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A Review on Current trends in solar photovoltaic and zero emission vehicle impact on Climate Change Mitigation

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ABSTRACT

Recently concluded Paris Conference 2015 notes that, even after complying by pollution reduction commitments by various nations, estimated greenhouse gas (GHG) emissions in 2025 and 2030 will reach 55 Giga tons of carbon emissions, and will not reduce the global average temperature rise to below 2˚C above pre-industrial levels. The Intergovernmental Panel on Climate Change (IPCC) predicts that if greenhouse gas (GHG) emission levels continue to rise, future changes are likely to be even more extreme, with millions of people displaced by rising sea levels and global food supplies under threat. The only possible recovery from this imminent danger appears to be in the form of global cooperation in mitigating climate change at a pace unprecedented in modern history. Adoption of Paris Agreement 2015 will not be beneficial, unless, reduction in energy demands in the form of fossil fuel as well as resources consumption by people around the world and other mitigating measures are employed at mass scale, the most important being one switching to cleaner energy. According to IPCC report (2014) electricity generation and transportation together contributes 39% of global greenhouse gas emission. A very promising way to achieve this daunting task of reduction in GHG emission is by switching to cleaner sources of energy such as solar photovoltaic and fuel cells away from fossil fuel based electricity production and transportation. Recent data suggest that contribution of solar energy has already crossed 1.5% of global electricity demand and it is the fastest growing energy market in China which is the second largest GHG emitter in the world. Whereas, fuel cells possess the capacity of becoming the future power house. The present paper intends to illustrate and discuss current as well as future prospects of these sources of clean energy, their contribution in mitigation of climate change and imminent danger of unchecked climate change.

Keywords: Climate change mitigation, Solar PV, Fuel cell, Greenhouse gas (GHG), Electric Vehicle (Ev), Carbon Dioxide (Co_2).

1. INTRODUCTION

Since climate record-keeping began a century ago, human footprint in rising global temperature, pollution levels and its possible ramification on our climate has become more than evident. The dangers of climate change are more imminent than ever in the light of recent scientific data. Atmospheric CO_2has increased by 80 ppm (parts per million) in just last 60 years [2]. This quick rise in carbon emissions is closely followed by steady rise in global average temperature since industrial revolution, leaving no doubt that this change is anthropogenic in nature, caused primarily due to Greenhouse gas (GHG) emissions [3]. The Earth has already warmed by 0.85°C relative to pre-industrial levels (between 1880 and 2012) [4]. If it warmed by more than 2°C then it will start an irreversible climate change whose ramification will be catastrophic for us. Rising sea levels, mass migration, shifting precipitation patterns, increasing numbers of severe heat waves, and more intense precipitation events, persistent drought and submerged cities will merely be the beginning of our problems [2].The question is less of if, and more of when will this begin to happen. As there is no single magic bullet to this daunting problem, its solution will employ a combination of measures. Clearly, business as usual is not going to help as evident from this future emission projection in Figure 2, emissions must be brought down as per the fourth emission scenario. According to IPCC report (2014), electricity generation and transportation together contributes 39% of global GHG emissions in 2010 [5]. A very promising way to achieve this daunting task of reduction in GHG emission is by switching to clean sources of energy such as solar power and Zero Emission Vehicles (ZEVs), in electricity production and transportation respectively.

Solar Photovoltaic (PV) is the most promising renewable energy sector both in capacity and potential. The great thing about solar power is that it is a technology and not a fuel. It is unlimited and the more it is deployed the cheaper it would become. In 2016, solar PV reached the milestone of contributing 1.5% in global electricity production which is 303 GW or 50 times more than it was 10 years ago [6]. Solar PV will gradually become less costly to install than carbon based energy sources and will eventually phase them out.

Fuel cell electric vehicle (FCEV) is another innovative technology and a promising alternative fuel source for fossil fuel based transportation. It incorporates desirable qualities of gasoline and electric vehicles (EVs) and discards their useless aspects. Its well-to-wheel GHG emission is considerably less than conventional vehicles. FCEV emits no GHG at all while running. The only limitation it faces is availability of Hydrogen as fuel source and its production. Moreover, Electric Vehicles (EVs) have become the latest disruptive technology. Its appeal as well as sale has grown to 2 Million vehicles in past 5 years, and has added a new 'cool' with the advent of Tesla's Model S and Model 3 iconic EVs [7]. Thus, these ZEVs are going to be the biggest transformation in Fossil fuel based transportation world.

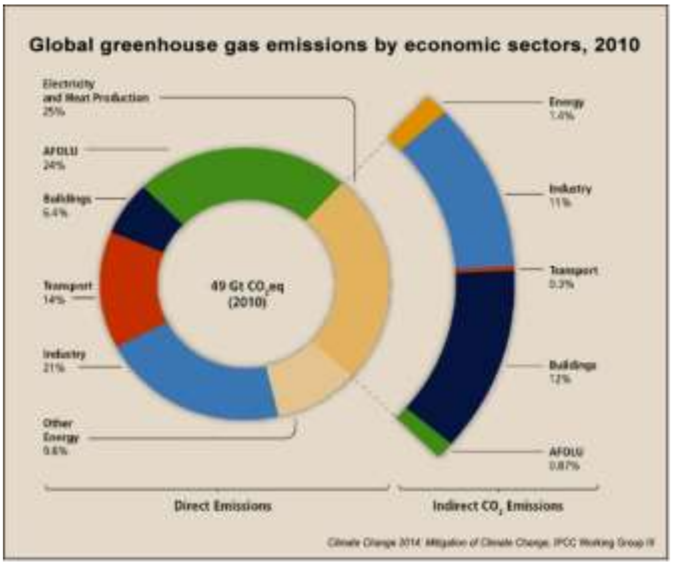

Figure 1. Global GHG emissions by economic sectors [3]

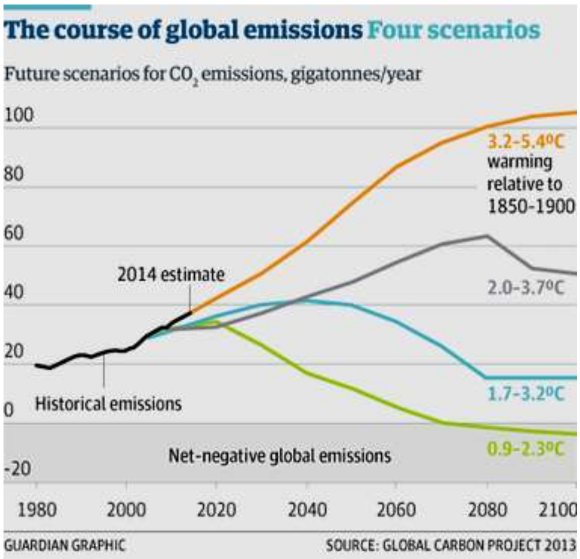

Figure 2. Future projections of emissions four Scenarios [9]

2. Literature Review

2.1. Gloomy Future

Based on present trends in carbon emissions, the future looks gloomy. Eight of the world's ten deadliest heat waves have occurred since 1997. According to NASA and NOAA, 2016 was the hottest year in 137 years of historical record keeping, preceded by three consecutive hottest years [8]. Out of the 17 hottest years on record, 16 have occurred in the 21st century. Figure 3 depicts global temperature change in the past four decades and it speaks for itself [11]. The Global warming has raised global sea level by 8 inches since 1880, and the rate is accelerating. Polar ice caps are rapidly shrinking [10]. As evident from Figure 5, in 2010, 77% of all GHG emission was from CO_2 [5]. Levels of CO_2 in the atmosphere has risen from 270 ppm in the pre-industrial world to 400 ppm now and with it the global temperature [2,3] as depicted in Figure 4. To prevent further rise in temperature beyond 2˚C, it requires that we halt the rise in the stock of carbon dioxide before it reaches 450-480 ppm. In dangerous times there is no sin greater than inaction. Our world appears to be heading on a collision course of destruction, to prevent this inevitability, representative of 196 nations, responsible for more than 90% emissions came together in Paris to forge an agreement of concrete measures against Climate Change in 2015 [9]. The issue of climate change transcends national borders, therefore it has to be addressed with global cooperation. Without a shadow of doubt, significant cut in carbon emissions must be done in a relatively short span to mitigate climate change. For this to happen, tapping into clean energy sources are our only hope.

