ELECTRIC VEHICLES (EVs)-EVOLVING TRENDS IN THE MARKET & THE SUPPLY CHAIN: TRAJECTORY ANALYSIS

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ABSTRACT
The basic purpose behind this paper is to understand the underlying dynamics at play in the context of the emerging landscape of EV industry, as well as the related economic and technological ambitions of countries like India. This paper is largely based upon information from secondary, but highly reliable sources. The data that has been used in this paper has been gathered from authentic sources on the internet such as from freely accessible research papers, newspaper articles, working papers and expert committee reported. The authors have extensively reviewed literatures related to the topic, and the conclusions that have been arrived at in this paper,arelargelyanchored in the output generated from this literature survey.
This paper seeks to study all the dimensions of the EV industry such as its genesis, the people who shaped the industry during its infancy, the factors that derailed the industry during early 20th Century, when it looked set for a great future, the reasons behind the success of ICE vehicles industry over EV industry, factors that ultimately led to the resuscitation of the EV industry from the dawn of the 21st Century etc. In addition to all this, the authors have also sought to examine the impact of the expected boom in EV industry on parameters such as public health, pollution, economic & employment growth, international trade & geo-politics etc. Finally, in the paper, there is also an attempt to identity the opportunities & threats that countries like India can expect during the coming decades when EV industry would be spreading its tentacles throughout the world.
Keywords: Electric Vehicle, Technology Adaptation, Climate Change, Global Supply Chain Diversification, Customer Expectations, International Trade in Oil &Gas, Opportunities & Challenges for EV Industry, Challenges, Future, Economy.

Introduction

The story of oil price, one of the principal drivers behind the demand for EVs

In so far as its dependence on petroleum is concerned, world has never really seen a realistic alternative ever since large-scale deposits of oil were discovered first in Persia [1] in 1930 and later in Saudi Arabia [2] in 1938[3]. In fact, such has been the scale of the addiction to the black gold[4] that with every passing year, with every country moving up from a pre-industrial to an industrialized mode of production, with every wave of strong global economic growth, the demand for the stuff has only zoomed up, except for brief periods of lull brought about by factors such as wars, geo-political tensions, economic recessions and more recently, a once in a century kind of pandemic.

In fact, to really appreciate the stubbornness of the demand for oil, one really has to look at the worst periods, from the point of view of buyers, in global oil markets. Such epochs when oil prices suddenly shoot up, are collectively called oil shocks. Chronicles of global oil market tell stories of five major oil shocks to the world.

1 https://education.nationalgeographic.org/resource/oil-discovered-saudi-arabia
2 https://www.pbs.org/wgbh/globalconnections/mideast/timeline/text/teconomics.html
3 https://www.hgs.org/civicrm/event/info?id=1880
4 https://www.britannica.com/dictionary/black-gold

The first one was in 1973[5], when the major oil producers from the middle east, angered by western support to Israel during the Arab-Israel War, also known as Yom Kippur War, imposed an oil embargo against the western nations, and coalesced to bring down the total supply of the commodity in the world market, in the process precipitating a price hike of near 300% to reach a hitherto unthinkable level of $12 per barrel[6]. The persistent decline in the value of US dollar, the currency in which the transactions in the global oil markets were denominated, was definitely another contributing factor behind the rise in price of oil. But mainstream opinion has always held that it was only a relatively minor factor. The major contributor is believed to be the geo-politics around Arab-Israel relations.

The second oil shock[7] was experienced during 1979 in the aftermath of the Iranian Revolution of 1978-79. Iran was one of the three top producers of oil in the world at that point of time. In response to the forces of upheaval unleashed by the Islamic revolution in the country, Iranian oil fields were gripped by massive labor strikes and lockdowns. As a result of the debilitating impact of the labor unrest on the output levels of Iranian oil fields, by 1979, cumulative oil production went down by around 5 million barrels per day, or about 7 percent of the global output at that point of time. Other producers did try to chip in with additional production. But even their combined effort could not prevent a net decline in production of around 5 percent. This imbalance in demand and supply scenario, coupled with the fact that the global oil markets were spooked by the prospect of long-term decline in supplies coming from Iran, led to a situation where, by mid-1980, price of oil skyrocketed to $ 34 per barrel against $19 at the beginning of 1979 and $12 during 1973.

Iran-Iraq War (1980-88), Iraq's invasion of Kuwait in 1990, Operation Desert Storm of 1991 which was nothing else but American response to the Iraqi invasion of Kuwait in 1991, and the 2nd Gulf War of 2003 when USA invaded Iraq to topple the regime of Saddam Hussein, were the other periods when the world witnessed major oil shocks. More recently, as a result of the ongoing Russo-Ukrainian war, oil prices have once again experienced severe pressure, which resulted in benchmark crude touching prices of $111 per barrel [8] in the month of March, 2022

One thing that can however be noticed throughout, is the fact, that except for periods of brief hiatus, shock or no shock, global demand for oil & gas has never really gone down in any significant manner. Usually, a sustained drop in demand for oil has happened only as a result either of severe economic recession, massive economic upheaval caused by hyper-inflation, a total shutdown of economic activity brought along by the force majeure phenomenon like the corona virus pandemic, or a combination of all of these. And, considering the hectic demand for the commodity in Asian countries, the price of the resource is not going to go down anytime soon, unless a viable alternative emerges.

Tracing the Ursprung[9] -A brief history of electric vehicles:

As a concept, electric vehicles (EVs) are not really new. In fact, the idea of an electric car was first floated around a hundred years ago. It is rather difficult to pinpoint any single event or person as the point of origin of theconcept of electric car, as it is understood today. It was in fact a series of breakthroughs, starting with the battery itself, and extending to the other components of the vehicle, during the early-1800s that ultimately birthed the first electric vehicle on the road. During this period, innovators in Hungary, Netherlands and United Statesbegan toying with the idea of an electric powered vehicle. Two prominent names spring up in our minds in this context. One of them was a man named ÁnyosIstvánJedlik[10], a Hungarian innovator, engineer, physicist, and a Benedictine priest. He is regarded as one of the pioneers behind a wonderful device, one that later came to be known as the electric dynamo. In 1828, he invented an electric motor. Later, using his newly invented electric motor as the power source; he created a small electric car. At around the same time, in 1832 to be precise, Robert Anderson[11], a Scottishinventor, designed a crude electric carriage that gathered lots of eyeballs during its time.

While the idea of an electric vehicle was taking roots in Europe, being germinated in the great scientific minds of the time, America too was not far behind in action. Among the notable American names that merit recognition in

5 https://history.state.gov/milestones/1969-1976/oil-embargo
6 https://www.britannica.com/topic/oil-crisis
7 https://www.brookings.edu/blog/order-from-chaos/2019/03/05/what-irans-1979-revolution-meant-for-us-and-global-oil-markets/
8 https://www.business-standard.com/article/markets/crude-oil-prices-surge-as-supply-risk-grows-from-russia-ukraine-war-122032200051_1.html
9 A German word meaning Origin
10 https://www.lindahall.org/about/news/scientist-of-the-day/anyos-jedlik
11 https://www.energy.gov/articles/history-electric-car

this context, Thomas Davenport[12], a blacksmith from Vermont, comes out as one of the earliest purveyors of the idea. In 1834, two years after Robert Anderson's magic in Britain, he invented the first ever direct current electric motor in North America. The next year, Davenport once again gave a taste of his brilliance as an engineer-inventor. Thomas Davenport dazzled once again in 1835, when he, harnessing the power output from his electric motor, managed to run a small carriage around a circular track. That event is regarded as the first recorded demonstration of a functional electric railway, albeit on a small scale. He went on to receive a patent for "Improvements in propelling machinery by magnetism and electromagnetism" in the year 1837.

It must however be noted that almost all of these experiments were being carried out using non-chargeable batteries, also known as primary cells. Rechargeable batteries were yet to arrive on the scene. When it comes to the birth of rechargeable batteries, the name of John F. Daniell[13], an English Chemist, stands up to be noticed. Mr. Daniell, in the year 1836,builta battery that produced, compared to the existing volta cells, a much steadier stream of current flow.The next big stage in the story of the rechargeable batteries arrived in France, where in 1859, a physicist named Gaston Planté[14]developed a lead-acid system. In the subsequent decades, inventors elsewhere did a fine job of incremental improvements on what Planté had managed. However, what is remarkable about Planté's invention is the fact that even today, lead-acid system, or any of its derivatives, is essentially the technology that is being most widely used to build rechargeable batteries.

In the continental United States, in so far as a fully functional electric vehicle, one that could ferry 5-6 passengers, is concerned, the next big breakthrough came in 1890 through a chemist from Iowa named William Morrison[15]. The vehicle developed by him could reach a top speed of fourteen miles an hour. In almost all other aspects, when seen in the context of what we understand by the term 'car', his vehicle was essentially an electrified wagon, but, riding on the strength of its operational capabilities, it did spark lots of curiosity. The next few years were periods of intense activity in the United States. Automakers of all kinds started coming up with different models, each trying to outperform the others. Such was the level of the buzz in the market in U.S., that by the year 1900, New York City even had a fleet of more than 60 electric taxis. By this time, electric vehicles had come to constitute around a third of all vehicles on the road.

Beginning of the Dark Ages for the EV Industry - The Twilight Years (1930 – 1990)
Age before the era of resurrection in the 21st Century

From the dawn of 20th Century, especially after the end of the 1st world war, when both good quality roads and gasoline became ubiquitous, especially after the discovery of oil in the Spindletop Well[16] in Texas in 1902, in the US, the largest hub of industrial innovation in the world, total number of people who preferred to commute on their own personal vehicles, was rising all the time. Thus, through a combination of factors such as construction of good quality highways, availability of cheap oil and multitude of incremental innovations in the IC engine driven vehicles, electric vehicles began giving way to gasoline fueled vehicles.And by 1935, electric vehicles had all but disappeared from American roads. The three subsequent decades i.e., the 40s, the 50s and the 60s were barren decades from the point of view of electric vehicles.

The waves of green movements raging through the world during the 60s, led to rising awareness about the need for alternative fueled vehicles as a potent means to fight the aggravating problem of emissions. In addition, because of the aggravating geo-political situation in the middle-east, most of the consuming countries, primarily in Europe and North America, were increasingly nervous about their dependence on imported energy as the base of their economic engines. Engineers in various companies were hard at work, trying to find a solution to the problem. The process saw certainnoticeable attempts to rise up to the challenges being thrown by a combination of economic and environmental circumstances.

A Notable example of the players who tried to answer this demand for an alternative to gasoline powered vehicles, was a company called Boyertown Auto Body Works[17]. It formed a joint venture with Smith Delivery Vehicles Ltd. of England, and the Exide Division of the Electric Battery Company. The name of that cooperative venture was Battronic Truck Company[18]. In 1964, Potomac Edison Company became the first customer of the

12 https://edisontechcenter.org/DavenportThomas.html
13 https://www.lindahall.org/about/news/scientist-of-the-day/john-frederic-daniell
14 https://www.britannica.com/biography/Gaston-Plante
15 https://www.britannica.com/technology/automobile/Early-electric-automobiles#ref918185
16 https://stateimpact.npr.org/texas/tag/oil-production-in-texas/#:~:text=Oil%20was%20first%20detected%20in,%2C%20near%20Port%20Arthur%2C%20Texas.
17 https://avt.inl.gov/sites/default/files/pdf/fsev/HistoryOfElectricCars.pdf
18 https://ntrs.nasa.gov/api/citations/19820011331/downloads/19820011331.pdf

Batronic electric trucks. Later, between 1973 to 1983, the company joined forces with General Electric (GE) to produce utility vans that found application in a range of tasks in utilities industry. During the mid-70s, the company also ventured into the business of manufacturing electric passenger buses.

In this context, another worthwhile name that comes to the mind, is that of Jet Industries of Austin[19], Texas. This company specialized in converting gasoline powered vehicles to electric traction. The company did not survive for very long. However, during the time that it was alive, it produced a number of vehicles, including its best-selling product called 'Electrica'. The 'Electricas' were primarily Ford Escort and Mercury Lynx running on electric motors. To build its 'Electricas', the company used to buy the "gliders" i.e. body and chassis without engines from Ford Motor Company. And, on that platform, the company used to mount its own electric drive trains to produce the 'Electricas', its flagship model in the market.

Throughout 1970s and 80s, many more companies attempted to come up with electric vehicles that could live up to the expectations of the consumers and the market. But, except occasional flicker of hopes in the form of Battronic Truck Company, Jet Industries of Austin, Sebring-Vanguard Company with its 'Citi Cars', most of the companies that existed in that space have not even survived to this date.

Literature Review

Sarode (2020) talk about how electric mobility technology has been slow to arrive in India. They also talk about Indian consumers have so far not been able to find perfect ease with the new technology. The authors have also talked about some of the most critical issues, like range related issues faced by owners of electric vehicles. They have also talked about key infrastructural constraints such as inadequate battery charging infrastructure in India.

