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Recent Changes Automobile Companies have Made in an Attempt to Exploit Greener Alternatives from using Toxic Heavy Metals to Produce Electric Cars

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ABSTRACT

The aim of this project is to outline the need for government and companies to adopt a different approach to achieving automobile sustainability by improving the legislation involved in the introduction of electric vehicles containing toxic heavy metals. Kampman et al. (2010), suggests that alternatively fuelled vehicles present a great opportunity to achieve sustainability in the automobile industry. However, the success of the introduction of these vehicles, focusing on the Electric car, depends on the nature of their entry into the marketplace, putting the proper policies in place, the appropriate technological readjustments made to their batteries and performance, and effectively meeting the needs of the consumer. The potential of delivering zero or lower emissions and the efficient use of energy resources specifically renewable sources is also vital. This project would involve a review of the available policies that regulate activities in the automobile industry with specific reference to electric vehicles and how these policies can be modified to support the introduction of electric cars. It also involves a review of heavy metals used in making electric vehicles, the legislation restricting their usage and the toxicity of these metals with a view to suggesting ways in which these heavy metals would not constitute an environmental nuisance. Also with, an analysis of the portion of the electric vehicle where toxic heavy metals are contained, that is, the batteries, its energy conservation capability and the cost implication of buying the electric vehicle or replacing its batteries. Finally, the business implication of the emergence of the electric vehicle for automobile companies is analysed, along with the potential of this as an alternative to the internal combustion engine.

Keywords: Electric Cars, Renewable Energy, Heavy Metals, Sustainability, Environment

INTRODUCTION

Sustainable development advocates activities that would solve today's problems and not jeopardise the chances of solving tomorrow's problems as well, effectively doing no harm to the environment and its constituents [1]. Those activities we could carry out that lead to the deterioration or degradation of the environment and its resources and our ability to abstain from these activities defines sustainability. [2] opines that the improvements in living standards on offer through technological exploits should be done based on managing the environment and its resources. Human beings in an attempt to solve their problems, develop technologies that continually meet their needs, but are devastating to the environment, even as these technologies become more advanced. Then there is a need to re-address these technological "breakthroughs" and pay greater attention to the issue of environmental sustainability, which in effect determines man's well-being and survival on planet earth.

Transportation plays a significant role in our lives; and it can influence our lifestyle and location at a given time. This includes how we get to our workplace, deciding on where to have a home and where we go to relax. It is also vital to the economy because it provides a convenient means for trading and business; and economic growth can be measured on this basis. This is because, an increase in income can lead to the desire to travel more distances via quicker means, and this in return has greater energy requirement, thereby releasing more emissions. This makes transportation a major part of energy usage, which is constantly on the increase. However, because of this, a major source of fuel for transportation is gotten from the combustion of hydrocarbons that release mainly carbon dioxide into the atmosphere. Therefore, meeting emission goals seem almost impossible especially with the constant increase in demand, which the automobile industry faces [3].

However, because government policy regarding the transport, energy and environmental sector is not distinctive this problem persists. In the 4th IPCC report, the climate was said to be definitely experiencing a warming up of its system and the higher temperatures been experienced since the mid-20th century is as a result of higher anthropogenic greenhouse gases. The atmosphere consists of two major gases- nitrogen, which constitutes 78% and oxygen another 21%. Other gases are carbon dioxide (CO2), nitrous oxide (NOx) and methane; which constitutes a critical 1%. This is so because only a slight increase in this 1% can prove costly to the environment [4].

In the United Kingdom, the transportation sector has a work force of about 700,000 and constitutes about £8.5 billion worth of economic value. However, for about 10 years now, the average new car carbon emission has dropped to about 20% (144.2 g/km CO2). The low carbon program is been taken up and forms a centre focus for UK automobile industry. This is what has driven huge investments in research and development, so that more environmentally sustainable vehicles are produced. The responsibility comes because the UK is the major manufacturing site of about 15 (7 volume and 8 commercial) vehicle manufacturers including specialist (about 300) vehicle manufacturers and virtually all of the top suppliers in the world (SMMT 2011).