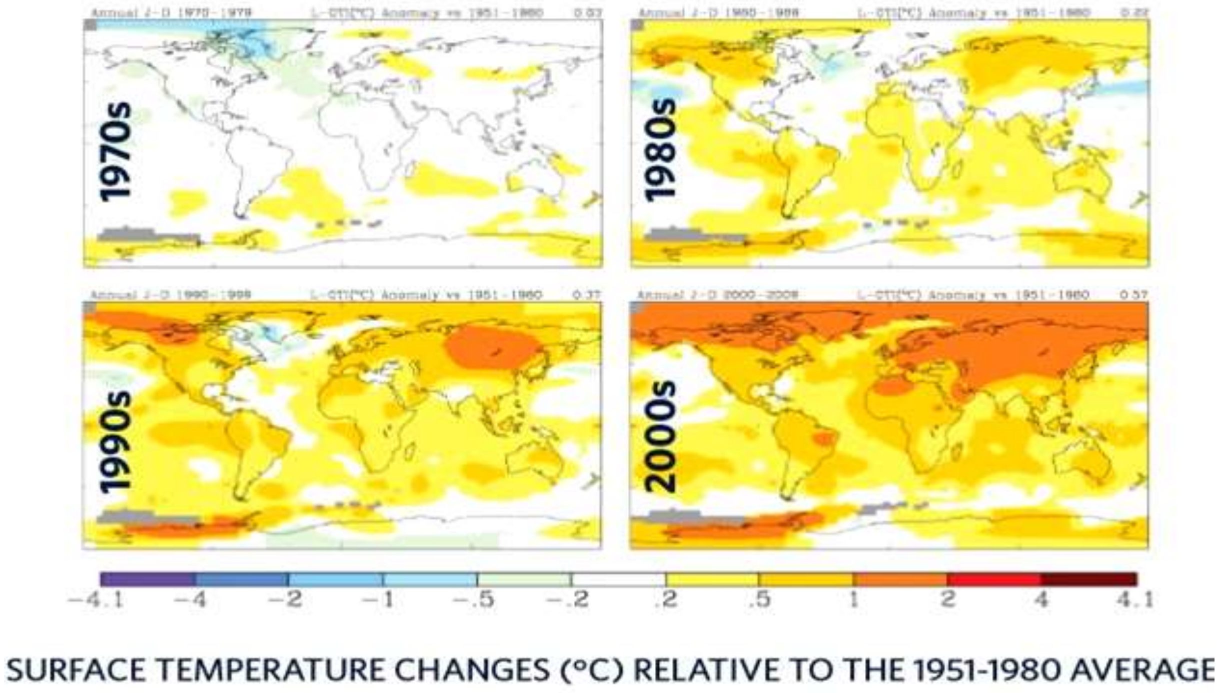

Figure 3. Global temperature changes in last four decades [11]

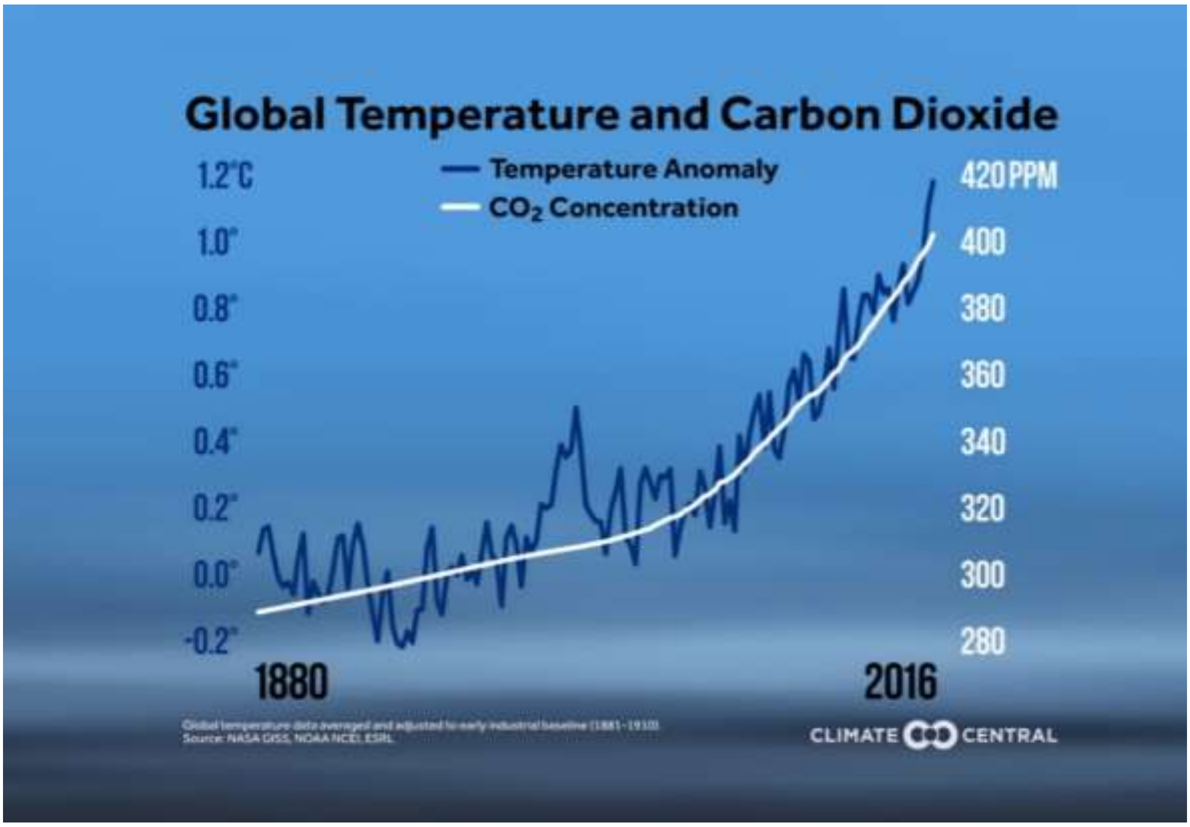

Figure 4. Global Temperature and CO_2 relationship since pre-industrial era [2]

