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ALTENATIVE ENERGY SYSTEMS

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Abstract: **This paper reviewed the history of energy usage and transition from one period to another, and the associated benefits of the various energy systems categorized under renewables and non-renewable sources. The paper established that the dominance of the fossil fuel energy system will jeopardize the future of the earth, due to its high carbon emission as greenhouse gas into the atmosphere. The paper noted that renewable energy sources have the potentials of providing solutions that will both mitigate the climatic and environmental problems due to its low carbon content and provide a more secured and sustainable alternative energy sources. However, the paper further noted that the transition from fossil fuel to renewables have been greatly hampered due to the lack of collective policy drive by major emitting countries such as United States, China, India and Russia plus 9 other countries that contribute 72% of the global carbon emission. As would be expected, the paper observed that none of these 15 countries appeared in the top 10 countries on the World Economic Forum Energy Transition Index for 2019. Ironically, the top 10 countries on the index only account for 2.6% of global annual emissions. This has resulted in a rather slow transition that will continue to see fossil fuel playing significant role in the global energy mix beyond 2040, especially as fossil fuel companies struggle to come to terms with how to manage the existing investments in the industry, and therefore continue to lobby and subsidize the use of fossil fuel in the energy mix. The paper therefore recommended that for any meaningful energy transition to take place it would require a focussed and very pragmatic push from top 15 emitting countries. The energy transition must also focus on the critical sectors such as transportation, electricity and heat, buildings and in manufacturing and constructions. Also, since CO2 contributes about 74.4% of the total greenhouse gas, while investing on renewable sources, the paper further recommended that there must also be investments towards accelerating carbon capture, and carbon removals. Tree plantings, which are less expensive can take out a lot the carbon dioxide from the atmosphere, plus carbon sequestering in natural soil to reduce carbon emission in the atmosphere. Also, another means of reducing emissions for towns and cities to plan such that people can safely and conveniently use public transit, walk, or bike, instead of using private vehicles, also reduces energy demand. Finally, while renewables can provide ready solutions for the high carbon emissions, the paper also noted potential vulnerabilities and strategic energy security challenges with renewables as not all countries have the technology to convert the natural resources into renewable energies, and therefore recommended for the need to begin discussions on how to avoid geopolitics in renewable sources as were the experiences with fossil fuels**

Keywords: **Alternative Energy System, Renewables, Non Renewables, Greenhouse Gas, Carbon Emissions, Emitters, Energy Transition Index.**

1. INTRODUCTION

Energy, undoubtably is the catalyst that propels economic growth, and therefore, the desire of energy security has been in the forefront of human civilization. This has led to successful innovation of alternative energy system to the existing form of energy in use, in the quest for survival, and sustainable growth and development. Energy has been evolving with human development and therefore is always under pressure to guarantee secured supply to meet the ever-increasing demands for industrial processes and the provision of public services such as lighting, heating, cooking, information and communications technology, and mobility. It is therefore continuously undergoing unprecedented change, due to forces such as technological innovation, changes in consumption patterns, supply dynamics, environmental concerns and geopolitical dynamics, and policy shifts. (World Economic Forum Insight Report, 2018).

Alternative energy, according to the New World Encyclopedia is a term for any nontraditional energy form, source, or technology differing from the current popular forms, sources, or technologies. (New World Encyclopedia). Technically, Energy sources are categorized into Renewable or Non-Renewable sources, and both sources have always been with man from the beginning, with either of them becoming an alternative source at any point in time. Renewable energy is derived from sources that are regenerative in nature and can easily be replenished, while non-renewable are depleting sources that cannot be easily replenished. Non-renewable energy sources include those from petroleum – oil and gas, and coal, which are also classified as fossil fuels, mainly due to their process of formation. Fossil fuels are formed from organic remains of plants and animals or fossils, under the actions of pressure and temperature in the presence of microbes with increasing depth over millions of years. Another source of non-renewable energy is nuclear energy produced from uranium, which is also a depleting source. Renewable energy sources include solar, geothermal, wind, biomass, and hydropower energy. (IEA, 2019).

Historically, humans started with renewable energy sources such as the sunlight as principal sources of energy, and biomass or wood from plants for fire, and heating, before the discovery of fossil fuels, as the alternative energy source due to their quest for a more secured, efficient and sustainable energy sources (Mason, 2020). Besides biomass, the early civilization also relied on oxen,horses and camels as means of transportation and mechanization to drive ploughs or turn millstones, while innovations in the use of wind helped to sail his boats across long distances for trade, and dams created out of water sources to harness the power of the fluid motion. (Mason (2020). Energy transition from renewables to fossil fuel as the alternative source was triggered by the quest for more efficient and sustainable energy source due to the rapid economic growth and development during the industrial revolution. The transition started with Coal which though had existed as a form of energy as far back as the 2nd and 3rd century AD by the Romans (US Department of Energy, Fossil Energy Study Guide), and even more than 1000 years by the Chinese, only became the principal source of energy with the invention of the first modern steam engine by Thomas Newcome early 1700 to pump water from mines greatly. (Dahl, 2015, pp 24). A further improvement of the steam engine to run machines by James Watt in 1765 transformed the agrarian society into an industrial economy. Though steam engines could either use coal or wood, coal quickly became the preferred fuel due its efficiency over wood, as a half-ton of coal could produce four times as much energy as wood, and coal was also cheaper to produce and despite its bulk, easier to distribute, thus making it the fuel for coal-fired steam locomotives, and steam ships. Machine powered by coal enabled

breakthrough in productivity while reducing physical toil, and coal accounted for the largest share in primary energy mix in the 1780s, surpassing wood for the first time. However, environmental concerns at the dawn of the 20th century, coupled with technologies led to a shift to an alternative source of energy, which as at then, became petroleum, oil and gas. Besides the environmental concerns, petroleum was a flexible and adaptable fuel than coal. This is even as the kerosene refined originally from crude became more reliable and relatively inexpensive compared to “coal-oils” and whale oil for fuelling lamps. With improving technology in the 20th century, oil became the preferred fuel to power the global economy with electricity and transportation as key drivers of that energy transformation. Oil also became a strategic energy source and critical military asset in its role during World War 1 in powering ships, trucks and tanks, and military airplanes. (EKT Interactive, 2020, Oil 101). According to Ague and Oristaglio (2017), Petroleum product became prominent as alternative fuel during World War I as countries use more advanced war fares, for instance, the British as at World War I in 1914 had only 800 military motor vehicles, which skyrocketed to 56,000 trucks and 36,000 cars by the end of the war after only four years. Oil and Gas with increasing demand for more efficient energy sources and progress in exploration and production technologies soon overtook coal by contributing more than 50% of the energy mx by 1965. (Caineng et al (2016).

The world is now undergoing another energy transition, this time from fossil fuel back to renewables due to the obvious environmental and climatic challenges attributed to the fossil fuel energy sources. Evidently, the demand for green ecological environment, will promote the use the renewables and more of the cleaner natural gas in increasing quantity in the global energy mix. Figure 1 shows the global energy transition from one dominant source to another. Coal was dominant from 1800 to 1940, while Oil and Gas took over from 1940, and became dominant source of fuel from 2011 to date, with increasing injection of renewables into the energy mix.

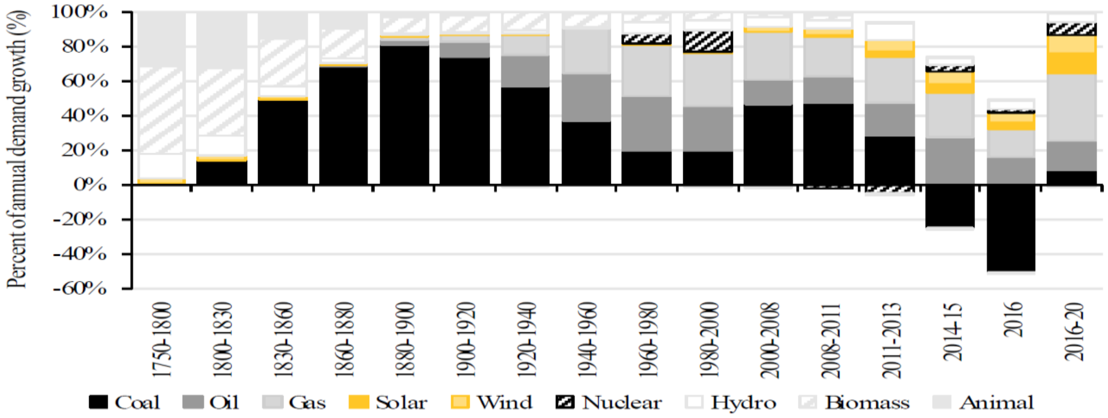

Fig. 1: Global Energy Supply by Source (percent). Source: Fattouh et al 2018. (Oxford Institute of Energy Studies)

Alternative Energy in contemporary use today refers to an alternative source from fossil fuels and is therefore also used interchangeably with renewable energy sources. Accordingly, the New World Encyclopedia on Alternative Energy, captured several definitions for renewable energy some of which are reproduced below:

- The US Environmental Protection Agency defines renewable energy as "Energy resources that are naturally replenishing such as biomass, hydro, geothermal, solar, wind, ocean thermal, wave action, and tidal action."

- The EPA's Green Power Partnership defines the term as "renewable energy includes resources that rely on fuel sources that restore themselves over short periods of time and do not diminish."

- The Intergovernmental Panel on Climate Change defines renewables as "energy sources that are, within a short timeframe relative to the earth’s natural cycles, sustainable, and include non-carbon technologies such as solar energy, hydropower, and wind, as well as carbon neutral technologies such as biomass."

This paper therefore presents the transition from the high-carbon fossil fuel into alternative low carbon, cleaner and environmentally friendly renewable energy sources.

