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Nanotechnology for Reduction of Greenhouse Gas Generated in Road Transport

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Abstract - Green road transport at global scale is expected to reduce the emission of CO_2 in three scenarios –The State Polices Scenario (STEPS), The Announced Pledges Scenario (APS), The Net Zero Emission by 2050 Scenario (NZE).Conventional Vehicles are based on internal combustion technology whereas the electric vehicles uses electric motors for propulsion .Nanotechnology is the manipulation of matter within the range of 1to 100 nanometers .Nano- coating, nanofilters, nanomaterial etc. have been used in electric vehicles. Li-ion batteries are used in electric vehicles. Lithium, Nickle, Manganese Cobalt Oxide, $LiNiMnCoO_2$ (NMC) battery is suitable for electric vehicles. The Nanomaterials in electric vehicles are in batteries in the form of cathode nanomaterials, Anode nanomaterials, the electrolyte nanomaterial and the separator nanomaterials. Moreover, nanomaterials help in augmentation of mechanical sturdiness of electric vehicles body and slashing the heaviness of electric vehicles.

Keywords: Three Scenarios, Nanotechnology, Li-ion battery, Nanomaterial, Sturdiness of body of electric Vehicles, Slashing the heaviness.

I. INTRODUCTION

Green road transport at global scale is expected to reduce the emission of CO_2in three scenarios:

A. The Stated Polices Scenario (STEPS):

It explores how energy system evolves under today᾽s polices and private sector momentum .This scenario is not developed with a particular outcome in mind, but rather explores where current efforts are likely to lead global energy system. The STEPS does not take for granted that all Government targets will be achieved, instead, it takes a granular, sector-by-sector look at the concrete policies and measures in effect as of August 2024, and assesses their impact on energy demand and supply. The STEPS also takes into account private sector action, including fuel production and manufacturing capacity of clean energy technologies, and assesses how these market dynamics impact future trends.

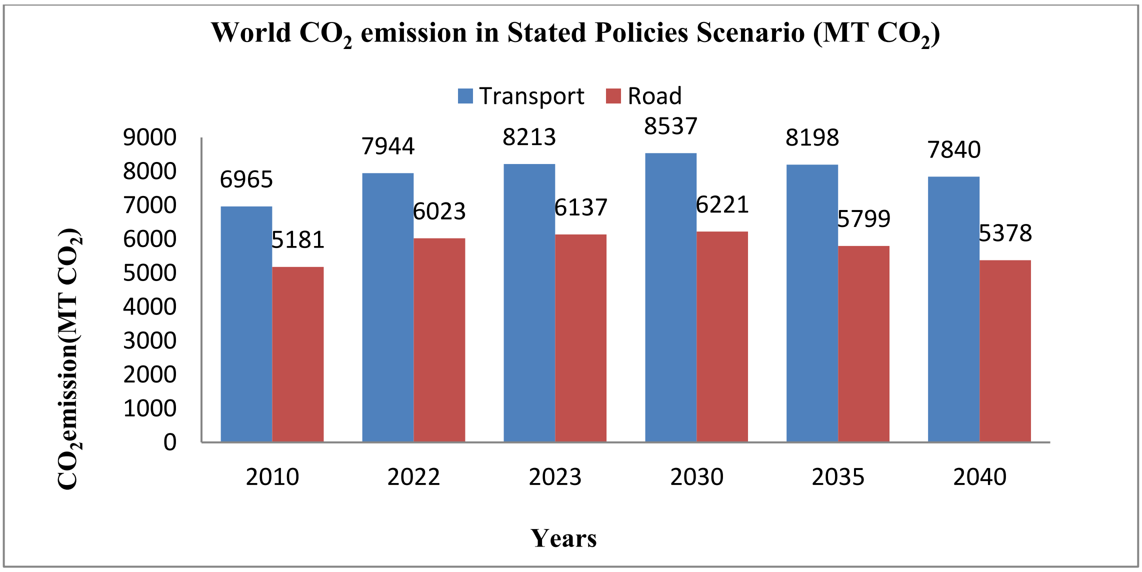

Fig.1: Total world CO_2 emission under started policies scenario by all means of transport and road transport.