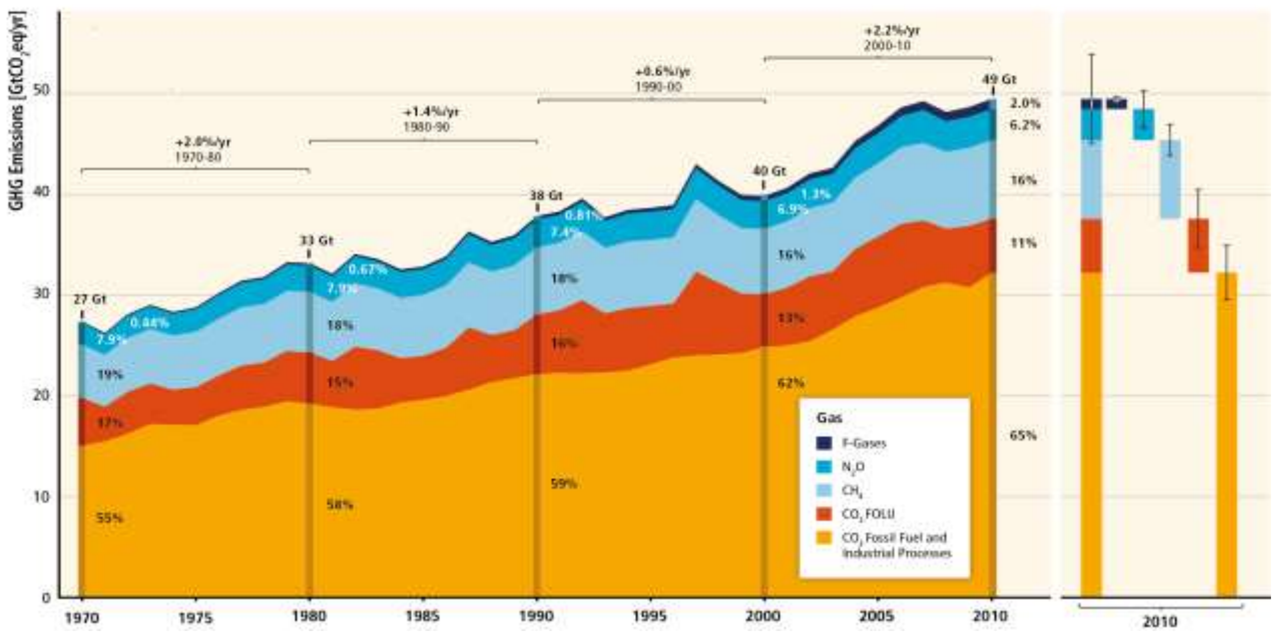

Figure 5. Total Annual Anthropogenic GHG Emissions by group of gases during 1970-2010 (4)

2.2. A Ray of Hope – Photovoltaic (PV) growth

With the beginning of new millennium, renewable energy sources have witnessed a tremendous growth. Of all the renewable sources, solar power shows tremendous potential and growth in becoming the leading future clean energy source. In 2016, the share of renewable energy stood at 24.5% in global electricity production (excluding nuclear energy).In the same year, solar PV reached the milestone of 1.5% global electricity production which is 303 GW or 50 times more than it was 10 years ago. It witnessed new addition of 75 GW, the largest yearly addition till date. Astonishingly, more than 77% of all PV capacity in operation worldwide at the end of 2016 was added over the past five years [6]. According to Bloomberg New Energy Finance (BNEF) New Energy Outlook 2017 Report, Wind and Solar energy will account for 48% of installed capacity and 34% of electricity generation world-wide by 2040 [12]. By 2040, renewable energy penetration will reach 49% in India**.** India and China aims to install 100 GW & 110 GW of solar power by 2022 and 2020 respectively. India ranks 7thglobally in total solar PV capacity, equivalent to 9.1 GW [6].With 850 MW of solar power capacity, Longyangxia Dam Solar Park, China is currently (as of April 2017), the world's largest solar farm [15]. As fossil fuel based energy productions are the major cause of GHG emissions as shown in Figure 5**,** replacing them with solar power can significantly reduce emissions before it reaches the tipping point. This century is destined to be the age of solar power as all odds are in its favour. There are several reasons to expect solar power becoming future power source. Figure 6 shows tremendous addition in solar PV power over the past decade [6]. It also has a symbolic resemblance to keeling curve of CO_2 increment, suggesting that, as the past century was wasted in creating the GHG mess, this new Century is dedicated to clean up those mess, with even more vigour. Also, Figure 7 contrast the rate of development in Solar PV sector in comparison to other Renewable energy sector. It clearly eclipses all other competing sectors by a large margin. This robust growth in Solar PV industry is mostly due to plummeting price of solar modules and subsequently huge investments, subsidies and a favourable atmosphere in response to the ever-growing threat of Climate Change.

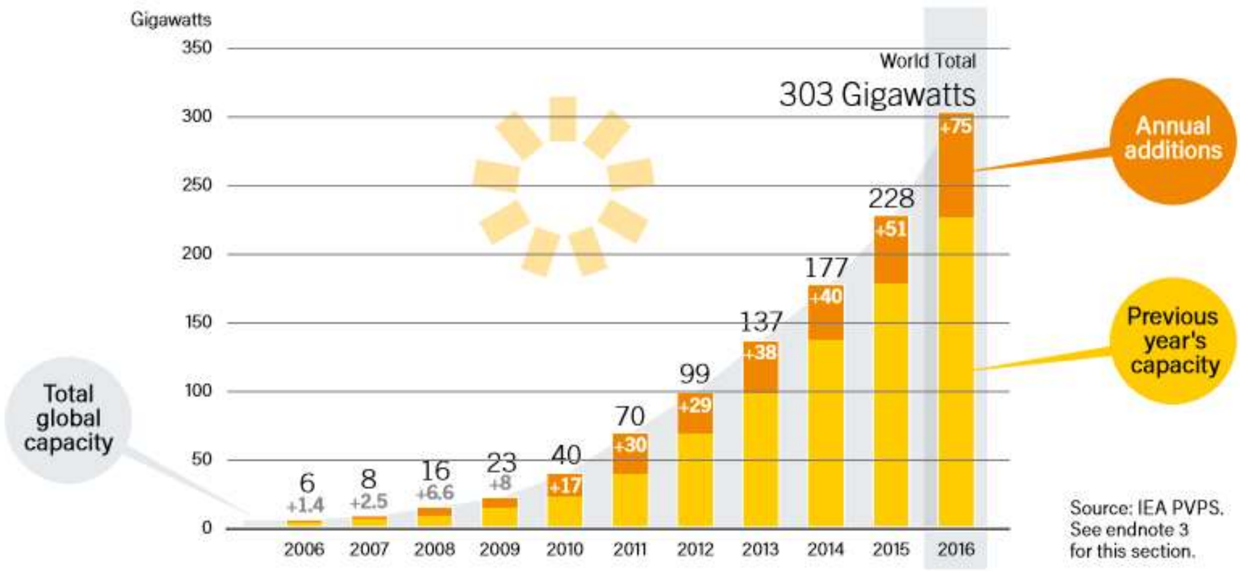

Figure 6. Solar PV Global Capacity, 2006-2016 [6]

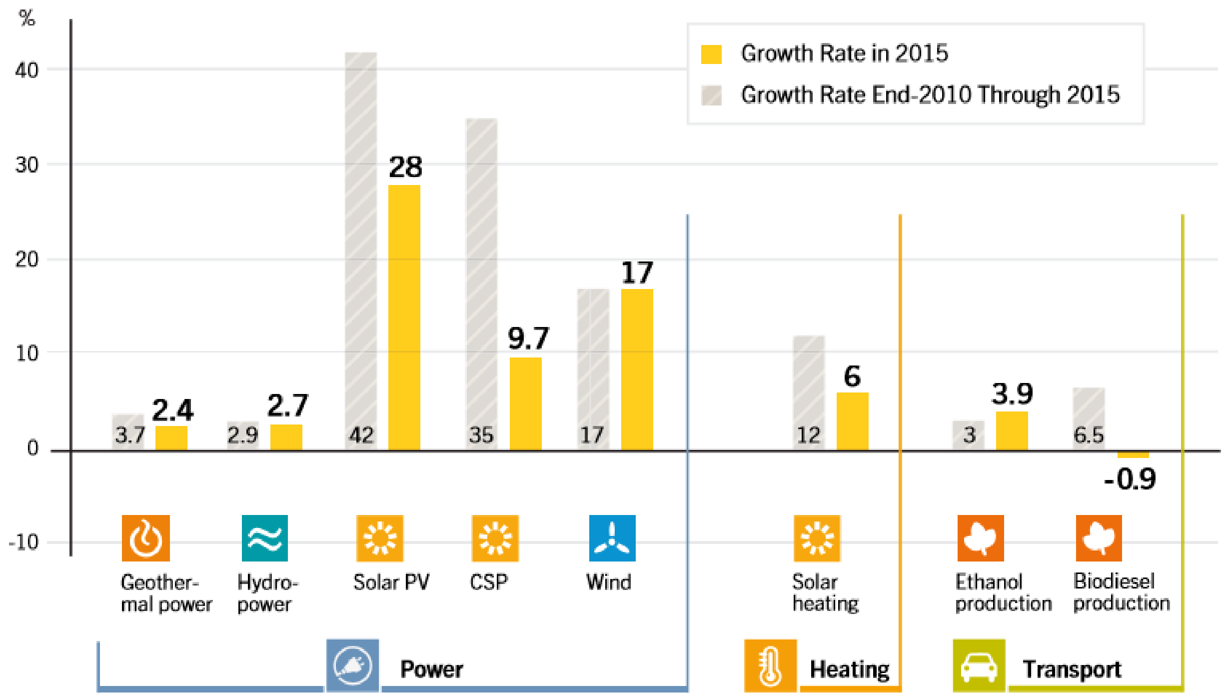

Figure 7. Average Annual Growth Rates of Renewable Energy Capacity [6]