2. DESCRIPTION

The current energy transition from fossil fuel to renewables, is primarily to curtail global warming and the associated extreme weather conditions caused by its high carbon emission into the atmosphere. Renewables, in all intents should limit the global average temperature change, caused by the greenhouse gases (GHG) from fossil fuel as agreed at the 2015 Paris Climate Summit (or COP21). Five gases contribute about 95% of the total global warming:

1. Carbon dioxide (CO2), which is a by-product of fossil fuel, deforestation and production of cement and other materials contributes about 52% of all global warming. 80% of the emitted CO2 can last for 200 years while the balance 20% can take up to 30,000 years to disappear.

2. Methane is a by-product of livestock production, agriculture, sewage treatment, natural gas and oil distribution, coal mining, fossil use and is also given off from wastes. Though it contributes only 15% of global warming, it is about 84 times more potent than Carbon Dioxide, over two decades., and can last for about 12 years in the atmosphere.

3. Halogenated compounds such as CFCs, HCFCs, HFCs, PFCs, SF_6 and NF_3 contribute only 11 % of global warming. They are chemical products from diverse sectors such as refrigeration and air conditioning, electrical and electronic equipment, medicine, metallurgy, etc., and depending on the type of compound, they can last from a few months to tens of thousands of years in the atmosphere. The CFCs, HCFCs, HFCs, and PFCs have been banned in much of the world because they have heat-trapping potential thousands of times greater than CO2

4. Tropospheric ozone also contributes about 11% effect on global warming. This gas is a product of the reaction between carbon monoxide (CO), nitrogen dioxide (NO_2) and VOCs (Volatile Organic Compounds), given off during the burning of fossil fuels. These gases only last for a few months in the atmosphere.

5. Finally, nitrous oxide contributes around 11% to the global warming, and it is a product from the use of fertilizers, fuel use, chemical production and sewage treatment, and can last for about 114 years in the atmosphere. Nitrous oxide is 264 times more powerful than CO2. (Acciona, 2019).

According to Lindsey and Dahlman (2020), it takes a tremendous amount of stored heat to raise the earth's average surface temperature considering the size and tremendous heat capacity of the global oceans. Consequently, the rise in global temperature of about 2-degree increase since the pre-industrial era of 1880-1900 might seem small, but it shows a tremendous amount of accumulated heat in the atmosphere. This quantity of stored heat is now driving regional and seasonal temperature extremes, reducing snow cover and sea ice, intensifying heavy rainfall, and changing habitat ranges for plants and animals. Figure 2 is a chart of historical global average anomaly from 1870 to 2020, showing clear steep temperature rise from 1940, while Figure 3 shows a chart indicating number of extreme weather events and associated costs from 1990 to 2016.

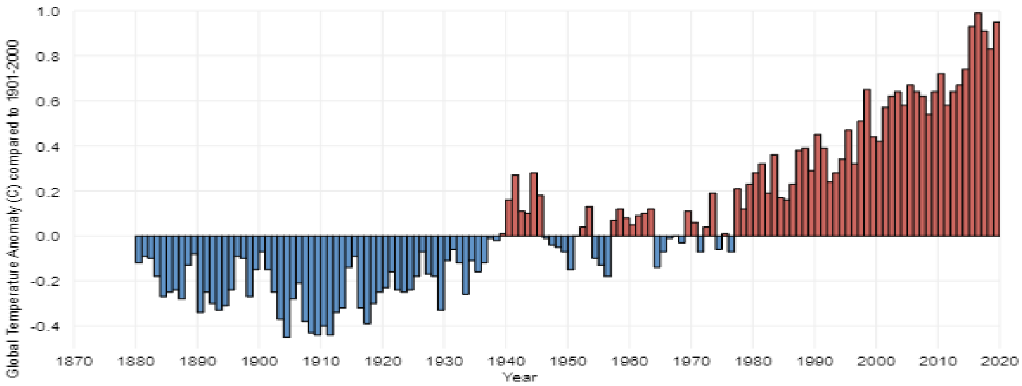

Figure 2: History of global surface temperature since 1880; Source: Lindsey and Dahlman (2020)

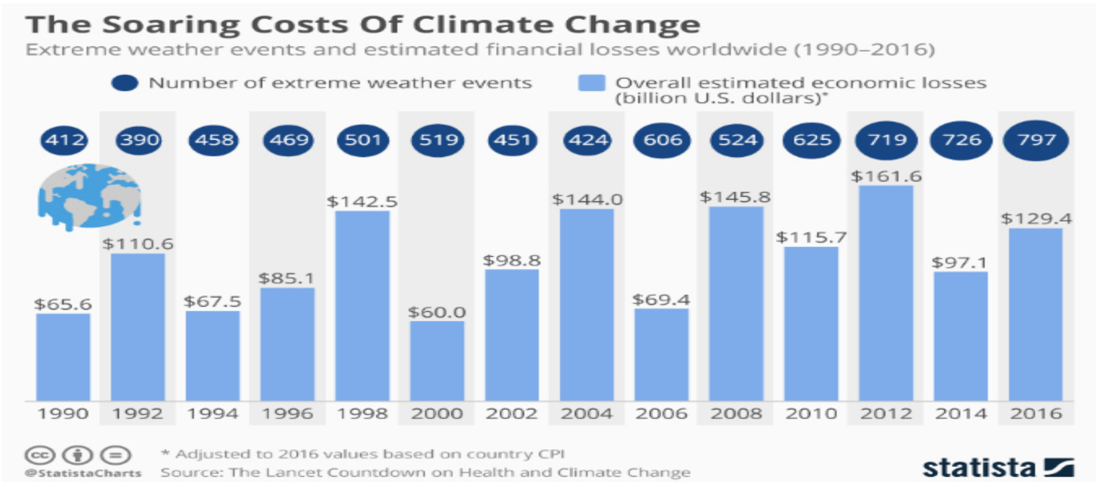

Figure 3: The Souring Costs of Climatic Change: Source: McCarthy, 2017

Again, the reality is that, with increasing human population, there will be more demand for energy, and unless the world pushes quickly to low carbon emission fuel system such as the renewables, its sustainability for future generation will be compromised. This is because, there has been very extreme climatic and associated weather conditions nearly in all the parts of the earth such as high temperatures in summer, record lows in winter and increased frequency of typhoons and hurricanes, while other areas are experiencing wild bush fires, and floods. Fortunately, most renewable energy sources, and the technology deployed for the conversion have low carbon emission, however, while achieving zero emission might be a long-time venture, renewables will reduce the carbon footprint in the atmosphere (Marson, 2020).

A recent data by the IEA (2020) on global carbon emissions showed that energy related emissions flattened in 2019 after two years of growth as shown in figure 4. This flattening was due to decline in emissions from electricity generation in advanced economies, as these countries adopt more renewable (solar PV and wind) energy, and fuel switching from coal to natural gas and higher input in nuclear energy in the power sector.

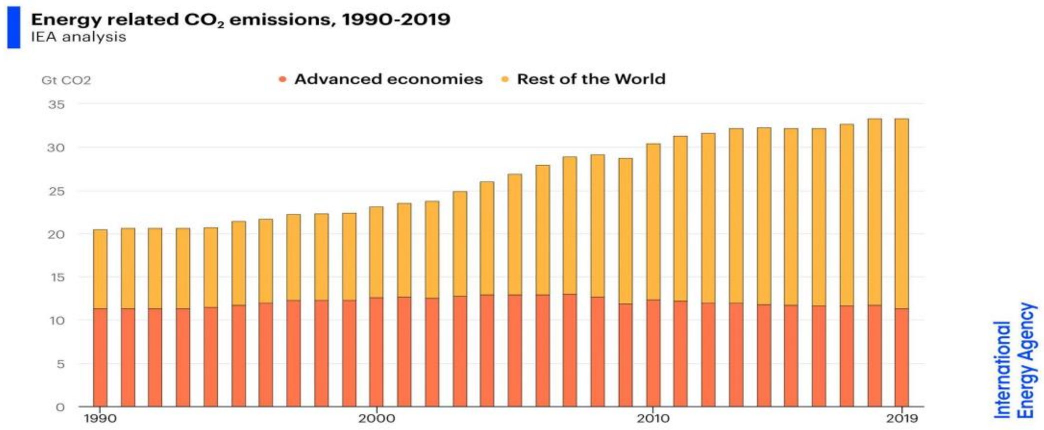

Figure 4: Energy Related CO2 emissions, 1990 – 2019: Source- IEA, 2020

The secondary objective underlying this recent quest for alternative energy system is to guarantee energy security as non-renewables sources deplete with time. Even before the current discourse on renewables, the idea of an alternative energy system already been captured as far back as in 1912, that fossil fuels might soon run out. This notion gave rise to the Peak Oil Model by Hubbert in 1950s that elicited the drive towards renewables. Hubbert in 1956, using statistical production data postulated that fossil fuel production would with time follow a roughly bell-shaped curve as shown in figure 5 below.

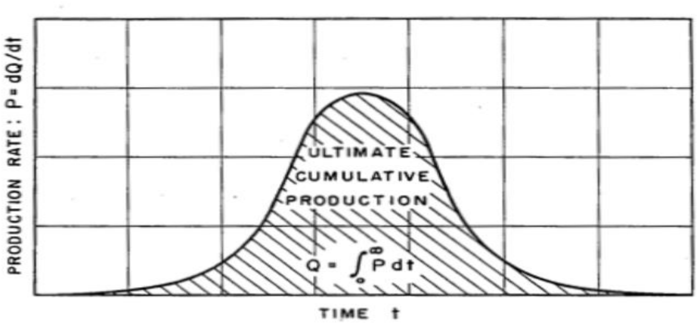

Figure 5: Hubert's Peak Oil Model on Fossil Fuel. Source: Ague and Oristaglio (2017).