Mierlo, Van (2018) is of the view that electrification the transport system would generate around one million additional jobs in Europe by 2030 and double of that by 2050. These jobs, according to Van andMierlo would on one hand be generated within the factories, but also in the context of downstream services, such as charging infrastructure, vehicle maintenance & repair facilities etc. Van Mierlo also talks about how electrification will help Europe reduce its dependence on imported forms of energy such as oil. Another interesting theme that Van Mierlo touches upon is the synergy that can be seen to be appearing between EV technology and the evolving technology of autonomous mobility.

Jin et al. (2017) talk about the general lack of consumer awareness about the options being made available by EV technology. They discuss how key pieces of information such as the ones related to the incentives being extended to the consumers by both the Governments as well as the manufacturers of EVs. The authors have stressed upon the need to generate higher level of consumer awareness vis-à-vis the EVtechnology.

Juyal,Shikha (2018) pointed out that India stands to gain immensely by replacing its vast pool of ICE (internal combustion engine) vehicles with electronic vehicles (EVs) at the earliest. Among the benefits cited by the authors are significant reduction in import bill and thus huge savings of foreign exchange. Another benefit counted by the authors relates to the worsening problem of air pollution, caused in a big way by the fuel guzzling transport sector of today. Among other advantages, the authors have cited the possibility of India emerging as a leader in small and utility electric vehicles.

Tupe (2020) stats that in view of the fast-depleting fossil fuel reserves, and the ever-increasing prices of petroleum, India urgently needs to find a solution to eliminate its dependence on fossil fuels to power its transport infrastructure. The authors have talked about certain Government initiative such as fighting pollution by promoting EVs, giving subsidies on purchase etc. Government has also rolled out a well-defied FDI policy aimed at attracting investment in the EV space. Authors have also stressed upon the importance of Government agencies and manufacturers joining hands to build the infrastructure and create a positive environment for EVs.

Lee (2018) have recounted how the past couple of decades have witnessed an unprecedented interest, both among manufacturers and consumers, in electric vehicles. With reference to the American context, the authors have tried to understand as to whether the Americans drivers are on the cusp of replacing their gasoline-powered cars with electric vehicles. The authors have also dealt with other key questions, such as will the gasoline stations be superseded by fast-charging stations, will the transportation sector of the future be fully electric?
M, Mohammad (2018) stated that the implementation of EVs in India aspire primarily to reduce greenhouse gas emissions and cut oil expenses whereas the vision 2030 put forth by the Indian Government is an ambitious and difficult task. The Government should make the most out of the opportunities available and find suitable ways to

19 https://avt.inl.gov/sites/default/files/pdf/fsev/HistoryOfElectricCars.pdf

tackle the challenges impending over the implementation of EVs. India's responsibilities towards many environment friendly agreements have given it a situation where it is prompted to implement vision 2030.

Goel (2021) stated that Electric vehicles are an important option for reducing emissions of greenhouse gases whereas electric vehicles not only reduce the dependency on fossil fuel but also diminish the impact of ozone depleting substances and promote large scale renewable deployment. Khurana (2019)statedpollution of the environment is currently a global concern. Toxic emission from internal combustion engines is one of the primary air pollutants. In order to mitigate the effects of fossil fuel emission and address environmental concerns (ECs), electric vehicles (EVs) are being promoted aggressively all over the world.

Ali (2021) said that Electric vehicles offer great potential to recuperate efficiency within the transport system. This is majorly on roads, reducing traffic accidents, increasing productivity, and minimizing our environmental impact in the process. However, they have also seen resistance from different groups claiming that they are unsafe, pose a risk of being hacked, will threaten jobs, and increase environmental pollution from increased driving as a result of their convenience.

Barapatre (2018) stated that as of today, each vehicle has its own characteristic that makes it better than the other. Only time and technological improvements will tell which vehicle will excel in the future. Silvana Secinaro (2022) stated research on consumers of electric vehicles appears to offer significant contributions relative to the behavior factors that stimulate purchase. Although it is one of the topics most endorsed by international organizations, a holistic compendium of the literature is not provided. Therefore, different research directions necessitate a clear systematization.

Objectives of the Paper

In this paper, an attempt has been made to trace the evolutionary trajectory of electric vehicles and thereby gain an understanding of how it is likely to shape-up in future. Other issues that been explored in this paper are related to impact of propagation of EVs on international trade, especially in energy, impact on environment, supply chain disruptions, impact on and response of traditional automakers etc. There are following objectives taken into consideration for the study-

1. This study pre-requisite to examine the impact of the rise of EV industry on political-economy of India.
2. To explore& examine the critical issue of consumers' response to the electric mobility options.

Research Methodology

The analysis done in this paper is based upon secondary data collection from various internet sources like research papers, websites, reports, literature, working papers etc. We have studied various aspects concerning electronic vehicles, people's awareness, willingness of consumers to adopt the new technology, technological and commercial challenges before the industry and finally the future prospects of the industry. This paper is divided into different sections**.** Every section deals with a specific theme related to the larger theme of electric vehicles. The paper starts from an overview of the EV industry, its evolution over the years, individuals and organizations that played crucial roles on the way, setbacks and windfalls received by the industry over the years, public policy towards the industry, changing perception of the consumers towards electric vehicles etc.

In so far as application of statistical tools in concerned, this paper uses the concept of correlation & regression, long-period averages, future value etc. to establish relationships between disparate data elements, mainly concerning oil prices, sales of EVs and hybrid vehicles from legacy automobile companies, sales of EVs from Tesla, performance of Tesla stocks over the years, performance of legacy automotive sector, emission of greenhouse gases coming from vehicles on the roads and impact of fuel imports on the foreign exchange reserve position of India, in an efforts to find out the nature of the relationship that exists between those data points.

Finally, based upon the results thrown by the chosen statistical operations, the authors have come out with a set of conclusions, including some data points for policy makers in India to consider.

Data Analysis

Factors that prevented the EV industry from taking off during the early 20th Century

Onset of the age of railroads, gasoline and highways - Carpet bombing of the fortunes of EV industry in the US

Over the decades, just like today, electric vehicles have suffered from a serious problem of perception that has been defined as range anxiety. Because of the low energy density of the batteries, they just could not be used to undertake long voyages. However, ironical though as it might sound, one thing that went in the favor of electric vehicles industry, right until the first couple of decades after the end of the First World War, was the fact that the concept of interstate highways had not yet taken off in United States in a way as it did during the subsequent

decades. High quality motor able road infrastructure was largely confined to the city limits. Thus, given the problem of range anxiety that had stubbornly stuck to it, lack of a highway system was an ideal situation for electric vehicles industry to exploit, and the then automakers making EVs did precisely that.

From this period onwards, the fate of electric vehicles industry started taking a different and largely unexpected turn. It must be noted that till the dawn of the 20th century, horse drawn carriages were still the most popular reliable form of transport, including for long distance ones. America, riding on the strength of an era of almost 50-year long industrial boom, had become quite prosperous. More importantly, even the average person in America was much wealthier than anything that the previous generations had seen. The increasing prosperity created a class of people who had the money and the desire to acquire personal vehicles that were different from the usual horse drawn carriages. At that point of time, personal vehicles came with all forms of propulsion, namely steam, electric and petroleum.

It was also the time when the era of construction of long-distance roads in United States was commencing in great earnest. As stated above, one of the reasons that helped the EV industry tide over the problem of low range was the lack of good quality, motorable roads outside of the cities in United States. The paucity of good highways meant that vehicles were used mainly for intra-city, short-range transport, thus negating the obstacle posed by the range problem associated with electric vehicles. Once motorable roads came into existence, the capacity of vehicles to traverse long distances was sure to become a factor affecting the decision of the consumers, and it surely turned out that way.

However, along with the development of the road sector, United States also saw the birth of another completely new industry, one that was going to have a pronounced effect on the fate of not just the electric vehicles industry, but also on the whole concept of long distance travelling by road. From the point of view of the rail road industry, during 1870s, America witnessed the rise of three great corporate heroes namely Cornelius Vanderbilt, the man who built the first great railroads industry in America, Andrew Carnegie, the man who provided cheap and good quality steel that could be used to build, among other things, railroads on large scale, and J. P. Morgan, richest man of the time, one who had the financial muscle to bankroll the construction of railroads in United States. These three people and the industries created by them, coalesced to create highly efficient long-distance railroad infrastructure in United States. In fact, such was the scale of this infrastructure that it soon emerged as the most preferred mode of transport to haul both men and materials.

Apart from construction of a sturdy network of highways, and the emergence of a highly efficient railway system, one factor that had the most damaging impact on the long-term prospects of the EV industry in the United States, was the rise of cheap and abundant oil. It is worth noting that after being discovered by Edwin Drake[20] in 1859 in a well in Pennsylvania, American oil sector witnessed steady stream of investments aimed at building the industrial capabilities to discover more and more of the extremely valuable liquid. Because of the millions of dollars' worth of investments into exploration, over a period of a tad less than 50 years, the face of oil industry in United States was transformed in a dramatic way.

In 1867, a businessman named Charles Pratt[21], one of the earliest champions of the petroleum industry in the United States, in partnership with his friend Henry Rogers, founded a company called Charles Pratt & Company. That company would later merge with Rockefeller's Standard Oil in 1874, thus laying the foundation for the biggest oil giant in the world. With the coming on stream of Standard Oil, American oil industry soon started building the scale needed to supply cheap and abundant gas to the consumers.

Incidentally, this was also the time that witnessed the rise of one of the greatest personalities in the automobile industry, Henry Ford[22], the man who turbo-charged the automobile industry, perhaps forever. Starting his career as an apprentice in James F Fowler & Brothers, Ford went on to rise to the position of Chief Engineer in the Company founded by Thomas Edison, who became so impressed with the engineering prowess of young Henry Ford that he became a lifelong friend and mentor to Henry Ford.

On June 16, 1903, at the age of 40, Henry along with 12 partners managed to pool together a sum of $28,000 to found a company called Ford Motor Company. Thereafter, automobile industry never remained the same ever again, at least not from the point of view of the EV industry. In 1908, eight years after the appearance of fleet of electric taxis in New York, Ford Motor Company introduced the historic Model T in the market. With the

20 https://time.com/4008544/american-oil-well-history/
21 https://catalog.pratt.edu/undergraduate/about/history/
22 https://corporate.ford.com/articles/history/henry-ford-biography.html

introduction of that product, and the consequent rapid gains accruing to the Ford Motor Company as a result of the economies of scale achieved through that product, nothing else in the market was in a position to compete with the company's products, in pricing, as well as in the quality of engineering that went into its products.

The success of Ford Motor Company spawned several automobile companies in Detroit. Like Ford, all those companies, to the detriment of the EV industry, focused on gasoline-powered vehicles. Thus, with the entry of every new company, and the resultant expansion in the scale of operations of the ICE vehicles industry, the gap between IC engine-based automobile industry and electric vehicles industry, in terms of the ability to produce vehicles at a price point that could be eagerly lapped up by the market, increased substantially. And, it has kept on increasing ever since.

This, coupled with ever expanding technological improvements in the internal combustion engine technology, meant that the cost of gasoline-powered vehicles was continuously declining, especially when compared to the electric vehicles, that were still mired with problems such as range, low speed, low power, and when compared to the rapid strides being made in the IC engine technology, very slow pace of improvement in battery and other underlying elements of the electric motor technology.

By 1912, the IC engine-based cars, led by Model T of Ford Motor Company, were available for as little as $650. On the other hand, at the same time, an electric roadster[23] was sold in the market at a price point of $1,750. Incidentally, in the same year, Charles Kettering, a notable inventor, introduced the electric starter, thus doing away with the need for the hand crank, a problem that deterred many people from buying gasoline powered vehicles. This improvement too contributed to the popularity of IC engine-based vehicles, as against electric vehicles.
Ironically, even the great Mr. Henry Ford, the man whose finest innovation, the much-celebrated Model T, had, in a way, sounded the death knell for the nascent EV industry in the US, had at one time toyed with the idea of building electric cars. It is true that gasoline cars were drawing a lot of attention in the market. But, people like Mr. Ford realized that it was not that the ICE vehicles did not have their own share of teething problems. Gasoline vehicles required a lot of manual effort, such as while changing gears, while constantly pressing the clutch, each time the gear was to be shifted or the brake was to be applied. Even to start a gasoline vehicle was no mean task, and involved lots of strenuous cranking. Moreover, they were also very loud and emitted extremely noxious fumes.

Electric cars didn't pose any of the challenges usually associated with other forms of traction such as steam or gasoline. Unlike steam or gasoline vehicles, they were not only surprisingly quiet, but also required very little maintenance effort and were also very clean. At around the time when Henry Ford was laying the foundations for his assault on the EV industry, cost of electricity was coming down massively. And, with the falling cost of production and rising consumer base, electricity grids needed to expand big and fast. With the expansion of the reach of the U.S. electricity grid, the task of charging the batteries that powered the electric cars became less and less problematic and more and more economical.

