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Renewable Energy Generation and Impacts on E-Mobility

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Abstract. This paper gives information about Renewable Energy Generation and its impacts on E-Mobility. By 2050, the two pillars of modern transformation are E-Mobility and Renewable Energy. This transformation requires adaptation to meet demographic and economic growth without increasing pollution and congestion. The modern world needs affordable, secure and inclusive, sustainable and integrated with customer-centric infrastructure and services. There is a great fundamental change needed in road transportation sector, which is to achieve its objective of a long term transition to a low-carbon economy. Electric Vehicles when charged with the electricity generated from Renewable Energy Sources can reduce future emissions of greenhouse gases and air pollutants from road transport. Electric Vehicles combined with renewable energy paint a different picture from the oversimplification of gas miles versus electric miles.Smart Mobility and Smart Grid technologies make people live more sustainable and efficiently.

1. Introduction

By 2050, electricity will become the central energy barrier which increases its consumption from 20% to 50%, doubling the gross electric consumption. Renewable Energy Generation can compensate this bulk energy global power demand. The primary cause of the increase in energy consumption demand is due to the increased sales of Electric Vehicles. Energy generated by RES would supply two-third of final energy demand. Electric Vehicles when supplied by RES, reduces the emission of greenhouse gases and air pollution from road transport. This leads to a decarbonized transport system which meets the goal of 80-95% greenhouse gas emission reduction by 2050. The additional energy generated needs to be integrated into grid infrastructure across the world.

There will not be much influence on the electric powers system until 2030, due to the increase of additional demand by EVs. But, in the long future, due to huge sales of EVs in the market by 2050, the required energy demand is going to increase drastically, which will impact on the world's power system. The electricity consumption rate reaches 80% by electric vehicles in 2050, which are going to vary from 3% to 25% of total electricity demand across the European Union-28 member states depending upon the number of electric vehicles anticipated in every country. On an average European Union-28, the proportion of total electricity demand required in 2050 is 9.5% compared with 1.3% assumed in the European Commission's projection. Overall additional electricity capacity of 150 GW is needed to charge the electric vehicles. Figure 1.Shows the EVs energy demand as a percentage of total electricity demand in 2050. The major problem comes when RES is integrated with EVs because the RES generation of energy is unreliable which depends upon the environmental conditions. The large share of electric vehicles on roads in the future will have implications for the electricity generation and distribution infrastructure. The integration of additional energy demand possesses diverse challenges. There is a great need to get closer coupled with road transport and energy sectors to balance the integration of government policies and investments across both the sectors [1]-[3].

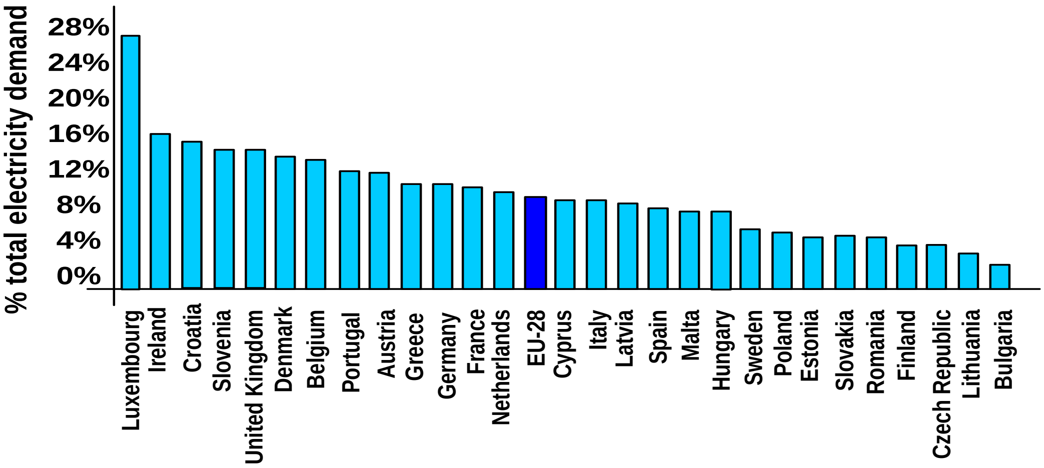

Figure 1. EVs Energy Demand as a percentage of total electricity demand in 2050

EVs are one of the most important economic resources and decarbonised transport system. Replacing conventional vehicles with EVs not only helps to reduce emission but also helps us to generate more electrical energy from RES for charging of EVs. A system transformation is needed with the development of renewable energy generation towards the commitment of efficient, green and competitive low-carbon economy. This paper details how solar and wind energy generation is impacting Electric Vehicles.

