Are Electric Vehicles real alternative for Petroleum based vehicles? An Analysis

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Abstract - *This paper focuses upon how much our environment is being affected by the use of electric vehicles. It forces us to think if electric vehicles are actually a revolutionary change or just an escape from our current environmental crisis. People have often ignored the perplexity of using an electric vehicle and are deceived by the illusion that electric vehicles are zero emission vehicles. People marginally think about the hardship of recycling the batteries and its environmental impacts. The mineral crisis that will be caused after lithium is depleted is often ignored. This paper tells us if the current electric vehicles are actually zero emission vehicles or if zero emission vehicles are just a myth. It also throws light upon about what actions should be taken to avoid a gigantic environmental crisis.*

Key Word: **Electric vehicles, Emission, Alternate fuel, Petroleum fuel, Lithium, Bangalore.**

1. INTRODUCTION

Battery powered electric vehicles are going to play a dominant role in future transportation scenario. However the environmental impact of recycling and disposal of batteries is often ignored. Recent researches have clearly shown that electric vehicles are going to have a grave impact on the earth. Problems like production, utilization and disposal of batteries have to be considered before adapting ourselves to electric vehicles. Electric vehicles emit a lot of greenhouse gases, as the electricity produced to charge them is not green. There has also been debate about how long the precious lithium ore can last if we mine lithium in such a large scale for production of millions of batteries.

In this paper we have compared the pollution caused by an Electric vehicle using a Li-ion batteries with the pollution caused by gasoline ones. We have considered all the aspects through which an Electric vehicle can cause pollution.

We have classified them into three categories:

1. Pollution caused due to production of co2
2. Pollution and problems caused due to recycling
3. Availability of Lithium

2. Production of CO_2:

Considering a scenario where all the cars on earth are converted into electric cars, there will be consequent impact of this on the consumption of electricity and the emission of CO_2.

The electricity requirement in this case will be higher, considering the fact that electricity is used to charge the batteries for electric cars.

There will also be a similar and parallel impact on the emission of CO_2. Though drastic reduction in the carbon emission from cars is an accepted and an expected consequence, its impact will be overshadowed by fact that coal burnt to produce electricity will also contribute to the CO2 in the environment.

However, different modes of electricity generation led to considerable variations in the results. Using a Battery Electric Vehicle with electricity from an average hard coal power plant was observed to increase the environmental burden by 13.4%. On the other hand, using electricity from an average hydropower plant decreased environmental burden by 40.2%. When the two cases are compared, it can be seen that there is a decrease in the environmental burden caused by electricity generation from 41.8% to 9.6% if the battery was charged with electricity used from hydropower plants.

When comparing vehicles, it is also necessary to add the green gas production of the vehicle itself as the quantity that was observed during the production of fuel for internal combustion engine ICE or the electric energy production for electric vehicle. This section reveals simulation results of CO2 emission produced by different types of cars driven. Although electric vehicles are assumed to be "Zero emission vehicles", their CO2 path is dependent on the sources and technology used in the production of electricity. This has been calculated here.

In addition to this, expansion of automobile traffic has brought new difficulties like the serious environmental problems associated with gas emission and fuel consumption.

Greenhouse gas emission of vehicles brought these ecological problems to the forefront, and the expected growth of automobiles is much higher compared to the expected growth of inhabitants.

The estimated growth of automobiles over the whole earth is shown in the graph here. It is sure that these values will influence the production of greenhouse gases too.

Considering all the earth's resources, the total greenhouse gas production is shown, and the world production of CO_2 is also shown. If the present trend and future trend continue, we have to conclude that it is our duty to accept facts and regulations of this dangerous development.[2]

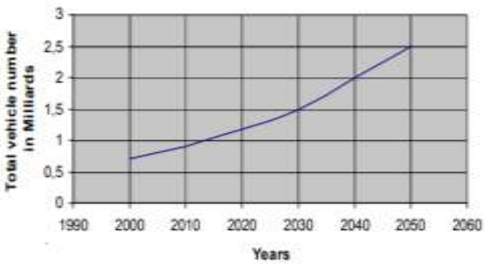

Chart-1 : TOTAL WORLD PRODUCTION OF CO_2 [2]

