as compared to conventional energy storage.

Table 1: Advantage and disadvantages of PCMs

PCM	Advantages	Disadvantages
Organic	Non corrosive	Low thermal conductivity
	Self Nucleating	expensive material
	Non toxic	low heat capacity
	Higher thermal stsbility	low flash point
	higher chemical stability	low enthalpy
Inorganic	High thermal conductivity	Corrosive
	High enthalpy	No self nucleation
	High heat capacity	Low thermal stability
	cost effective	Low Chemical stability
	high flash point	Toxic substances

3.3. Renewable Energy for sustainable society.

This is one of the forms of energy that is capable of completely removing GHC emission which is released upon the burning of fossil fuel. This GHC can be responsible for causing global warming alone. There is an alarming need to properly utilize renewable energy before we lose all our sources of non-renewable energy. This will cause a secure and sustainable supply of energy with a less negative impact on society.[5]

The renewable source of energy is mainly solar and in some cases, it is non-solar. Solar energy sources are hydro, wind, biomass and wave whereas the non-solar mode of energy is (geothermal, tidal and ocean) [6-7] as given in figure 3.

3.3.1. Wind Energy

Wind energy is one of the most viable forms of clean energy present in the present scenario of sustainable energy. A machine called wind turbine converts the wind power into electrical power. The system connects wind turbines into electrical networks thus producing energy. This electrical network comprises battery charging circuits, isolated or island networks, large utility grid, and residential-scale power system. The modern wind turbine is based upon the basic aerodynamic force to creating a torque on the shaft, this will finally produce the mechanical energy which will be converted to electrical energy. A major problem that is with the wind turbines is that it can only provide energy when it's the primary source that is wind is available. The drawback that comes after this is that

this process cannot store the source of its creation that is the wind.

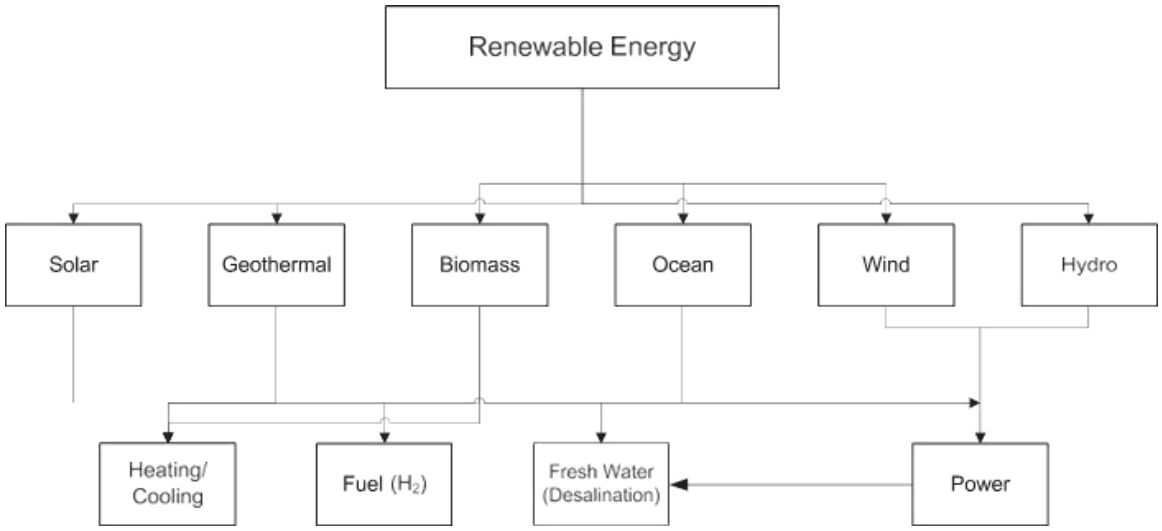

Figure 3: Types of renewable energy sources along with their associated outputs

To have a more detailed understanding of the concept of the power output of a wind turbine, a characteristic performance curve was analyzed. This curve gives information on the hub height wind speed. A study on the total capacity of wind energy of some leading country was reviewed to develop a vivid idea about the present usage of wind energy given in Table 2.