Hubbert argued that fossil fuel reserves which are non-renewable will with more extraction reaches a peak production and then begins to decline until it approximates an exponential decline. Though Hubbert attempted a peak oil model in 1956, new technologies and demand patterns have reconstructed the model to peak at 2040 as shown in Fig 6. Evidently, with the advent of non-conventional hydrocarbons through shale and novel exploration and production technologies that can now work in deep and ultra-deep basins of the world, the world oil and gas resources may have extended to more than 300 years life time

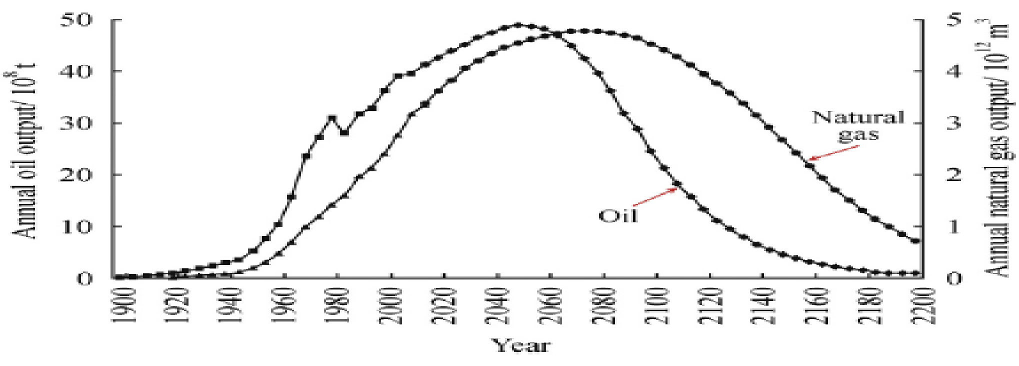

Figure 6: Reconstruction of Peak Oil Model: Source: Caineng et al (2016)

Though the peak oil theory fuelled the quest for alternative renewable energy sources, the desire for national energy security by non-resource countries, also propelled the search for an alternative energy to fossil fuel, as oil has now become a major geopolitical weapon against any perceived enemy. Besides using oil as a geopolitical tool, oil producing nations may also suffer from internal crises such as armed conflict or political instability that can create shocks in the global supply chain, and hence economic tension to a buyer-countries. Examples of such disruptions exist such as the Arab Spring that swept across Algeria, Tunisia, Libya, Egypt and Syria in the middle east, and the on-going civil war and ISIS in Syria, all of which have caused the rest of the world to worry about their energy security. Also, the tension between Russia and the West over Ukraine and Syria, have further raised serious concerns on energy supply. Evidently, such supply disruptions also cause price hikes in international energy markets, with direct impact on productivity in most dependent countries. (Marson, 2020).

3. GENERAL ANALYSIS

This section presents the various forms of renewable energy sources, and their technologies for energy generation.

There are about 8 different types of renewable energy sources, and these are: Solar, Wind, Geothermal, Water power or hydropower, Biomass which comes in Biofuel (bioalcohols, biodiesel, biogas, other biofuels), Waste, and Wood. We also have Tidal power, and Wave power, and Hydrogen fuels. (New World Encyclopedia, 2018)

3.1 Solar Energy

Solar energy is harnessed from the sun radiant light and heat and converted for practical purposes for alternative energy generation. On the average about 174 petawatts (PW 10^{15} watts) of solar radiation reaches the Earth's atmosphere annually, out of which approximately 70% or estimated 3,850,000 exajoules (EJ) is absorbed by clouds, oceans and the land mass, while the remaining 30% is reflected back to space. Of the 70% that is absorbed, the earth surface receives roughly 50%, which on the average generates about 1000 watts per square meter on a cloudless day at noon. Each square meter of earth surface collects a daily energy of about 4.2 kilowatt-hours. Figure 7 is a picturesque presentation of the solar energy transmission process.

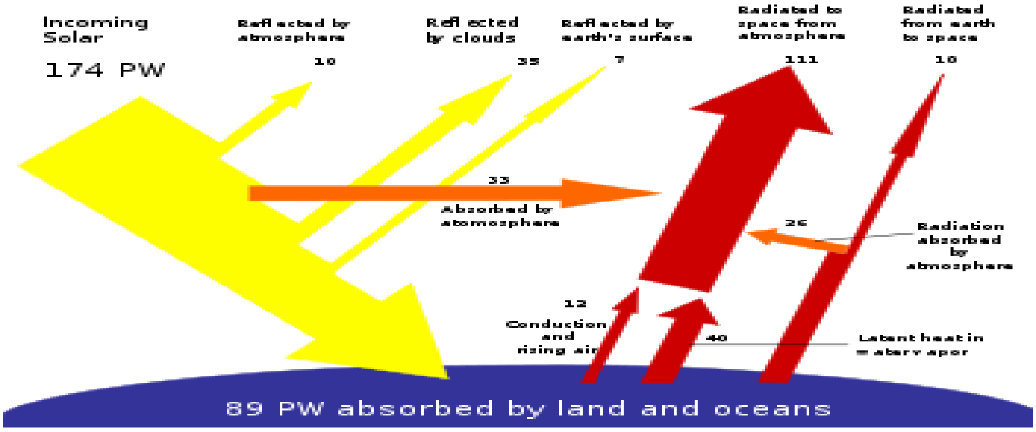

Figure 7. The transmission process of Solar Energy

Solar energy from the sun is harnessed using a range of ever-evolving technologies which are: (1) directly using photovoltaics (PV devices) or "solar cells"; or (2) indirectly using solar thermal/electric power plants. The PV method uses individual PV cells to create solar panels, which can vary from those than can power watches and calculators, or single homes or much bigger panels to power industrial estates. The second method uses lenses or mirrors to concentrate the solar radiation onto a small area called concentrated solar power (CSP), which produces electric power as the light converts to heat energy drive heat engine connected to an electrical power generator. (New World Encyclopedia, 2018).

3.2 Wind Power

Winds like most renewables, except for tidal and geothermal power, is also derived from the sun due to uneven heating of the Earth's atmosphere, surface, the irregularities of the earth's surface, and rotation of the earth. Technically, wind flow patterns are modified by the earth's terrain, bodies of water, and vegetative cover. Also, about 1 to 2% of the solar energy is converted into wind energy, which is about 50 to 100 times more than the energy converted into biomass by all plants on Earth. (Salameh, 2014**).**

According to Salameh, 2014, wind power can be characterized into seven classes according to power density: class 1 is the lowest and class 7 is the greatest as shown in table 1 below. The wind power density is proportional to the wind velocity cubed, and for adequate utility system, class 4 or higher energy classes are usually required.

Table 1: Wind Power Classification.

Power Class	Resource Potential	Wind Power Density @ 50m-W/M^2	Wind Speed @ 50m- M/S	Wind Speed @ 50 m-MPH
1	Lowest			
2	Marginal	200-300	5.6- 6.4	12.5-14.3
3	Fair	300-400	6.4-7.0	14.3-15.7
4	Good	400-500	7.0-7.5	15.7-16.8
5	Excellent	500-600	7.5-8.0	16.8-17.9
6	Outstanding	600-800	8.0-8.8	17.9-19.7
7	Superb	800-1000	8.8-11.1	19.7-24.8

Source: Salameh Z (2014).

Wind power is a readily available renewable energy source, and is widely distributed, clean and not produce emissions during operation. It can be installed at low cost has thus become one of the fastest-growing renewable energy technologies, with global installed wind-generation capacity at both onshore and offshore increasing by a factor of almost 75 in the past two decades, from 7.5 gigawatts (GW) in 1997 to some 564 GW by 2018. This increase brought wind energy to account for 14% of the electricity generated by renewables in 2018 as shown in figure 8.

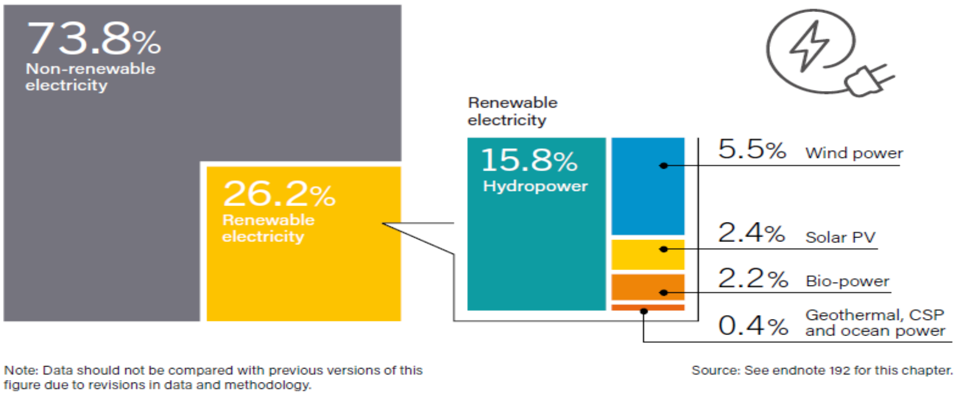

Figure 8: Renewable Share of Global Electricity Production: Source: REN 21. 2019 report

Though many parts of the world have strong wind speeds, but as we have pointed out earlier, the locations that can generate class 4 wind power are best for wind energy. Wind is converted to energy through wind conversion systems, (WECS) or wind turbines, designed to convert the energy of wind movement into mechanical power, which is converted into kinetic energy as the wind hits the turbine blades and cause them to rotate. This produces rotational energy, that moves a shaft that is connected to a generator to produce electrical energy through electromagnetism.

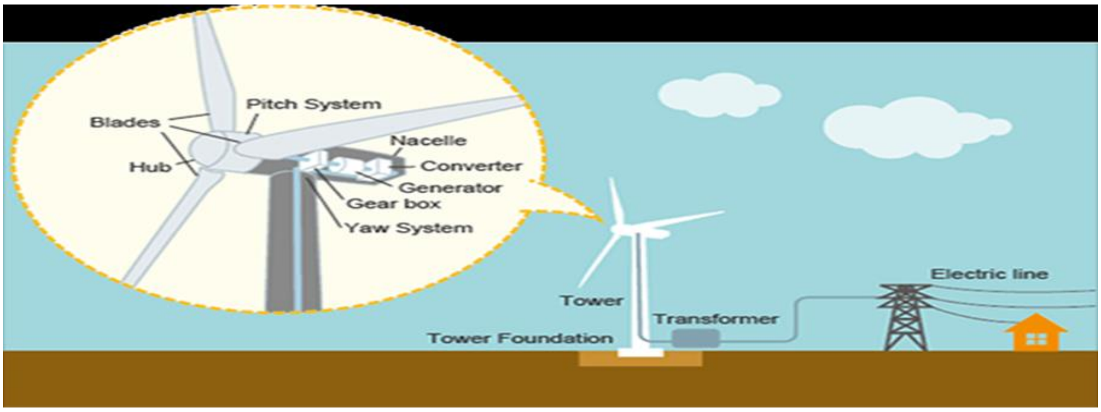

Figure 9: Wind Power Generation using Wind Energy: Source: (Toshiba Energy Systems, 2020).