2.2.1. Increased Investment

New investment in renewable energy in 2016 continued to be dominated by solar (mostly solar PV) and wind power. Past five years have witnessed massive influx of investments and growth, mostly propelled by declining PV module cost. However, it suffered 34% decrease in dollar invested in comparison to previous year, mostly due to significant cost reduction. Despite that, Solar PV saw a market increase of nearly 50% relative to 2015 [6]. Solar power was the leading sector in terms of money committed during 2016, accounting for $113.7 billion, or more than 47% of total $249.8 billion new investment in renewable power and fuels (not including hydropower >50 MW) as illustrated in Figure 8. China's energy agency vowed to spend more than $360 billion on renewable energy sources such as solar and wind by 2020. BNEF 2017 Report estimates that $10.2 trillion will be invested in new power generation capacity worldwide to 2040. Of this, 72% will go to renewables, or $7.4 trillion. Solar power will take $2.8 trillion and wind $3.3 trillion. Investment in renewable energy will increase to around $400 billion per year by 2040 that is 2-3% average annual increase [12].

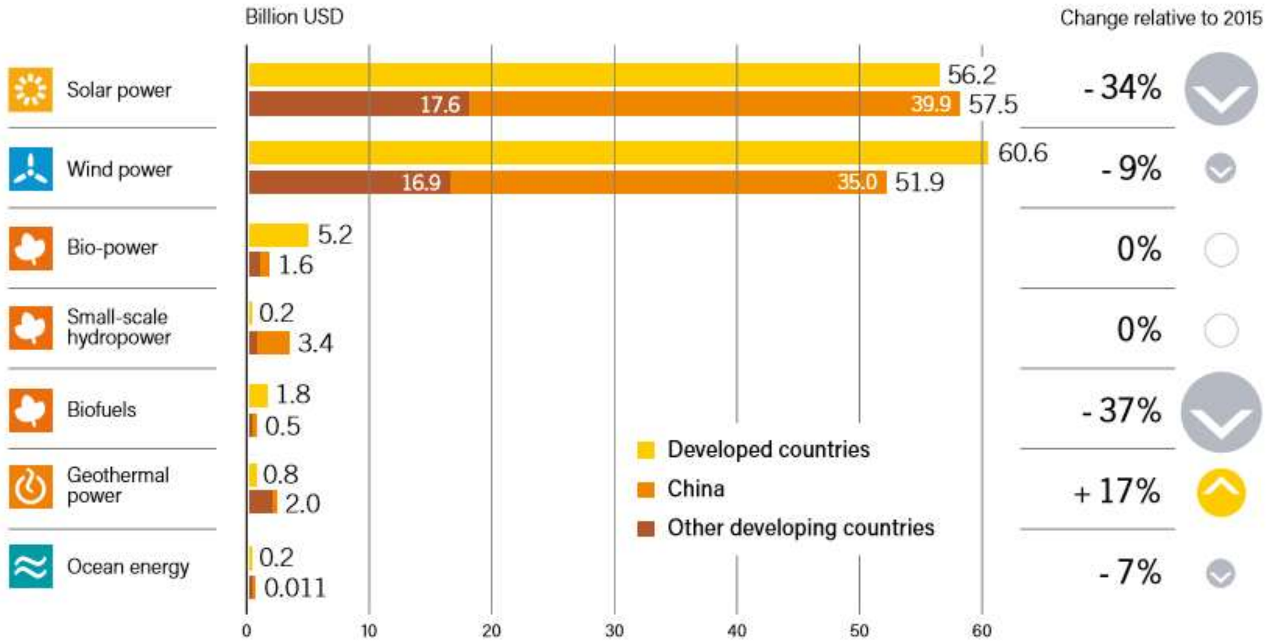

Figure 8. Global New Investment in Renewable Energy by Technology in Developed and Developing Countries in 2016 [6]

2.2.2. Decreasing Cost

Rapidly falling costs of electricity from PV has made unsubsidized solar power economically viable today in certain regions of the world. Crystalline silicon solar cell prices have fallen from $76.67/watt in 1977 to an estimated $0.64-0.67/watt in 2014 which is seen as evidence supporting Swanson's law, which states that solar cell prices fall 20% for every doubling of industry capacity [14]. Moreover, PV installations can operate for 100 years or even more with low maintenance so after the initial capital cost of building any solar power plant, operating costs are extremely low compared to existing power technologies. A 0.75 GW solar farm in Rewa, Madhya Pradesh saw Levelized tariffs as low as Rs. 3.3 per kilowatt-hour (KWh), the lowest so far [16].

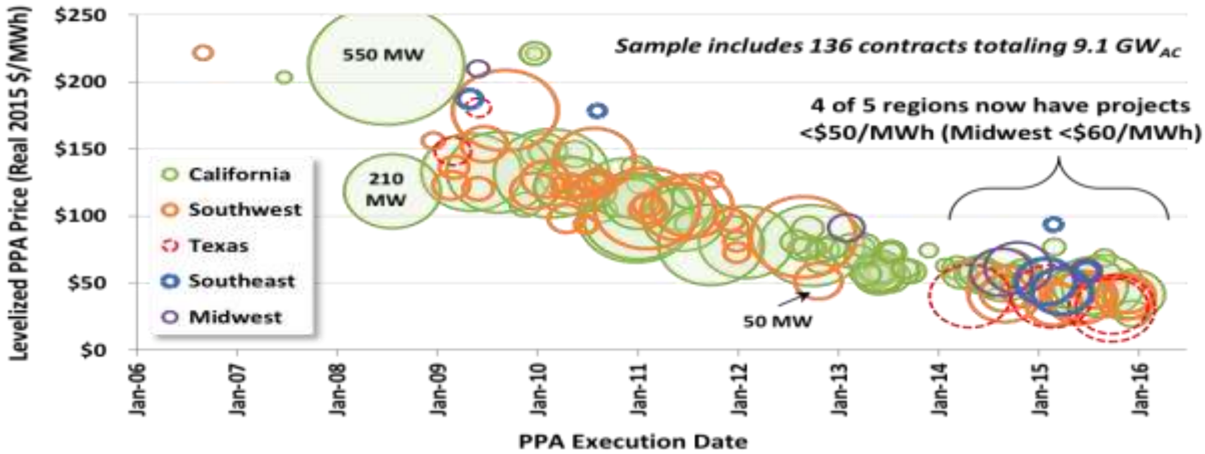

Figure 9. Levelized PPA Prices by Region, Contract Size, and PPA Execution Date [14]

This rapid decline in total installed price for solar has led to rapid deployment of solar power plants and utilities, each one breaking its predecessor record in installed capacity. Solar power costs are even lower in certain parts of the world including Hawaii, Alaska and many others. But it has yet to achieve grid parity at places where grid electricity, comprising mostly of fossil fuel electricity, is still cheaper than what solar has to offer. But, with government subsidies even this gap can be filled. A recent report published by Lawrence Berkeley National Laboratory (LBNL), analysed that the total installed prices have dropped by 5% for rooftop residential solar systems and 12% for larger utility-scale solar farms compared to 2015, bringing current total installed prices in between \$2.6-\$5/watt, for both utility scale plant and rooftops solar installation [13,14] .