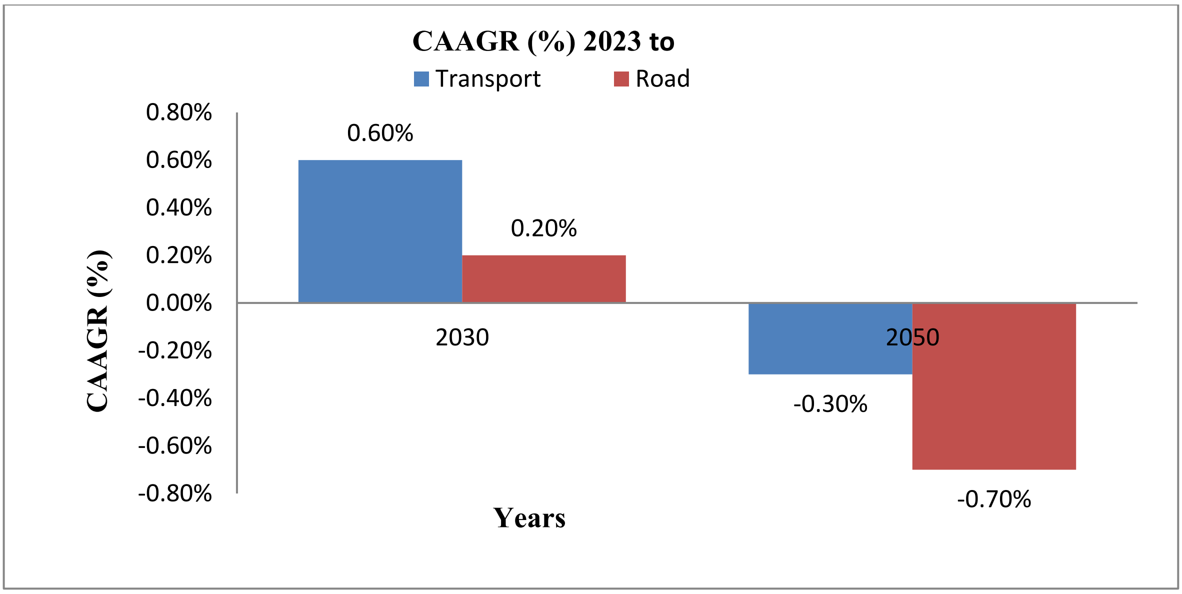

Fig. 2: Compound average annual growth rate of CO_2 from 2023 to 230 and 2050 respectively.

B. The Announced Pledges Scenario (APS):

It assumes that the governments will meet all climate commitment, including their Nationally Determined Contributions and longer - term net zero emissions target. The APS starts from the policies and trends in the STEPS and identifies additional efforts needed to reach national climate and energy targets. In some cases, one national target may require other targets to not be achieved exactly by the date or in the manner specified. In most cases, National long- term Net Zero emissions targets are achieved in the APS. Still, other interim targets have a strong influence on the pathways in which countries achieve their long-targets. Countries ambitious long-term pledges are assumed to benefits in this scenario from the accelerate cost reductions and wider availability of clean energy technologies.