Table 2 Depicts energy sources generated from wind. {Source: IRENA [8]}

County	Capacity (MW) 2016	Capacity (MW) 2017	Capacity (MW) 2018	Capacity (MW) 2019
China	168,690	188,232	211,392	236,402
Germany	50010	56132	59311	61357
Spain	23075	233170	223494	25808
Canada	11898	12239	12816	13413
Brazil	10740	12763	14707	15452
Sweden	6519	6691	7407	8804
Canada	11898	12239	12816	13413
India	28665	32848	35129	37506
European Union	153,730	169,319	178,826	192,020
France	12065	13759	15309	16643
Brazil	10740	12763	14707	15452
Italy	9257	9479	9958	10512

3.3.2. Geothermal Energy

Geothermal energy is abundant and clean. Though we claim that Thermal energy is a renewable source of energy but a study has revealed that Geothermal energy is not completely renewable. When they are exceeding the heat extraction rate than the reservoir replenishment rate then they cannot be called a renewable source of energy.

Another problem that comes up with geothermal is that regarding disposal of spent cooled fluid after use. The steam that is produced changes into the water which has a high salt content and disposal of this waste is highly important as this polluted water.[9] The requirement for a successful geothermal project

- Proper evaluation of reservoir
- Proper monitoring of reservoir
- Good reservoir management practice
- Problems with Geothermal energy
- The emission of hydrogen sulfide emission is very high.
- Set up cost and maintenance is high.
- Landscape change and subsidence.[10]

Table 3: Geothermal Energy distribution

County	Capacity (MW) 2015	Capacity (MW) 2018	Share of national generation
USA	3450	3591	0.30%
ITALY	916	944	1.50%
JAPAN	519	542	0.10%
MEXICO	1017	951	3.00%
INDONESIA	1340	1948	3.70%
ICELAND	665	755	30.00%
NEW ZEALAND	1005	1005	14.50%
PHILIPPINES	1879	1868	27.00%

Geothermal energy distribution has been the growing source of energy in recent time, in table 3 a detailed usage of geothermal energy of some countries are shown [11-16].

3.3.3. Hydropower Energy

One of the leading producers of renewable energy is Hydropower Energy. They have grown in a huge amount in recent times as they contribute to one-fifth of the total power world-wide. Some countries use this source of energy as the only source to produce domestic electricity. Hydropower projects are made according to the need and applications of a particular region. All the hydro-power projects work with the single goal to lessen the use of non-renewable energy so that fossil fuels are not replenished. [17] They make use of a dam to store water. Water stored such are used to manufacture energy. They are mainly used for large scale projects. Despite providing energy with great efficiency some individuals believe that hydropower cannot be a sustainable and renewable resource as it causes a serious threat to natural resources, mainly fishes.

As far as sustainability is concerned to make a system sustainable, the system should preserve resources and should not create a negative impact on the environment. Hydropower though fulfills all the goals of sustainable energy but still, it cannot be called an ideal sustainable energy resource as it also causes deviation in the path of water

bodies. And hence hinder the natural ecosystem to some extent.

Hydropower plant leaves behind a legacy, of renewable energy as a normal hydropower plant lasts for several years. This hydropower plant allows future generations to focus more on renewable energy in different parts of the world (Fig 4). Proper management and study of the Aquatic ecosystem and terrestrial ecosystem before starting a hydro project will make the whole system of hydropower more sustainable than it is now.[18]