2. Determination of the optimal points of divergence in the power grid with RES

The power station is set to pick up points from the same point of view to the main station of the most obvious power generation plants. A model of permissive business is invoked is more optimal than the minimum setting of the charging station according to the criterion of the minimum time and time required for transmission. Keeping the loss of active force, the method of external substances is selected in the power grid. The vector of nodal currents J consists of the vectors of the defining currents of the nodal loads J_{LOAD} and the generating currents of RES (PV– $J_{GEN\ PV}$ and WPP– $J_{GEN\ WPP}$) and is defined as

$$\dot{\mathbf{J}} = \dot{\mathbf{J}}_{\mathrm{LOAD}} - \dot{\mathbf{J}}_{\mathrm{GENPVPP}} - \dot{\mathbf{J}}_{\mathrm{GENWPP}} \tag{1}$$

Node Conductivity Matrix of the Main Line of the power grid(PG)

$$\dot{\mathbf{Y}} = \mathbf{M} \cdot \dot{\boldsymbol{z}}^{-\mathbf{1}} \cdot \mathbf{M}^{\mathrm{T}} \tag{2}$$

where z – matrix of circuit resistance, M – the first incident matrix, M^T– transposed the first incident matrix.

Taking into account (1) and (2) the vector of voltages between nodal voltages at the balancing node voltage:

$$\dot{\mathbf{U}}_n = f\left(\dot{\mathbf{Y}}, \dot{\mathbf{J}}_{LOAD}, \dot{\mathbf{J}}_{GENPVPP}, \dot{\mathbf{J}}_{GEN\ WPP}\right)$$

$$\dot{\boldsymbol{U}}_n = \dot{\boldsymbol{Y}}^{-1} \cdot (\dot{\boldsymbol{J}}_{LOAD} - \dot{\boldsymbol{J}}_{GENPVPP} - \dot{\boldsymbol{J}}_{GEN\ WPP}) = \dot{\boldsymbol{Y}}^{-\mathbf{1}} \cdot \dot{\boldsymbol{J}} \tag{3}$$

The vector of node voltages with consideration (3) and the voltage of the balancing node:

$$\dot{\mathbf{U}}_n = \dot{\mathbf{Y}}^{-1} \cdot \left(\dot{\mathbf{J}}_{LOAD} + \dot{\mathbf{J}}_{GENPVPP}, - \dot{\mathbf{J}}_{GENWPP}\right) + \dot{\mathbf{U}}_0 = \dot{\mathbf{U}}_n + \dot{\mathbf{U}}_0, \tag{4}$$

where $\mathbf{U_0}$– is the voltage of the balancing node (we assume that the balancing node coincides with the base node and is in the center of the power supply).

Taking into account (4) the node power vector:

$$\dot{\mathbf{S}}_{\mathrm{b}} = [\dot{\mathbf{Y}}^{-1} \cdot (\dot{\mathbf{J}}_{\mathrm{LOAD}} - \dot{\mathbf{J}}_{\mathrm{GEN\ PVPP}} - \dot{\mathbf{J}}_{\mathrm{GEN\ WPP}})] \cdot \mathrm{diag}(\hat{\mathbf{J}}) = \dot{\mathbf{U}} \cdot \mathrm{diag}(\hat{\mathbf{J}}), \quad (5)$$

where $\hat{\mathbf{J}}$–vector column of complex conjugate values of nodal currents.

Given (5) the vector of power flows in the circuits of the scheme:

$$\dot{\mathbf{S}}_{\mathrm{b}} = \boldsymbol{\xi} \cdot [\dot{\mathbf{Y}}^{-1}(\dot{\mathbf{J}}_{\mathrm{LOAD}} - \dot{\mathbf{J}}_{\mathrm{GEN\ PVPP}} - \dot{\mathbf{J}}_{\mathrm{GEN\ WPP}}) + \dot{\mathbf{U}}_0] \cdot \mathrm{diag}(\hat{\mathbf{J}}) = \boldsymbol{\xi} \cdot \dot{\mathbf{S}}, \quad (6)$$

where $\boldsymbol{\xi}$ – the matrix of the interconnection of nodal capacities and power flows in the system (the rows of this matrix correspond to the circuits and the columns are the nodes of the plot under consideration. If the node receives power from the corresponding branch, then the value of the corresponding element of the matrix is 1 if the node does not receive power from the considered element, then the element of the matrix is zero).