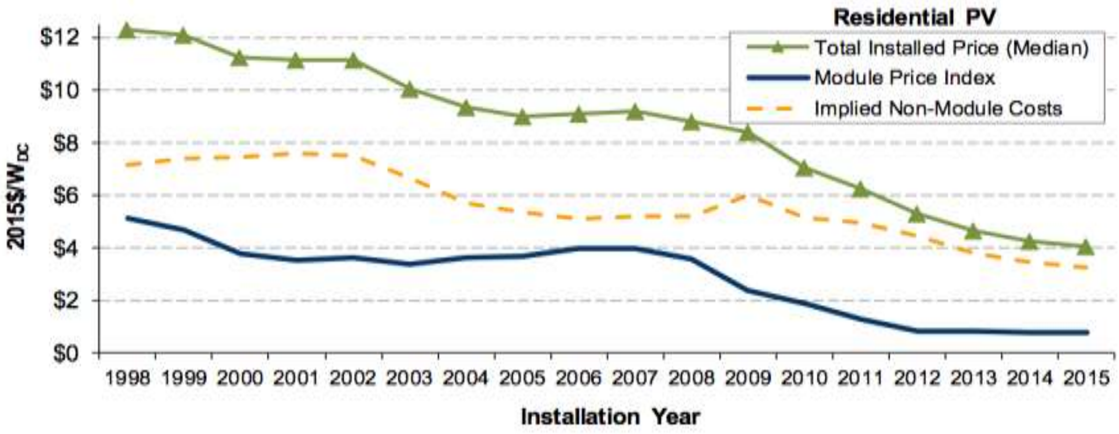

Figure 10. Installed Price, Module Price Index, and Implied Non-Module Costs over Time for Residential PV Systems [13]

But, trend in the price of solar power purchase agreements (PPAs), meaning the price paid for long-term contracts for the bulk purchase of solar electricity, reflects fall in prices below \$50 per MWh (or 5 cents per KWh) in 4 of the 5 regions analysed(14). Currently, conventional grid electricity price, which mostly run on fossil fuel, is between \$30 to \$40 per MWh, so solar is poised to match the price of conventional power generation if prices continue to decline. This data covers 136 power contracts totalling around 9.1 GW in US.

2.2.3. How clean is solar power?

Although, solar power do not produce any GHG emission during operation, same cannot be said about its Life Cycle Assessment (LCA). Manufacturing of solar panels consume a lot of energy, significant amount of CO_2 is also emitted by the smelting plants in the process which runs on fossil fuel. So, when a new solar panel is put to work it starts with a “carbon debt” that, from a GHG saving point of view, has to be paid back before that panel becomes part of the solution. To clear the air, a recent study published in Nature Communication, provides convincing conclusion in solar power’s favour(17). In that study, the researchers calculated the energy required to make all the solar panels installed around the world between 1975 and 2015, and the CO_2 emissions associated with producing that energy. They also looked at the energy these panels have produced since their installation and the corresponding amount of CO_2 they have prevented from being released into the atmosphere. After considering various parameters for production of solar panels, for *e.g.*, location and time of manufacturing of panels, it was found that solar panels made today are responsible, on an average, for around 20 grams of CO_2 per KWh of energy they produce over their lifetime (estimated as 30 years, regardless of when a panel was manufactured). That is down from 400-500 grams in 1975.

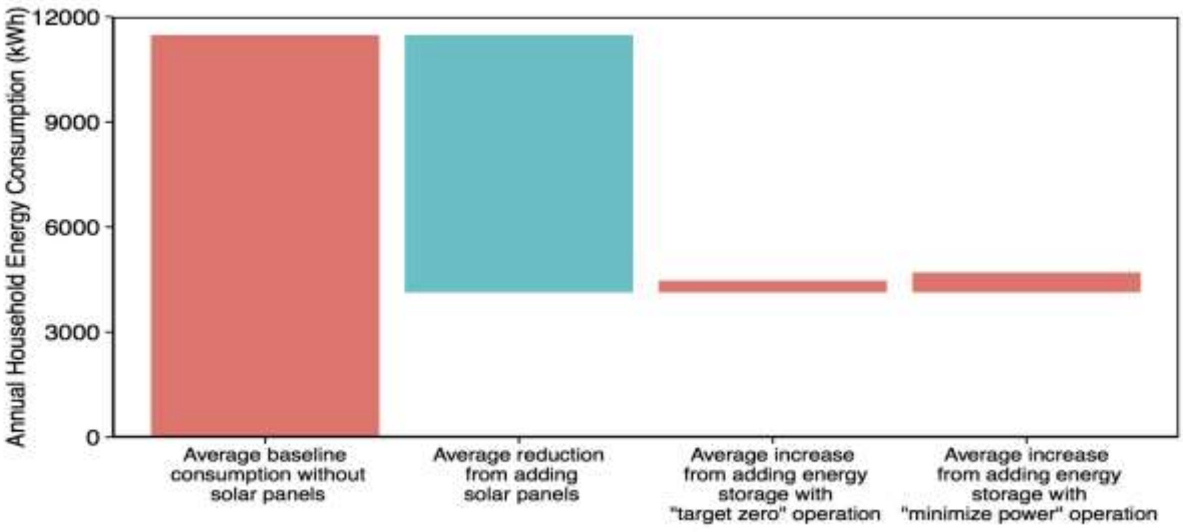

Figure 11. Effect of presence and absence of solar panels on annual energy consumption in households [18]

Likewise, the amount of time needed for a solar panel to produce as much energy as was involved in its creation has fallen from about 20 years to two years or less. As more panels are made, the manufacturing process becomes more efficient. The team found that for every doubling of the world's solar capacity, the energy required to make a panel fell by around 12% and associated carbon-dioxide emissions by 17-24%. In worst case scenario, break-even will reach by 2018. Figure 11 from another study clearly depicts the reduction in grid energy consumption from addition of solar panels and it eclipses the energy increment from addition of solar panels. The increase in energy consumption from adding energy storage is much smaller than the decrease caused by adding solar panels in the first place, so storage would provide energy and emissions benefit if it directly enabled a new solar installation [18].

2.2.4. Storage batteries: Solving the intermittency Hurdle

Things would have remained great for solar power if it weren't for its intermittency problem which plagues its power production during non-availability of sun. The intermittency or non-regularity of solar power is the biggest hurdle in the growth of this clean energy sector. Intermittent renewables are challenging because they disrupt the conventional methods for planning the daily operation of the electric grid. Their power fluctuates over multiple time horizons, forcing the grid operator to adjust its day-ahead, hour-ahead, and real-time operating procedures [19]. However, batteries can smooth the ebbs and flows associated with wind and solar power by supplementing the grid when those resources are not available. In the absence of suitable storage medium for solar power, this gap in energy supply during night is filled by utilizing electricity from the grid, which run mostly on fossil fuel. But, with the advancement in battery storage technology and its falling prices, especially with the advent of Tesla's Power pack battery storage system and operational status of its 50 GWh capacity massive battery manufacturing unit- Giga factory, things have changed for good. Tesla Energy has installed various solar plus battery storage systems in utility scale such as 1.4 MWh plant in America's Ta'u island, 12MW/53 MWh solar plus storage farm in Kaua'i, Hawaii and20 MW/80 MWh Power packs system for grid storage in Southern California Edison Mira Loma substation, making it the largest lithium ion battery storage project in the world [20]. Take the case of Kaua'i Island, Tesla's energy project will save about 1.6 Million barrels of fossil fuel per year, running the island with solar power during daytime and consuming the battery power by night. This battery storage provides the much needed missing link in the quest of living completely independent of the conventional electric grid or 'going off the grid'. This idea has now become a reality so much so that, there is a threat of grid defection. However, as this study points out, leaving the grid is not yet economical, rather, remaining connected to the grid and installing Solar plus battery system and selling excess power back to the Electric grid could be a common feature of future grid and more reasonable for now, resulting in significant reduction of energy demand per connection point as PV-battery price further decline [18].