The Greener Alternative

Vehicles that rely on a battery partially or fully to function with the batteries recharged by plugging them into electricity supply are referred to as Electric Vehicles (EVs). Different types of electric vehicles exist and they include

- Pure Electric Vehicles (Pure EVs) - They are a typical electric vehicle powered only by batteries and capable of covering 100 miles
- Plug In Hybrid Vehicles (PHVs) - These are capable of covering 10 miles, switching to hybrid mode afterwards. They make use of batteries and an internal combustion engine (ICE)
- Extended Range Electric Vehicles (E-REVs) - The difference between these vehicles and pure EVs is that the batteries cover less distances (around 40 miles) with an internal combustion engine generator that gives it the ability to cover more distances. They rely only on electricity for functionality (SMMT 2011).

Fossil fuel is the main source of energy for electric cars, which remain an alternative to carbon emission reduction from conventional (ICE) vehicles. A major setback for electric vehicles is an electricity saving medium, this is because batteries do not possess the density levels that petrol does and the time taken to recharge batteries is a lot more than refuelling a conventional vehicle. The challenge therefore, is to manufacture a battery that will last longer than the ones on the market, be devoid of toxic heavy metals and less heavy (Nature.com 2001).

For many years, the term “heavy metal” is used to refer to metals or semimetals that are toxic or possess certain toxic properties, and legislations that have been passed which include a number of metals referred to as heavy metals are usually contradictory, referring to different categories of metals but making use of the term heavy metals (IUPAC 2002). Some studies refer to heavy metals as those that exist in the periodic table between copper and lead with specific gravities of more than 4, having some radioactive attributes (Spiritus-Temporis.com 2005). Some rare earth metals constitute the heavy metal category, and they are used in various proportions to improve performance in electric vehicles, solar systems, wind turbines and other industrial applications, however, their usage has generated great concern. Metals are referred to as “rare-earth” because they possess similar chemical characteristics and are found in the earth's crust embedded in other materials that are radioactive, therefore processing and extraction of these metals are a real challenge in terms of the process, cost environmental pollution and disposal (The Economist 2011). Rare earth metals are generally called lanthanides in the periodic table and this is shown below

The Periodic Table of elements showing Metals particularly rare earth Metals

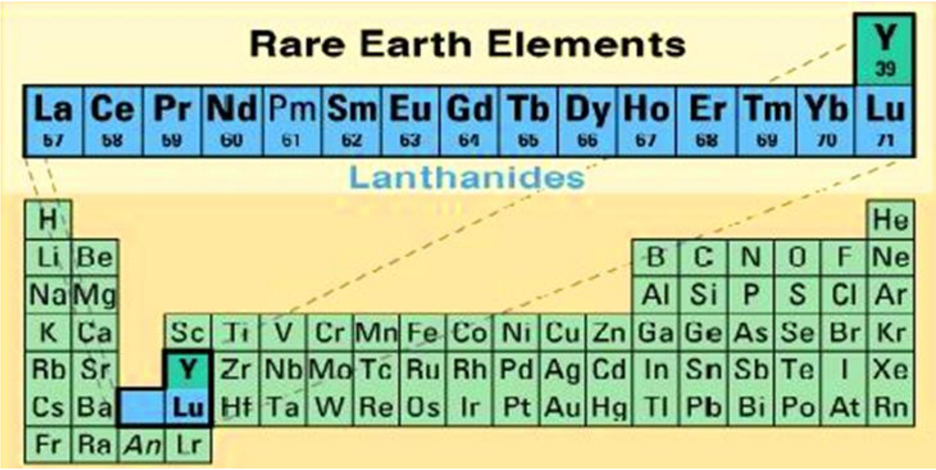


Figure 1 (Lifton 2010).

For the purpose of this project, the focus would be on those heavy metals referred to in the end of life vehicle regulation, which include cadmium or hexavalent chromium, mercury, and lead. Other heavy metals constituting environmental nuisances would also be looked at briefly, such as nickel, arsenic, selenium and copper.

Legislating the Alternatives

The End of Life Vehicle legislation was developed to enable manufacturers and companies intending to introduce vehicle products and their parts to the UK marketplace including those obliged with handling, registering, recycling and scrapping these vehicles at "end of life". It is aimed at protecting the environment from pollution at end of life. It involves technical requirements for M1 passenger vehicles having 9 seats and N1 goods vehicles weighing 3.5 tonnes. The End of Life Vehicles Regulations 2003 is bound by UK law the following restrictions of the EC ELV Directive (2000/53/EC)

- The use of specific heavy metals in vehicle and any of its part's production is restricted
- Vehicle parts containing rubber and plastic, and data on disassembly and design is published
- The emergence of Certificate of Destruction
- Vehicles introduced from 1st July 2002 and "Free take-back" available for them
- Standards of operation and licensing for authorized treatment plants (BSI, 2010).