Power losses in power grid containing WPP and PVPP:

$$\boldsymbol{\Delta S}(\dot{\mathbf{J}}_{\mathrm{LOAD}}, \dot{\mathbf{J}}_{\mathrm{GEN\ PVPP}}, \dot{\mathbf{J}}_{\mathrm{GEN\ WPP}}) = \sum_{k=1}^{n-1} \frac{[\dot{\mathbf{S}}_{\mathrm{bk}}(\dot{\mathbf{J}}_{\mathrm{LOAD}}, \dot{\mathbf{J}}_{\mathrm{GEN\ PVPP}}, \dot{\mathbf{J}}_{\mathrm{GEN\ WPP}})]^2}{\dot{\mathrm{U}}_{\mathrm{k}}^2} \cdot \dot{Z}_k \quad (7)$$

where $S_{bk}(J_{load}, J_{GEN\ PV\ PP}, J_{GEN\ WPP}) = S_{bij}$ – power flows along the ij branch, which depend on the corresponding branch of the values of the nodal load currents, the generation of Photovoltaic Power Plant (PVPP) and Wind Power Plants (WPP) and are the elements $\mathbf{S_в}$, U_k – voltage in the k-th node, z_{ij} – resistance of ij-th branch; i=1..n-1 –number of the begin of branches, j=i+1..n – number of the end of branch, k –the sequence number of the branch and the element in the power flow column by the ij branch, n – the sequence number of the node in the power grid [4]. The proposed method lets it possible to quickly define from which power source the station is currently healing. In the vast majority, such charging stations are powered by sources of renewable energy, which are unstable in their generation. Therefore, it is advisable to revise the power schemes often as possible in order to reduce power losses when transmitting energy at a distance and to provide reliable power to charging stations. The method is easy to use, which make site as to automate the process of selecting stations from which the power will be supplied by writing the appropriate software.

3. Electric Vehicles Impact on the Generation of Solar Energy and Wind Energy

The main reason for the transition from the Internal Combustion Engine (ICE) to Electric Vehicles (EVs) is the downfall of crude oil and air pollution. The transition to E-mobility not only gives environmental benefits but also gives highly efficient cars. The research statistics show that running EVs using RES, offers a 30% reduction in Global Warming Potential (GWP). The main impact on environmental due to EVs depends on the usage of energy sources generating electricity for charging the batteries and their thermal sources locations. EVs become more efficient only when proper energy sources are used for charging the battery. This can be 100% possible only by using RES. This increases the need for implementation and generation of new Renewable Energy Sources. According to IRENA, an inter-government organization that supports sustainable energy and explores all types of renewable sources including solar and wind, access to energy, energy security and the use of carbon-free electricity generation technologies, the rapid increase in Renewable Energy Sources (RES) is shown in the Figure 2 & Figure 3 show the statistics of solar and wind power generated in the world and in Europe, Figure 4& Figure 5 show the statistics of solar and wind power generated in India and Ukraine from 2010 to 2016. The statistics show that there is a drastic increase in renewable energy generation [5]-[6].