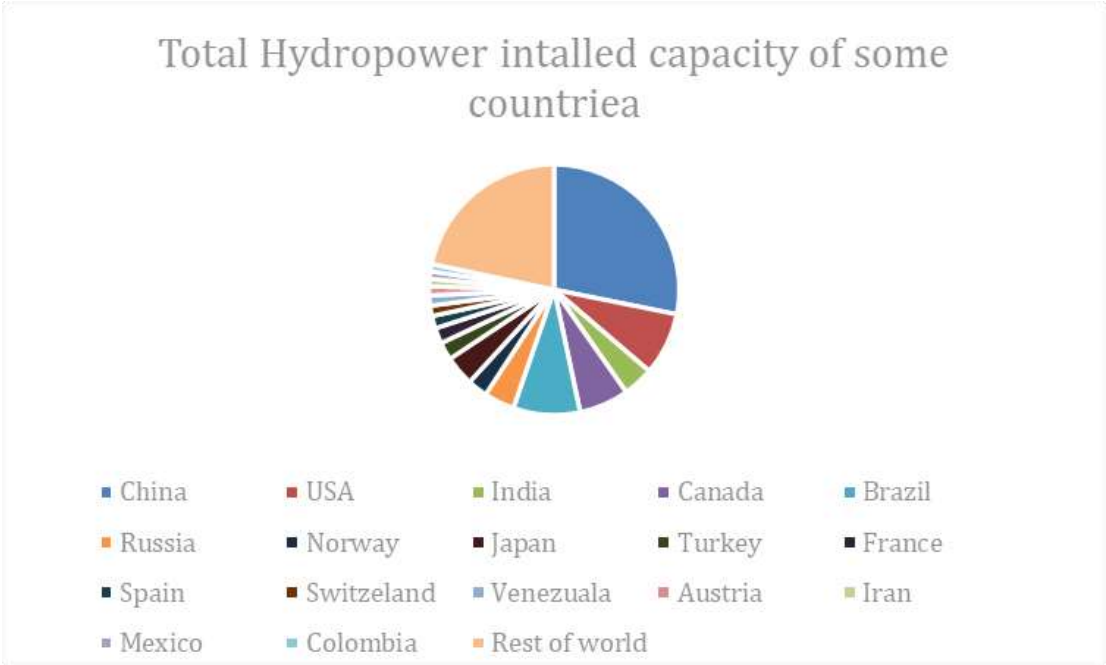

Figure 4: Hydrothermal installations in different countries

3.3.4. Solar energy

It is estimated that the total sunlight striking the Earth in an hour is greater than the total energy consumed by us in an hour. The fact is that solar energy resources are too large when compared with fossil renewable and fossil-based energy resources. (Solar energy 1) The present solar energy market is worth more than $10 billion/year.

There are three types of modern architecture for the intake of solar energy:

Passive intake - It is a direct process of absorbing solar energy. In this process, the intake of the sun's irradiation is done without the help of any device, and the absorbed energy is converted directly. These types of passive objects indicate knowledge of local climate conditions such as the number of sunny days in a particular area, humidity, temperature, etc.

Active intake- This process is performed using devices for thermal, photovoltaic, and hybrid sun irradiation conversion, and solar energy is absorbed indirectly.

Hybrid Conversion- Hybrid Conversion of Sun's irradiation implies the synchronized transformation of the sun's irradiation into thermal and electrical energy. For hybrid conversion, hybrid collectors are used which are different from thermal collectors.

The only problem that still needs to be addressed with solar energy is cost-effective as the process of solar energy conversion and storage is still costly. But with Apart from

this, the whole technology of solar-based energy needs to be operated with better efficiency as more research along with science and technology breakthroughs are highly required. One way of storing heat is by using the latent heat of phase change of a substance, usually from solid to liquid, as it can provide high energy densities. Then, when this stored heat is needed, it can be released by leaving the material temperature decrease, becoming a solid again. Materials used for this purpose are known as phase change materials (PCM). PCM are being implemented in different systems, active or passive, and for several applications, cold storage, building comfort, medium and high temperature. In 2019 the Solar PV comprised around 10.7% of total energy generation in Honduras and considerable shares also in Greece (8.3%), Chile (8.1%), Italy(8.6%), and Germany (8.3%).[20-21]

Table-4 Growth of Solar energy usage (Source IRENA)

County	Solar Energy in GWh in 2020
China	198,071
United States of America	10,184
Japan	72667.67
Germany	49784
India	39066.803
Italy	28663.313
United Kingdom	32857.351
Spain	20,744
France	160568.737
Australia	23930

In this above table 4 electricity generation by solar energy is depicted. Referring to the above table 4, among the top 10 countries, China generates maximum electricity of 178,070.754 GWh whereas other countries such as the USA and Japan produce 85,184.000 GWh and 62,667.671 GWh of electricity respectively.