Wind energy increases with the cube of the wind speed, which makes it more efficient to install wind turbines in areas of higher wind speed. (Toshiba Energy Systems, 2020).

Technically, the size of the turbine and the length of the blades determine the amount of power to be generated. Since wind power is proportional to the wind velocity cubed, theoretically when wind speed doubles, wind power potential increases by a factor of eight. Wind-turbine capacity has increased over time, as typical turbines in 1985 had a rated capacity of 0.05 megawatts (MW) and a rotor diameter of 15 metres. Today's new wind power projects have turbine capacities of about 2 MW onshore and 3–5 MW offshore. Commercially available wind turbines have reached 8 MW capacity, with rotor diameters of up to 164 metres. The average capacity of wind turbines increased from 1.6 MW in 2009 to 2 MW in 2014. (IRENA-Wind)

3.3 Geothermal Energy

Geothermal energy originates as heat energy from reservoirs of hot water that exist at varying temperatures and depths below the Earth's surface. Geothermal energy is a form of renewable energy as the heat energy is continuously produced inside the earth.

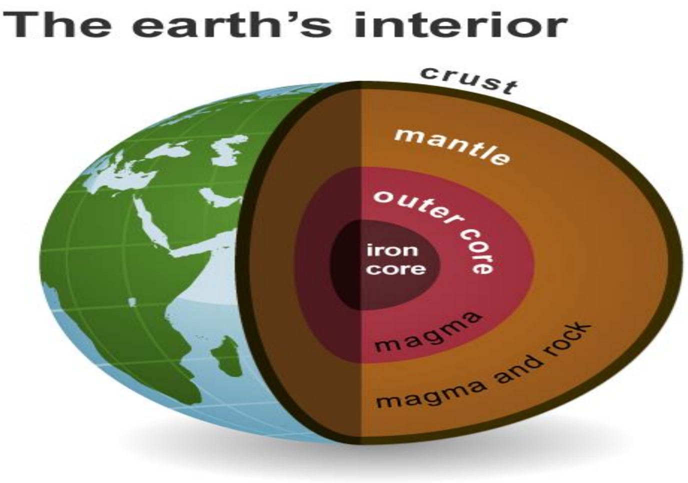

Figure 10: Geothermal Explained, Source: EIA, 2019

Technically, the geothermal energy is produced from the slow decay of radioactive particles in the earth's core. As shown in figure 10, the earth core has four major parts or layers:

- A solid iron inner core that is about 1,500 miles in diameter
- An outer core of hot molten rock called magma that is about 1,500 miles thick.
- The outer core is surrendered by a mantle of magma and rock that is about 1,800 miles thick
- And finally, a crust of solid rock that forms the continents and ocean floors that is 15 to 35 miles thick under the continents and 3 to 5 miles thick under the oceans.

Geothermal hot springs are produced at depth from the earth crust with temperatures ranging between 392 deg F within the mantle, 7,230 deg F at the mantle-core boundary, and finally about 10,800 deg F at the earth's inner core. The heat energy generated from the magma are absorbed by the water, which becomes the geothermal hot springs. (EIA, 2019).

The geothermal source according to Lund, 2018, is accessed by drilling wells to depths of about 9,100 metres to encounter the hot water, which is then extracted by pumping or through natural artesian flow. The hot water is then transmitted through pipes to the power plant to generate electricity. They can also be transported through buried insulated pipelines or sometimes placed aboveground for domestic or industrial heating and cooling applications. Due to the loss of heat and energy in extended pipes in excess of 1.6 km (1 mile), most economically efficient facilities are located close to the geothermal resource.

Three types of geothermal power plants are known; dry steam, flash and binary. Dry steam directly transfers steam out of the ground to drive the turbine, while flash plants convert high-pressure hot water into cool low-pressure water. Finally, binary plants pass hot water through a secondary liquid with a lower boiling point, which turns to vapour to drive the turbine. (Unwin, 2019).

The main advantage of geothermal energy over other renewables, is that its base load is available 24 hours per day, 7 days per week, whereas solar and wind are available only about one-third of the time. (Lund, 2018). Another advantage is that Geothermal power plants are compact; using less land per GWh (404 m^2) than coal (3642 m^2) wind (1335 m^2) or solar PV with center station (3237 m^2). They are also one of the cleanest energy sources as modern, compared to other renewables, its emissions are four times less than solar PV, and six to 20 times lower than natural gas. They also consume consume less water on average over the lifetime energy output than the most conventional generation technologies. (EERE)

Despites these advantages, geothermal energy also have some drawbacks such as its high initial investment cost in facilities and infrastructure, and this is coupled with the associated high risk of proving the resources. Also, though it has low CO_2 production geothermal has been associated with other emissions like sulphur dioxide and hydrogen sulphide. Like fracking, geothermal power plants have been the cause of mini tremors in the area they operate. It is also described as “the most location-specific energy source known to man” due to its activity being along the tectonic plates of the earth’s crust. (Unwin, 2019). Other environmental effects include the changes in land use associated with exploration and plant construction, noise and sight pollution, the discharge of water and gases, the production of foul odours, and soil subsidence. Technologies now exist to mitigate these challenges, so that geothermal uses have no more than a minimal impact on the environment. (Lund, 2018).

3.4 HydroPower

Hydroelectric power, is electricity generated from a falling or fast moving flowing water through the use of generators driven by turbines. The turbines convert potential energy of the water into mechanical energy which is further converted to electrical energy by generators. The plants are thus located around dams which raises the level of water to created the needed potential energy for the turbines. Since the potential energy depends on the head of water, smaller hydropower plants can be installed with the required head of water with a small volume of water. In this case of a flowing water, the hydropower plant is usually installed within the dam. (Britannica, 2020). Generally, hydro energy can be derived from four main sources; potential energy from high heads of water in dams, kinetic energy from fast flowing water, tidal barrages, and finally, kinetic energy from the movement of waves on relatively static water masses as shown in Figure 11.

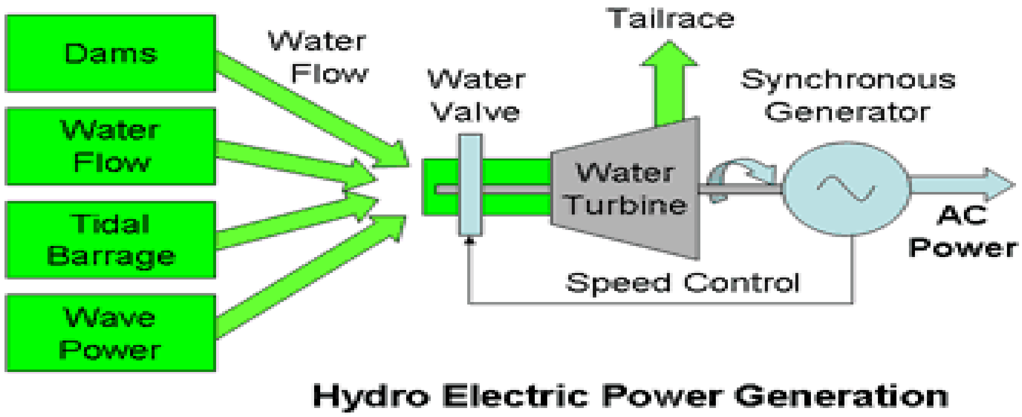

Figure 11: Forms of Hydro Electric Power Generation: Source- Electropedia, 2005

There are three types of hydropower facilities: impoundment, diversion, and pumped storage. Some hydropower plants use dams and some do not. An impoundment facility uses a dam to store river water and releases the water through a turbine that spins to activate a generator that produces electricity. A diversion system channels a portion of a river through a canal or penstock that eventually generates the electricity. It may not require the use of a dam.

The third type is the pumped storage that works like a battery by storing the electricity from solar, wind, and nuclear which is used to pump water to reservoir uphill to create a water fall that will spin the turbine that will in turn cause the generator to produce electrical energy.