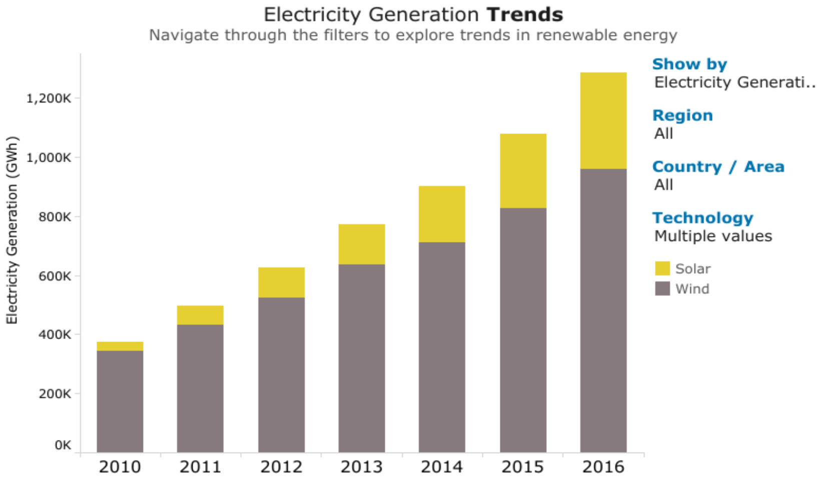

Figure 2. Solar and Wind power Generation in the world

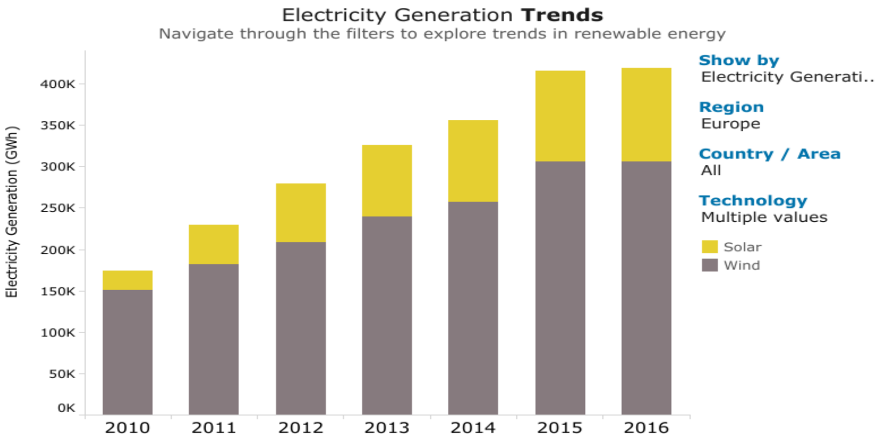

Figure 3. Solar and Wind power Generation in the Europe

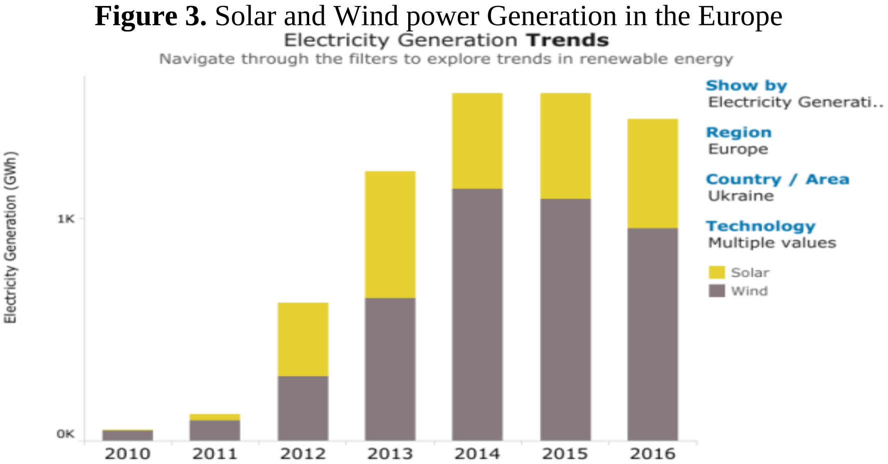

Figure 4. Solar and Wind power Generation in the India

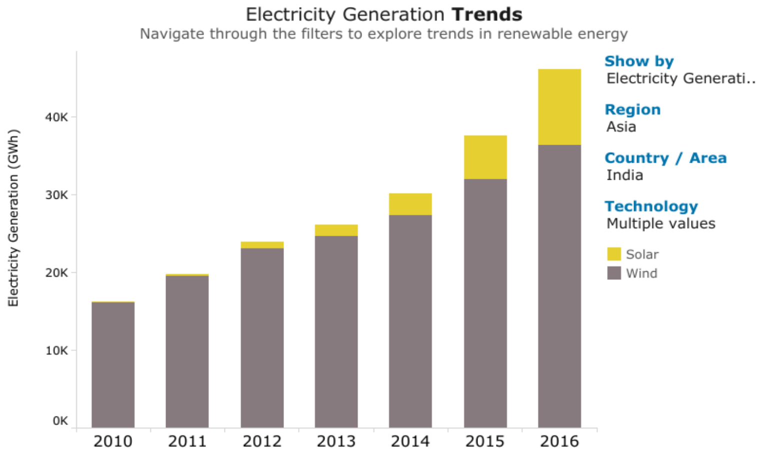

Figure 5. Solar and Wind power Generation in the Ukraine

According to IRENA by the end of 2018, the total amount of global energy generated by Renewable has amounted to 2351 GW. The highest share is taken by the hydropower plant with an installed capacity of 1172 GW. Wind and solar energy are accounted for with 564 GW and 486 GW capacities. The total increase in renewable energy generation is 171 GW. The solar energy generated is 109 GW and wind energy generated is 51 GW. The increase in Renewable energy Generation is mainly due to newly installed solar and wind plants. These new installations accounted for 84% in 2018. In 2018, Asia accounted for 61% of new capacity and in Europe a 4.6% increase. The increase