Heavy metal restrictions come under regulation 6 in part Ill of the requirements for design of vehicles and their parts. Only if used in certain applications and concentrations in vehicles as stipulated in schedule 1 of the regulations, manufacturers are restricted from using materials with lead, mercury, cadmium, and hexavalent chromium. To prevent further environmental pollution, vehicles and their parts that were in the marketplace prior to the introduction of this regulation, would be excluded. However, the exclusion is not applicable to wheel balance weights, electric motor carbon brushes and brake linings because these parts have been dealt with in Annex II of the End of Life Vehicle Directive, only if they were in the marketplace prior to the implementation of this regulation. The regulations and their guidance should be used together with the 2010 End of Life regulation, keeping in mind more recent adjustments been made (BSI 2010).

Other relevant transport regulations that affect Electric Vehicles

- Renewable Energy Directive (RED) (EC, 2009c)
- Regulation on CO2 from Vehicles (EC, 2009a)
- Fuel Quality Directive (FQD) (EC, 2009b) [5].

LITERATURE REVIEW

In 2008, nearly 66% of the total emission came from the road transport sector, with 12.5% of the total carbon dioxide emissions from cars and 85% of greenhouse gas emissions as a result of human activities come from CO2 emissions. From 2007 to 2008, vehicle carbon emissions had a decline of 3.1%, in spite of the increasing number of vehicles been used and the length of journeys covered. To be able to effectively assess impact in terms of the economic, environmental and social aspects of an automobile's life cycle, the "use phase" clearly outlines certain facts. However, it is with these analysis that the impact alternatively fuelled vehicles will have can be evaluated because these percentages below are expected to change (either increase or decrease) (SMMT 2009).

CO2 Emissions in the UK

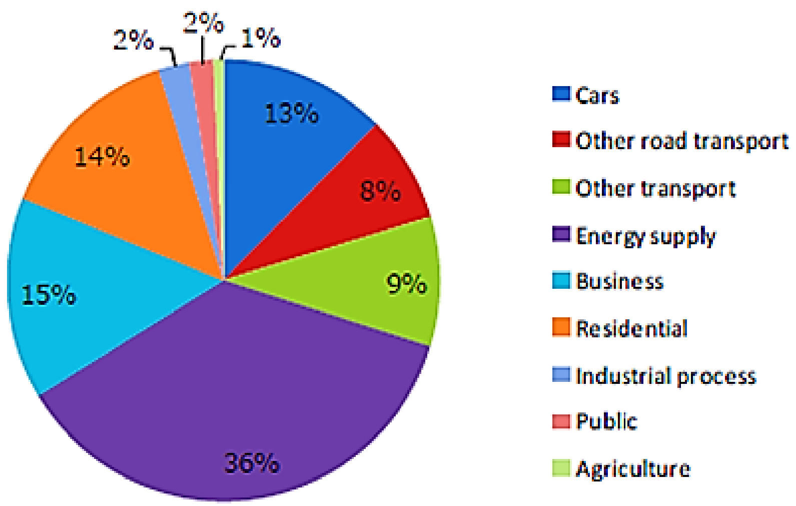


Figure 2 (SMMT 2009).

From the diagram above, it is shown that energy consumption produces the most emissions of all economic activities, which is about 36%. However, the implication of this illustration is clearer when percentages that involve the automobile industries are considered. These are cars, other transport, businesses, industrial processes, and other road transport, which all add up with the energy supply needed for these activities to take place. Therefore, when considering the entire life span of a vehicle, the CO2 emissions can be analysed as follows in figure 3.