Hydropower is also classified according to size; Large, Small and Micro Hydropower. Large hydropower has capacities of more than 30 megawatts (MW), while small hydropower projects can generate 10 MW or less of power. Micro hydropower plants have capacities of up to 100 kilowatts. (EERE)

Hydroelectric power generation is the most efficient method of large scale electric power generation, as shown in the Comparison chart generated by Electropedia (2005) in figure 12. Other advantages of hydropower systems over other sources include: its source is continually renewable due to the hydrologic cycle; It does not produce atmospheric or thermal pollution, It thrives well in areas with heavy rainfall and with mountainous or hilly regions. A major negative environmental impact is the danger of the dams overflowing which has potentials of submerging or displacing ecological and human communities. (Britannica Encyclopedia, 2020)

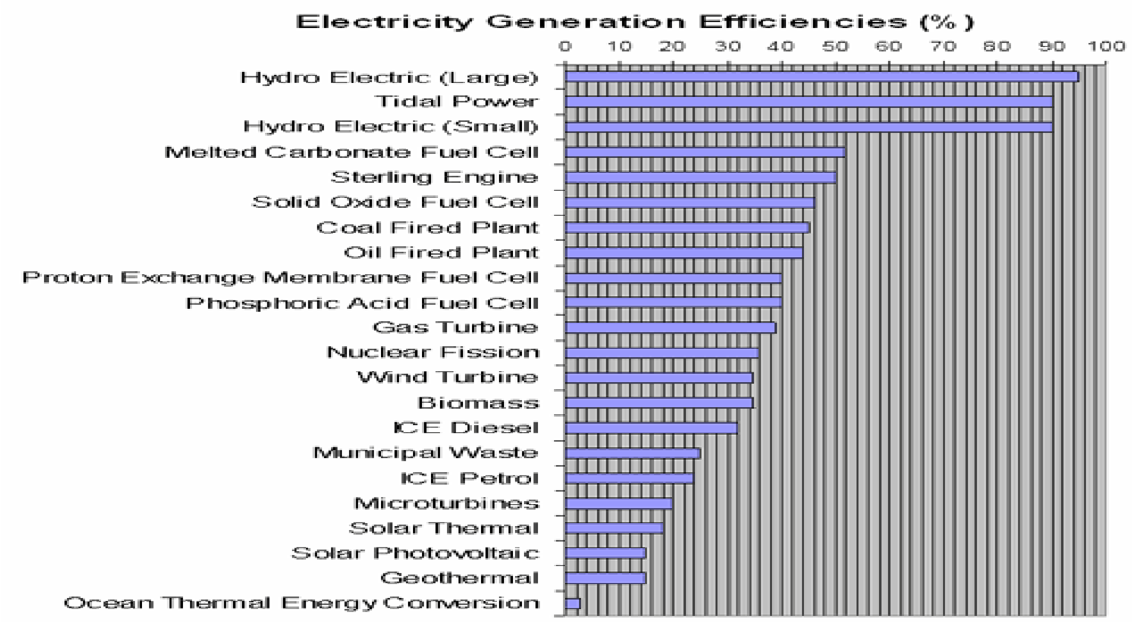

Figure 12. Comparison of the efficiency of power generating systems. Source: Electropedia, 2005.

3.5 Tidal Power

Tides are the result of the periodic movement of sea water caused by the interaction of the gravitational fields of the earth, moon and sun. The tidal movement is caused mainly by the moon, while the Sun contributes only 46 per cent of that created by the moon The tide can rise and fall more than 12 m vertically in order to create potential energy, while the flow of the flood and ebb creates kinetic energy. (IRENA, 2014). Technically, tides are different from sea current, for while tides are the vertical rise and fall of the water, tidal currents are the horizontal flow of the sea. Compared with other sources of energy, unlike other sources of energy, one of the major advantage of tidal energy is that it is less vulnerable to climate change. (Mendi et al, 2016). Despite this advantage, tidal energy production is still in its infancy stage, as it only accounts for a small portion of the global energy mix as only very few commercial-sized tidal power plants are known globally. The first tidal plant was in La Rance, France, while the largest facility is the Sihwa Lake Tidal Power Station in South Korea. (National Geographic)

Tidal energy is generated through tidal streams, barrages, and tidal lagoons. A tidal stream is a fast-moving water body that turns a turbine placed in the stream to generate electricity. The world's first tidal power station was constructed in 2007 at Strangford Lough in Northern Ireland. A Barrage is a large dam constructed either across tidal rivers, bays and estuaries, that allows water to spill over the top or through turbines. Turbines inside the barrage harness the power of tides the same way a river dam harnesses the power of a river. The barrage gates are either open or closed during high or low tides. When the gates are closed, the water forms a pool, which is then released through the barrage's turbines, creating energy at a rate that can be controlled by engineers. Environmentally, construction of a barrage system disrupts the land in the tidal range. Also, marine animals can be caught in the blades of the turbines. In terms of cost of installation, a barrage is a much more expensive tidal energy generator than a single turbine. Although there are no fuel costs, barrages involve more construction and more machines. Unlike single turbines, barrages also require constant supervision to adjust power output.

Lastly, tidal lagoons are a body of ocean water that is partly enclosed by a natural or manmade barrier. They can also be estuaries, and thus can function much like a barrage, however, unlike barrages, they are mostly constructed along the natural coastline. Technically, the turbines spins whether the lagoon is filling or emptying, and therefore provides a continuous source of power. Tidal lagoons are more environmentally friendly and poses minimal risks to the ecosystem. The lagoon is safe for both animals and smaller organisms. It can also accommodate smaller fishes. Regardless of these advantages, plants and animal lives can be negatively impacted due to the change in water level in the tidal lagoon. As with dams across rivers, fish are blocked into or out of the tidal lagoon. In comparison with barrages, tidal lagoons generate much lower energy. (National Geographic, 2011)

3.6 Biomass

Biomass are non-fossil organic materials such as plants, animals and vegetable, and microorganisms. Biomass unarguably forms the world's fourth largest energy source, behind coal, oil, and natural gas. According to Jawaid et al (2017) Biomass includes products, by-products, residues, and waste generated during processing or operation from agriculture; wood from forests; agricultural residues such as straw, stover, and cane trash; green agricultural wastes, forestry; and biodegradable organic fractions of industrial/ municipal solid wastes (sewage, human, and animal wastes), such as black liquor from paper manufacturing, sugarcane bagasse, and rice husk. Animal wastes include manures, slurries, animal bedding such as poultry litter, and grass silage. It also includes gases and liquids recovered from the decomposition of nonfossilized and biodegradable organic materials and food wastes from many food materials during processing stage to remove components that are inedible or not required such as peel/skin, shells, husks, cores, pips/stones, fish heads, pulp from juice, and oil extraction

Jawaid et al (2017) further categorized biomass into woody and nonwoody origin with forests as the principal source of the woody materials, while agricultural sources provide both woody and nonwoody biomass for bioenergy production. Agriculture provides nonwoody bioenergy such as cellulosic materials like plant leaves, stems, and stalks; sugar; starch (i.e., grains); and oil-producing plant materials (e.g., soybeans) needed for bioenergy production. These materials are can be derived either from commodity crops like corn and soybeans, residues collected after harvest of annual crops grown for food or feed, or from perennial crops such as grass and tree crops. What is extracted from biomass for conversion into bioenergy include cellulose, hemicelluloses, lignin, extractives, lipids, proteins, simple sugars, starches, water-soluble substances, hydrocarbons, ash, and small amounts of alkali, alkaline, and heavy metals and other compounds. Among all these components, cellulose, hemicelluloses, and lignin are the three principal sources for bioenergy. Major types of bioenergy are biodiesel and bioethanol, which are alternative energy used as transportation fuels.(Rasool and Hemalatha, 2016).

Bioenergy is produced through a variety of technologies, from conventional combustion process to advanced biofuels technology. These technologies besides converting biomass to bioenergy also reduce the overall waste from biomass. The Biomass conversion systems also reduces greenhouse gas emissions through prevention of methane emissions.

According to Zafar (2019), conversion routes for biomass wastes are generally thermo-chemical or bio-chemical. The thermal conversion processes include combustion in excess air, gasification in reduced air, and pyrolysis in the absence of air. Direct combustion is the most used technology for converting wastes to heat. Gasification is the production of flammable gas by heating biomass wastes in an environment with restricted supply of air or oxygen at temperatures up to 1200–1300°C. The gas produced—synthesis gas, or syngas—is cleaned and filtered and then burned in a gas turbine in simple or combined-cycle mode, to produce a final fuel gas which consists principally of carbon monoxide, hydrogen and methane with small amounts of higher hydrocarbons. This fuel gas can be used to generate heat or processed as fuel for gas-fired engines or gas turbines to drive generators. Biomass is also burnt through pyrolysis, that is thermal decomposition in the absence of oxygen to form a combination of a solid char, gas, and liquid bio-oil, which can be used as liquid fuel or upgraded and further processed to value-added products.

The second process is the biochemical technologies which utilizes anaerobic digestion, during which organic material is decomposed through the metabolic pathways of naturally occurring microorganisms in an oxygen depleted environment. Anaerobic digestion is the natural biological process which stabilizes organic waste in the absence of air and transforms it into biogas and biofertilizer. Other fuels that can be produced from biomass waste include ethanol, methanol, biodiesel, Fischer-Tropsch diesel, and gaseous fuels, such as hydrogen and methane. Ethanol is made principally from lignocellulosic biomass wastes, from agricultural residues (corn stover, crop straws and bagasse), herbaceous crops (alfalfa, switchgrass), short rotation woody crops, forestry residues, waste paper and other wastes (municipal and industrial). (Zafar, 2019).

As a renewable energy source, bioenergy is environmentally friendly compared to petroleum based fuels, and they help in reducing greenhouse gas emissions. Finally, they can be produced from various inexpensive sources, including wastes from crops, used vegetable oils, non-edible oils, animal fats, etc. One major disadvantage is the potential shortage of food if crops are grown primarily for biofuels. Also, biofuel crops require large volumes of water to maintain, which may also put a strain on water resources. Finally, in order to meet energy levels from fossil fuels, larger quantity of bio materials would be required. (Rasool and Hemalatha, 2016).