in solar energy took place in Asia with a capacity of 64 GW (70% of global expansion in 2018), followed by China, India, Japan, and the Republic of Korea. The increase of wind energy is accounted for by 20 GW by china and 7 GW by the USA. The countries with more than 1 GW generation are Brazil, France, Germany, India, and the United Kingdom.
The real-time generation of solar power in the Vinnytsia region is shown below. Detailed daily graphs of days with minimum and maximum generation relative to the installed capacity of the Solar Power Plant (SPP) in June at the Vinnytsia region of Ukraine are shown in Figure 6 and Figure 7.

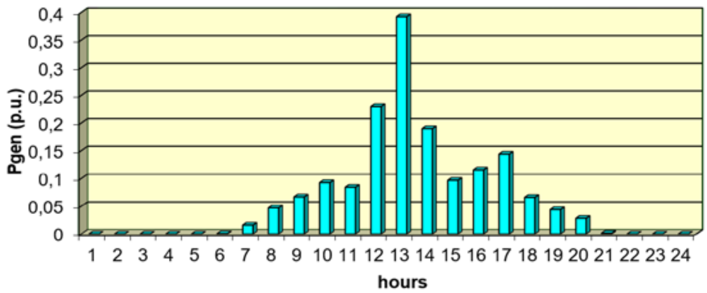

Figure 6. Minimum hourly generation of SPP installed capacity in June

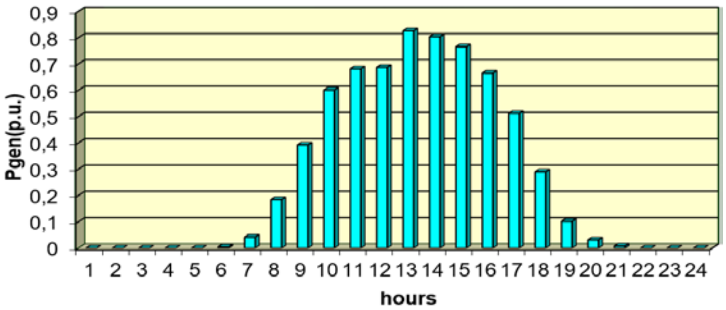

Figure 7. Maximum hourly generation of SPP installed capacity in June

Detailed daily graphs of days with minimum and maximum generation relative to the installed capacity of the SPP in December of the Vinnytsia region of Ukraine are shown in Figure 8 and Figure 9.