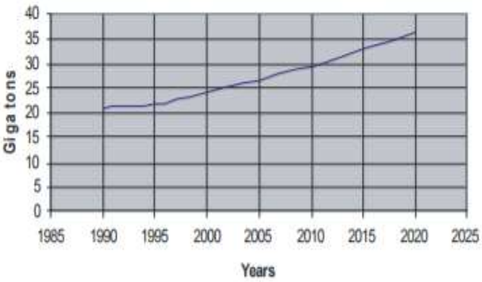

Chart-2 : ESTIMATED NUMBER OF VEHICLES ON EARTH [2]

Total CO_2 production by classical vehicles and electric vehicles:

In this section, battery electric cars and IC engine vehicles are compared. When speaking on vehicle CO_2 production, usually only the production of vehicle is taken in account. But it is also necessary to add the amount of CO_2 produced while acquiring the fuel. We must also add the CO_2 that is emitted while producing electricity from electric plants for the electric vehicles. These are the quantities that are being produced in places other than on the road or street in towns. But this attitude is only an objective. From this point of view, vehicles do not exist without greenhouse gas production. To see the real scenario, it is important to determine what quantity of CO_2 is produced for 100km journey. The solution for future mobility is found by papers considering this aspect as an objective. This section tries to set down the first steps in this direction. The situation of electric or hybrid electric car is a little more complicated. The reason lies in fact that different technologies of electric power stations produce different CO_2 quantities per one kWh.

Source for electricity production	CO_2 Emissions
EU Mix	650 g CO_2/kWh
Austrian Electricity Mix	440 g CO_2/kWh
Photovoltaic	100 g CO_2/kWh
Hydro Power	40 g CO_2/kWh
Wind Power	20 g CO_2/kWh

Table-1: CO_2 emissions for various source of electricity production.

* EU Mix accounts to the mix of various electric power stations in EU.

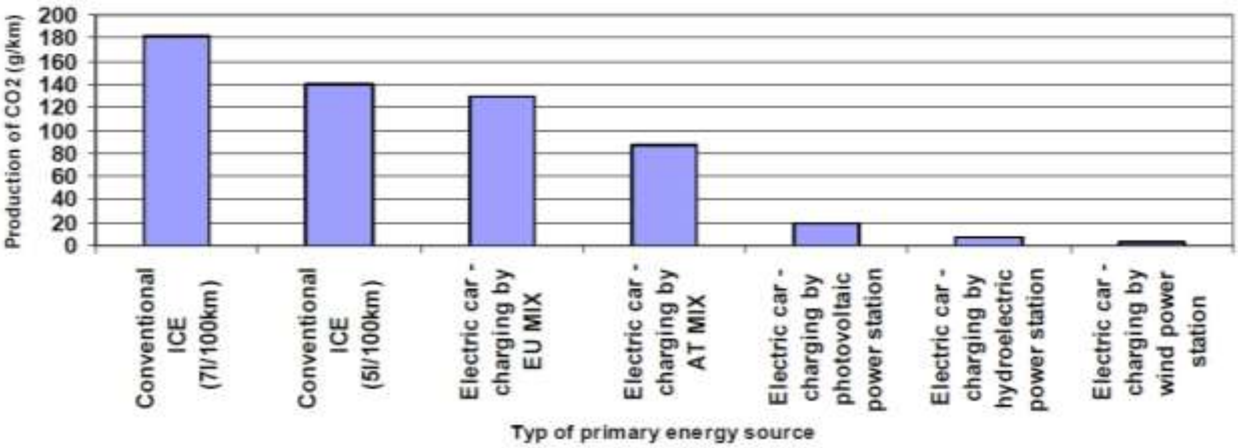

Chart 3: COMPARISON OF CO2 PRODUCTION PER 1KM FOR DIFFERENT CARS AND ENERGY SOURCES [2]

If hybrid electric cars and automobiles with IC engines are compared, the following observations can be made. On a regular basis, 15-20kWh Electric energy is used to run the Hybrid Car for a 100km Journey. The same, when considering an IC Engine Automobile with a consumption of 7 Litre petrol/100km, an equivalent of 60kWh/100km will be needed. In the graph here, the total CO2 production for 1 km is shown , where 30g CO2/km was added to the technical declared car CO2 production. This amount of CO2 is said to be necessary to acquire fuels for ICE cars. Similarly, in the case of electric cars, the traction energy consumption of 20kWh/100km was calculated here. [2]

2.2 Now, let us practically see how effective electric vehicles are.

Suppose we convert all the vehicles in a major city like Bangalore into electric ones, how much reduction in CO_2 can be seen?