Many innovators noticed the huge potential, functional and financial, associated with the electric vehicles. Ferdinand Porsche[24], the founder of the sports car company by the same name, was one such person. In his attempts to exploit the market for electric vehicles, he came up with an electric car, the P1, in 1898. At around the same time that he was unveiling his all electric P1, he also introduced the first ever hybrid car, a vehicle that could be powered by both electricity as well as gasoline. Like many other innovators of the age, even the great Thomas Edison was impressed with the possibilities being promised by the electric vehicles. He seriously believed that electric vehicles were technologically superior to the IC engine-based vehicles. In his opinion, lot more improvements could be introduced on an electric vehicle, than on a gasoline one. Edison therefore commissioned a project to build better batteries. In this project to build next generation of batteries, Henry Ford, a friend of Edison, decided to become a partner.

However, much to the dismay of most of the enthusiasts of the idea of electric vehicles, the promises thrown by the EV concept were very slow to be converted into reality. On the other hand, perhaps because of the network effect, in so far as the gasoline vehicles were concerned, the time gap between the conception of an idea, and its actual manifestation on the road, was reducing with each passing year. Later on, as the gasoline vehicles industry gathered additional momentum, sucked in more investment and attracted more talent, the gap between the performance levels of an EV and a gasoline vehicle deepened even more.

23 https://www.energy.gov/articles/history-electric-car
24 https://www.porsche-holding.com/en/history/ferdinand-porsche/inventive-genius

From that time onwards till the turn of the 21st Century, EV industry could never really recover its lost glory vis-à-vis its competitor, the ICE vehicles industry. It is only now, in the 21st Century, after the emergence of Elon Musk and Tesla that the tables have begun to be turned all over again, this time in favor of electric vehicles. However, such is the scale of the manufacturing process acquired by the traditional automakers, that even today, not even Tesla can compete with them in so far as initial cost of acquisition of the vehicle is concerned.

Biden Administration's Energy Policies and its Consequences for World Economy

Oil prices, global economy and the automotive industry since the outbreak of the war in Ukraine:

In recent years, especially since the time of a change of Government in United States, there have been major changes in the energy policies of the United States. Everyone knows that the U.S. is the largest consumer of energy in the world. However, it must be noted that over the last decade or so, United States had emerged as a major exporter of energy in the world market. Therefore, anything that does not reduce domestic consumption of energy, mostly oil & gas, in the United States, but reduces the volume of the commodity that is supplied to the world market by the US, must be treated as a destabilizing factor in the context of the demand-supply equilibrium in the global oil market.

That is precisely what happened inside the US, ever since there was a change of guard in Washington DCin 2020, when the Democrats trounced Donald Trump led Republican party to cease the reins of the White House. In line with his pre-poll promises to bring down America's dependence on oil & gas, President Biden and his administration, went about the task of promulgating policies that aimed at curtailing the size of the footprint of American oil & gas industry, especially on the production and distribution side. Instead of first supplying the market with the alternatives to oil & gas, the new administration in United States went about the task of curtailing the domestic production capacity. This included steps like revoking the exploration licenses that had already been issued, not issuing any more oil exploration licenses, revoking the permission given to key energy transportation projects such as Keystone Excel Pipeline project, and increasing the taxes on the American fossil fuel sector etc.

While the American administration changed its orientation from fossil fuels to green energy, American economy did not do so. Therefore, in the absence of any countervailing action to balance the loss in production capacity, prices in US started shooting. And, in order to control the domestic price position, USA resorted to buying from the other producers. This meant that the quantity available to other buyers, more specifically those in the developing world, went down by that much. So, a particular line of policy decision of a major producer and consumer had the effect of stoking the inflation for the rest of the world.

Russia-Ukraine War And Its Impact On Oil Prices – The Much-Awaited Manna For The EV Industry

Another major factor that has had an overall inflationary effect is the ongoing war in Ukraine. In fact, at one point of time, at the height of Western response in the form of economic sanctions on Russia as a reaction to the Russian action in Ukraine, at one point of time, Brent went as far as $130 per barrel[25]. While for the oil producers like Russia, it was nothing short of a windfall, for the rest of the world, including the automakers, it was nothing short of catastrophe. It threw the budgets of many small and vulnerable countries into tailspin, from which many like Sri Lanka could just not recover.

The high oil prices have substantially dampened the demand for automobiles in most of the major markets of the world. But it is not just low demand that has been triggered by this conflict. In fact, the entire supply chain on which the global auto-majors rely, has been severely constrained by the unforeseen circumstances that have been unleashed by the war in Ukraine. The war and is multi-dimensional impact on the global economy has created a situation, where even the auto giants like Mercedes, Volkswagen, BMW etc. have been forced to resort to extreme measures like plant-shutdowns[26], and deferring production schedules to cope up with roadblocks like uncertainties in key components like computer chips etc.

However, it is not just the auto sector that has been severely impacted by the Russo-Ukraine war. Whether it is metals industry, shipping, agriculture, especially the export of agricultural commodities, fertilizers, aviation, banking & finance, tourism & hospitality, almost all sectors have had to bear the brunt of the ongoing conflict. But, at the base of the ongoing global inflationary pandemic is the instability caused in the price of fuels.

25 https://www.ft.com/content/424fd3ff-28e2-448e-ab38-535a282526be
26 https://www.euronews.com/next/2022/04/04/ukraine-war-car-prices-could-soar-even-higher-as-russia-s-invasion-worsens-supply-chain-cr

Whether it is countries in the global south or north, almost all the major non-producer oil consuming countries like India, China, most of Europe, United States etc, have been badly mauled by the frequent flare-ups in the global oil prices. And, as we know, during every episode of high inflation accompanied by an unstable job market, there is a marked decline in consumer confidence wherein consumers want to save more, to preserve the cash that they have. Naturally, consumers are now very conscious about how much it costs them to fill their fuel tanks. It is in this scenario that electric vehicles are finally forcing their stories back into the mind space of the consumers once again, a good 120 plus years after its triumphant march on the streets of New York in 1900, in the form of 60 strong, very large number for its time, fleet of taxis on the streets of the city.

We have finally reached a situation where the vast difference in operating costs of electric vehicles and gasoline-powered vehicles can no longer be ignored. In fact, from an operating cost point of view, according to an estimation done by the Advanced Vehicle Testing (AVT)[27] Centre of Idaho National Laboratory (INL), on an average, electric vehicles in the US cost around 60% less than vehicles running on gasoline.

The results thrown by this study are also endorsed by U.S. Department of Energy[28], thereby putting a stamp of approval on the reliability of this study. Another study conducted by University of Michigan has concluded that the average annual cost of operating an EV in United States is $485, while the same cost for gasoline powered vehicles is $1117. Here too, the results are by and large in agreement with the results obtained by the INL.

Other studies conducted by other agencies have obviously come up with different results. But those differences are more about the extent than about the overall direction. More or less, every study that we encountered as part of the research on this topic, came to the same conclusion, that cost of operating an electric vehicle is significantly lower than cost of operating a traditional vehicle, even if one were to factor in the probability of rising cost of electrical power. Data for Europe too has been similarly crunched and the results too are more or less the same.

	TYPE OF ENGINE	
	ELECTRIC ENGINE	**IC Engine**
CONSUMPTION PER 100 KM	15 kWh (electric power)	8 litres (Standard gasoline)
PRICE / UNIT	0.2 EUR / kWh	1.3 EUR / l
PRICE / 100 KM	3 EUR	10.4 EUR

Table – 1 Types of Engine
(Source: https://www.evexpert.eu/eshop1/knowledge-center/cost-of-operating-and-maintainingelectrocarev)

The Clear Turn Towards Electric Mobility As The Solution Of Choice

Many approaches such as nuclear, hydrogen, solar etc. have been considered at various points, as potential alternatives to fossil fuels. But, in so far as mass public transportation is concerned, almost all of these technologies are yet to deliver the results. Some like nuclear are just too scary to be adopted at mass scale, while some like wind, hydro, solar have not yet reached the technological maturity to be miniaturized or scaled up to the required degree. Only battery powered electric vehicles have been able to achieve the energy density[29] needed to successfully compete with internal combustion engines.

Public opinion the world over seems to favor efforts to create an environment where traditional auto industry and the EV industry would compete on equal terms i.e. one where they would be judged based upon their true costs of production, one that would include externality related costs too such as environmental cost. With that in mind, in order to level the field, Governments the world over are coming out with plans to provide subsidies to the automotive industry, at least till the time that it acquires parity in economies of scale vis-à-vis the traditional auto industry.

Therefore, it is not just Tesla, or any other single company, that is trying to exploit this situation. In fact, today we have a situation where almost all leading automakers, from Mercedes to Toyota, Volkswagen to General Motors, Ford to BMW, almost every automaker has rolled out ambitious roadmaps for their EV plans. Although the ICE age is continuing to maintain a dominant presence in the market, but that is more a result of legacy advantages than any unfolding story. On the contrary, if one were to go purely by the trends, momentum is shifting so decisively in favor of the EV industry. That some of the reports are predicting that by 2050, in about

27 https://avt.inl.gov/sites/default/files/pdf/fsev/costs.pdf
28 https://afdc.energy.gov/fuels/electricity_charging_home.html
29 https://energyeducation.ca/encyclopedia/Energy_density

25-30 years, EV vehicles would account for between 60-80% [30]of global automobile sales.

Road ahead for the EV industry – A near to medium term perspective

Just like products and companies, every industry too has a lifecycle, one during which it passes through a set number of phases in its life. The first of course is the birth of the industry, followed by a period of rapid expansion, a process that is strongly aided by feverish pitch of innovation & product development. Then comes the period of consolidation and attempts to rationalize the costs, mainly around ideas such as process reengineering, automation of the production process, rebalancing of the supply chain etc. And finally, when the societal need that the industry serves to satisfy, ceases to exist, and the industry is not able to locate another societal need to satisfy, its raison d'etre ceases to exist, leading to the ultimate death of the industry, or to a dramatic shrinkage in its scale of operations in order to establish a new equilibrium with the aggregate demand in a very small leftover market.

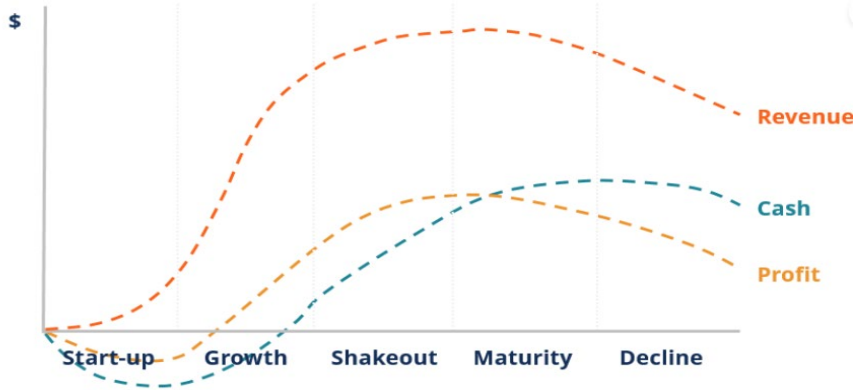

Fig -1 Industry Lifecycle Phases
(Source:https://corporatefinanceinstitute.com/resources/knowledge/strategy/industry-life-cycle/)

Such a thing happened in the past to industries like video cassette industry, pager industry, horse carriage manufacturing industry, chain armor manufacturing industry etc. Usually however, the need that the industry satisfies does not vanish; instead,the market usually develops a penchant for a new, usually a technologically superior product to satisfy the same societal need, and the existing players in the industry, instead of sticking around with their existing product lines, switch over to the new products to satisfy the same old need. For example, the societal need for instant communication has not disappeared, its just that people now prefer to satisfy that need with a vastly superior product, the mobile phone, than with the pager.

However, whether it is retooling of the entire industry to build the new products, or the dramatic shrinkage of the industry to remain in sync with the drastically reduced market size, in both cases, there is tremendous churning in the market. And, the process invariably leads to the elimination of certain players from the market and reorientation of the supply chain. Sometimes, the birth of a new technology dramatically speeds up this entire process.

EV industry at the moment is passing through a similar phase. Companies in the automobile market know that ICE vehicles do not have a very bright future. However, not all companies have an equal elbow room to man oeuvre with their production processes and supply chains. Some, like the erstwhile Hindustan Motors and Standard Motors, have so much of legacy burden that they simply do not find enough resources to pull-off what is required. As a result, they invariably die. But, the process of the reorientation of the industry continues, albeit with new players, new processes and new supply chains.

Evolution of the global economy over the last few decades, especially since the advent of the process of globalization in the early 1990s, has established certain new realities in the global supply chain. For example, companies have realized that in so far as large-scale manufacturing is concerned, OECD [31]countries are not the best places. Experience has taught companies that for large-scale manufacturing, ideal destinations are countries with very large, in fact, the larger the better, supply of adequately skilled manpower, large supply of raw

[30]https://www.forbes.com/sites/neilwinton/2020/10/20/electric-car-sales-will-accelerate-but-gasoline-power-will-retain-big-global-share/?sh=79969e2b6705
[31]https://www.oecd.org/about/

materials, well developed transport infrastructure, robust banking & credit system, excellent linkages with global sea lanes and a functional & trustworthy system of governance, including that of dispute resolution.