3.7 Hydrogen Fuel Cells.

A fuel cell which is illustrated in figure 13, is a device that converts chemical potential energy into electrical energy. A typical Proton Exchange Membrane (PEM) cell uses hydrogen gas (H_2) and oxygen gas (O_2) to produce water, electricity, and heat, and is therefore far more environmentally friendly than the internal combustion engines, coal burning power plants, and nuclear power plants, that produce harmful by-products. Given that oxygen is readily available in the atmosphere, the other feedstock, hydrogen come from several processes, both domestic or at an industrial scale. Hydrogen can be produced from the domestic resources from natural gas, nuclear power, biomass, and also from solar and wind.(EERE)

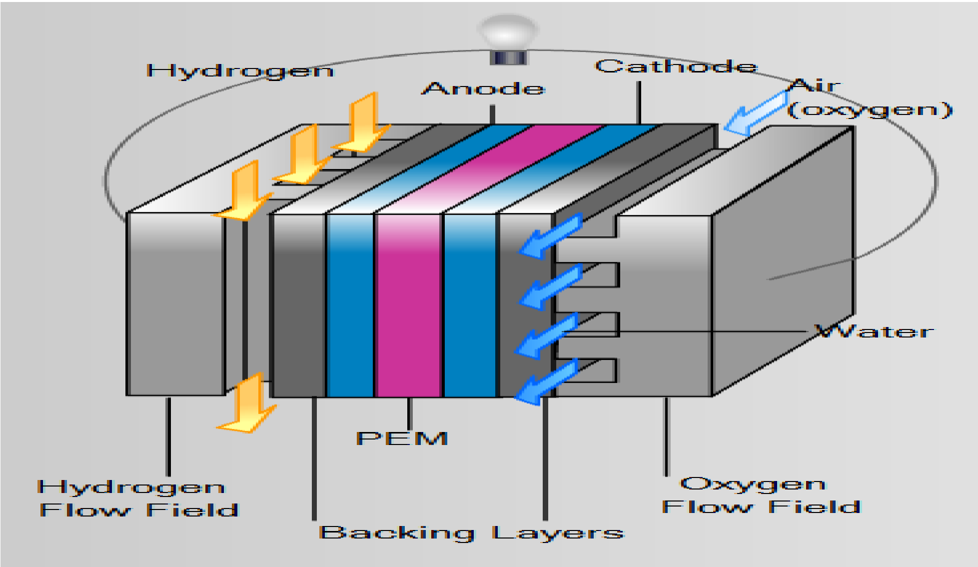

Figure 13: Hydrogen Fuel Cells. Source: Hydrogenics, 2020

Technically, hydrogen can be produced through four processes which are (a) thermal process, (b) electrolysis (c) solar driven and (d) biological processes. The thermal mode is a steam reforming process under a high-temperature process where steam reacts with a hydrocarbon fuel such as natural gas, diesel, gasified coal, or biomass, to produce hydrogen. About 95% of all hydrogen is produced from steam reforming of natural gas. The second process, electrolytic process separates water into oxygen and hydrogen through an electrolyzer which functions much like a fuel cell in reverse—where an electrolyzer creates hydrogen from water molecules. The solar-driven processes use the sunlight as the agent for hydrogen production. Some of the solar driven processes include photobiological, photoelectrochemical, and solar thermochemical. Photobiological processes use the natural photosynthetic activity of bacteria and green algae to produce hydrogen. Photoelectrochemical processes use specialized semiconductors to separate water into hydrogen and oxygen. The thermochemical process uses concentrated solar power to drive water splitting reactions often along with other species such as metal oxides. Finally, the biological processes use microbes such as bacteria and microalgae to produce hydrogen through biological reactions. The microbes directly break down the biomass or wastewater to produce hydrogen, while the microbes are assisted by the sunlight under photobiological processes to breakdown the biomass. (Hydrogenics, 2020)

A typical hydrogen fuel cell or a proton exchange membrane (PEM), consists of four basic elements; the anode, the negative post, that conducts the freed electrons from the hydrogen molecules, and the cathode, which is the positive post that distributes the oxygen to the surface of the catalyst, and back to the catalyst in order to recombine with the hydrogen ions and oxygen to produce water. The third component is the electrolyte which is the proton exchange membrane that only conducts positively charged ions as the membrane blocks electrons. The last component is the catalyst, which is a special material, made of platinum nanoparticles very thinly coated onto carbon paper or cloth, that facilitates the reaction of oxygen and hydrogen. Generally, the catalyst is rough and porous and so allows the maximum surface area of the platinum to be exposed to the hydrogen or oxygen.

The fuel cell works by allowing pressurized hydrogen gas (H_2) to enter on the anode side, and forced through the catalyst by the pressure. Upon encountering the platinum on the catalyst, the H_2 molecule splits into two H+ ions and two electrons (e-). The electrons pass through the anode, and return to the cathode side of the fuel cell. On the cathode side oxygen gas (O_2) is forced through the catalyst to forms two oxygen atoms with strong negative charge, which attract the two H+ ions through the membrane, where they combine with an oxygen atom and two of the electrons from the external circuit to form a water molecule (H_2O). (Hydrogenics, 2020). Hydrogen fuel cells have some advantages such as being more efficient than combustion engines, as fuel cells directly convert chemical potential energy into electrical energy, whereas combustion systems have to convert chemical potential energy into heat, and then into mechanical work before converting to electrical energy. Also, hydrogen fuel cells only emit just water and a little heat, and do not have, and are thus more reliable than traditional engines. (Hydrogenics, 2020).

4. ACTUALIZATION

The current transition to or quest for an alternative energy system is driven by the need to provide energy security in the face of the vulnerabilities of the present oil and gas, fossil fuel driven global economy, and secondly, because of the devastating ecological and climatic problems arising from greenhouse gas emissions.

The vulnerabilities facing the oil and gas energy supplies include geopolitical risk, weather events caused by climatic changes, terrorist and insurgencies activities, industrial accidents, and cyberattacks. For instance the attack on Saudi oil facilities caused significant disruptions to the global oil supplies. The Gulf Coast hurricanes, and high winds in California that caused widespread power outages have all brought the subject of energy security onto global headlines. When this is added to the climatic problems that are ravaging the globe, it is imperative for a much secured and environmentally friendly alternative energy source, and this is where the subject of renewable energy becomes topical on the global agenda. (Finley, 2019).

Tim Eggar, the chairman of the UK's Oil and Gas Authority (OGA), as cited by Simon, 2020, stated that growing public awareness about climate change has put the survival and sustainability of the oil and gas sector at stake. According to Eggar, shifting public attitudes towards climate change is "the biggest challenge" facing the oil and gas industry", and therefore stressed the need for the oil and gas industry to "act much, much faster and go farther in reducing the carbon footprint". To achieve this, according to Eggar, would require ambitious thinking, capital investment and bold leadership, and requires action and not just talk or more analysis. He went further to state that "The licence to operate for the industry has changed fundamentally and – unlike the oil price – forever," he said. "If the industry wants to survive and contribute to the energy transition it has to adapt," . Based on the progress made in the push towards a carbon zero energy regime, BP in their 2019 Energy Outlook projected the global energy mix up to 2040 as shown in figure 14.

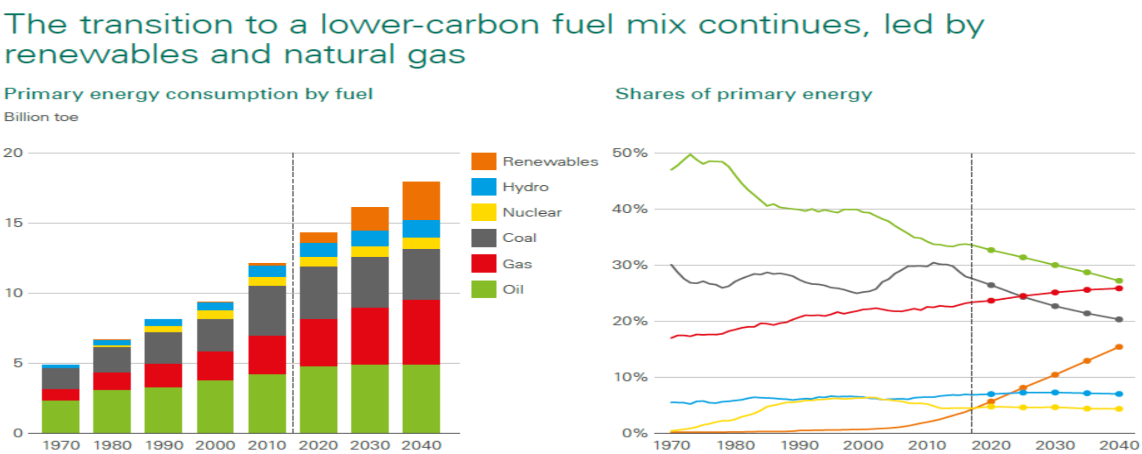

Figure 14: Energy mix from 1970 with a projection to 2040. Source: BP Energy Outlook, 2019.

The chart in figure 14 shows that renewables have the fastest growth to contribute about 15% of the global energy mix by 2040, while oil would have fallen significantly to below 30% of the energy mix by 2040. This is as gas, a much cleaner source than oil, will also increase rapidly to contribute about the same share as oil in 2040.

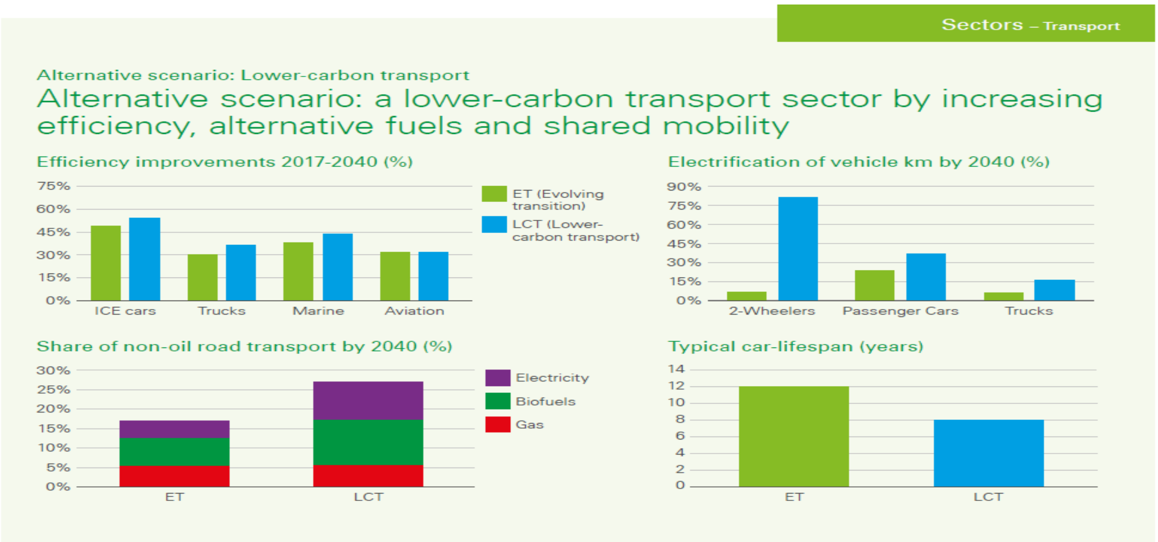

Figure 15: Projection of Low carbon transport from 2017 to 2040. Source: BP Energy Outlook-2019.