Vehicle CO2 Emissions' Life Cycle

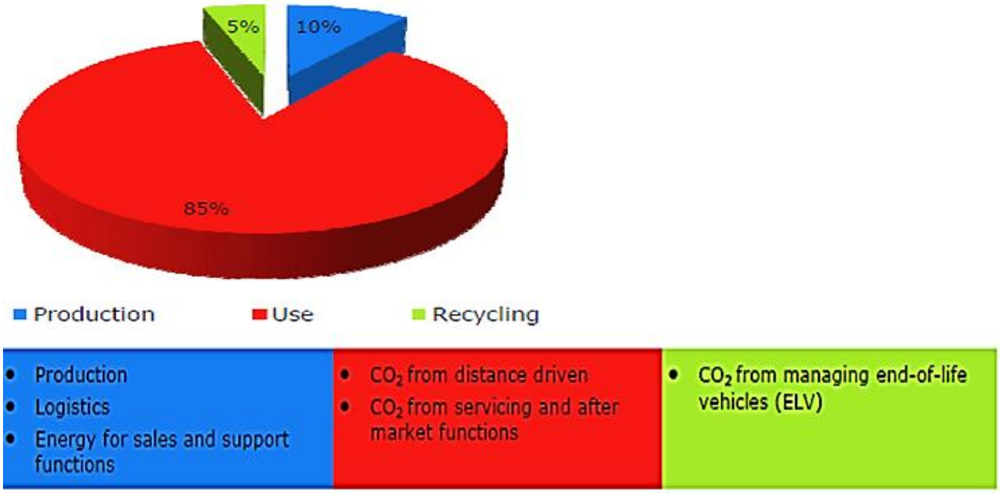


Figure 3 (SMMT 2009).

Exploiting Fuel Alternatives

In SMMT (2011), certain facts about alternatively fuelled vehicles are outlined and they include

- The sales of hybrid and electric cars is low even though they produce little or no carbon emissions compared to conventional cars
- The markets consist predominantly of petrol and diesel vehicles, and in 2010, diesel vehicles having very high performance levels
- The emissions from diesel vehicles are somewhere around 5% to 20% lower than their petrol vehicle counterparts

In terms of tailpipe emissions, pure electric cars have zero emissions and most hybrid vehicles have CO2 emissions that are under 100 g/km providing customers with vehicles that are more environmentally friendly. Moreover, more recently some diesel and petrol vehicles have cut emissions to this level (that is around 100 g/km). Petrol and diesel vehicles are still the most widely used in the market and constitute about 98% of the new vehicle registration in 2010 with the diesel vehicle accounting for about 46.1% of this market share. Due to the introduction of alternatively fuelled vehicles and improved diesel vehicles, petrol vehicles account for only about 50% of the vehicle market share as opposed to the 85% it accounted for in 2000 (SMMT 2011).

The average carbon dioxide emission in 2010 for petrol vehicles came to 144.7 g/km and for diesel vehicles; it came to 144.5 g/km, which shows that they are almost the same. While for their hybrid counterpart, it was 105.9 g/km, which is 26.5% lower than the average market limit. In 2010, there was a rise in the number of registered alternatively fuelled vehicles of about 52.8% from 0.8% in 2009, which represented a market share of 1.1%. This was a significant growth from the market share in 2000 for alternatively fuelled vehicles, which was 0%. Hybrid vehicles accounted for about 96.9% of the entire alternatively fuelled vehicle market and the number of registered pure electric vehicles increased in 2010 to 167 units from 55 in 2009 and this is represented in figure 3 (SMMT 2011).

Brief History of the Electric Vehicle

According to [7], there have been research into developing the electric vehicle since the 20th century, but this was taken over by the more convenient volume production of gasoline vehicles. However, in the 1960s, due to growing of concerns for the environment and receding energy sources, discovering a more suitable environmental mode of transport was revived. From the cost implication of electric cars, to how heavy the batteries to be used were, in addition to their reliability posed a challenge for the technology available. Robert

Davidson designed the first electric vehicle in 1837, and in the 1890s electric vehicles were produced and purchased in Europe and America with more of the vehicles on the roads being electric ones. In 1890, William Morrison produced electric vehicles that enjoyed market success. S. R. and Edwin Bailey also were involved in components manufacture and fitting in 1898, this was however, not much of a success because of its weight. In 1908, they had better success with the fitted components and made to cover about 50 miles in distance after which it required a recharge.