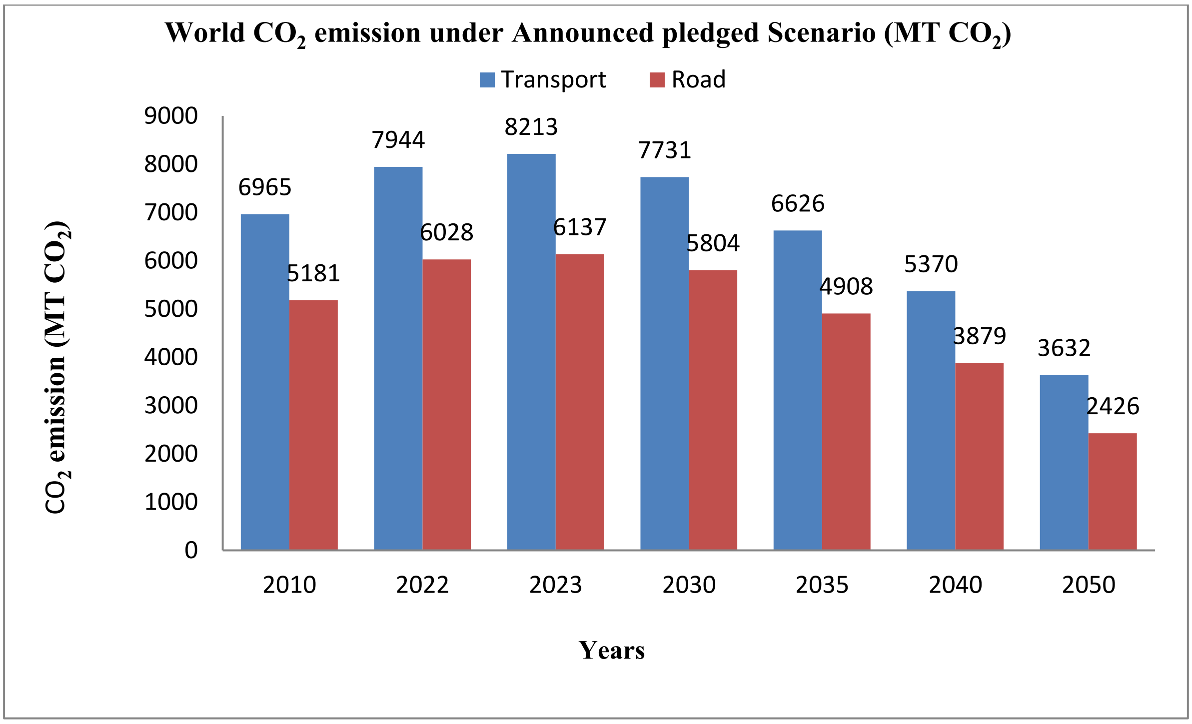

Fig. 3: Total world CO_2 emission under Announce Pledged Scenario by all means of transport and road transport

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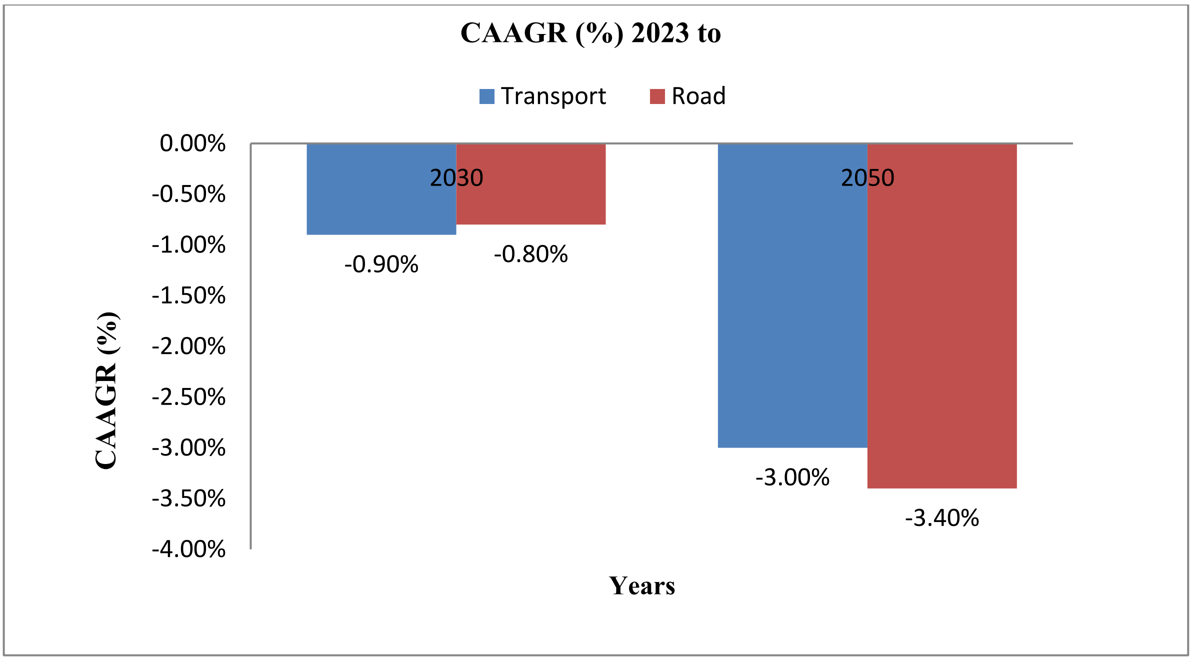

Fig. 4: Compound average annual growth rate of CO_2 from 2023 to 230 and 2050 respectively.

C. The Net Zero Emissions by 2050 Scenario (NZE):

It depicts a narrow but achievable pathway for the global energy sector to reach net zero energy –related co_2 emission by 2050by deploying a wide portfolio of clean energy technologies and without offsets from land-use measures. It recognizes that achieving net zero energy sector CO_2 emissionby2050 depends on fair co-operation with advanced economics taking the lead and reaching net zero emission earlier in the NZE scenario than emerging market and developing economics. This scenario also achieves universal modern energy assess by 2030, consistent with energy- related targets of the United Nation Sustainable Development Goals. The NZE Scenario is consistent with limiting the global temperature rise to 1.5°C (with at least a 50% probability) with limited overshoot.**[1]**