Figure 15 shows the transition from oil to low carbon and renewable transportation by 2040. Its projected that half of global sales of new trucks and buses will be electric, or hydrogen powered by 2040. Also, biofuels in road transport are expected to grow in OECD and China by 20% in 2040, and 10% in the rest of the world. Also, biofuel will contribute to about 20% of aviation fuel by 20% in developing economy. In terms of investment, the energy transition has therefore spurred total global investment in renewable power and fuels in 2018 to some USD 288.9 billion, and the fifth consecutive year in a row that investment exceeded the USD 230 billion mark. Nearly all the investment was in solar PV and wind power as shown in the growth of Solar PV in Figure 16 below

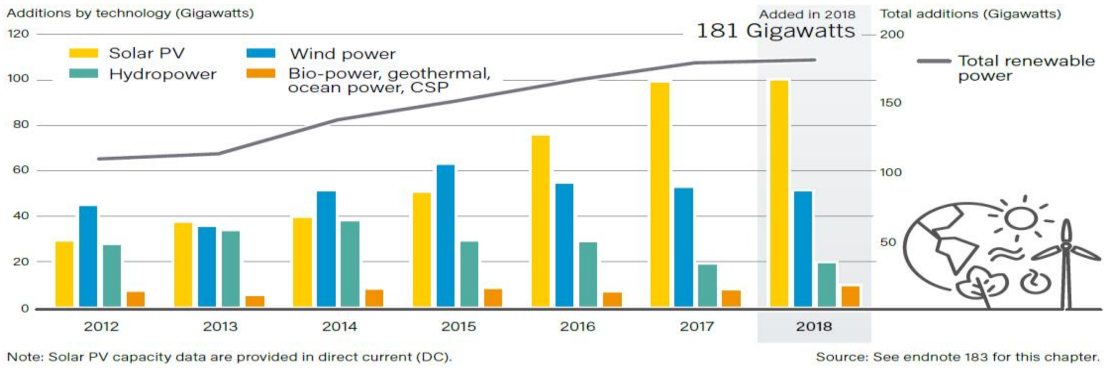

Figure 16: Annual Additions of Renewable Power Capacity, by Technology and Total, 2012 – 2018. Source: RN21, 2019

Developing and emerging economies accounted for 53% of total renewable energy investment, with China alone accounting for 32% of the total. According to the REN 21. 2019 report, renewables are more dominant in electricity generation with very slow progress in heating, cooling, and transportation. This is due to lack of strong policy support and by slow developments in new technologies. Renewables thus contributed more than 26% of global electricity generation in 2018 and accounted for about 11 million employment globally in 2018. The report showed that renewable power capacity grew globally to around 2,378 GW in 2018, which outpaced net installations of fossil fuel and nuclear power combined. The breakdown showed that solar photovoltaics (PV) added about 100 GW which accounted for 55% of renewable capacity additions, closely followed by wind power (28%) and hydropower (11%). In general, renewable energy now account for for more than 33% of the world's total installed power generating capacity. In terms of countries, more than 90 countries had installed at least 1 GW of generating capacity in 2018, while at least 30 countries exceeded 10 GW of capacity. The report further showed that through there were significant growth in renewables, energy-related carbon dioxide (CO_2) emissions grew an estimated 1.7% in 2018 mainly from fossil fuel consumption as fossil fuel companies continued to spend hundreds of millions of dollars on lobbying to delay, control or block climate change policies and on advertisements to influence public opinion. Regardless of this sabotage by the fossil fuel companies, the REN21.2019 report showed that Renewable power has become cost-competitive compared to conventional fossil fuel-fired power plants, such that by the end of 2018, electricity generated from new wind and solar photovoltaics (PV) plants had become more economical than power from fossil fuel fired plants in many places. Renewables, such as wind and solar PV are even more cost-effective to build in some locations than to continue to run existing fossil fuel power plants.

Writing in the Financial Times of March 2, 2020, Patrick Jenkins, pointed out that one of the major challenge with this energy transition is that many fossil fuel assets will be left untapped, resulting into huge losses that will cause spill over effects on lenders and insurance companies and asset managers that invested in these assets. He further reported that, according to a study by Financial Times team, limiting global warming to 2 degree centigrade would leave 29 per cent of oil reserves stranded and untapped, which would wipe out about $360bn from the value of the top 13 international oil companies by reserves. However, reducing this to meet the target of 1.5 degree centigrade would more than double the figures to nearly $890bn. This will greatly impact on banks since they provided about $654bn in financing to fossil fuel companies in 2018. Consequently, according to Jenkins, 2020, major fossil fuel companies are beginning to realign their investment portfolio amid louder protests from campaigners and investors. BP has already promised to be net zero by 2050, while Equinor, a Norwegian oil company abandoned a A$200m ($132m) plan to drill for oil and gas in the deep waters of an Australian marine park, and another company, Teck Resources in Canada, walked away from a $15bn oil sands project.

5. DISCUSSIONS

The current energy transition as stated in earlier section of this paper is a transition from fossil fuels to a system based on renewable energy, in order to cut back on global greenhouse gas emissions and avoid the most serious impacts of a changing climate, on the one hand, and to also guarantee energy security for economic growth and development.

According to Adnan Z. Amin, the Director-General, International Renewable Energy Agency, the last transition from traditional biomass energy 200 years ago, to fossil fuels was based on resources that are geographically concentrated, which created geopolitical power play especially by resource based countries. The current transition to renewable provides one with potential abundance of resources for almost every country on the globe, this is as almost every country will have some degree of energy independence in the new energy system. This shift according to Amin, 2019, will have profound impact on the global economy. While renewable sources are ubiquitous, one of the greatest challenges is that fossil fuel dependent economies may have to adopt a new, diversified, economic model, and this is already emerging around the world. The United Arab Emirates has already put in place energy strategy that is premised on 70 per cent decarbonization and 44 per cent clean energy power generation by 2050. However, Amin 2019, stated that some other countries may not that prepared considering the possibilities of a fast-moving energy transition. Therefore countries like Nigeria, Angola, Gabon and others that are highly dependent on fossil fuel, may face very severe economic challenges unless they have ambitious strategies of economic diversification.

One other strategic benefit of renewables is that it will serve as the "defence policy of the future" according to Adnan Z. Amin, the Director-General, International Renewable Energy Agency. He posits that fossil fuels, particularly oil, have caused all shades of conflicts over the last 100 years, as the global energy transition moves more into renewables, the relative importance of fossil fuels will begin to decline, which will also shift frequency and location of geopolitical conflicts. Potentially, the risk of confrontation over contested hydrocarbon reserves, such as in the Middle East or in the South China Sea, may diminish, and may therefore generate a 'peace dividend'. Besides, minimizing the geopolitical conflicts, renewables will also play an essential role in all strategies to combating climate change. Amin (2019) added that transiting to renewables will also mitigate against wider socio-economic stresses and shocks and hence frequent conflicts by improving access to energy to about 1 billion people who are energy-poor, creating jobs, reducing local pollution, promoting sustainable development and alleviating competition over scarce natural resources. He reported that, already, renewable energy sector has employed over 10 million people globally.

Another benefit of renewable according to Fattouh et al, 2019, is that energy generated in the form of usable electricity is immediately available to consumers, while only around 40% of the energy content from coal can be captured as electricity. Energy from gas provides about 50% to customers in a combined-cycle gas turbine, while internal combustion engine, delivers only less than 20% of the energy in gasoline. Therefore, when considered from the perspective of end demand, one of the most valuable disruptive effects of renewables is that each TWh of generated energy can displace 2.5 TWh of coal supplies or more than five TWh of gasoline supplies. Commenting on the current energy transition, Fatouh et al 2019, stated that energy transition requires a radical shift from an existing model to a new paradigm. That, as a multidimensional, complex, non-linear, non-deterministic, and highly uncertain phenomenon, and although it is often assessed based on the speed of changes in the tangible dimension, it is a multilayered process with multiple actors. According the World Economic Forum Insight Report for 2018, a successful energy transition would involve changes in three interrelated dimensions : (1) the tangible elements such as technology, infrastructure, market, production equipment, consumption patterns,and distribution chains; (2) actors and their conduct, which include new strategies and investment patterns, as well as changing coalitions and capabilities of actors; and finally (3) socio-technical regimes that contain formal regulations and policies, institutions as well as mindset and belief systems, discourse and views about normality and social practices. To avoid any unpleasant disruption, the transition must consider a future energy system that delivers an optimal balance across the three triangle imperatives: economic development and growth, universal access to secure and reliable supply, and environmental sustainability.

Consequently, though the world is moving towards renewables, projections show that renewables will only contribute about 15% of the global energy mix by 2040. Its major contribution for now being in electric power generation, as cooling, heating, and transportation are all at low scale due to lack of strong policy support and by slow developments in new technologies. This according to Fattouh etal (2019) is consistent with historical data and evidence of past slow energy transitions. In reality, energy transition relies heavily on the availability of infrastructure, which often takes time and is very costly to build. Growing this infrastructure requires a huge sunk cost, therefore generator owners tend to keep existing assets running for as long as it is economically and technically feasible. New energy sources gradually improve their performance and competitiveness (through learning curves and economies of scale). This will result in the slow replacement of incumbents in energy markets. One other challenge with the transition to renewables, according to Finley, 2019, is that renewable energy is almost exclusively domestically produced, production of inputs to these energy sources are frequently produced abroad, and—at least for now—are highly concentrated in a few countries which will also create future energy security problems. For example, China dominates the global production of rare earth metals (an important component for batteries), solar power panels, and batteries for electric vehicles, while two-thirds of the world's cobalt production (another battery, solar panel, and wind turbine component) is concentrated in the Democratic Republic of Congo, a country with a history of human rights abuses and corruption. Also, the expected growth in renewable energy and batteries will also require an unprecedented increase in the mining and refining of ores. Now since it takes a rather long time to develop new mines, coupled with the environmental and social issues that come with mining and refining of these rare ores, such growth poses a risk of future supply shocks. Moreover, both the US and Europe are highly dependent on ores that are mined and refined outside of their borders.