In Karnataka $15.09*10^{12}$ grams of CO_2 is released due to road transport.

In Bangalore there are 60 lakhs vehicles, and the amount of CO_2 released from them is around $2.7*10^{12}$ grams per year.

Now let us find out how much CO_2 would be emitted if all the vehicles are made electric.

An electric car does 80-100 km per 10kwh of electricity.

And the amount of CO_2 emitted for the production of 1Kwh of electricity is 0.852-0.969 grams.

So the total amount of CO_2emitted from 1 Electric car in its life time would be $1.2*10^{12}$ gram per year

(Here we consider the average distance covered by a car in an year is 11,000 km)

2.3 Discussion:

Now, it is evident that all vehicles contribute to the production of greenhouse gases. They also contribute to the additional CO_2 from petrol production for ICE or electric energy transportation for charging electric vehicle batteries. The production of greenhouse gases and consumption of energy world resources has become a serious problem. Simulations were done with the mathematical model of different electric vehicles and compared with classical cars. The gas emissions of electric cars are influenced by the technology that is being used in electric plants that produce energy for battery charging. Though the advantages of battery electric vehicles are quite evident, they still have a serious impact on the environment.

3. Pollution and problems caused due to recycling

The Recycling of Lithium ion batteries has not yet been classified as good or bad. There has been a long-ranging debate about the benefits of recycling of Lithium Ion batteries over the benefits of disposing them. When automotive batteries are considered, the environmental benefits are clear, with exceptions that vary with the type of battery or the recycling method. If a small amount of usable materials can be extracted from the used batteries, there is a resultant reduction in the amount of raw materials that need to be extracted. But the recycling of batteries is not simple. There are a lot of disadvantages associated with recycling, one of which is the recovery through Pyro metallurgical process which has a lot of Environmental Consequences. Under some specific US Regulations, Lithium ion batteries are classified as Class 9:Miscellaneous hazardous materials and Pb-Acid batteries are classified as Class 8 : Corrosive hazardous materials.[3]

In future mobility scenarios, battery powered Electric vehicles play an important role. However, there is very less clarity about the environmental impact of the production, usage and disposal of the lithium ion battery. This makes it difficult to compare the environmental impact of battery electric vehicles with that of internal combustion engine cars.

In order to deal with this, a rough life cycle research was done on Li-ion Batteries and the Life Cycle Assessment of the Battery Electric Vehicles was done to have a clear vision of the scenarios. The Environmental burdens of mobility are dominated by the operation phase regardless of whether a Battery Powered Electric Vehicle is used or a Gasoline Powered Vehicle is used. The share of the total environmental impact of Electric-mobility caused by the battery is 15 %. The impact caused by the extraction of lithium for the components of the Li-ion battery is less than 2.3%. But, more than these, the supply of Cu and Al for the production of Cathode and Anode with the production of other cables for the battery, contributed majorly to the Environmental Impact.[3]

Lithium Ion Batteries are used by most of the car manufacturers because lithium is the lightest of all metals and also offers a great electrochemical Potential and a high amount of Power. Also, from the Information and Communication Technology (ICT) industry, extensive experiences were gained, that have led to safe, long-lasting, and affordable products. Comparatively, lithium ion batteries need less maintenance which makes them better than the other batteries.