With Tesla's Giga factory and several other large battery manufacturing facilities coming on stream in 2017, we are going to see a further reduction in battery prices of at least 15% this year, after a 70%reduction in the past five years [21]. The reliance on battery storage system is likely to grow as these can be utilised in many other fields which require continuous supply of power such as Wind Power, and other Renewables.

The rapid growth in demand and efficiency of these battery will eventually stabilise the volatile arena of grid electricity through renewables. This, may prove vital in the quest of phasing out fossil fuel usage from the electricity grid in the foreseeable future.

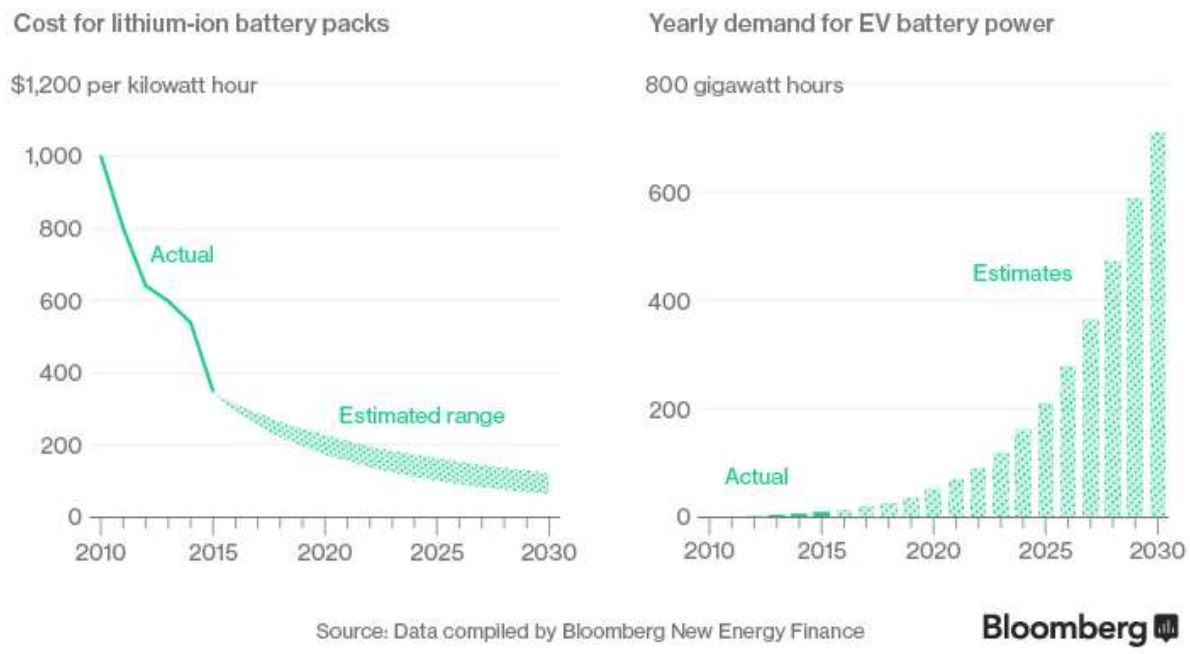

Figure 12. Current and projected relationship of cost and demand of Lithium-ion battery packs [21]

2.3. Zero Emission Vehicles (ZEV): Solution of other half of the problem

Transportation sector contributed 14% of GHG emission in 2010 [5]. It now accounts for about 28% of overall energy consumption and for 23% of energy-related greenhouse gas emissions. Oil products account for around 93% of final energy consumption in transport [6]. There are three main entry points for renewable energy in the transport sector: the use of 100% liquid biofuels or of biofuels blended with conventional fuels; natural gas vehicles and infrastructure that can be fuelled with gaseous biofuels; and the electrification of transport, which can use batteries or hydrogen produced by renewable electricity. It is the third option which has gained most traction, as other options are limited by their availability.

As the need for carbon free transportation is increasing, Electric Vehicles (EVs) and Fuel Cell Electric Vehicles (FCEVs) together called Zero Emission Vehicles (ZEVs) are beginning to offer a desired alternative. FCEV can be considered the optimum solution for the two big problems of EV: range of Electric vehicle per charging and charging time of batteries, whereas EV can be considered more efficient, less expensive and have relatively more robust recharging infrastructure than FCEV. However, both types of ZEV can complement each other's weaknesses and help combat the climate change. Future may utilize a hybrid of the two vehicles. FCEV rely on Hydrogen, to generate electricity through a fuel cell, which drives the vehicle producing zero carbon emission during running. However, if this Hydrogen is produced using renewable energy such as solar power, it could eventually provide a pathway to zero or negative GHG emission. Emissions occur not only during vehicle use, but also during fuel production, vehicle manufacturing, and other life cycle stages. For better understanding of a vehicle's effect on GHG emission, life cycle assessment is done. Regardless of the type of vehicle technologies, life cycle studies agree that deep GHG reductions cannot be achieved without increased vehicle electrification and/or alternative fuels with very low well to wheel WTW (fuel-cycle) GHG emissions [22]. For example, renewable electricity (solar) powered Hydrogen production for FCEVs as well as Battery Electric Vehicles offer the lowest GHG-emitting options, which could reduce life cycle GHG emissions by up to 85% compared to the current gasoline-fuelled internal combustion vehicles as depicted in Figure 13.

We propose that, integration of Fuel Cell infrastructure with Solar PV will co-benefit each other as it will solve the power storage problem of solar power during intermittency and PV will help produce Hydrogen as a fuel for Fuel Cells using clean energy, thus significantly and quickly reducing GHG from atmosphere. Electric cars will reduce the cost of battery storage and help store intermittent sun and wind power. In the move toward a cleaner grid, electric vehicles and renewable power create a mutually beneficial circle of demand.

Fuel cells are becoming well established in a number of markets where they are now recognised as a better technology option than conventional internal combustion engine generators or batteries. In 2013, Fuel Cell Today forecasted that annual shipments of fuel cell systems will increase by 46% to reach a total of over 66,800 for the full year. Annual megawatts (MW) shipped are expected to grow by 29%, to reach 215.3 MW [23]. Hydrogen refuelling stations will continue to be added in 2015 as a number of regions prepare for the commercial release of FCEV in 2015. Almost all major car manufacturers including Hyundai, Toyota, General Motors, Daimler, Nissan to name a few have introduced FCEV emphasising that the future of Commercial Vehicles has arrived.

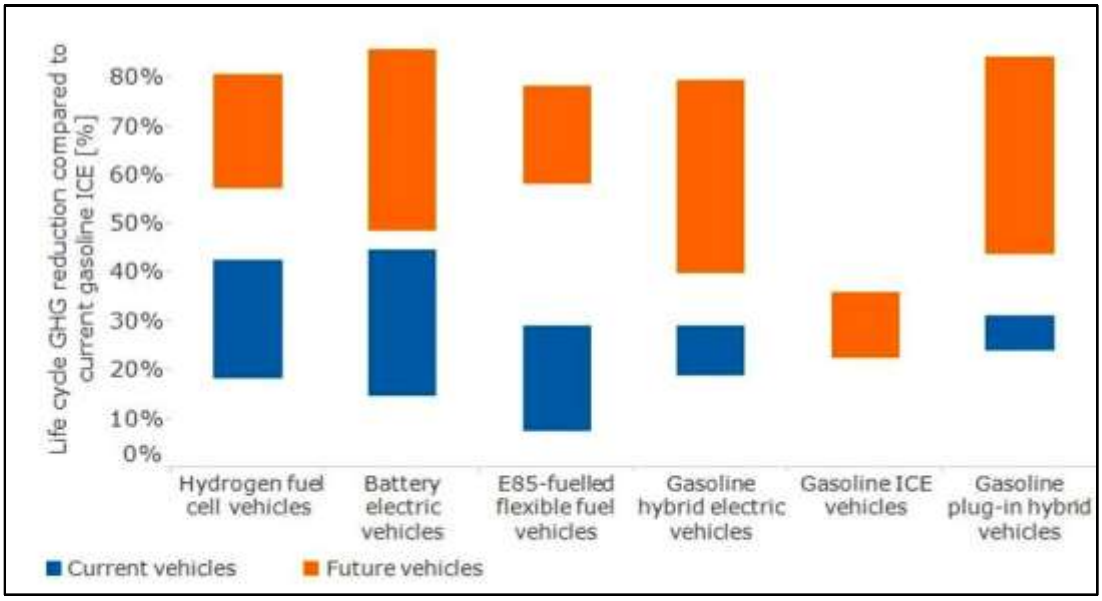

Figure 13. Life cycle GHG reduction of current and future alternative fuel and vehicle options compared to the current gasoline ICE vehicles [22]

On the other hand electric vehicles (EVs) have become the new ‘Cool’ after success of Tesla’s Model S. In 2016, EVs sales grew by about 60% worldwide. Battery prices fell 35% last year and are on a trajectory to make unsubsidized EVs as affordable as their gasoline counterparts and on parity by 2025, according to a new analysis of the electric-vehicle market by Bloomberg New Energy Finance [12].