Over the years, a few locations in the world have emerged as the preferred destinations for companies to reroute their production chains. China, South-East Asia and now India have proven themselves to be destinations that satisfy, most, if not all of the conditions that companies look for, while taking momentous decisions, like the one involving relocation of their factories. Now, in fact, with the rapid up skilling of their workforce, developing countries are competing with the developed ones, even in areas such as destinations for high-tech manufacturing and other forms of high-end jobs such as designing, computer programming and R&D in general.

EV industry too has no choice but to take advantage of these existing realities of the market. In fact, EV industry has to be more cognizant of these, since it is not just another version of the automotive industry of yore; instead, it is a completely new industry standing at the crossroads of automotive, telecommunication, IT and precision engineering. Its supply and value chains are therefore far more complex than those of traditional automobile manufacturing companies.

It is precisely because of such reasons that even a pioneering company like Tesla hitched on to the idea of spreading its production capacity to countries like China, Australia and now, probably even India. In fact, given the advantages of economies of scale and the significantly lower cost of product development enjoyed by traditional automobile manufacturers, EV companies like Tesla have no other choice but to go ruthlessly after steps that could help them lower their overall cost of production vis-à-vis the traditional automobile manufacturers.

Because of all this, there is a huge opportunity for developing countries in general, and for countries like India in particular to register their presence strongly in the global supply chain by emerging as the destination of choice for companies, not just to manufacture their EVs there, but also to undertake even higher value added functions such as designing the semiconductor chips to enhance the performance of the vehicles, coding to extract the best out of the various computerized processes that run the vehicles, conducting research to build entirely new types of batteries, optimizing telecommunication processes to get the best out of new technologies such as 5G and IOT etc.

Among the developing countries, India's is in many ways a unique story that can be compared with no other country except perhaps China. Like China, India too is firmly on a path of transition of the energy base of her transport sector in general, and road transport sector in particular. The National Electric Mobility Mission Plan (NEMMP) 2020, aims at paving the way for a shift away from fossil fuel-basedmobilitytoanelectric-poweredone.Themissionsetsanambitioustargetof6–7millionelectric vehicles in the country by 2020 (TERI-2019).

On their part, countries like India would have to be continuously on their toes to come up with policy measures such as in taxation, subsidies, infrastructure improvement and up skilling of their population to retain and maximize their existing competitive advantages over richer countries such as those in OECD nations. Based upon the existing and expected policy lines of the Governments in India, China and South-East Asia, the countries are doing all that they can to remain in the reckoning.

However, a few recent developments in the geo-political arena are pointing to a new twist in the story. Tension is slowly but surely ratcheting up between China and the West over China's position on certain key international issues such as Hong Kong, Taiwan, South-China Sea, Japan, Korea and China's bellicose stance on several issues. On its part, the west seems to have finally given up on the dream of grooming China to be more democratic and cosmopolitan in a 'western' way. It is now increasingly more unwilling to let China run roughshod over western interests.

All this means that going forward, Governments in western countries, source of most of the FDI money sloshing around in the world, home of most of the companies contemplating offshoring related moves, and home base of most of the key technologies in the world, would not be very supportive to the idea of companies from their countries having key processes operated out of China. And, given the fact that India is almost a like to like, a person to person, substitute for China in almost all aspects, including in the scale of operations, India would be very nicely positioned to attract investment that would otherwise have gone to China, or is contemplating a movement away from China. In that sense therefore, for EV industry supply chain, India, if it can pull its act together quickly, would have a similar position as the one that was enjoyed by China for mass manufactured goods.

Consumers and EVs – An Evolving Relationship

	2020 Global Auto Consumer Study[32]											
	France		**Germany**		**Italy**		**UK**		**China**		**USA**	
Your greatest concern regarding all BPEVs?	2018	2020	2018	2020	2018	2020	2018	2020	2018	2020	2018	2020
Driving range	31%	28%	35%	33%	4%	27%	26%	22%	25%	22%	24%	25%
Cost/price premium	32%	22%	22%	15%	19%	13%	24%	16%	9%	12%	26%	18%
Time required to charge	11%	15%	11%	14%	18%	16%	13%	16%	12%	15%	10%	14%
Lack of charging infrastructure	16%	22%	20%	25%	44%	32%	22%	33%	18%	20%	22%	29%
Battery related safety concerns	4%	11%	5%	10%	7%	10%	6%	12%	22%	31%	8%	13%
Others	6%	2%	7%	3%	8%	2%	9%	1%	14%	0%	10%	1%

Table-2 Global Auto Consumer Study

Just like any other product from a radically different type of industry, consumer perception about electric vehicles was never going to be a simple, linear story of fast paced adoption. Just like any good story, the relationship between consumers and electric vehicles has been full of ups & downs, twists and turns, progress & retreat etc. As we have noticed in the previous sections of this paper, electric vehicles were initially nothing else but a result of insatiable scientific curiosity of pioneering innovators in 18th, 19th and early 20th Century. Like most other inventions that were appearing on the scene during those years, for ordinary people i.e. for consumers, electric vehicles too were nothing more than wondrous objects, things that amazed, but lacked any concrete application at the time.

Slowly, with the passage of time, with advancements in key technologies such as that of batteries, electric motor and power train, and with the product being better engineered to gain critical capabilities to handle real life assignments, people's attitude towards EVs slowly acquired the shape of cautious optimism and willingness to try, from one of sheer curiosity but nothing more.By early 20th century, just before the discovery of massive reserves of oil in Persia and Arabian Peninsula, there came a time, when EVs, in so far as product capability was concerned, were gaining parity with fossil fuel powered vehicles, at least in the context of intra-city commuting. The arrival of large fleets of EV taxis in New York in the early 20th Century, signaled a moment when it seemed as if EVs would take over from traditional vehicles to emerge as preferred alternative for transportation needs within the city premises.

However, as discussed in the previous sections of this paper, a few key developments such as good quality highway systems in US, discovery of oil, successful completion of key technological innovations such as self-start mechanism, advancements in IC engine technology, and above all, the development of assembly line method of mass manufacturing, created a situation where the tide, from being delicately balanced between EVs and ICE vehicles, turned decisively in favor of the later. In the face of increased and continuously increasing performance capabilities and price of ICE vehicles,incentives to switch over to EVs suddenly evaporated, and the IC engine vehicles were catapulted into the frontlines of the automotive stage.

When seen in the context of the advantages, such as ability to undertake long journeys without any range anxiety, ability to handle tough road conditions, lower cost of acquisition & operation, ease of servicing & repair, and above all, a promise of many more improvements in the near future, being offered by the ICE vehicles, consumer preference veered strongly in the direction that offered more, and promised to offer even more in the future. Since then, except for the modern era, when the EV technology has truly begun to deliver what it had so far been only promising, EV industry has not been able to gain consumer mind and wallet share, as much as ICE vehicles.

There have of course been periods, when jolted by events like oil shocks and deteriorating environmental concerns, both the automobile industry and the consumers have shown flickering signs of a rethink on their

[32]https://www2.deloitte.com/content/dam/insights/us/articles/22869-electric-vehicles/DI_Electric-Vehicles.pdf

preferred transportation solution. However, all such periods of uncertainty were temporary, therefore the circumstances that could have forced the consumers to shift permanently towards the EVs, could not be sustained. Therefore, in the absence of any adverse pricing and public perception related pressure, business environment for ICE vehicles practically continued in a business-as-usual manner. This ensured that the average consumer continued to treat the ICE vehicles just like EVs, as yet another form of transportation. This in turn had the effect of practically perpetuating the market and consumer mind-space dominance by traditional automakers, i.e. by ICE vehicles.

However, this situation where the ICE vehicles industry had established a near perfect harmony with its business environment finally changed during the early 2000s, in the aftermath of the outbreak of the 2nd Gulf War on March 20th, 2003. That event, as alluded to in the previous sections of this study, unleashed a chain of events that led to periods of sustained inflation in global oil markets. Eventually though, even this period was followed by reasonably long periods of cooling down of oil prices, triggered by factors such as appearance of reasonably priced and abundant shale oil, USA's emergence as a net exporter of energy, periods of global slowdown due to factors such as subprime crisis, outbreaks of epidemics such as Ebola and more recently Corona, an increasingly cornered and desperate Russia willing to flood the market with oil etc.It's only now that there is a fear in the market that the current round of fuel price inflation is going to become structural, rather than cyclical. This fear in turn has begun to show consequences in the market such as in the form of superior performance of stock prices of EV companies, or companies with strong EV portfolio, as compared to companies that are in the business of manufacturing ICE vehicles.

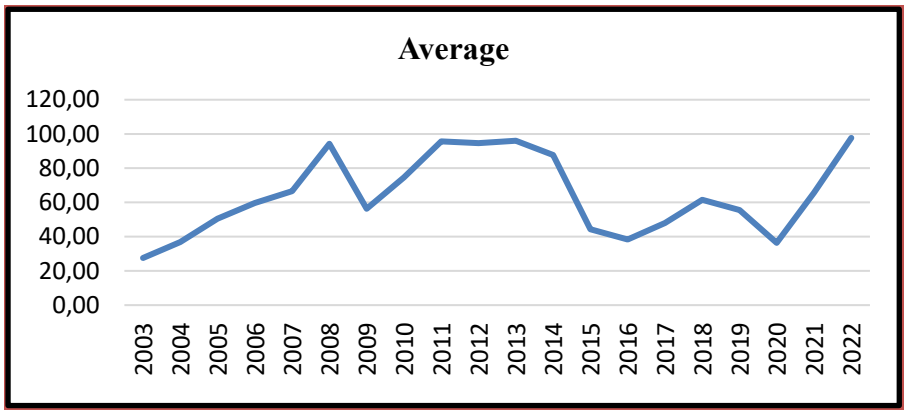

Fig-2 US Energy Consumption

However, the spike that was triggered by the 2nd Gulf war certainly proved to be more durable than most spikes of the past. This time, unlike in the previous eras, the upward trajectory in oil prices was also significantly steeper than anticipated. This fact can be verified from the oil price data[33]for the subsequent years, which shows that, from being just a tad over $27 per barrel in 2003, oil prices shot up to reach a five-year average of US $65 per barrel during 2005-09 and around US $90 during the period 2009-14. During the period 2014-19, the prices moderated a little, to hover at around US $50 per barrel, and for the period from 2020-2022,oil prices have been loitering at around US $ 66 per barrel, and for the five-month period of January 2022 to May 2022, the prices have continued to hang around in the vicinity of US $100 per barrel.

This kind of sustained high oil prices were bound to have an impact on the consumer preferences when it came to their choice of vehicles to meet their transportation needs. This time, together with pressure from high oil prices, consumers also had to contend with variables like unstable job markets, stagnating GDP growth rates, especially in the West, devastation of the market in the aftermath of the sub-prime crisis, stagnation in real wages etc. All this meant that the average consumer was far more sensitive towards any further squeeze on his wallet. As a result, in such an environment of uncertainty, all those options that could help the consumers save money, and EVs were certainly one of those, were slowly but surely picking up steam in the market. This conclusion is also supported by three pieces of data, one about the sales of EVs and hybrid vehicles in general, the other about the vehicle deliveries by EV only companies like Tesla, and finally a third one about the comparative sales performance of the two types of vehicles, in a timeseries kind ofsense

[33]https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=f000000__3&f=m

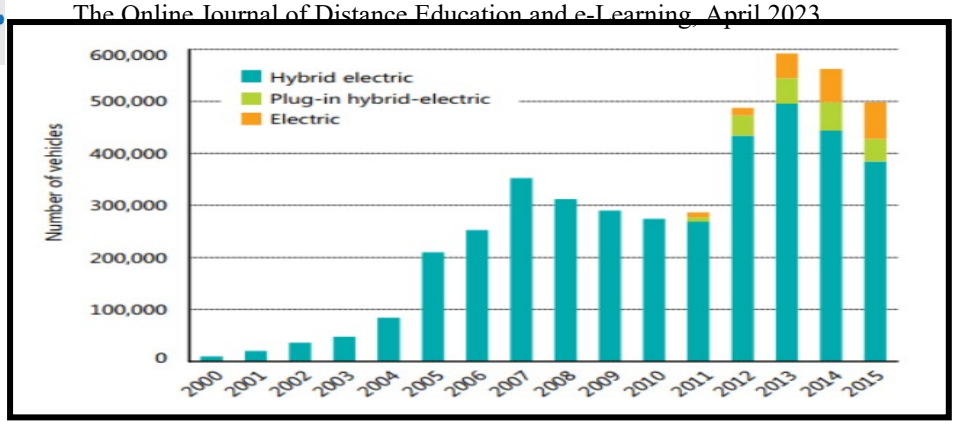

Fig-3 Graphics showing sales of EVs, plug-in and hybrid vehicles since 2000
(Source: U.S. Department of Energy, Energy Information Administration, Alternative Fuels DataCenter, Maps and Data, www.afdc.energy.gov/data as of October 2016)