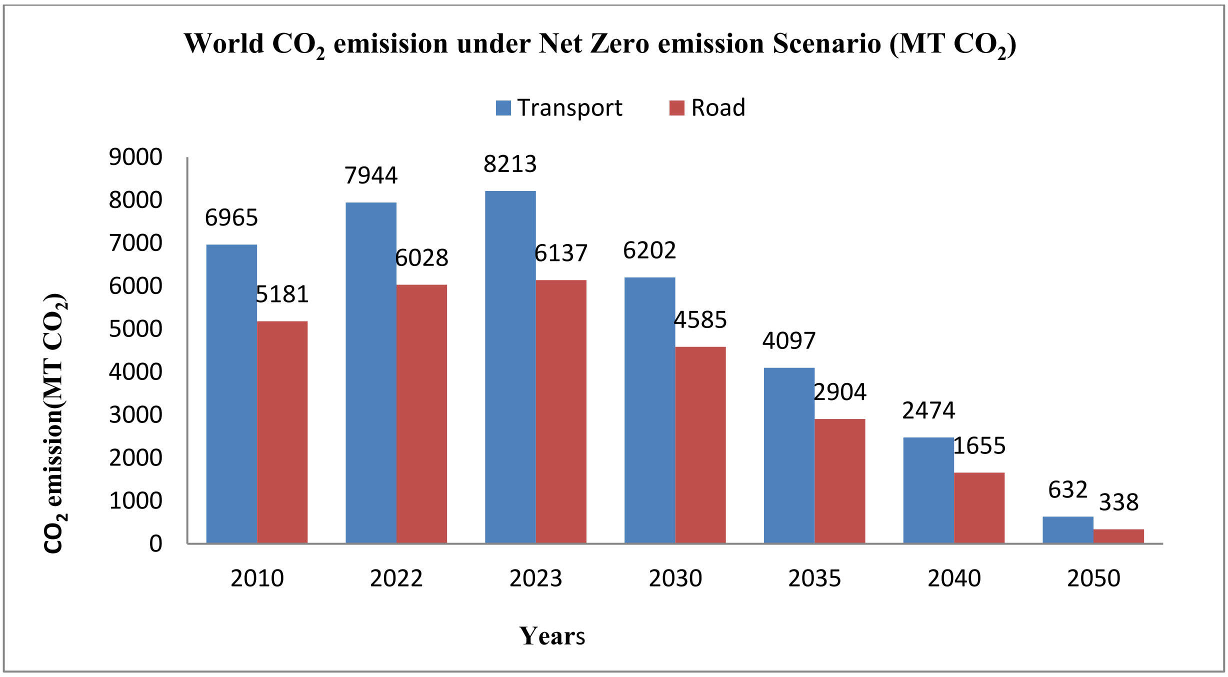

Fig. 5: Total world CO_2 emission under Net Zero emission Scenario by all means of transport and road transport

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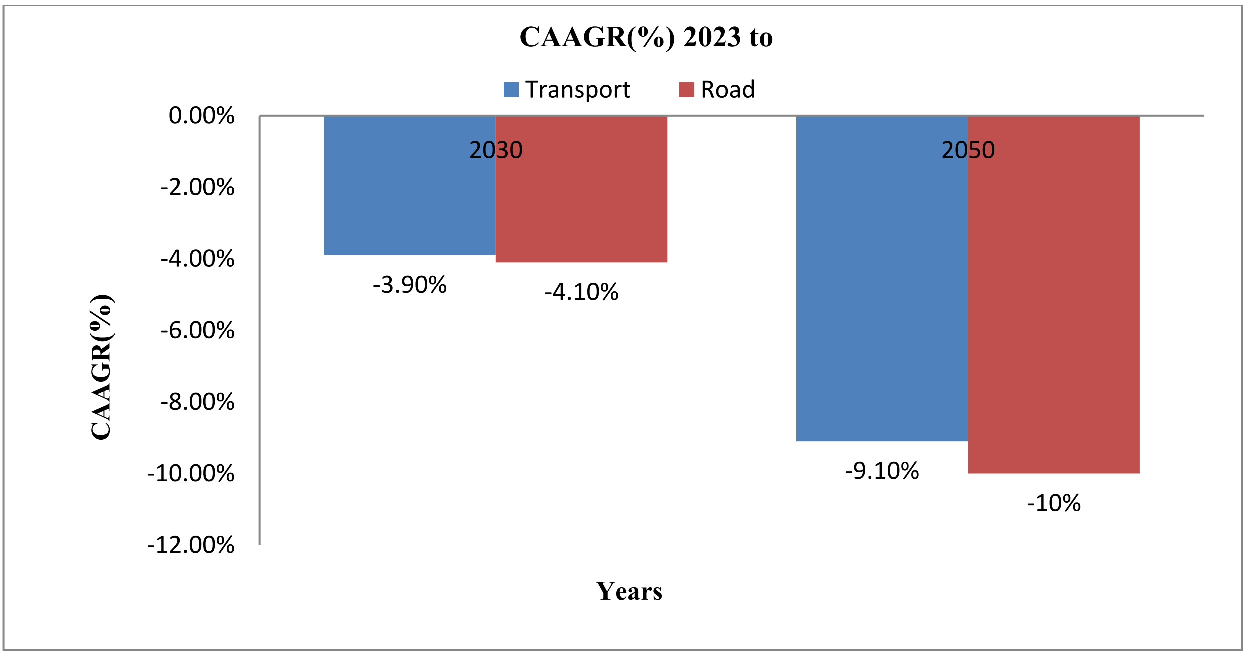

Fig. 6: Compound average annual growth rate of CO_2 from 2023 to 230 and 2050 respectively.