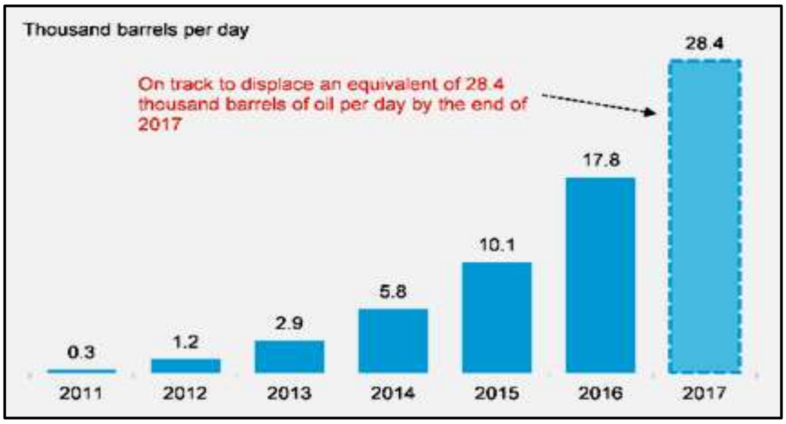

Figure 14. Fuel displaced by EVs on the road, 2011-2017 [24]

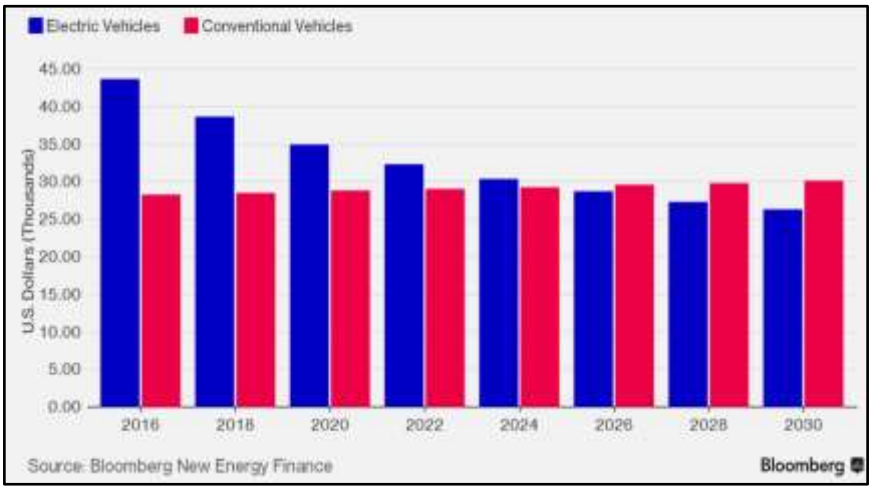

Figure 15. EVs won't match price parity with conventional vehicles until 2015 [25]

With rise in EV, need for recharging infrastructure has also grown. Consequently, In Europe, the EV charging infrastructure has expanded rapidly, from 30,000 stations in 2014 to 100,000 stations in 2016. In late 2016, auto manufacturers BMW Group (Germany), Daimler AG, Ford Motor Company (United States) and Volkswagen Group announced a joint venture to deploy, starting in 2017, a network of high-powered 350 kW charging stations in Europe to enable long-range travel for EVs. This charging capacity is more than double the 2016 capability of Tesla Superchargers and allows EVs with a range of 400 km to reach a full charge in 12 minutes [6]. Needless to say all these automobile giants have planned to sell big. Several long-established vehicle manufacturers have realigned their strategies, with plans to increase the share of EVs in their future sales. In 2016, Volkswagen Group (Germany), announced plans to bring more than 30 pure-electric models to market and to sell 2-3 million EVs annually by 2025, equivalent to 20-25% of its total projected sales. As part of this strategy, the company plans to develop battery technology as a new core competency and has expressed interest in building its own battery factory. Daimler AG (Germany) announced in 2016 that it would invest USD 10.5 billion in EVs, and the company expects to have 10 different models by 2022 [12]. In July 2017, Volvo announced to manufacture only electric or hybrid vehicles by 2019, starting the beginning of the end of combustion vehicles monopoly in transportation sector. Whereas, Tesla's Model 3 has received nearly 500,000 reservations by the end of 2016. Most of these cars have driving range of over 300 Km, and as mentioned earlier Charging infrastructure are expanding more quickly. Thus, minimizing the two major hurdles in its growth. But, above all, the need is to make the electric grid mix more renewable energy based.

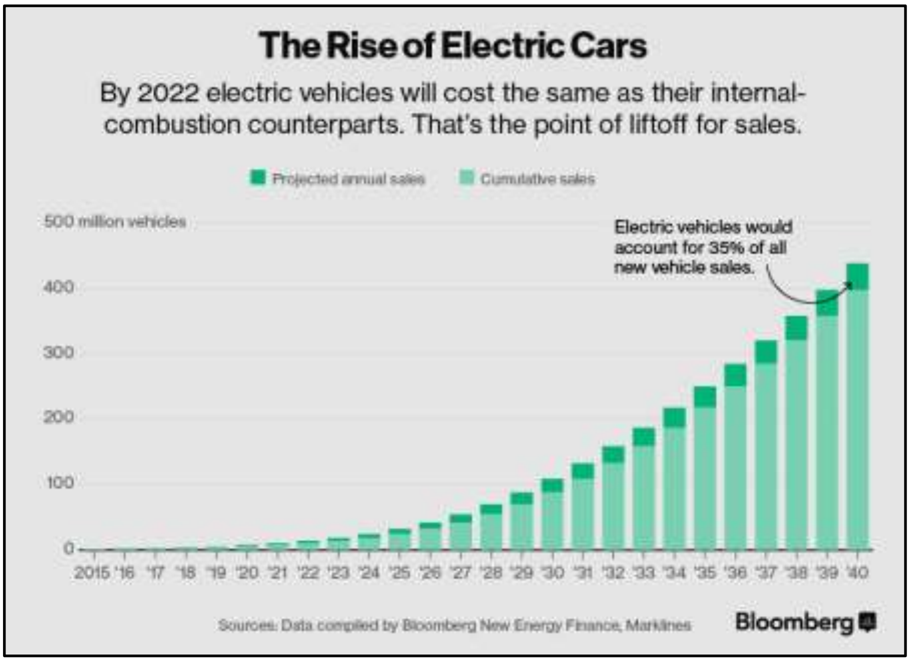

Figure 16. BNEF growth projection of Electric Vehicles [21]