Vehicle Deliveries by Tesla since 2012[34]

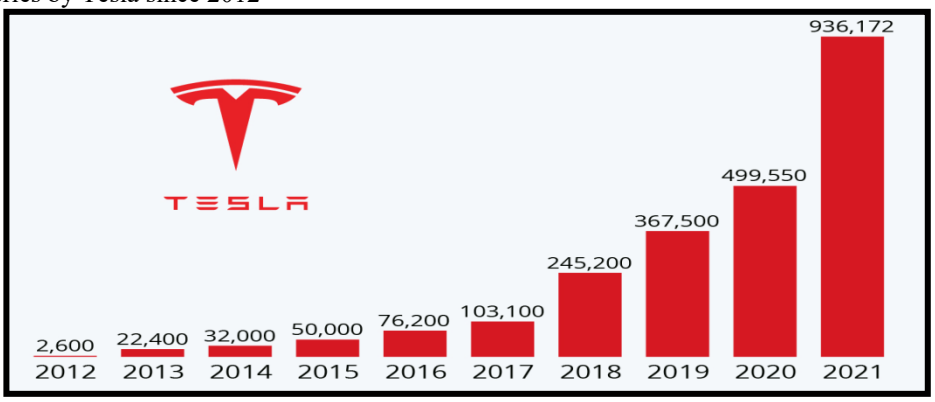

Fig- 4 Vehicle Deliveries by Tesla since 2012

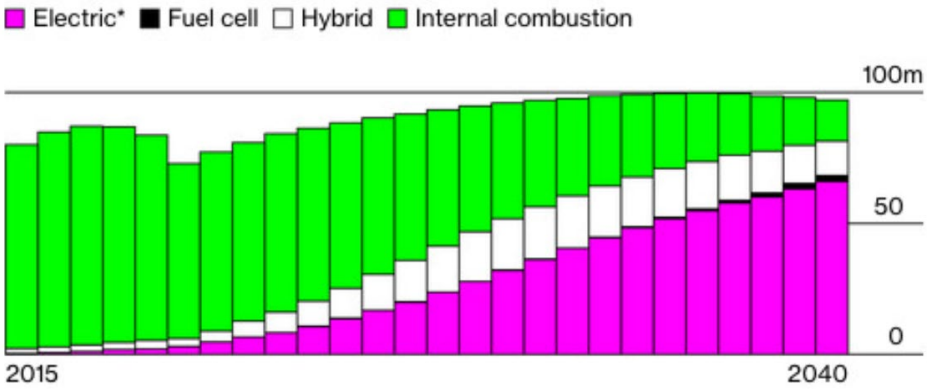

Fig- 5 Graphics showing the comparative sales of ICE vehicles and EV vehicles in a time series
(Source: Bloomberg NEF Economic Report)

From the three info graphics presented above, one can see a very clear trend, a secular rise in sales of EV vehicles from all kinds of automakers, and electric vehicles consistently outperform ICE vehicles in sales. The very fact that between 2012-2019, vehicle deliveries by Tesla have increased by over 300 times,definitely tells a story that cannot be ignored. Another point that comes out from the figures above is that, till today, in spite of so much of efforts to promote pure EVs, traditional ICE vehicles, still constitute a large part of overall vehicular sales.

Challenges/Barriers in EVs
Electric vehicles continue to be plagued in a big manner by the followingchallenges:

High upfront and downstream costs
- The upfront cost of buying an electric vehicle is significantly more than most of the vehicles powered by

[34]https://www.statista.com/chart/8547/teslas-vehicle-deliveries-since-2012/

traditional vehicles.

- During the initial years, maintenance too would be relatively costly, in view of factors such as expensive spare parts, inadequate vehicle & customer service network etc.
- In view of the very fast pace of technological developments in the EV industry, there is a need for highly specialized technicians for after sales services. But such technicians are very few in number and are very hard to find.

Supply chain dependence & challenges posed by nascent technological base

- The driving range of EVs in a single charge is a major concern for consumers, at least for those who undertake long journeys in their cars. Even though huge strides have been made to improve the range per charge, the difference between the range provided by traditional ICE vehicles and electric vehicles continues to be significant even till today.
- At the moment, rare earth elements like lithium are a big component of the batteries that power EVs. Other elements like nickel, phosphate manganese, graphite, and cobalt are also used to manufacture EV batteries. Lithium, being a rare earth element, is both expensive and quite difficult to get hold of. But the other elements mentioned here, are also not that abundant, and certainly quite expensive. On the other hand, internal combustion engines are made of abundant and inexpensive materials such as aluminum or steel, or a combination of the two (SonaliGoel). And, compared to the rare earth elements, and the other materials required to produce EV batteries, aluminum and steel are both quite abundant and relatively much easier to mine & smelt. EV industry therefore needs to find ways to reduce its dependence on materials like rare earths. Until that happens, the issue would continue to plague it.
- In view of the persistent range anxiety and the need to eliminate worries related to this issue, EV industry is desperately trying various measures. One of those measures is to enhance the size of the battery that could power the vehicles over longer distances. But a larger sized battery also means additional dead-weight for the vehicle, and therefore that much longer charging time, and hence that much more dependence on a robust battery charging infrastructure.
- Compared to the ICE vehicles, EV vehicles have to contend with one more issue. With usage, battery efficiency decreases, thus adversely affecting the performance of the vehicle. The only good fix for this problem is a full replacement of the battery. This creates its own set of problems such as significant cost for the consumer, and generation of a significant quantity of toxic waste. In fact, such is the toxicity associated with batteries that they end up creating their own environmental concerns. And, since one of the raison d'etre of EVs is reduction in pollution generated by transport sector, any significant generation of pollution by EVs puts the very logic of EVs under question mark.
- Battery, and consequently the vehicular performance, is affected by external factors such as ambient temperature and humidity. Other significant technical challenges are posed by factors such as dangers of fire due to overcharging, fire caused by collision, structural damage due to persistent vibration, dangers of short circuits etc. Although there are incremental improvements being achieved every day, yet these problems continue to pose significant challenges to the overall credibility of EVs vis-à-vis ICE vehicles.

Challenges posed by a policy environment that is out of sync with market realities

As mentioned in the opening sections of this paper, because of various factors, EV industry continues to suffer from multiple disadvantages vis-à-vis ICE vehicles.These disadvantages cumulatively have a big bearing on multiple fronts, most important of which is the total cost of ownership for the end customer. Factors like significantly lower economies of scale, need for very high R&D investments, dependence on scarce and expensive inputs, ultimately result in higher cost of production, unstable supply chain of key materials and components, inadequately developed battery charging infrastructure etc.

Most of these challenges cannot be optimally solved by the EV industry alone. In fact, there are steps, such as reduction in R&D cost by creating dedicated, publicly funded research institutions to aid the R&D efforts of the industry that only a well-designed Government initiative can accomplish. Similarly, when seen in the context of the environmental and economic benefits generated by the EV industry, and the damaging impact of the ICE vehicle on both these fronts, there is a need for a taxation milieu that could help level the playing field between the two industries. The Government also has a massive role to play when it comes to securing a dependable supply line of key materials, such as lithium, and components such as computer chips. In the absence of an environment where the Government shows willingness to take proactive measures to smartly play the role that only a Government can play, it is very difficult for any country to attract sizeable investments from EV industry.

Often, given their contribution to the economy, to the exports, to job creation, and to the health of the public tax kitty, the hold of the ICE vehicles industry on the thought process of the policy makers is so intense, that many a times the EV industry faces an uphill task to convince the policy makers to discriminate in its favor, at the cost of the ICE vehicle industry. However, no matter how tough this task is, EV industry has no other choice but to proactively engage the policy makers, and to impress upon them the need to act in favor of EV industry.

Impact of EVs on Employment & Economic Growth

With the coming of age of the concept of electric cars, it is being speculated that even a company like Apple is contemplating its foray into EV industry. And, if Apple enters the market, what would prevent a Samsung, or a Google too to take a plunge? As it is, given its heavy reliance on technology such as electronics and computer programming, various tech companies are already active in the EV space, if not as an OEM, then certainly as providers of key components and solutions. Moreover, given the big plans of the traditional automakers for their EV ambitions, one thing is for sure, the EV market is set to experience a huge boom in investments. And, as we know from basic economics, whenever an entire industry goes on an investment spree, the result is always positive for the economy.

Huge investments are expected not just in plants to produce the vehicles, but also in factories to produce the key components, in downstream facilities such as in charging infrastructure etc. In fact, in large continental sized countries like the U.S., China and India, the need for investments in charging infrastructure alone is expected to be so high, that it by itself presents a hugely lucrative business opportunity to companies that may not have had anything substantial to do with auto industry so far.The interest shown by Elon Musk to start a plant in India, if it materializes, would trigger many more companies to invest in India. It is widely expected that if Musk decides to invest in India, it would have a similar impact on India's EV manufacturing landscape, to the one that was seen when Samsung and Apple committed huge investments to produce mobile phones in India. These investments, and other similar investment opportunities elsewhere in the world, such as in Giga-factories in China, Australia and possibly in India too, would not only provide investment and growth opportunities to companies themselves, but also to the countries that would be hosting these investments.

Not just that, countries like India, that, during the 1970s and 80s, missed the bus of industrialization that was triggered in the wake of decision taken by western corporations to invest big in emerging markets, to begin with, in East Asia, later on in South-East Asia and China too. India joined the party quite late. By that time, a lot of investment had already been committed into the countries that showed initiative when it mattered. But, during this latest round of massive capital reallocation on a global scale, when global industry is once again expected to invest huge sums to realign its supply lines, countries like India would have the opportunities to attract a large part of that investment.

And, just like what had happened during the long period of the expansion of the auto industry after the end of the 2nd world war, growth of EV industry too would necessitate setting up of maintenance, repair and service facilities. These would be the indirect employment opportunities that would be created as a result of the boom in the EV industry. Besides, if past experience with the ICE vehicles industry is any indicator, number of jobs created in such downstream facilities can be expected to be substantially higher than the numbers created inside the factories that would produce the vehicles themselves.

And, as noted in the previous section, the relatively small number of the highly trained technicians needed for these jobs, would spawn the growth of institutions to train such mechanics, or existing technical training institutions such as polytechnics, would create entirely new courses to create the manpower to handle these roles. Whatever be the case, no matter which part of the auto supply chain one is talking about, the coming boom in the EV industry would create vast demand for a host of new skills. Therefore, there is a lot that the youth can look forward to, in terms of good paying, stable jobs in companies in EV space.

Impact of the Rise of EV Industry on Environment and Public Health

Environment and health related impact of EVs

With every passing day, with larger and larger number of experts analyzing vast data troves on air pollution and its impact on health of living beings, vast majority of experts have begun to agree that air pollution poses a deadly threat to global health. Data on this is unequivocal. Information collated from multiple sources, from multiple countries spread across multiple geographies, is pointing out to the fact that worldwide, one in nine pollution related deaths are directly linked to air pollution. Exposure to particulate pollutants such as PM2.5[35], a major constituent of vehicular pollution, is widely regarded as of particular concern in this regard.

Data gathered over decades is showing that rising instances of deadly health conditions such as stroke, heart diseases, lung diseases and cancer can be attributed to rising levels of exposure to particulate pollutants such as PM2.5. High levels of other similar fine particles also contribute to other illnesses such as diabetes, high blood pressure and bronchitis. Quite a few studies have also come to the conclusion that there is a strong association between prevalence of these pollutants in the environment of a place and impairment of cognitive development

[35]https://www.epa.gov/air-trends/particulate-matter-pm25-trends

of children in that place.

Since EVs do not emit exhaust gases that are full of polluting particles, every ICE vehicle that an EV displaces from the road, means one less source of air pollution on the road. Thus, at an aggregated level, the more petrol and diesel vehicles that are displaced by EVs, the better it is for the environment. Thus, a growing fleet of EVs on the road is by definition a better sign for the environment.

However, it must be kept in mind that EVs are not completely free from pollution. As discussed in the previous section of this document, at the end of the day, the batteries that power the EVs, are made out of materials that cause a lot of pollution while being mined and refined. In addition, at the end of their lifespan, batteries have to be replaced. Therefore, the pollution that can be attributed to the batteries is a recurring phenomenon, although not at a very high frequency.

In addition, batteries have to be charged. Hence, the larger the fleet of EVs, the stronger the demand for electricity from a sector that had so far not been a source of any significant demand for electricity. And, as we know, even today, the most common fuels used to power electricity plants are coal and natural gas, one a huge source of pollution and the other a relatively smaller source, but one nevertheless. Therefore, it is important to keep in mind the fact that large scale introduction of EVs would not eliminate environmental pollution; it would only reduce it significantly.