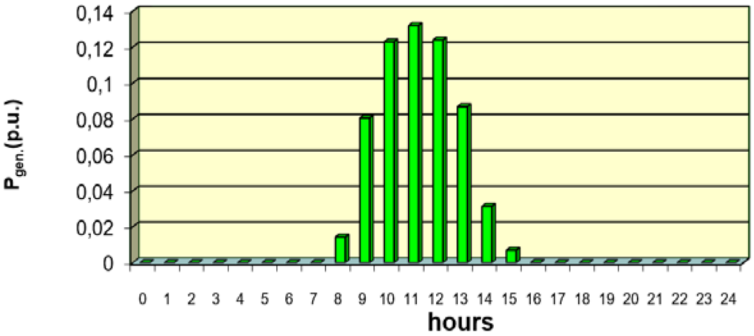

Figure 8. Minimum hourly generation of SPP installed capacity in December

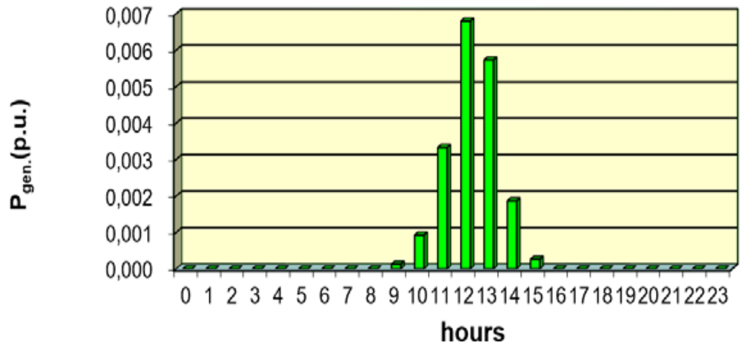

Figure 9. Maximum hourly generation of SPP installed capacity in December

4. Electric Vehicles integration with Renewable Energy Sources

The main reason for the expansion of electricity and for accelerating energy transformation is due to the E-mobility revolution is gaining pace. Electric Vehicles both Battery Electric Vehicles and Plug-in hybrid consumed 2 million units of electric energy in 2018, around 58% growth when compared to previous years. Globally 5.6 million battery electric vehicles were sold by the end of 2018 and EVs sales grew to 40% in Norway in the year 2018. The increase in global sales of EVs compared to 2017 is around 64%. Battery Electric Vehicles sales are around 69%, Plug-in hybrids sales around 31% by the end of December 2018. All types of EVs have gained around 3% share since 2017. The main increase in EVs sales took place in China, 1.2 million in 2018, 56% of plug-in sales. Sales in Europe are around 34%. In the USA the sales reached 79% whereas in Japan the sales went down. In countries like Canada and South Korea, EVs sales are growing very faster. This switching transformation of E-mobility is not only taking place in case of cars but also they are taking place in buses and other types of transportation systems. Figure 10 show the global monthly sales of Plug-in Electric Vehicles in 2016, 2017, 2018 and EV sales and Figure 11 show the % growth in the year 2017, 2018. This data has been collected from EV volumes. The Internal Energy Agency (IEA) reports say that in 2016 nearly a quarter of the global emission is due to transportation. When compared to 1990 the emission level is 70 % higher. This creates a demand for global warming in making the transportation sector more sustainable. There is a need for accelerated phase-out of fossil fuel-dependent vehicles, alongside continued growth in Renewable energy sources to ensure EVs run on the cleanest power. EVs have zero low-carbon free emission compared to petrol and diesel vehicles when the energy to charge the EVs battery is fed from zero-emission fuels. BNEF (Bloomberg New Energy Finance) predicted that by 2040, 57% of global vehicle sales will be EVs. Many projects are taking place in the world to making sustainable EVs and RES. EVgo, the project on EV fast-charging network in the United States, started in May 2019 is 100% renewable energy for powering EV charging. The first kind of project taking place in the U.S to charge EVs with clean energy. The next project is EV100, a corporate leadership project which is making 82% of companies to charge their EVs using RES. In Europe, a project CleanMobileEnergy, connecting all cities to integrate RES storage networks and EVs under smart energy management by ensuring EVs powered by renewable energy [7]-[8].