II. Study Area

Conventional vehicles are based on internal combustion technology. Internal combustion engine is a heat engine in which the combustion of fossil fuel likes gasoline and diesel happens. Fossil fuel combusts with an oxidizer like air in combustion chamber that, in turn, produce gases having high temperature and high pressure. This, in turn, transforms chemical energy into kinetic energy that propels the vehicle. These gases are Greenhouse gases. Electric vehicles use electric motors or traction motors for propulsions. The powering system of electric vehicles technology can be external.

In the contemporary era, road transport is the one of the means to commute. Electric vehicles provide the vital system to decarbonize the road transport. The goal of this paper is to focus and alleviate the problem of emission of CO_2 generated in road transport at the global scale in general and at the country level in particular.

The Electric Vehicles Initiative (EVI) is a multi- governmental policy forum set up in 2010 under the Clean Energy Ministerial (CEM) for acceleration to adoption of EVS worldwide. The International Energy Agency serves the coordinator of the initiative. Canada, Chile, People^s Republic of China, Finland, France, Germany, India and Japan, The Netherlands, New Zealand, Norway, Poland, Portugal, Sweden, United Kingdom and United States of America are member countries of EVI. Electric car sales neared 14 million in 2023, 95%of which were from, China, Europe and United States.

Expansion and improvement of road transport is a catalyst for socio-economic development of India. But the irony of road transport is environmental problem of emission of CO_2 nitrogen oxides (NO_X) and particulate matter (PM). Road transport cause 12% of India's CO_2 emission and is leading contributor of air pollution of urban areas. In the STEP scenario CO_2 emissions will peak in 2040s and after that it will decline marginally.

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Fig. 7: World Map and India Map

III. MATERIAL AND METHODS

Nanotechnology and Nanomaterials:

Nanotechnology is the manipulation of matter at nanoscale that is within the range of 1 to 100 nanometers. In other words, nanotechnology imply the design, fabrication, characterization and application of materials and devices at the nanoscale .This comprises the application of several devices and know-how such as scanning probe microscopy, electron microscopy, molecular self-assembly and nanolithography. Nanotechnology has been increasingly applied in automobile sector. Nano-coating, nanofilters, nanomaterials etc. have been used in electric vehicles. Moreover, nanoparticles augment the functioning of electric motors or traction motors of electric vehicles. Further, carbon black is used in manufacturing of tires of electric vehicles.

Type of batteries and their efficiencies:

In electric vehicles, the batteries used are Li- ion batteries. The chief constituent of a Li-ion cell include a cathode, anode, electrolyte and separator. The material of the cathode defines the naming of the Li-ion cells. Lithium Iron Phosphate (LFP), Lithium Manganese Oxide (LMO) , Lithium Nickel Manganese Cobalt oxide(LNMC) and Lithium Cobalt Oxide(LCO) are the most common materials used for the cathode. A comparison shown in table I. [**2**]

Table I: Types of Batteries and their specifications

Specifications	**NMC**	**LMO**	**LFP**	**LCO**
Lifecycle	1000-2000	500-1000	1000-2000	500-1000
Specific energy (Wh/kg)	140-180	100-135	90-120	150-190
Voltage(V)	3.6/3.7	3.8	3.3	3.6
Upper Voltage limit(V)	4.2	4.2	3.6	4.2
Safety	Medium	medium	High	Low
Thermal runaway(^{0}c)	210	250	270	150

Feature of Lithium Nickel Manganese Cobalt Oxide ($LiNiMnCoO_2$)-NMC battery:

One of the best –setting Li-ion system is a cathode composite of Nickel- Manganese- cobalt(NMC) .This combination is suited for energy cells or power cells. This significance of NMC rests in compounding Nickel and Manganese. Nickel has the

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characteristic of high specific energy. Moreover Nickel has the deficiency of below par stability. Manganese has the characteristic of fabricating a spinel structure that results in low internal resistance but gives a low specific energy. Fusing the metals strengthen each other firmness.