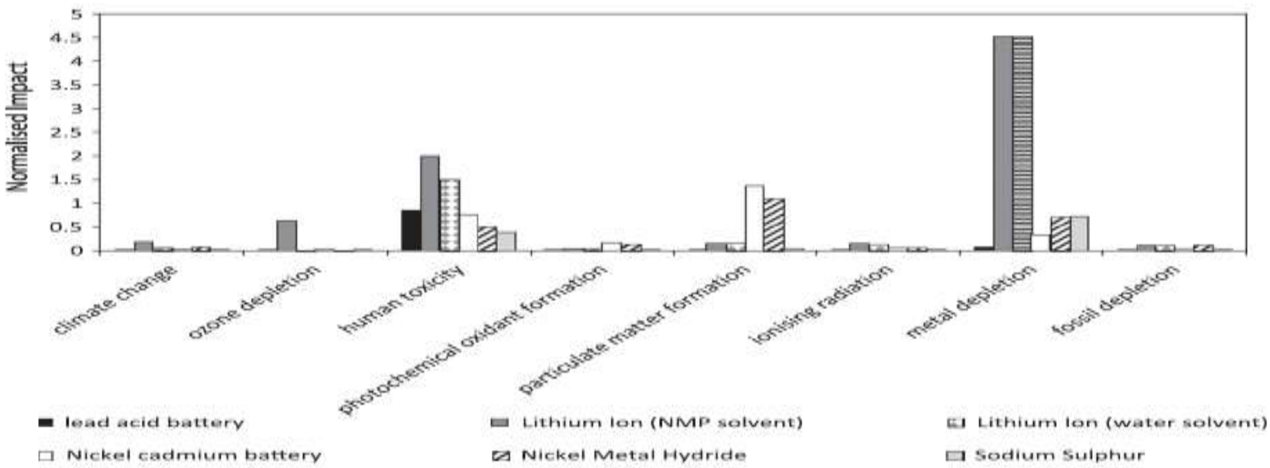

Chart 4: NORMALISED IMPACT OF VARIOUS TYPES OF BATTERIES ON THE ENVIRONMENT [4]

The usage of Lithium Ion Batteries is predicted to increase as a result of increase in the use of electric vehicles and small scale industry energy generation. The graph above represents the data on the basis of per kg production and on the energy capacity.

According to the results, considering the materials required for battery production, lithium ion batteries contribute the most towards metal depletion and greenhouse gas production, but it can be observed that nickel metal hydride batteries have a more significant cumulative energy demand.

While many materials being used to produce batteries are exhaustible resources, it is the unlikely minerals such as lithium which will be exhausted in the near future due to our use of batteries. However, the impact of mining is still high, and in order to stay balanced, increased recycling and material recovery must be adopted. [4]

When compared to Lead acid batteries and Ni-Mh batteries, Li-ion batteries are very difficult to recycle because of the following reasons:

Each individual cell of a Lion battery has a variety of materials. These materials are in the form of powder, which are coated onto metal foil. It is necessary to separate these different materials during recycling. A typical Li-ion pack is said to have 100 or more individual cells. These cells are connected into modules and are assembled into a pack with control circuitry attached to each cell. All of this may also include a thermal management system. These components could be recovered intact or may also contain materials that can help in recycling the battery. The chemical compositions of active materials, within the cells , vary with manufacturer and battery function. These may never be standardized .The most common material used as a cathode for the batteries now in consumer electronics is $LiCoO2$ (LCO), but in order to replace the cobalt I, various combinations of Ni, Mn, and Al can be used , which would also optimize performance while lowering raw material cost, which is a prominent factor in the automotive batteries. Another cathode material having a low raw material cost is $LiFePO4$ (LFP). While Silicon is being used for the anode, many manufacturers also use forms of graphite.

There are no regulations regarding the recycling of lithium ion batteries right now. For many recyclers, this condition may be favourable as there are no restrictions for them in the design of the process. Battery technology is still evolving on a regular basis. Recycling processes designed for any battery can get out-dated quickly because of the improving battery technology.

3.1 Pyrometallurgical recycling (Smelting):

Lithium ion batteries are first dismantled to the module level. After this, they are fed to a high temperature shaft furnace, where a slag forming agent is added. This slag forming agent includes sand and limestone. During this process, the plastics and electrolytes burn to provide energy for the smelting process and the metals present are reduced into an alloy of iron, cobalt, copper and nickel. These metals are later recovered by the Leaching process. These clean up steps are used whilst these processes occur so as to avoid the release of potentially toxic by-products. This process of smelting is currently commercial in operation and is economical only for batteries containing Cobalt and Nickel.

There has always been a question asking if the recovered materials could perform as well as virgin materials. The reason being the impact of this in the battery power and efficiency. Manufacturers have been reluctant in using recycled components because of performance concerns. Recovered materials could be used in cases with less power requirements. This, collectively reduce the value of any recycled product.