3.3.5. Bioenergy

Bioenergy is the production of electricity and gas from organic matter, otherwise called Biomass. Bioenergy also includes transport fuel produced from organic matter. Bioenergy is divided into two categories:

Traditional - It involves combustion of biomass informs such as wood, traditional charcoal, and animal waste.

Modern - Includes liquid biofuels that are processed from bagasse, biorefineries, etc.

Around three-quarters of bioenergy is used as the world's renewable energy, with more than half of that using traditional biomass. In 2015 Bioenergy comprised of total final energy consumption and 1.4% of global power generation. Biomass can be directly

burned for heating or power generation, and it can be directly converted to produce oil or gas substitutes. Liquid biofuel which is a substitute for gasoline is mostly used in the transport sector. [22]

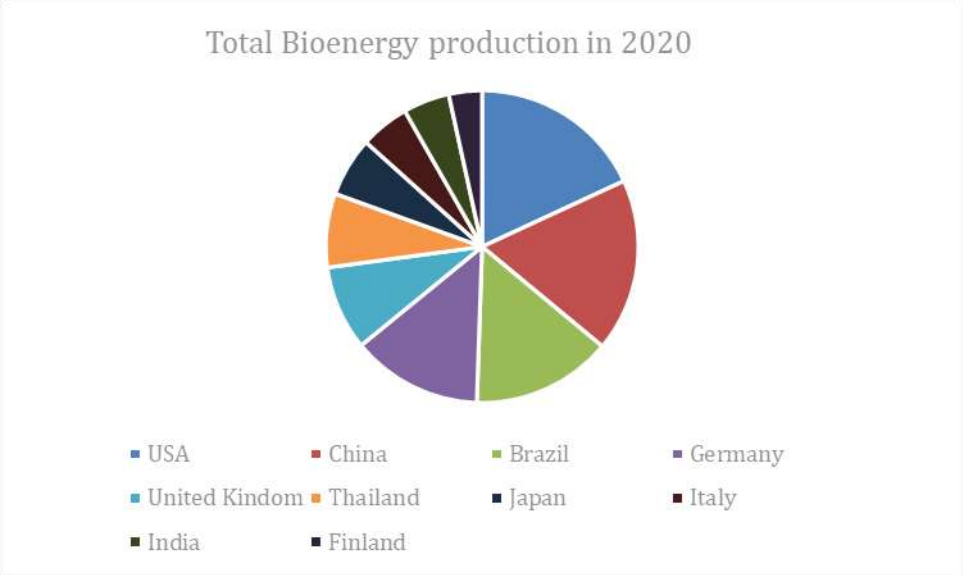

Figure 5: Bioenergy production and storage

The figure 5 above depicts a healthy distribution of Bioenergy throughout the world.

3.3.6. Ocean energy

Wave energy is the seizure of wind waves for the generation of electricity, water desalination, etc. It is different from tidal energy which energy is captured caused by the gravitational pull of sun and moon.

Ocean energy represents a very small amount of promise in renewable energy development compared to wind power, hydropower, and solar power due to infrastructure-related problems. Despite the lack of development in the sector, ocean power industries started working with semi-permanent installations and different arrays of devices. In 2019 net additions in the ocean power industry were around 3MW with an operating capacity of approximately 535MW at year's end of 2020. Ocean power has been mostly centralized in Europe, where tidal wave devices generated 15 Gigawatt hours in 2019 and which was 50% greater than the output obtained from 2020.[23]

A study conducted in Australia which was led by CSIRO Oceans and Atmosphere with support from the Australian Renewable Energy Agency created the Australian Wave Energy Atlas which provided a 4D interactive map of the greater Australian coastal area.[23] This showed that the Southern Coastline of Australia has an exceptional wave resource and thus provides ideal conditions for wave energy production. The research concluded that wave energy could make up to 11 percent of Australia's energy by 2050 which could give a strong competition in Australia's Renewable Energy mix. [24-25]. The figure 6 below clearly depicts the leader in the marine energy generation Republic of Korea with 479.930GWh and France with 485.35GWh this shows that there is a requirement for the other countries to focus more on the generation of Marine Energy.