NMC is the suitable for electric vehicles. The cathode combination has the characteristic of one-third Nickel one-third Manganese and one-third Cobalt that is also famous as 1-1-1.Cobalt is high priced and scares. Battery producers are slashing the volume of cobalt that results in weaken efficiency. The best selling combination is NCM532 with five piece Nickel, three piece Cobalt and two piece Manganese. Other combinations are NMC622 and NMC811 Cobalt stabilizes nickel. New electrolytes and additives facilitate charging 4.4V/cell and higher to enhance capacity. Following data illustrates the traits of NMC. [3]

Quality of NMC group is diversifying:

The features of Lithium Nickel Manganese Cobalt Oxide battery are followings:

Cathode $LiNiMnCoO_2$, Anode Graphite.

Table-II: features of Lithium Nickel Manganese Cobalt Oxide battery

Voltages	3.60 V,3.70V nominal, typical operating range 3.0-4.4V/ cell, or higher
Specific energy(capacity)	150-220 Wh/kg
Charge(C-rate)	0.7-1 C, Charges to 4.20 V, some go to 4.30 V, 3h charge typical .Charge current above 1C shortens battery life. Charge must be turned off when current saturates at 0.05C
Discharge(C-rate)	1 C,2C possible on some cells; 2.50 V cut-off
Cycle life	1000-2000(related to depth of discharge, temperature)
Thermal runaway	210^0C (410^0F) typical. High charge promotes thermal runaway
Cost	~$420 /KWh
Applications	Electric vehicle

Use of nanomaterial in manufacturing electric vehicles Batteries:

The requirement of electric vehicles Batteries are high energy, power densities and long cycling life. Nanomaterials can be applied to the design and fabrication of electrode materials. The electrolyte is used to provide a medium for the shuffling of ion during the redox reactions at the cathode and the anode .The cathode, the electrolyte, and the anode are associated with ion transport. Moreover the separator is placed between the cathode and anode and is used to prevent any form of physical contact between two electrodes while enabling the free flow of Li-ion between them.

Cathode Nanomaterials:

The nanostructured lithium, nickel, manganese, cobalt oxide is used as cathode of electric vehicles batteries. By reducing the composite internal resistance, reduced polarization under high current densities and the further improvement in high rate capacity can be achieved. The specific surface area is increased as application of nanostructured materials. Applying nanostructured cathode reduction in polarization at high current rates and before reaching the voltage cut-off a higher capacity can be achieved from the cathode. [4]

Anode Nanomaterials:

Graphite is commonly used as anode of Lithium Nickel Manganese Cobalt Oxide battery. Carbon nanomaterials of graphite structure enhance energy conversation process and energy storage performance of battery. Carbon nanomaterial have a typical multi-layered hollow structure, being coaxial circular tubes consisting mainly twelve layers of carbon arranged in a hexagonal pattern. Carbon nanotubes have a large specific area, so they can combine much higher concentration of Lithium.**[5]**CNT- based electrode can enhance the performance of Lithium Ions battery. Carbon Nanotube has characteristic of ultra-lightweight. Therefore, carbon nanotube cause lesser use of an exotic binders and additive materials. This, in turn, cause the battery becomes lighter and more compact.

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The electrolyte Nanomaterials:

The most commonly used electrolyte material in Lithium Nickel Manganese Cobalt Oxide battery is 1M Lithium hexafluorophosphate/ Ethyl carbonate, as it has the highest electrical conductivity. This electrolyte is in fact a concoction of organic solvents and electrolytes salts. The organic solvents and electrolytes salts are made from nanomaterials.

The Separator nanomaterials:

The selection of proper separator material is very crucial as it increases the electrical resistance and cell density, adversely impacting the performance of cell. The common materials such as polypropylene. Various types of nanoparticles, such as carbon nanotubes, graphene, nanocellulose, halloysite and other nanoparticles have used to produce polypropylenes. The porosity of the separator varies from 30% to 50% and the pore sizes .range from 0.03 to 0.1 µ m.

Augmentation of mechanical sturdiness of vehicle body and slashing the heaviness of electric vehicles:

Currently the metal frames and battery cover increase much weight to electric vehicles. That requires additional innovation to manufacture them lightweight carbon fiber composites that are 50% and 30% lighter than the steel and aluminum respectively have been used by BMW for electric vehicles. Carbon fiber reinforced thermoplastic provides great strength.**[6]** Tesla has developed a lightweight, marked tough and lasting material for automotive parts using carbon fibers .Carbon fibers are selected because of their high strength to weight ratio. The carbon fiber strands are woven into cloth and then encapsulated in epoxy resin. The combination of this layering maintains bending stiffness's comparable with steel body panels. In addition, 50 pounds of weight is reduced in comparison of glass fibers composites.**[7]**The battery packs consist of steel battery enclosure that accounts for approximately 30% of the total mass of the battery.**[8]**It has already been observed that battery cases constructed of glass fiber reinforced plastic and carbon fiber reinforced plastic display very high strength and stiffness. In addition, a carbon fiber reinforced plastic based battery case can save up to 40% of weight compared to aluminum and steel cases.**[9]**Saudi Basic Industries Corporation(SABIC) is working on reducing the weight and cost of the battery pack of electric vehicles using long glass fibers in a PP matrix with thinness and more crash-resistant properties.**[10]**