6. GENERAL RECOMMENDATIONS

The world no doubt is in another phase of securing an alternative energy source, from fossil fuel to low carbon renewables energy system, driven by the need for a sustainable energy system and secondly, to arrest the deteriorating climatic challenges caused by greenhouse gas emissions. However, since fossil fuel, mostly oil may continue to play significant role in the global energy mix beyond 2040, due to the huge investment required to fully transit into renewables, and on how to manage the existing investments in the fossil fuel industry, it has become rather imperative for the global actors to enforce pragmatic policies towards achieving this transition. Figure 17 by Fleming, 2019, of the World Economic Forum, shows the top 15 countries in global CO2 emissions, with China and the United States, the two biggest economies, ranking 1st and 2nd on the list. According to Fleming, 2019, these top 15 countries collectively account for 72% of CO2 emissions, while the rest of the world's 180 countries account for only 28% of the global total. Figure 18 is a chart from World Resource Institute which shows that the energy sector contributes about 72.9% of the total global emission, while of the greenhouse gas, CO2 contributes about 74.4% of total greenhouse gas effect.

These data clearly indicate that any meaningful energy transition would require a focussed and very pragmatic push from these top 15 emitting countries. Expectedly, none of these 15 countries appeared in the top 10 countries on the World Economic Forum Energy Transition Index for 2019 as shown in figure 19. The World Economic Forum's Energy Transition Index, ranks 115 economies on their balance between energy security and access with environmental sustainability and affordability. Sadly, according to the World Economic Forum, the biggest challenge to a quick energy transition to renewable energy is the lacklustre disposition of the world's largest emitters, including US, China, India and Russia towards this global objective. Ironically, the top 10 countries on the index only account for 2.6% of global annual emissions.

Rank	Country	Emissions in 2017 ($MtCO_2$)	% of Global Emissions
#1	China	9,839	27.2%
#2	United States	5,269	14.6%
#3	India	2,467	6.8%
#4	Russia	1,693	4.7%
#5	Japan	1,205	3.3%
#6	Germany	799	2.2%
#7	Iran	672	1.9%
#8	Saudi Arabia	635	1.8%
#9	South Korea	616	1.7%
#10	Canada	573	1.6%
#11	Mexico	490	1.4%
#12	Indonesia	487	1.3%
#13	Brazil	476	1.3%
#14	South Africa	456	1.3%
#15	Turkey	448	1.2%
	Top 15	26,125	72.2%
	Rest of World	**10,028**	**27.7%**

Figure 17: Top 15 Countries in Global CO2 emissions. Source: Fleming, 2019.

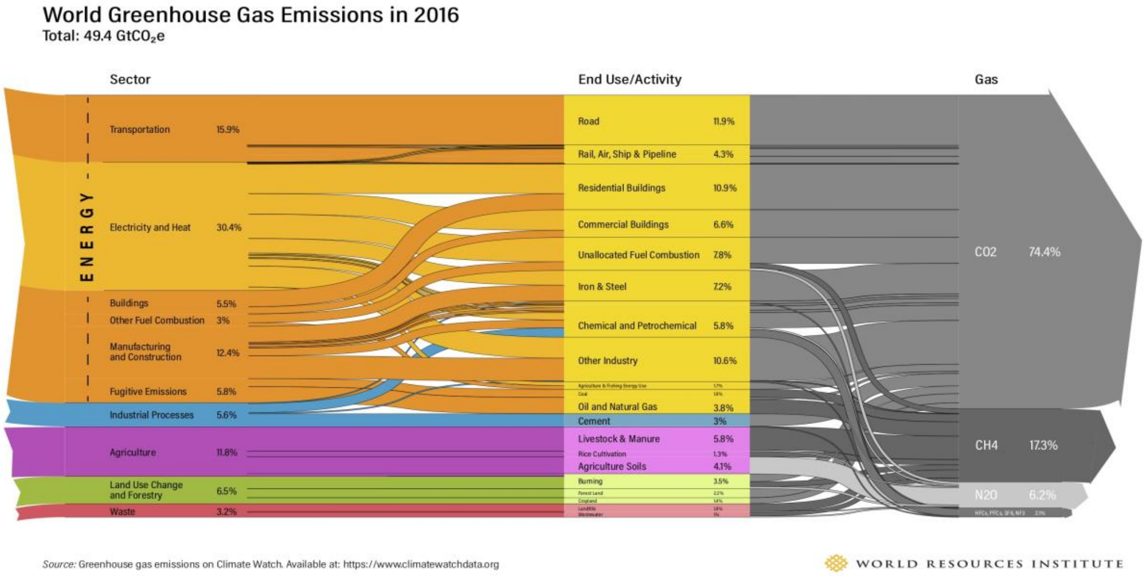

Figure 18: World Greenhouse Gas Emission in 2016 by Sector. Source: World Resource Institute, 2019

The energy transition must also focus on the critical sectors such as transportation, electricity and heat, buildings and in manufacturing and constructions.

Top 10 Countries
Energy Transition Index 2019[1]

	Score	Rank
Sweden	74.9%	1
Switzerland	74.3%	2
Norway	73.4%	3
Finland	73.0%	4
Denmark	72.2%	5
Austria	70.7%	6
United Kingdom	70.2%	7
France	68.6%	8
Netherlands	68.5%	9
Iceland	68.5%	10

Note 1: The Energy Transition Index benchmarks countries on the performance of their energy system, as well as their readiness for transition to a secure, sustainable, affordable, and reliable energy future. ETI 2019 score on a scale from 0 to 100%.
Source: Fostering Effective Energy Transition Report 2019, World Economic Forum

Figure 19: Top 10 Countries Energy Transition Index 2019. Source- Fleming, 2019.

Since CO2 contributes about 74.4% of the total greenhouse gas, while investing on renewable sources, there must also be investments towards accelerating carbon capture, and carbon removals. Tree plantings, which are less expensive can take out a lot the carbon dioxide from the atmosphere, plus carbon sequestering in natural soil to reduce carbon emission in the atmosphere. (Roberts, 2019). Another means of reducing emissions is to plan towns and cities where people can safely and conveniently use public transit, walk, or bike, instead of using private vehicles, also reduces energy demand. (EESI).

While carbon capture and removal processes are going on, there has to be a strong political will by major stakeholders such as the United States, China and other rich economies to support the transition to renewables, though China recorded highest installed renewable energy in 2018 as shown in the IRENA chart in figure 20, but the fact that it did not feature in the top 10 countries on the Energy Transition Index for 2019 shows that it has a lot to do to transit from fossil fuel to renewable energy.

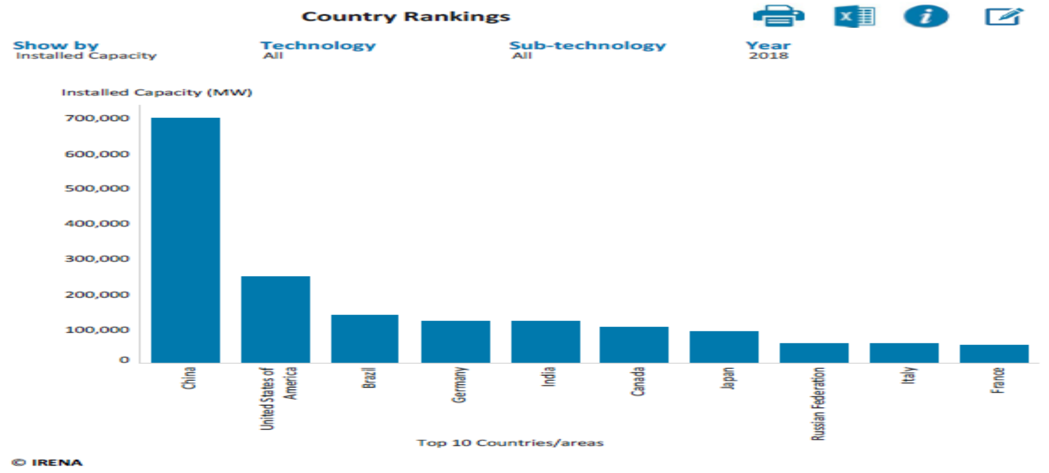

Figure 20: Renewables Country Ranking as at 2018. Source, IRENA

7. CONCLUSION

The world must transit into cleaner and less carbon emission alternative energy sources in order to achieve the zero carbon by 2050, and renewables are the best alternatives towards achieving these goals. However, though they are abundant in nature, the technology for efficient and sustainable conversions into energy are still evolving, especially for heating, cooling and transportation. Also, there is the challenge of fossil fuel companies continued lobbying and subsiding the use of fossil fuel in the energy mix. Another major set back is the position of the United States and China, the two biggest emitters and as well as biggest economies, in combatting the emission problems, as they continue to emit more carbon into the atmosphere. A very strong political will is therefore required amongst all stakeholders, especially from the top 15 emitters to push the renewable agenda on the globe. While renewables provide ready solutions for the high carbon emissions, there are also potential vulnerabilities and strategic energy security challenges as not all countries have the technology to convert the natural resources into renewable energies, and this is where it is also important to begin to discuss this on how to avoid geopolitics in renewable sources as we have in fossil fuels. Finally, since historically, energy transition takes much longer time, and which in this case is already evident in the pace of renewables in the energy mix, there must be efforts to reduce the carbon emissions through carbon capture, and carbon storage technologies. Naturally, nations must engage in more tree plantings as it is even seen, and carbon sequestering in soil, to reduce carbon dioxide in the atmosphere as the world move towards increased renewable in the global energy mix.

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