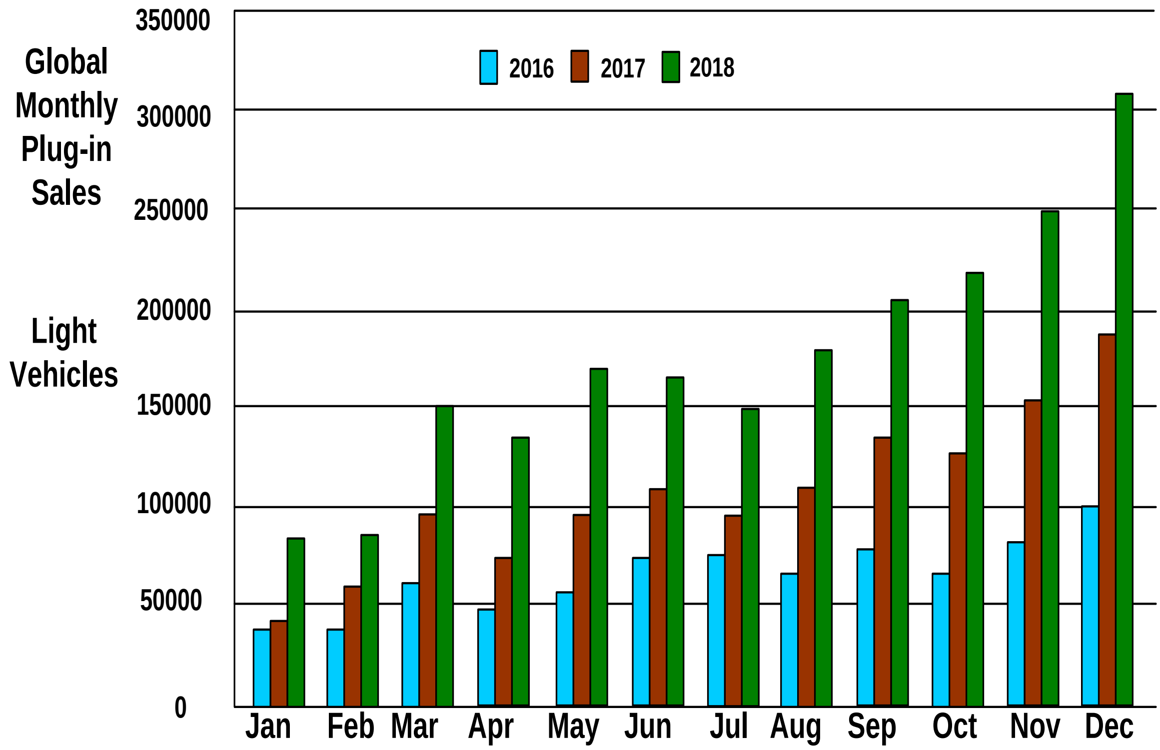

Figure 10. Global Monthly Plug-in Sales

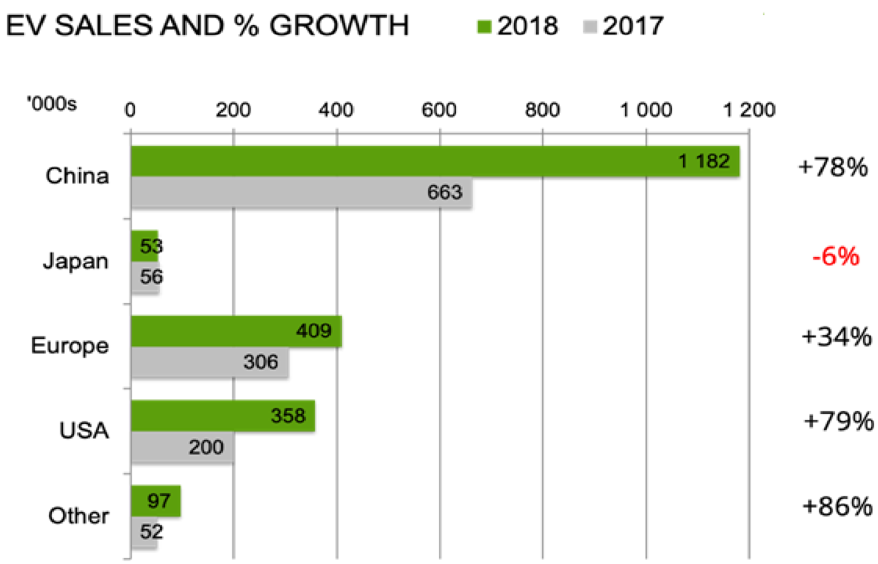

Figure 11. EV sales and % Growth

5. Conclusions

In this paper two technologies have been discussed, Electrification of Transportation called E-mobility and Renewable Energy Generation which are getting promoted by government policies and industry players to achieve the objective of sustainable clean energy transformation and meeting global energy demand. Electric Vehicles are moving at a faster rate and accelerating further in developing battery technology to give fast charging of EVs in a single switch operation. The ultimate aim of this impact is to reduce carbon emission and toxic air pollution with sustainable investment in Renewable Power. The innovative projects which link two solutions together, EVs and Renewable Energy Generation place significant challenges to improve energy sustainability in the electric power system and transportation system. Both the sectors together globally consuming 60% of total energy. Integrating renewable energy with EVs improves the growth of the EV market. There is a need for new communication and control infrastructure that must be deployed between vehicles and grid which makes the consumers participate and potential new regulations in the EV market. In this paper, also the mathematical analysis to find out the optimal points of divergence in the power grid with RES has presented.

6. References

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