Some reasons why recycling of lithium ion batteries is not viable are:

The separation technology for recycled cells is not yet certain, as there are different compositions in different batteries which makes it difficult to know what can be extracted from any specific battery. The method of separation of cathode after initial processes is also not certain.

It can be made viable if the recycling processes and the battery production processes are standardized, assuring that a prototype can be set to perform the recycling processes at a higher rate.[5]

3.2 Recycling could also be dangerous

In many cases, lithium ion batteries are introduced into secondary smelters that recycle lithium acid batteries, leading to terrific accidents. There are various reasons for the cross contamination. Currently, many lithium ion batteries and lead acid batteries are produced in a non-distinguishable manner, to be later used in motorcycles and other applications. In the same way, during the process of recycling lithium–ion batteries, it is important not to include lead–acid batteries in any case .The presence of lead in the batteries could harm the recycler and the acid could also react with the electrode substrates and cause hazardous Problems.[5]

3.3 Socio-Economic Problems of Recycling

A small percentage–5% of Lithium ion batteries are recycled in the EU. This has an impact on the environment. The batteries not only carry the risk of giving off toxic gases when damaged, but also the extraction of limited-availability main ingredients like lithium and cobalt causes water pollution and other environmental problems. When Considering the Smelting Process done by the Umicore, it is observed that the vital lithium cannot be recovered and forms a by product. It has been contended that lithium can be extracted from the by product, but this can only be done at very high costs.

By this, it is clear that The recycling of Lithium from Lithium-ion Batteries is not confirmed if not paid to do so.

According to investment banker Morgan Stanley, the current trend or wave of batteries would die, if there was no improvement seen in the recycling of lithium over the decade ahead and there would be insufficient resources and systems for the recycling of Batteries. Jessica Alford, head of the bank's global sustainable research was of the opinion that there still needs to be more development to get to closed loop recycling where all materials can be reclaimed. "There's a difference between being able to do something and it making economic sense."

The fundamental problem, as expressed by Francisco Carranza, Energy services MD at Nissan, is that while the cost of fully recycling a battery would fall toward €1 per kilo, the value of the raw materials that can be reclaimed is only a third of that.[6]

4. Availability of Lithium

It is desirable to adopt electric motors into vehicles to replace internal combustion engines. This will noticeably reduce greenhouse gas emissions and noise pollution. It would also be ideal to be able to replace the fossil fuel power plants with generating stations that use renewable sources such as solar and wind energy to produce electricity so as to reduce the emissions and pollution. Generation of electricity from renewable energy sources is generally intermittent and it is necessary to have grid storage to have widespread adoption. The development of reliable and affordable energy storage plays a very important role in the electrification of vehicles and expansion of grid storage capacity.

It has not been long since electric vehicles have come into market. 1.5 million electric cars were sold in between the years 2000 and 2010. This is a small number compared to the total of 60 million cars that were sold of all types in just 2011. It is said that the International energy Agency has come up with a plan to electrify all the cars round the globe. Basically, this plan expects an annual production and sales of at least 5 Million Electric Vehicle by the year 2020. It also predicts that out of the total number of cars manufactured by 2050, 50% would be Electric Cars. Current vehicles require approximately 4 kg of lithium for a battery pack, with 20 kWh capacity at a battery cost of USD6,000 to USD12,000 . The IEA plan expects new improvised and optimized versions of the current lithium ion batteries to be used in electric vehicles in the future and that any further improvements would require new battery technology and chemical compositions, which, the Agency expects to be developed by the end of this decade. Unfortunately, the improvised Batteries would still have to use lithium. There are no new technologies or alternatives to lithium in the batteries that can offer the same reliability and performance. Thus, it is reasonable to say that the commercialization of electric vehicles can only happen when there is ample supply of lithium at a reasonable cost which is less than the present rates.[7]

4.1 Lithium supply and demand

In 2013,Vikstrom el at conducted a detailed study of all world's reserves of lithium, it's availability and the production capacity. They completed this with the demand of lithium from the electric car sales according to the IEA Roadmap. They also examined the possibility of extracting lithium from oceans. This idea was later discounted considering the need of 5 million m3 of sea water being required to produce 1 tonne of lithium. A conclusion was made based on the study that the total accessible amount of lithium globally available would be 15 million tonnes.