But given the current state of heightened global concerns around climate change, the world seems more than happy to settle for an option which, although not free from pollution, goes a long way towards reducing the levels of pollution that can be attributed to transportation sector.

Statistical Analysis of Key Parameters Driving the EV Industry

Nature of the statistical relationship between number of vehicles on the road, and public health:

Entity	Year	No. of health complications attributable to Air pollution
G20	2005	42,19,760
G20	2006	41,88,783
G20	2007	41,89,905
G20	2008	42,37,761
G20	2009	42,19,409
G20	2010	42,41,736
G20	2011	42,69,176
G20	2012	42,78,865
G20	2013	42,96,609
G20	2014	42,86,600
G20	2015	42,97,452

Table-2 Health Complications due to air pollution in G20 countries (2000 – 2015)

Entity	Year	Number of vehicles in use
G-20	2005	7,96,05,505
G-20	2006	8,25,33,723
G-20	2007	8,49,90,492
G-20	2008	8,77,25,382
G-20	2009	8,99,82,673
G-20	2010	9,29,30,157
G-20	2011	9,62,04,547
G-20	2012	9,97,47,027
G-20	2013	10,34,25,317
G-20	2014	10,75,37,388
G-20	2015	11,14,77,399

Table-4 Total number of vehicles in use in G20 Countries

Entity (1)	Year (2)	Health issues due to Air pollution (3)	Number of vehicles in use (4)	Correlation between (3) & (4)
G20	2005	42,19,760	7,96,05,505	0.9150
G20	2006	41,88,783	8,25,33,723	0.9373
G20	2007	41,89,905	8,49,90,492	0.9188
G20	2008	42,37,761	8,77,25,382	0.9111
G20	2009	42,19,409	8,99,82,673	0.9016
G20	2010	42,41,736	9,29,30,157	0.8721
G20	2011	42,69,176	9,62,04,547	0.8327
G20	2012	42,78,865	9,97,47,027	0.6533
G20	2013	42,96,609	10,34,25,317	0.0575
G20	2014	42,86,600	10,75,37,388	0.9150
G20	2015	42,97,452	11,14,77,399	0.9150

Table - 5 Statistical operation to delineate the relationship between public health, and number of vehicles in use

Interpretation of Results

The results indicate that on an average, there is a near perfect direct and positive correlation between the number of deaths that can be attributed to air pollution and the number of vehicles on the road. This indicates a possible line of policy action to reduce the damage being caused to public health due to air pollution. Based upon these numbers, we can say that if the number of ICE vehicles on the road comes down drastically, the adverse effects of pollution on public health too can be substantially reduced.

Nature ofthe statistical relationship between public healthand fortunes of global automobile industry

Year	Total world in '000
2000	40,732
2001	40,144
2002	41,215
2003	41,782
2004	42,832
2005	44,892
2006	48,136
2007	49,997
2008	48,788
2009	42,296
2010	50,938
2011	51,998
2012	55,220
2013	56,432
2014	56,417
2015	55,770

Table – 5 Global automobile production (2000–2015)

Entity (1)	Year (2)	Sickness due to air pollution (3)	Sickness due to particulate matter pollution (4)	Total (5)
G20	2000	13,95,87,234.55	5,71,63,369.82	19,67,50,604
G20	2001	13,77,13,520.03	5,79,36,516.17	19,56,50,036
G20	2002	13,64,07,955.20	5,89,64,775.45	19,53,72,731
G20	2003	13,45,93,804.55	5,97,81,367.27	19,43,75,172
G20	2004	13,23,54,087.40	6,03,28,696.64	19,26,82,784
G20	2005	13,13,05,581.74	6,14,05,584.72	19,27,11,166
G20	2006	12,93,53,168.11	6,19,43,523.26	19,12,96,691
G20	2007	12,82,62,592.08	6,34,20,925.01	19,16,83,517
G20	2008	12,81,67,750.42	6,56,76,469.70	19,38,44,220
G20	2009	12,66,57,357.42	6,74,01,624.63	19,40,58,982
G20	2010	12,62,51,048.58	6,94,14,878.25	19,56,65,927
G20	2011	12,59,26,177.12	7,14,89,562.60	19,74,15,740
G20	2012	12,54,12,617.88	7,38,71,220.19	19,92,83,838
G20	2013	12,44,96,068.64	7,61,08,192.70	20,06,04,261
G20	2014	12,25,44,700.48	7,73,28,747.91	19,98,73,448
G20	2015	12,21,13,905.90	7,83,94,528.18	20,05,08,434

Table- 6 G-20: Data on health problems caused by pollution attributable to transportation sector

Year (1)	Total no. of automobile in the world (in '000) - (2)	Health Complications (3)	Correlation bet. (2) & (3)
2000	40,732	19,67,50,604	0.61814
2001	40,144	19,56,50,036	0.68140
2002	41,215	19,53,72,731	0.73380
2003	41,782	19,43,75,172	0.78331
2004	42,832	19,26,82,784	0.81403
2005	44,892	19,27,11,166	0.80182
2006	48,136	19,12,96,691	0.77734
2007	49,997	19,16,83,517	0.77522
2008	48,788	19,38,44,220	0.85356
2009	42,296	19,40,58,982	0.86313
2010	50,938	19,56,65,927	0.80253
2011	51,998	19,74,15,740	0.76033
2012	55,220	19,92,83,838	0.73402
2013	56,432	20,06,04,261	0.73284
2014	56,417	19,98,73,448	0.71209
2015	55,770	20,05,08,434	0.65940

Table- 7 Statistical operation to establish relationship between global automobile production on one hand, and health complications that are attributable to air pollution on the other

Interpretation of Results

The results indicate that the correlation between the health complications attributable to air pollution coming from the transportation sector, and the total number of vehicles produced in the G-20 group of nations, is quite strong in a positive direction. This means that the fortunes of global automobile industry (ICE vehicles industry) are directly proportional to the output of greenhouse gases in the world. In other words, unless the product portfolio currently being produced by the global automotive industry changes from ICE vehicles to EVs or any other non-polluting variant, the more the automobile industry flourishes, the worse-off would be the news for the

global climate change control efforts.

Impact of the ice vehicles industry on the emission of greenhouse gases

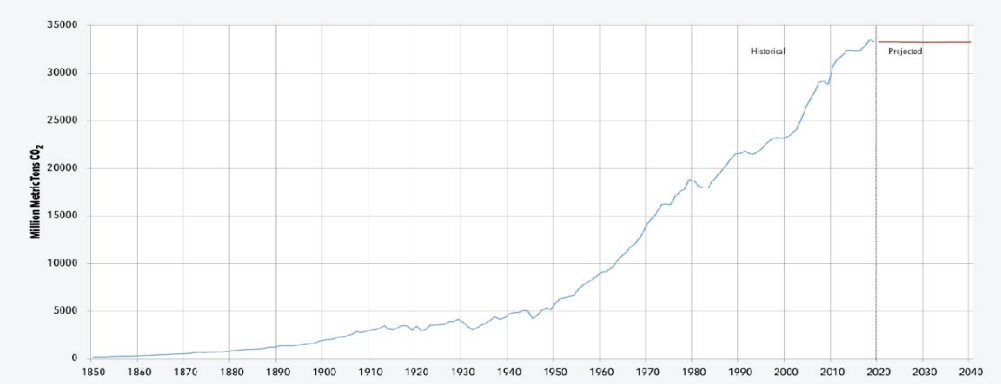

Fig- 6 Global Carbon Dioxide Emissions – 1850 – 2020

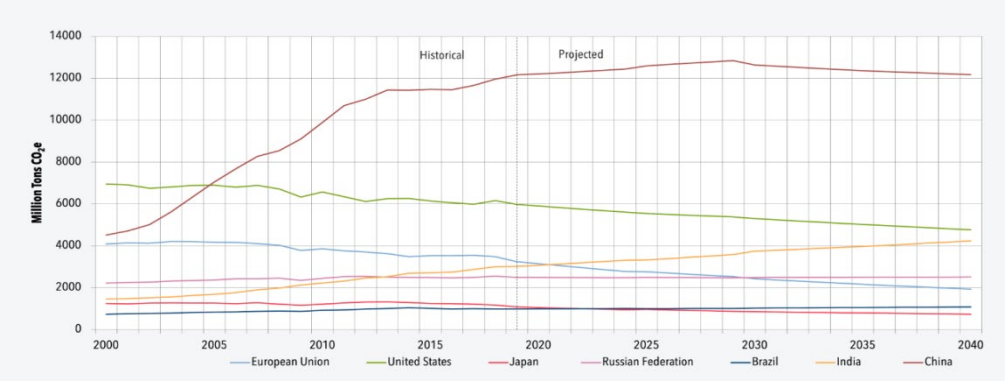

Fig- 7 Greenhouse Gas Emissions for Major Economies, 2000–2040
(Source:World Energy Outlook (International Energy Agency, 2020),CO2 Highlights (International Energy Agency, 2021), Global Non-CO2 Emission Projections (U.S. Environmental Protection Agency, 2019))

Sl. No.	Country / Entity	Avg. Emissions / Year	Avg. no. of vehicles in use / year	Emission per vehicle per year (in tonnes)
1	Argentina	17,11,48,408.71	1,01,32,250	16.89
2	Australia	39,51,68,366.62	1,53,45,763	25.75
3	Brazil	43,41,72,316.62	3,25,81,385	13.33
4	USA	5,63,90,87,209.86	25,03,11,189	22.53
5	Mexico	45,58,32,844.90	3,02,92,940	15.05
6	Canada	56,96,73,425.81	2,11,65,740	26.91
7	China	7,81,51,96,754.48	8,56,62,234	91.23
8	India	1,73,59,84,966.33	1,87,77,818	92.45
9	Japan	1,23,23,87,977.29	7,60,29,624	16.21
10	Germany	82,47,04,698.86	4,66,06,398	17.70
11	Indonesia	45,00,79,345.90	1,59,07,248	28.29
12	France	36,69,50,254.33	3,76,22,818	9.75
13	UK	48,84,64,519.95	3,58,28,228	13.63
14	Italy	42,18,15,145.90	4,11,97,799	10.24
15	EU	3,85,09,78,209.24	28,59,15,520	13.47
16	Saudi Arabia	49,06,35,125.10	49,71,172	98.70
17	Turkey	32,20,17,678.38	1,15,91,098	27.78
18	South Korea	56,73,78,226.81	1,79,63,305	31.59
19	South Africa	44,73,21,590.95	83,16,188	53.79
20	Spain	29,88,64,379.67	2,70,80,403	11.04
	Average global emission per vehicle per year			**31.82**

Table - 8 Total Emissions Vs No. of ICE vehicles on the road – Trend over the years

The Expected Boom in the EV Industry and its Impact on Emissions

In 2021, EVs consumed around 55 terawatt-hours of electric power, 10% of which was used by the two-wheelers on the roads of China. When seen on the larger canvass of total power consumption by different sectors of global economy during 2021, not more than 0.5% of global output of electricity was utilized by the electric vehicles. Current calculations suggest that during 2021, increased usage of EVs prevented around 40 million tonnes of carbon-dioxide equivalent of GHG emissions from being discharged into the atmosphere. Sceptics often say that EVs are not entirely free of GHG emissions. In this context, it must be noted that the largest part of the emissions that can be attributed to EVs, take place almost entirely during the production phase, i.e. while the vehicles are being manufactured. Once on the road, they consume only a fraction of the power that is required to produce them. On the other hand, ICE vehicles not only consume much more power during the production phase, but when they are on the road, they emit substantially more GHGs over their lifetime. Overall, in the larger scheme of things, the public debate around which type of vehicle is better for the environment, seems to be decisively turning in the favor of EVs.

Period	Expected CAGR	Units Sold	Avg. global emissions/vehicle/year (in tonnes)	Emissions saved (in tonnes)
2021	108%	67,50,000	31.82	21,47,85,000
Projections				
2022	29%	87,07,500	31.82	27,70,72,650
2023	29%	1,12,32,675	31.82	35,74,23,719
2024	29%	1,44,90,151	31.82	46,10,76,597
2025	29%	1,86,92,294	31.82	59,47,88,810
2026	29%	2,41,13,060	31.82	76,72,77,565
2027	29%	3,11,05,847	31.82	98,97,88,059
2028	29%	4,01,26,543	31.82	1,27,68,26,596
2029	29%	5,17,63,240	31.82	1,64,71,06,308
2030	29%	6,67,74,580	31.82	2,12,47,67,138

Table – 9 Expected Emission from EVs

Note: The expectation of 29% of annual CAGR in sales growth comes from a Deloitte report [36]on EV industry.The figure of 31 tons of annual emissions per vehicle per year comes from the computations done in this study

Interpretation

By 2030, adoption of EVs at the current rate would prevent an emission of more than 2 billion tons of greenhouse gases (GHGs) into the atmosphere.