IV. RESULTS AND DISCUSSION

Electric vehicles are greener than conventional vehicles. It is estimated that electrification of road transport at the global scale will curtail emission of CO_2 significantly. In the STEPS, the emission of CO_2 will be cut down by 2Gt CO_2 in 2023.**[11]**The level of battery storage capacity indicates the spread of electric vehicles. The more the number of electric vehicles used in road transport, the less would be the quantity of CO_2 generated in road transport.

The battery storage capacity, under STEP (GW):

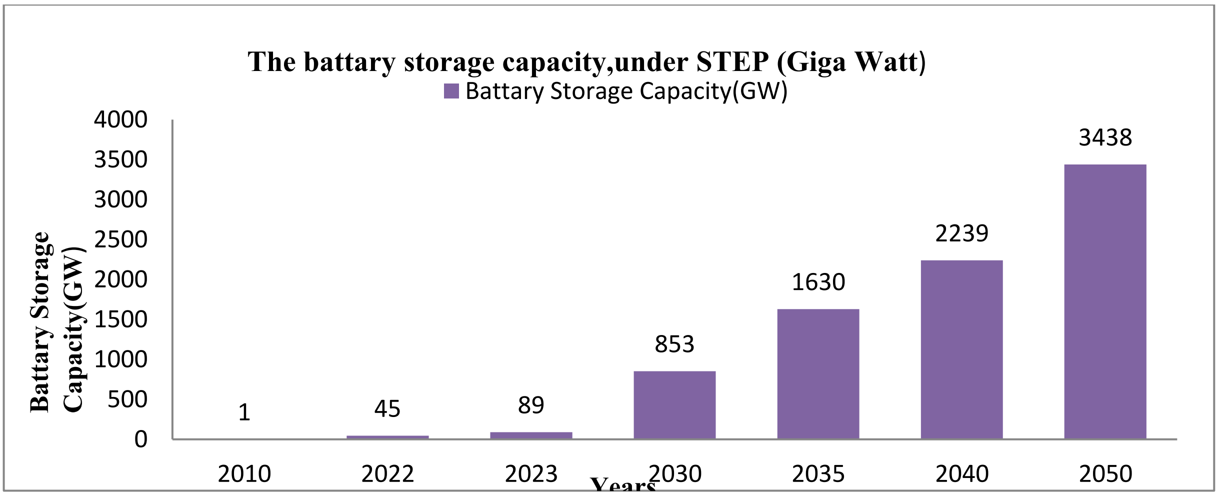

Fig.8: Total world battery storage capacity under started policy scenario

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The battery storage capacity, under APS (GW):

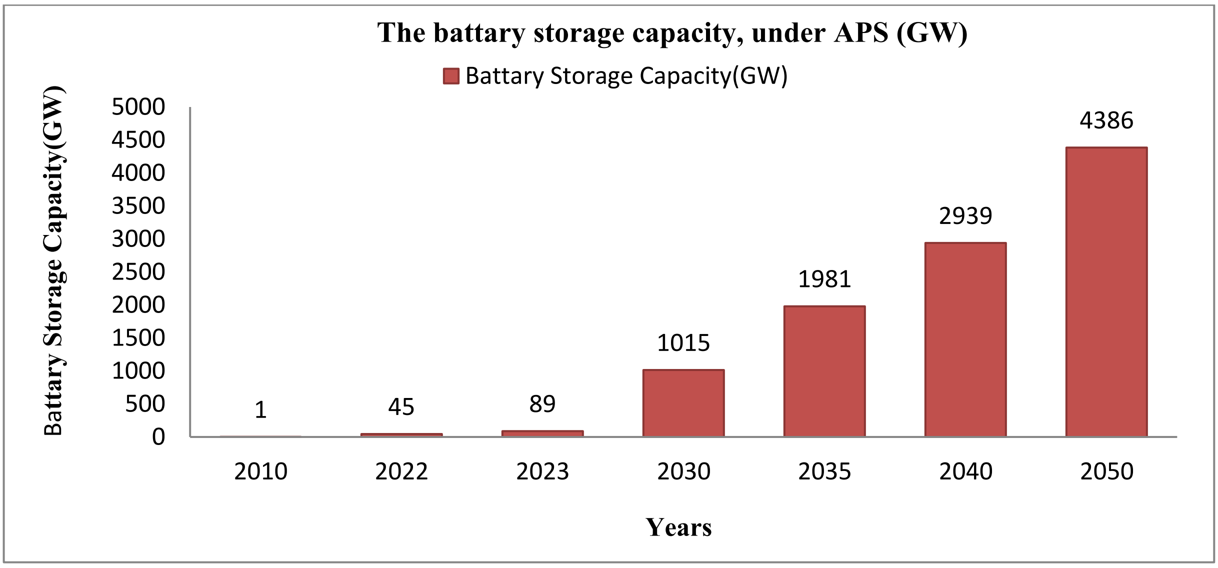

Fig. 9: Total world battery storage capacity under Announce Pledges scenario

The battery storage capacity, under NZE (GW):