Vikstrom et al predicted the production of lithium with models that forecast the production rates of lithium, rate if demand and the IEA scenario until 2050. These production models were made assuming that lithium would not be recycled. It was justified that this was because there are no large scale industries that could recycle lithium economically. This later concluded that the consumption of lithium would increase rapidly and demand electric cars with lithium ion batteries would build as predicted by the IEA Roadmap.

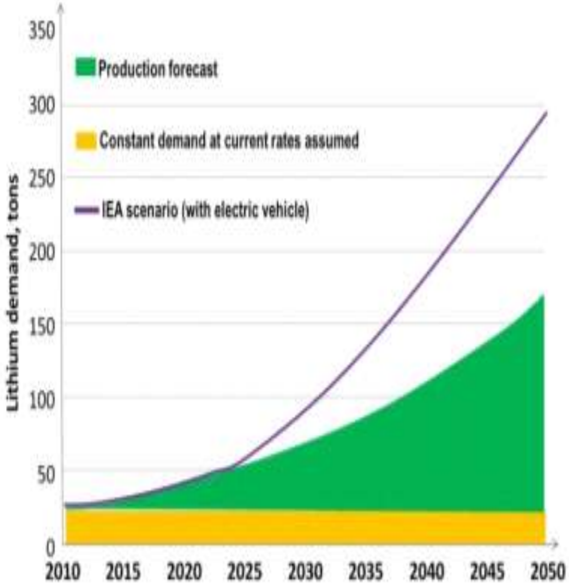

Chart 5: LITHIUM DEMAND AND PRODUCTION [7]

4.2 Discussion:

Even if we are to picture the most optimistic scenario, it can seen from the study that by 2023 , the demand of electric cars will overtake the supply rate. As can be seen from the IEA Roadmap / Plan, it is reasonable to say that the uptake of Electric cars will be aggressively high. This will increase the demand at the market level and the governments will have to simulate solutions to cope up with the demand. But, considering the environmental benefits of electric cars over internal combustion cars, it is unfortunate that the factor stopping the production of electric cars is the lack of supply of lithium as the demand increases. In order to avoid all of these potential issues, it is necessary to have an annual supply of lithium greater than the present mining rates. One good method that could solve the issue would be to recycle lithium from products that are used and at the verge of being scrapped. Gruber et al, who conducted a research in 2011 on this topic, discovered that recycling could have a very significant impact on the production of electric cars. His study was made considering the ideal intake and presence of lithium. In this study, it was also observed that it was possible to achieve a higher annual supply of lithium compared to present rates if at least 90% of Lithium could be recycled from the discarded lithium batteries. In such a scenario, batteries could be manufactured with 55-63% of recycled lithium and the remaining 45-37% of the battery's composition could be fulfilled by virgin lithium material.[7]

4.3 Supply and demand Conclusions:

Adoption of cars with electric motors rather than internal combustion engines and an expansion of grid storage capacity to accommodate intermittent renewable energy sources are ways through which reductions in green-house gas emissions can be achieved. Lithium ion batteries are the best energy storage option for electric cars for the near and mid future and are a good option for grid storage. A comparison of anticipated lithium demand to forecasted lithium supply shows that in the early 2020s, without recycling, supply will not be able to keep up with demand and therefore adoption of electric vehicles will likely be stalled. In order to ensure widespread adoption of electric vehicles, the methods of large scale recycling of lithium ion batteries, especially of automotive batteries, be developed has to be researched and developed to a greater extent.

5. Conclusion

Ideally, it is known by now that Electric vehicles are just a temporary escape from our current crisis. Electric vehicles are pollution the Earth just like the gasoline ones ,but in a rather relatively slower pace. The problem can be solved if there in uniformity in all the batteries produced which can make the process of recycling much more efficient. Batteries must be designed in such a way that, they can be easily distinguishable from one another. Strict and stringent laws should be made to regulate the transportation and storage of used batteries in the recycling facility .Also should be made to make sure that all the batteries end up only in the recycling facility after the use and must not be disposed. The recycled product should be of high quality so that it can be reused. All the batteries should be designed keeping recycling and reuse in mind. And all this should be achieves before we have an ocean of dead batteries lying all around us.

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