Over the next 20 years or so, if EV industry continues to grow at 29%, which is very unlikely, and ICE vehicles industry, riding on the strength of demand coming from emerging markets, continues to grow at the rate of around 8-10%, the total number of electric vehicles on the road would exceed the total number of ICE vehicles somewhere around 2050. However, in the near future, given the negative correlation that we have seen between oil prices and ICE vehicle sales, and the expectation of continuously rising oil prices, it is very much likely that the rate of growth of ICE vehicles in the near future would plummet substantially. So, in that kind of situation, even if the rate of growth of EV industry falls from the rate that is expected to persist upto 2030, the fall in the rate of growth of EV sales would be more than offset by an even sharper fall in the rate of growth of ICE vehicles.

By 2030, EV industry sales are expected to be 10 times of what it was in 2021

	Price of Oil in US $ per barrel[37]	G 20 auto production in '000[38]	Correlation bet. (1) & (2)
2000	26.71	55,554	0.71725481
2001	21.89	53,677	0.523245253

[36]https://www2.deloitte.com/content/dam/insights/us/articles/22869-electric-vehicles/DI_Electric-Vehicles.pdf
[37]https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=f000000__3&f=m
[38]https://www.bts.gov/content/world-motor-vehicle-production-selected-countries

2002	22.50	55,512	0.447895198
2003	27.55	57,075	0.345256581
2004	36.86	59,463	0.209915294
2005	50.53	62,031	0.061784123
2006	59.65	65,258	-0.052866638
2007	66.56	68,313	-0.125957987
2008	94.22	65,045	-0.16336097
2009	56.31	56,894	-0.051238758
2010	74.64	71,641	-0.574818115
2011	95.69	73,663	-0.766040508
2012	94.63	77,535	-0.827376825
2013	96.00	80,884	-0.910358777
2014	87.71	83,208	-0.869613626
2015	44.31	84,382	-1

Table - 10 Relationship between rising oil prices and fortunes of traditional automobile industry

Interpretation

The results in the table above narrate a very interesting story. Between 2000 to 2005, auto production figures moved in tandem with movements in oil prices. This means that during this period when the price of oil nearly doubled, the auto production figures continued to have a small positive correlation with the oil price and continued to rise, albeit at decreasing rates. But, in 2006, the year that saw a nearly 20% rise in oil prices, the correlation between oil prices and auto production figures became negative. This means that from this point onwards, the auto production figures and oil prices began to have an inverse proportionality. And, the strength of this negative correlation has continued to rise ever since. This means that between 2006 and 2015, every increase in oil prices began to have a negative impact on the production of the auto industry.

Year	**Tesla's annual revenue in USD[39][40] (1)**	**Avg. crude oil prices for the year in USD per barrel[41] (2)**	**Tesla's avg. yearly stock price[42] (3)**	**Correlation bet. (1) & (2)**	**Correlation bet. (2) & (3)**
2008	1,50,00,000	94.22	3.46	0.48679	0.38543
2009	11,20,00,000	56.31	4.07	0.60450	0.47009
2010	11,70,00,000	97.68	4.79	0.59682	0.99457
2011	20,40,00,000	65.67	5.51	0.81153	0.99480
2012	41,30,00,000	36.37	6.24	0.85995	0.99499
2013	2,01,00,00,000	55.57	21.73	0.84252	0.99514
2014	3,20,00,00,000	61.52	45.58	0.84699	0.99535
2015	4,05,00,00,000	47.95	46.36	0.88431	0.99559
2016	7,00,00,00,000	38.37	42.35	0.86951	0.99587
2017	11,76,00,00,000	44.31	62.82	0.79445	0.99628
2018	21,46,00,00,000	87.71	62.84	0.86479	0.99691
2019	24,58,00,00,000	96,00	55.42	1.00000	0.99858
2020	31,54,00,00,000	94.63	315.22	1.00000	0.99858
2021	47,23,20,00,000	95.69	805.44	1.00000	0.99996

[39]https://ir.tesla.com/#quarterly-disclosure
[40]https://www.macrotrends.net/stocks/charts/TSLA/tesla/revenue
[41]https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=f000000__3&f=m
[42]https://ir.tesla.com/#quarterly-disclosure

Table – 11 Relationship between rising oil prices and fortunes of Tesla, a representative of EV makers
Note-Tesla got listed on the stock exchange only in 2010. So, the stock price that has been mentioned here for the period 2008-2009, is an extrapolation based upon the growth shown by Tesla's shares between 2010–2011 and 2011-2012. The authors deliberately did not take the CAGR of Tesla's stocks over a longer period since after a few years of its listing, growth in Tesla's share price became exponential and hence could not have been predicted.

Interpretation

With respect to the relationship between oil prices and Tesla's revenues: When seen over the period from 2008 to 2021, the statistical relationship between Tesla's annual revenues, and the average annual crude oil prices, is given by the correlation between these two sets of numbers over this period. As the numbers presented in the table above show, there is a positive correlation between annual revenues of Tesla, and the average annual crude oil prices in the international market during this period. And, what is even more noteworthy about this relationship, is the fact that as we approach the end of the period, the strength of the positive correlation between these two sets of numbers is increasing.

With respect to the relationship between oil prices and Tesla's stock prices: Between these two variables, the nature of the statistical relationship is more or less the same as the one that exists between the company's revenues and oil prices. However, when compared with the relationship that exists between its revenues and oil prices, in this relationship, i.e. the one between oil prices and price of Tesla's stock, one can notice that the numbers clearly indicated a very-very strong possibility of future growth. The market was however slow to notice this trend, since the period of almost near perfect positive correlation between the two sets of numbers can be seen from 2010 itself, whereas the period of hyper-growth in Tesla's stocks began only from 2013, a good three years after the data began to indicate that such a thing was going to happen.

Impact of Rise of EV Industry on Bop Situation, Interest Rates and the Geo-Politics around Oil – An Indian Perspective

For the purpose of this analysis, we shall take the example of India, as a typical representative of the developing countries. We are deliberately choosing India because, in addition to being a developing country, India is also a country with the size and scale required to swing big decisions on investments of global corporate chieftains. And, in order to elucidate our point, we shall seek to establish relationship between data on balance of payments, current account deficits and rates of interest. Therefore, let us first take a look at the relevant pieces of data in this regard.

Period	Value of crude oil imported by India (in USD)
2012-13	144.52
2013-14	143.64
2014-15	116.44
2015-16	65.92
2016-17	70.71
2017-18	87.37
2018-19	114.04
2019-20	102.75
2020-21	59.48
2021-22	122.45

Table – 12 Crude Oil Imports by India – 2012-13 to 2021 – 22
(Source: Department of Commerce's Export Import Data Bank)

Date	Deficit ($M)	Deficit (%GDP)
2020-21	-3,40,318.00	-0.13
2019-20	-2,12,180.00	-0.07
2018-19	-1,72,334.00	-0.06
2017-18	-1,65,114.00	-0.06
2016-17	-1,63,390.00	-0.07
2015-16	-1,51,565.00	-0.07
2014-15	-1,44,188.00	-0.07

2013-14	-1,29,963.00	-0.07
2012-13	-1,37,979.00	-0.08

Table: 13Current Account Deficit (CAD) of India – 2012-13 to 2021-22
(Source: Department of Commerce's Export Import Data Bank)

RBI Repo Rate History			
Year	**Date**	**RBI Repo Rate**	**Avg. rate for the year**
2022-23	05-08-2022	5.40%	4.54%
	08-06-2022	4.90%	
	04-05-2022	4.40%	
	08-04-2022	4.00%	
	10-02-2022	4.00%	
2021-22	08-12-2021	4.00%	4.00%
	09-10-2021	4.00%	
	06-08-2021	4.00%	
	04-06-2021	4.00%	
	07-04-2021	4.00%	
	05-02-2021	4.00%	
2020-21	04-12-2020	4.00%	4.26%
	09-10-2020	4.00%	
	06-08-2020	4.00%	
	22-05-2020	4.00%	
	27-03-2020	4.40%	
	06-02-2020	5.15%	
2019-20	05-12-2019	5.15%	5.62%
	04-10-2019	5.15%	
	07-08-2019	5.40%	
	06-06-2019	5.75%	
	04-04-2019	6%	
	07-02-2019	6.25%	
2018-19	01-08-2018	6.50%	6.25%
	06-06-2018	6.25%	
	07-02-2018	6.00%	
2017-18	02-08-2017	6.00%	6.00%
2016-17	04-10-2016	6.25%	6.38%
	05-04-2016	6.50%	
2015-16	29-09-2015	6.75%	7.31%
	02-06-2015	7.25%	
	04-03-2015	7.50%	
	15-01-2015	7.75%	
2014-15	28-01-2014	8.00%	8.00%
2013-14	29-10-2013	7.75%	7.50%
	20-09-2013	7.50%	
	03-05-2013	7.25%	
2012-13		7.00%	7.00%

Table – 14 History of Interest Rates in India – 2012-13 to 2021-22

(Source- Monetary Policy Measures, Published March 2006 & RBI's Database on Indian Economy)

Period	Value of crude oil imported by India (in USD) (1)	Current Account Deficit (in USD) (2)	Correlation bet. (1) & (2)	Repo rate -2011-12 to 2020-21- (3)	Correlation bet. (1) & (3)
2020-21	59,48,00,00,000	-3,40,31,80,00,000	0.57	4.00%	0.6550
2019-20	1,02,75,00,00,000	-2,12,18,00,00,000	0.57	4.26%	0.5297
2018-19	1,14,04,00,00,000	-1,72,33,40,00,000	0.57	5.62%	0.6785
2017-18	87,37,00,00,000	-1,65,11,40,00,000	0.58	6.25%	0.8325
2016-17	70,71,00,00,000	-1,63,39,00,00,000	0.56	6.00%	0.8169
2015-16	65,92,00,00,000	-1,51,56,50,00,000	0.51	6.38%	0.7140
2014-15	1,16,44,00,00,000	-1,44,18,80,00,000	0.64	7.31%	-0.0713
2013-14	1,43,64,00,00,000	-1,29,96,30,00,000	1.00	8.00%	-0.8971
2012-13	1,44,52,00,00,000	-1,37,97,90,00,000	1.00	7.50%	-1.0000

Table – 15 Establishing statistical relationship between crude oil import bill, current account deficit and repo rate

Interpreting the numbers

- Correlation for the two sets of numbers, i.e. between crude oil imports and CAD is positive throughout the period under study. Not only that, the strength of the correlation is found to be increasing with increasing levels of crude oil imports. This means that, unless there are certain other factors at work, if India simply controls the import of crude oil, its current account deficit would automatically come under control.
- Correlation between figures for value of crude oil imports, and the repo rate for the corresponding period, shows that, for the first couple of years of the period under study, there was a strong negative correlation between the two variables. This suggests that there were certain other factors at work, perhaps inflow of dollars into India through FDI/FPI or remittances route. These factors, it seems, had such a huge weight that they completely negated the effect of negative correlation between the two factors. This relationship would however need greater investigation before one could zero down upon it as the final cause behind the behaviour of the numbers in the table above.
- Based upon the numbers in the table above, one can say that after 2014-15, the effect of other extraneous factors moderated significantly.
- In addition, the data in the table above, says that fuel imports cost, on an average, around US$100 billion per year. For India, a country that till recently, was struggling for foreign exchange, this kind of sum continues to be a large drain on her forex resources. Even today, when people say that BoP situation of India is comfortable, it is said only in a comparative sense. India neither has the comfort of a reserve currency like USA or EU countries, nor does it have vast reserves of Forex like China or Japan. Therefore, if India can, by cultivating the EV industry, reduce its need to import crude oil, that by itself would be a huge boon for herBoP related concerns.
- And, by reducing her dependence on imported sources of energy, India would also be able to create a substantial elbow room in her diplomatic and political dealings with oil producing countries such as those in the OPEC group.