According to latest International Energy Agency (IEA) reports, the number of EV on the road rocketed to 2 million in 2016 after being virtually non-existent just five years ago [7]. In 2016, global EV sales reached an estimated 775,000 units. The EV passenger car market (including PHEVs) accounted for around 1% of global passenger car sales in 2016 [6]**.** All this may still appear too little too late because according to IEA report, 600 Million EVs are needed by 2040 to limit the Global Warming to below 2°C.If current growth of 60% in electric vehicle sector is sustained for next decade, it is estimated that EV could displace oil demand of 2 million barrels a day as early as 2023. By 2040, long-range EV will cost less than $22,000 (in today's dollars) and 35% of new cars worldwide will have a plug according to BNEF report [21]. Battery cost contribute one half to one third of the EV cost and as its cost continue to decline due to increase in demand and eventually production, the cost of EVs will reach parity only after 2025. After that, EVs will cost lower than gasoline Cars [*25*]. As per BNEF 2017 report EVs are displacing 17.8 thousand barrels of oil per day as of the end of 2016 and are on track to potentially displace over 28.4 thousand barrels of oil per day at the end of 2017. To compare, total global oil consumption is around 96million barrels of oil per day [24]. Clearly, electric vehicles have started their contribution in mitigation of climate change. All it need is public acceptance. In this regard major developed nations have declared plans to ban sale of petrol and diesel vehicles in the next couple of decades. France and UK will do so by 2040 whereas Germany and India has similar plans ahead of 2030. Similarly, Netherlands and Norway are leading the charge against combustion vehicles by pledging to get rid of them by 2025 [26]. Clearly, the age of electric vehicles has dawned.

3. CONCLUSION

Reduction in the GHG emission within the specified time period especially in light of US pulling out of Paris Climate Deal, require the deployment of clean energy sources especially in energy and transportation sector. Solar Photovoltaic and Zero emission vehicles, with their present state of developments are beginning to lead the way. Huge subsidy given to fossil fuels need to be diverted in advancement and deployment of these clean energy sources. As the above data shows, solar photovoltaics and ZEV have tremendous capabilities of cleaning the mess we have created. Their robust growth trends over the last five years and huge capacity in reducing the carbon emission have bolstered the hope of mitigating the dangers of climate change within time. Massive adoption of solar photovoltaics as the major renewable energy option by nations across the globe demonstrates its immense potential. With maturity in battery storage technology, solar power is becoming the most reliable clean energy technology. Whereas, the other half of the environment problem in transportation sector is being solved by early adoption of electric vehicles at massive scale. In light of the encouraging data mentioned in this paper, we can safely argue that the age of solar power and electric vehicles has finally arrived. The only requirement from us is to invest in them judicially to make our planet sustainable again.

REFERENCES

1. Rogers, H., "Current Thinking", *New York Times Magazine*,http://www.nytimes.com/ 2007/06/03/magazine/03wwln-essay- t.html. June 2007.
2. Kennedy, C., "Climate Change: Atmospheric Carbon Dioxide", https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide, May 2016.
3. Climate Central, "Rising Global Temperatures and CO_2", http://www.climatecentral.org/gallery/graphics/co2-and-rising-global-temperatures, April 2017.
4. United Nations Framework Convention on Climate Change (UNFCCC), "Climate ChangE 2014 Synthesis Report Summary for Policymakers", Intergovernmental Panel on Climate Change (IPCC)'s Fifth Assessment Report (AR5), 2014.
5. IPCC, 2014, "Climate Change 2014: Mitigation of Climate Change, Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)", (2014).
6. REN21.2017, "Renewables 2017 Global Status Report", ISBN 978-3-9818107-6-9, http://www.ren21.net/gsr-2017/, May 2017.
7. Shankleman, J., "Electric Car Sales Are Surging, IEA Reports", https://www.bloomberg.com/news/articles/2017-06-07/electric-car-market-goes-zero-to-2-million-in-five-years, June 2017.

8. Thompson, A., “2016 was the hottest year on record”, *Scientific American*, https://www.scientificamerican.com/article/2016-was-the-hottest-year-on-record/, Jan 2017.
9. Harvey, F., “Everything you need to know about the Paris climate summit and UNtalks”, *The Guardian*, https://www.theguardian.com/environment/2015/jun/02/everything-you-need-to-know-about-the-paris-climate-summit-and-un-talks, Nov. 2015.
10. National Climate Assessment ,http://nca2014.globalchange.gov/downloads, Oct. 2014.
11. National Oceanic And Atmosphere Administration (NOAA), “Earth’s physical data andimages”, https://www.climate.gov/maps-data/datasets, (Accessed on June 2017).
12. Bloomberg New Energy Finance, “New Energy Outlook 2017: Annual long term economic forecast of the world’s power sector”, June 2017.
13. G. Barbose, and N. Darghouth, “Tracking the Sun IX:The Installed Price of Residential and Non-Residential Photovoltaic Systems in the United States*”, Lawrence Berkeley National Laboratory Reports*, LBNL Report No-1006036. August 2016.
14. M. Bolinger, and J. Seel, “Utility-Scale Solar 2015: An Empirical Analysis of ProjectCost, Performance, and Pricing Trends in the United States”, *Lawrence Berkeley National Laboratory Reports*, LBNL Report No- 1006037. August 2016.
15. The Financial Express online, “Longyangxia Dam Solar Park: Know all about world’s largest solar farm built by China on Tibetan plateau; NASA releases images”, http://www.financialexpress.com/world-news/longyangxia-dam-solar-park-know-all-
16. about-worlds-largest-solar-farm-built-by-china-on-tibetan-plateau-nasa-releases-images/591279/, March 2017.
17. Raghavan, S., “The historically low solar tariffs at Rewa”, The Hindu, http://www. thehindu.com/business/the-historically-low-solar-tariffs-at-rewa/article17330122.ece, May 2017.
18. W. G. Van Sark *et al.*,“Re-assessment of net energy production and greenhouse gasemissions avoidance after 40 years of photovoltaics development”, *NatureCommunications*, DOI: 10.1038/ncomms13728, December 2016.
19. R. Fares, “Storing solar energy in the home can increase energy consumption, emissions”, *Scientific American*, https://blogs.scientificamerican.com/plugged- in/storing-solar-energy-in-the-home-can-increase-energy-consumption-emissions,
20. January 2017.
21. R. Fares, “Renewable Energy Intermittency Explained: Challenges, Solutions, and Opportunities”, *Scientific American*,https://blogs.scientificamerican.com/plugged- in/renewable-energy-intermittency-explained-challenges-solutions-and-opportunities/, March 2015.
22. D. Muoio, “The new Tesla is powering an entire island with solar energy”, *Business Insider*, http://www.businessinsider.in/The-new-Tesla-is-powering-an-entire-island-with-solar-energy/articleshow/55566518.cms, November 2016.
23. T. Randall, “Here’s How Electric Cars Will Cause the Next Oil Crisis”, *Bloomberg*, https://www.bloomberg.com/features/2016-ev-oil-crisis/, February 2016.
24. U.S. Dept. of Energy,“Transformative Reduction of Transportation GreenhouseGas Emissions: Opportunities for Change in Technologies and Systems”, Technical report NREL/TP-5400-62943, DOE Office of Energy Efficiency & RenewableEnergy’s National Laboratory of Renewable Energy (NREL), Denver W Pkwy,Golden, April 2015.

25. Fuel Cell Today, “The Fuel Cell Industry Review 2013”, fuelcelltoday.com/media/1889744/fct_review_2013.pdf, September 2013.

26. Rybczynska, A., “How much oil are electric vehicles displacing?” Bloomberg NewEnergy Finance- Executive Summary, https://about.newenergyfinance.com/about/blog/much-oil-evs-displacing/, March 2017.

27. N. Soulopoulos, “When Will Electric Vehicles be Cheaper than ConventionalVehicles?” Bloomberg New Energy Finance: Executive Summary, https://about.newenergyfinance.com/about/blog/electric-cars-reach-price-parity-2025/,April 2017.

28. Taylor, M., Asthana, A., “Britain to ban sale of all diesel and petrol cars and vansfrom 20140”, *TheGuardian*,[Online],https://www.theguardian.com/politics/2017/ jul/25/britain-to-ban-sale-of-all-diesel-and-petrol-cars-and-vans-from-2040, July 2017.