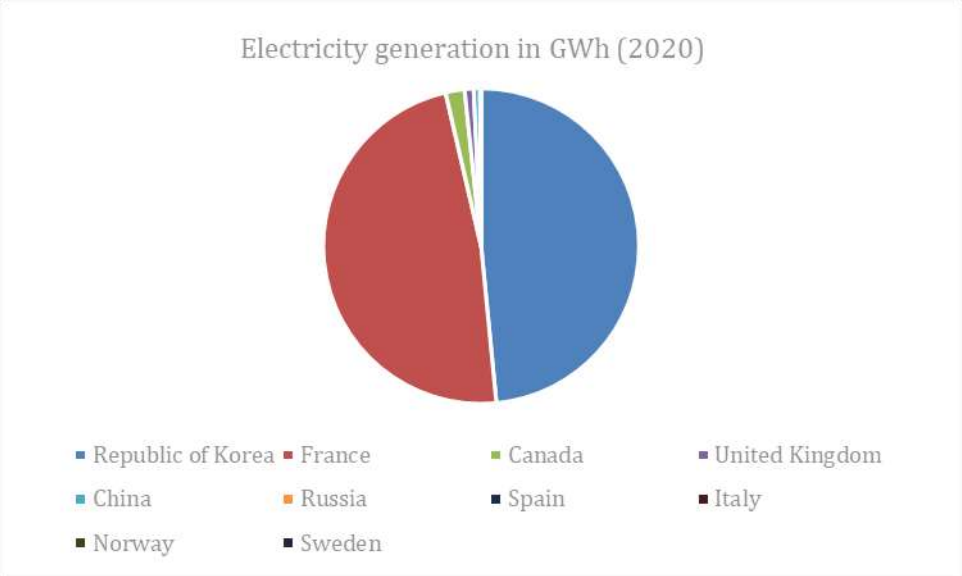

Figure 6: Electricity generation in ocean in different country

3.3.7. Nuclear Energy

1 gram of Uranium and thorium can release heat which is almost equal to heat obtained from 13bbl of petroleum or 3tons of coal. Black shales and phosphate rocks of low-grade release Uranium of nearly almost 100 million tons. This Uranium can which is almost equal to 1000 bbl of oil in each ton of rock or 250 tons of coals. Nuclear energy is considered a non-renewable source of energy as the material which it is made from is Uranium which is not a renewable source of energy. It is often considered along with other fossil fuels such as coal and gas however nuclear energy can be significantly used for a longer period especially if recycling of unused uranium fuels and fast reactors are used. [26]

We can refrain ourselves from causing further damage to mankind by using lethal weapons such as a nuclear weapon and use this source to develop a better future of mankind by using Nuclear Energy. This form of energy will help us to fight against global warming as the negligible amount of Carbon-di-oxide is released from this source of energy. They also provide us with a possibility to attain a capacity factor of high output (90%) having a long operation cycle.

Having established the fact, this form of energy comes up with problems regarding waste disposal, and radioactive wastes are a serious matter of concern. Secondly, this system has a lower efficiency rate of thermal when it comes to water cooled nuclear plants mainly. Severe accidents can cause damage not to a single person but a society, and in severe cases, this damage can be irreversible [27-28]. Upgrades are very much needed beyond the current builds which are now mainly in Asia to compete in the future. New generation nuclear power plants must possess thermal efficient close to that of thermal power plants and if these conditions are properly handled then nuclear energy has a bright future in the present world. [29-32]

3.4. Comparative study of Renewable energy

A comparative study of different sources of Energy production was carried out in the following Figure 7 where the data were taken from trusted sources like statistika and

IRENA. The figure shows that there is a steep rise is the production of Hydropower, clearly depicting that Hydropower is one of the most used accepted sources of Renewable Energy at present at is shown in the year 2018. The comparative analysis helps us to understand that other energy source are not yet explored much as we continued to focus on Hydro-power as our energy source which can be clearly as even in the year 2014 the highest source of Energy was Hydropower [33-34].