Future of EV Market – Expected Trends

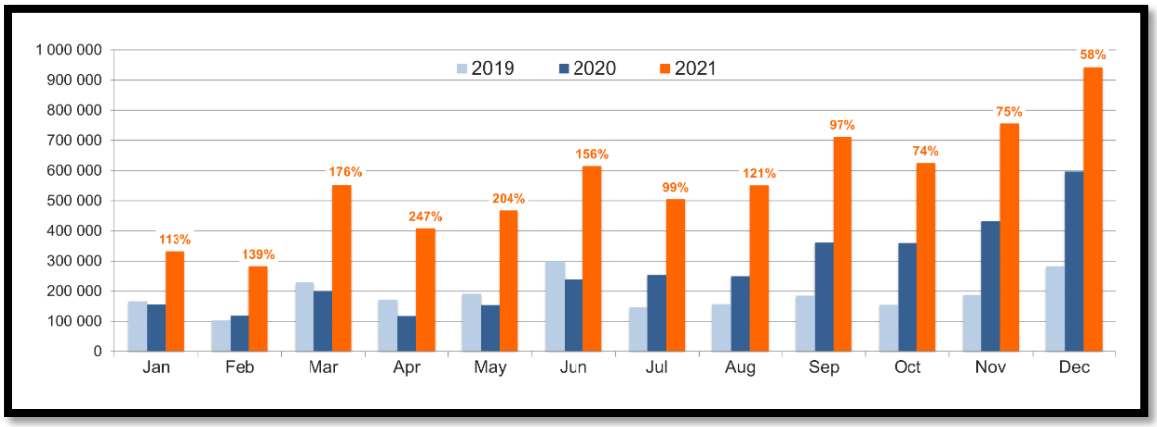

Fig-8 EV Production Trend over the years
(Source- The World Economic Forum)

Global EV Sales for 2021 – The basis for expectations about the future

Between 2017-18,the world saw the sales of electric vehicles soar by around 65 percent over the previous year. But the two subsequent years of 2019 and 2020, were nothing short of disasters. 2019 saw the EV industry sell 2.3 million units, against 2.1 million units that had been sold a year ago, indicating a YoY growth of only 9 percent. What followed in 2020 was even worse. The first quarter of that year brought the news of a 25% decline in the sales numbers. However, the subsequent quarters saw the industry recover some of the major in so far as the sales numbers were concerned.

In 2021, sales of EVs touched the figure of 6.75 million units, registering a growth of 108% over 2020. This volume comprised of all class of vehicles such as cars, trucks and light commercial vehicles. In 2021, in terms of their share in the global auto market, EVs (BEV (Battery EVs) and PHEV (Plug In Hybrid EVs)) reached 8.3% as against a figure of 4.2 % for 2020. Out of the total sales clocked by the EV segment, BEVs accounted for 71% while PHEVs provided the remaining 29%. In this context, it is worthwhile to note that this figure was achieved when the overall global auto market grew by a meagre 4.7% over 2020.

Tesla played a very important role during this period of sharp turnaround of the EV industry. The company led the pack of OEMs with 936,000 deliveries, 436,000 more than 2020. Among its products, the company saw its Model-3 achieve sales figures of 501,000 units, in the process becoming the 2nd best-selling brand after the Toyota Camry, the market leader. VW Group too achieved very good sales numbers to emerge as the second-best performing OEM, followed by BYD Group of China which, with deliveries of nearly 600,000 units, over 400,000 more than in 2020, was the next best performer.

2021 also saw EV sales in China emerge stronger than ever, especially when seen from the point of view of the disasters that were2019 and 2020. During this period, sales of EVs in China grew by nearly 2 million units, an increase of volume larger than what was achieved by all other regions combined. In Europe, sales figures were relatively muted. But, when seen in the backdrop of the boom seen during H2 of 2020, something like this was always expected. In North America, the sales efforts of electric vehicle makers were greatly aided by launch of several new offerings, led by Tesla's Model 3 & Y. Overall, even if the growth registered in this territory was not as astounding as the one seen in China, yet, it was highest since 2012.

Other markets too achieved consistently high growth during this period. Sales in South Korea increased by 64,200 units to reach 114,500 units. Israel, Australia, India and Japan too registered healthy sales numbers. Many smaller EV markets such as Brazil, New Zealand, and Singapore witnessed sales growth of around 200%.

However, it must be noted that the remarkable sales growth (108 % YoY) story of 2021 was achieved on the back of a very low base of 2020. Due to the devastation caused by factors such as regulations and Covid-19, both 2019 and 2020 were remarkably disappointing years for auto industry in general, and EV industry was no exception. The figures for 2021 must therefore be seen a return to normalcy in terms of overall volumes. But, to expect the same rate of growth to continue in future would be unrealistic. However, given the overall sentiment of the market, one can expect very healthy rates of growth in the near to medium term.

Growth in market share - doubling over a modest bas

While the overall auto market saw a marginal growth of just around 4.6% over the volumes achieved in 2020, EV industry, riding on the back of a 108% sales growth during the period, managed to double its share in the overall automotive market. However, it must be noted that this growth of 108%, or doubling of the market share, was not uniformly distributed among individual markets. Different regions grew at different rates. Some like China grew very fast, while others like middle-east region achieved relatively modest figures.

In Europe, the share of EVsin the overall automobile market jumped to 17% from 10%, that too in the backdrop of a near slump in the larger automobile segment. In Northern America, share of EVs in the automobile market increased to 4.4 % against 2.3 % during 2020.It was however China that saw a fastest rise in market share for the EV industry. The share of EV industry in China's automobile market jumped to 13.3% from 5.5 % for the previous period.

Among the vehicle categories within the larger EV umbrella, share of BEVs increased by 1%, with the second half of 2021 emerging as the star performing period. The volume of BEVs increased to 4.80 million units, PHEVs to 1.94 million units and FCEVs (fuel cell EVs)to15,400 units. The five-month sales figures for 2022

have seen EV industry already touch sales mark of 3.2 million units[43].

Projections about the time frames and the likely environmental impact of EVs

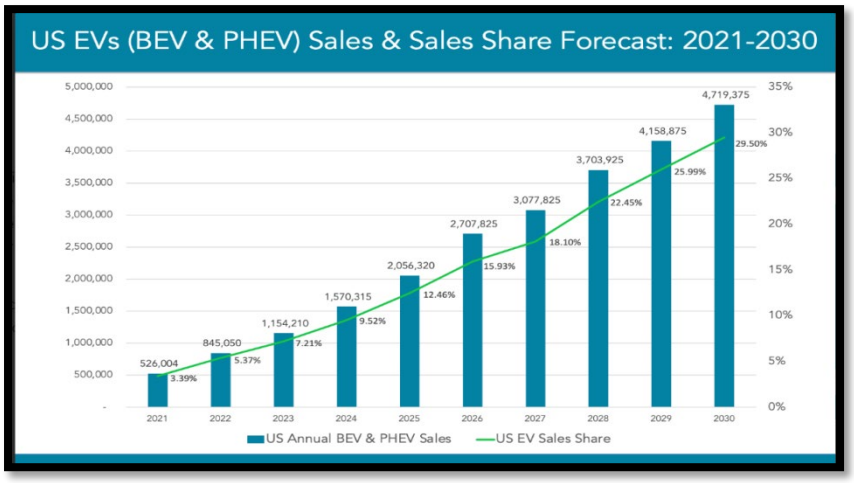

Fig-9 Sales Projections for the US Market
(Source-https://evadoption.com/ev-sales/ev-sales-forecasts/)

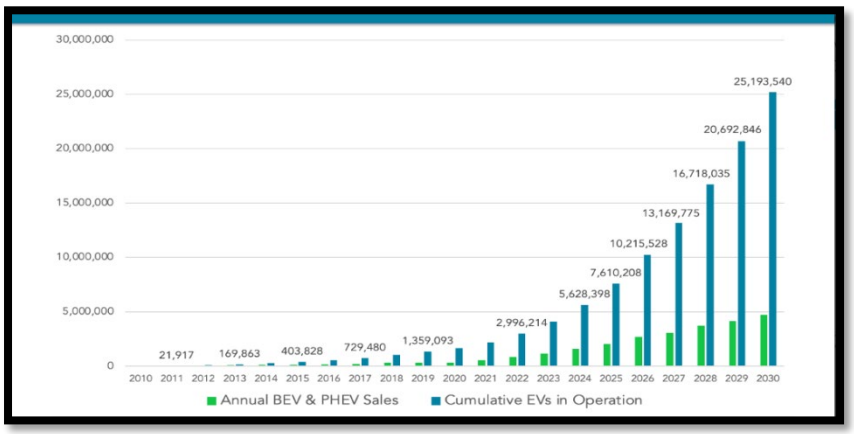

Fig- 10 number of EVs in operation in the US (2010 – 30)
(Source-https://evadoption.com/ev-sales/ev-sales-forecasts/)

Conclusion

Summarizing the significance of the rise of EV industry from the point of view of developing countries like India:

We are living in exciting times. The world is going through a period of transition from almost all possible points of view. Whether one looks at the unfolding global saga from an economic, social, political, strategic or environmental perspective, it is difficult to ignore either the pace or the extent of change being witnessed by the world.

In the economic domain, the world is seeing a massive shift of focus from the trans-Atlantic world to Asia. After a period of around 40 years of sustained growth, Asia has finally achieved the economic heft to be able to decisively impact the direction of global economy. No matter which industry one looks at, the center of gravity is definitely shifting from OECD countries to Asia. Supply chains are being readjusted to better align with the emerging global economic order, countries are rethinking about their trading, economic and diplomatic positioning in order to be able to better exploit the opportunities being presented by the changing world order, new companies from Asia are continuously conquering new territories and decisively changing existing perspectives about products and what can be expected off them.

This period of turbo-charged growth has also had quite a few unexpected outcomes. It is no longer possible to ignore the possibilities of complete industries being forced to relocate themselves in order to be able to survive

[43]https://www.virta.global/en/global-electric-vehicle-market#one

in the face of heightened competition from Asian companies. The wealth that is currently being generated in Asia, is also resulting in a noticeable change in the geo-political scene. The long-held power balance between countries is changing at a pace that could not have been envisaged even a few decades ago. The terrible economic devastation, especially in the OECD countries, caused by COVID-19 virus, is forcing a total rethink about future possibilities of growth and even the shape of what could be a functioning economic model.

From a climate related point of view, worryingly, the dreaded predictions about climate change finally seem to be translating into reality. When compared to the rich countries that are located in regions of milder or colder climate zones, the developing countries, especially those located near the tropics and the equator, are expected to bear a much severe brunt of the impact of climate changeover the coming decades. It is widely expected that countries like Indonesia, India, Malaysia, Myanmar, Thailand, Sri Lanka, Bangladesh, Maldives, and all those located near the coastal regions, would most likely be seeing massive flooding as a result of rising sea levels in not too distant a future.

According to various studies done by premier multilateral organizations like Intergovernmental Panel on Climate Change (IPCC[44]), unless urgent and drastic steps are implemented to arrest and ultimately reverse the damage that has already been done to the climate, the world should brace itself for climate disasters like rising sea levels, erratic rainfall, frequent draughts & floods, large swathes of farmlands becoming useless due to sustained exposure to sea water, and above all, a catastrophic human migration resulting from such apocalyptic climatic changes.

As a result, the imperative to act fast and decisively, is much stronger in countries facing imminent climate Armageddon, than in countries that are not just resourceful, butarenestedin the colder regions of the world. However, given the fact that almost all the developing countries would continue to face the pressure of providing decent livelihoods to meet the needs of their rising population, they would have no other option but to go for more and more intense levels of industrialization. Therefore, for countries like India, the only realistic alternative would be to not just adopt climate friendly technologies such as EVs, but also invest heavily to develop similar technology solutions for all the other industries.

Developing countries like India would also have to contend with the fact that some of the high-income and middle-income countries from the western hemisphere would most likely emerge as net beneficiaries from the process of global warming. Countries like Russia, Canada, Greenland, Norway, Sweden, Argentina and even United States, all having substantial parts of their landmass under the permafrost, would see the ice thaw from vast parts of their land. Such a thawing of the permafrost would vastly increase their agricultural potential. In addition, due to this process, the vast treasures of natural resources, currently buried in regions like Siberia and Polar Regions of Canada, would become extractable. And, these countries, especially Russia and Canada would also witness large influx of population, fleeing from the rest of the world.

All this would therefore place such countries in vastly advantageous situation especially in the context of the devastation that would be sweeping the large parts of the world at that point of time. It is therefore not very realistic to expect these countries to treat climate change related issues like life and death situation, as would be the case with most of the developing countries. Therefore, whatever needs to be done, would have to be done mostly by those countries that would suffer disproportionately as a result of the ensuing climate change induced devastation.

From India's perspective, there is one more angle that cannot be ignored. Over the past few decades, China has seen a much higher level of economic growth than India. The resultant disparity in the economic might of the two countries has created a situation where China has begun to cause severe discomfort to the strategic leadership of India. Unless something is done earnestly about it, there is a real danger of India being cornered into a very uncomfortable situation vis-à-vis China with its predatory intentions.

India therefore needs to do all that it can to become the most favored destination for big industries of the future, such as climate engineering industry, space industry, ocean mining industry, EV industry, nuclear power, solar power etc. As it is, China's behavior during and after the Corona epidemic, has made large number of countries extremely anxious about the intentions of China. This discomfiture is resulting into those countries and their companies being forced to seriously contemplate alternatives to the existing global supply chain. While India, given her vast population and the consequent need to provide for the same, must do all that she can to attract investment in all kinds of industries, the real opportunity would lie in futuristic industries like the ones

[44]https://www.ipcc.ch/

mentioned above. These, being nascent industries, are sure to experience exponential growth, which in turn would allow countries like India to create viable livelihood opportunities for vast numbers of people. And, EV industry, given the fact that it has already achieved substantial technological maturity, would be well placed to act as the anchor industry not only to power the economic ambitions of countries like India, but also to provide realistic solutions to the pressing climatic questions.

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