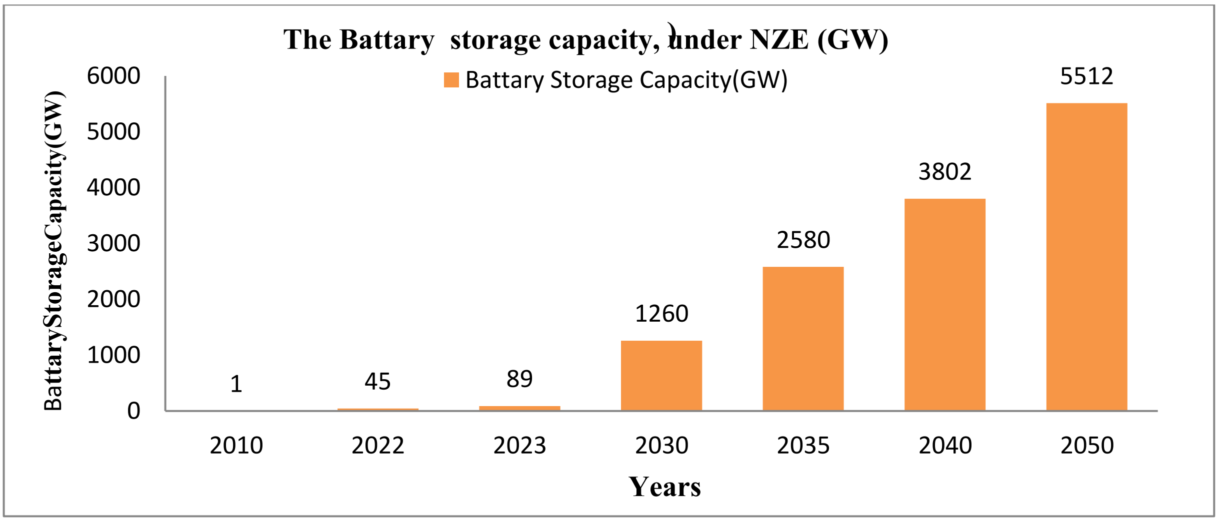

Fig.10: Total world battery storage capacity under Net Zero emission scenario

The battery storage capacity will remain same from 2010to 2023 in all three scenarios. In post 2023 era the battery storage capacity is expected to be highest in NZE scenario. Moreover, the battery storage capacity is expected to be higher in APS scenario than STEPs scenario. **[12]**

In 2021, India adopted the policy for reaching Net Zero Carbon emissions by 2070.According to APS, this policy could help reduce energy demand by 30% in 2050 relative to current policies, saving India 70 million tons of oil equivalent (80% of the sector's current energy needs) CO_2 emission will peak in the mid-2030s. Moreover, CO_2 emission will fall 20% below today's level by 2050. Electric vehicles have account for most of the over and above potential for mitigation of rising CO_2. **[13]** In India, electric car registration were up 70 % year on year to 80,000. Around 2 % of all cars sold are electric in 2024. By Procuring electric buses and trucks, the emission CO_2 generated in road transport will be, further, curtailed. Moreover, commitment to R& D must be in the DNA of the e-vehicle industry. Further, charging in infrastructure and testing agencies up gradation is also essential to use of electric vehicle. As for use of electric vehicles on large scale, Govt. of India has launched the programmes- Electric Mobility Promotion Scheme (EMPS) and the PME-DRIVE Schemes. These must be implemented in letter and spirit.

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V. CONCLUSIONS

Enormous efforts are underway to achieve carbon- neutral vehicles by adopting electric vehicles. The battery storage capacity is one of the most ingredients for use of electric vehicle at large scale. The carbon neutrality of electric is critically dependent on the electricity mix of, improvement in the battery technology and the material and design advances in reducing the weight of electric vehicles. The unique chemical properties of nanomaterials, using of nanocomposites in the body of electric vehicles and carbon fiber reinforced plastic, the mass of electric vehicles can be reduced significantly. Moreover nanotechnology makes an conspicuous impact in enhancing the performance of electric vehicle battery packs.

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