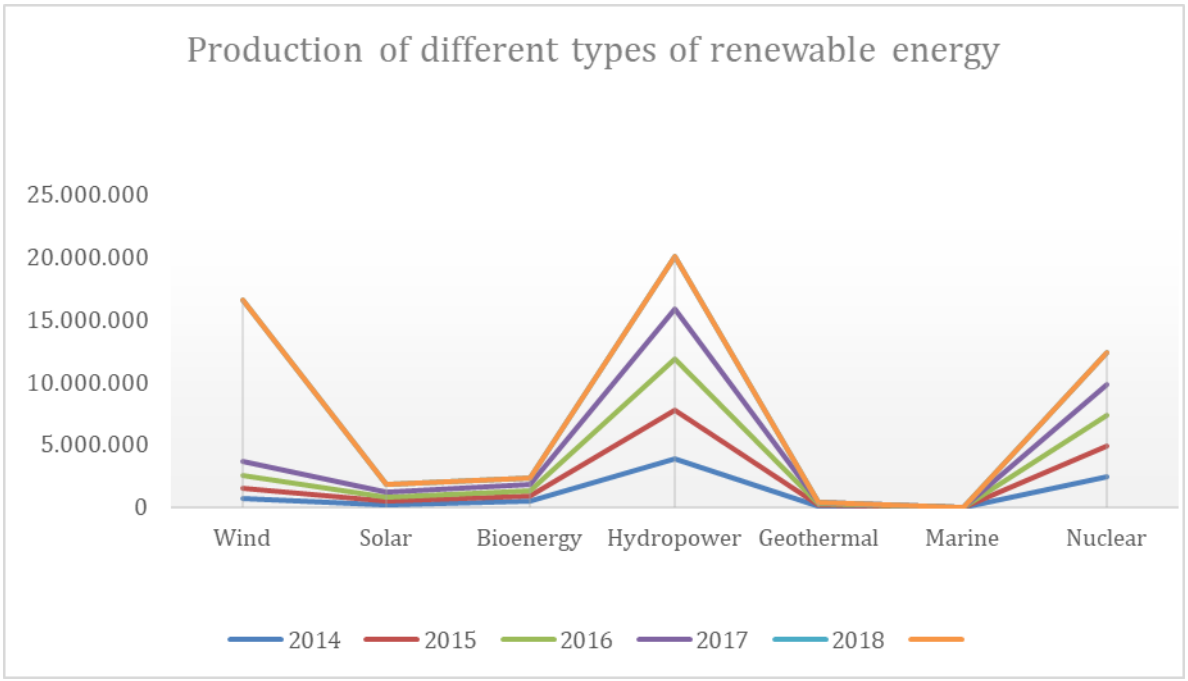

Figure 7: Depicting various forms of Energy sources and their production

4. Conclusions

Throughout this paper, we observed the different sources of Energy mainly renewable. An effort was made to make people aware of the present scenario regarding energy resources. Though different sources of renewable source of Energy were critically analyzed and we found that research regarding these sources is yet not enough to draw a perfect conclusion over the most suitable source of renewable energy. Some sources of energy were there which although is called renewable but is harming the environment in some other ways, some sources of energy were not at all efficient to serve the huge energy need of this modernized society. Among all these sources, Bioenergy could have been a source of production of Energy, but the problem lies with the efficiency of this material and hence keeping in mind and studying the demand increase in the future, the energy source of energy for the next generation would be nuclear energy. Nuclear energy seemed to have the capacity to fulfill the requirement of us in the upcoming years. Although major problems like nuclear waste disposal and leakage can cause a serious threat to us but with better waste management and proper care of reactors this form of energy can be a boon to the society at the same time

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