In 1890, H. Tudor produced the lead-acid battery, and in 1910, Thomas Alva Edison produced the nickel- iron battery. The coming of the nickel-iron battery boosted the manufacture of electric vehicles. Thomas Edison then joined hands with the Baileys where they used this battery to produce electric cars and this continued until 1915. The environmental concern generated by gasoline vehicles and the receding reality of energy resources reawakened the pursuit of the development of the electric vehicle. This pursuit has been pegged back by concerns regarding the performance and cost due to batteries. Electric vehicles have a reputation for savings in energy, cost, performance and carbon emission; which makes them environmentally friendly compared to other alternatives. Most of the reawakened interest in Electric vehicles is due to legislation, with manufacturers making major investments in this area based on the impression that consumers will share the same opinion and abide by these regulations. In 1990, General Motors developed a test electric vehicle known as "Impact" and later this prototype was a developed fully into an electric vehicle. The set back of this vehicle was the battery that had only a 2-year life span, which was a discouraging cost implication and lack of convenient charging infrastructures. Honda which brought its electric vehicle into the market in 1997, stopped manufacturing the vehicle in 1999 and the reason was inadequate support from consumers [8].

Automobile Batteries

Batteries are chosen based on some of the features shown in the table below and this will depend largely on the type of vehicle application of the battery in question. For instance, lead-acid batteries do not perform so well when used to power electric vehicles

Battery	Energy/weight Watt-hours/Kg	Energy/volume watt-hours/L	Power/weight watt/Kg
Lead-acid	35	65	180
Nickel-Zinc	65	170	900
Lithium-Ion	160	270	1800
Lithium-Polymer	170	300	2800

Table 1 (Allaboutbatteries.com 2011).

Other battery properties that should be considered are the energy costs, rate of discharge, and the life span (Allaboutbatteries.com 2011). Usage of these batteries in electric vehicles would depend on those that produce great power but possess little weight and consume less energy because of the energy and weight saving parameters of cognisance and significance.

Technological Improvement Alternatives in the Automobile Industry

Technology	Advantages	Disadvantages
Internal Combustion Engine (ICE)	-The technology is available and accepted -The technology has been tested and found to be reliable -The technology can be improved upon - Convenient and efficient refuelling with the necessary facility available	-Seen to produce more CO2 emissions than alternatives -High and increasing price of fossil fuels
ICE powered by biofuel	-Well to wheel emissions low -A wide range of feedstock can be used providing a variety of alternative sources	-The source of feedstock can be a problem sometimes -Lack of public acceptance for moral reasons -CO2 might still be emitted -The quality of the fuel is not certain
Hybrid	-The technology is available -Can cover considerable distance -The tailpipe emissions are less than an internal combustion engine	-The technology is intricate and it is costly to build -There are slight CO2 emissions
Pure Electric Vehicles (EVs)	-They have no tailpipe emissions -They are not difficult to drive and cost less to recharge and maintain	-The source of electricity plays a vital role determining whether it is an advantage or disadvantage -Takes make time to recharge -They have high cost implication due to batteries
Plug in Hybrid (PHV)	-These are similar to pure electric vehicles but with a better distance coverage	The same as electric vehicles but doesn't require new infrastructure
Extended Range EVs (E-Rev)	-These are similar to pure electric vehicles but with a better distance coverage	The same as electric vehicles but doesn't require new infrastructure
Fuel Cell	-These have zero tailpipe emissions -Hydrogen is readily available -It is fast in refuelling	-They have high manufacturing cost implication -To process hydrogen requires a lot of power -A refuelling infrastructure has to be put in place

Table 2 (SMMT 2011).

The Impact on the Energy Sector

The introduction of electric vehicles has generated controversy over the ability of the power grid to cope with the increased electricity demand that would be placed on it. Policy makers are considering various means to motivate investors who will participate in increasing the power supply from sustainable energy sources to compensate for the increase in demand. Various initiatives could be promoted as well, such as encouraging consumers to recharge at times when there is minimum load requirement on the grid like in the night-time and placing the recharging facility strategically to encourage this (SMMT 2011). Electric vehicles are beneficial because of the support it offers to the power supply facility by way of energy savings which the main power grid has access to for periods when the car is not functional as long as the energy needed by the vehicle is available later when they are to be used.

As opposed to the internal combustion engine, which can cover distances of about 500 miles before needing a tank refill that only takes a very short time; electric vehicles can only cover distances of about 100 miles and it takes them hours to be recharged. This creates uncertainty in the minds of consumers who wish to migrate to the electric vehicle. However, it is estimated that a vehicle will averaged be driven for not even up to 100 miles in a day, this hardly is a reason enough to encourage patronage. Industry however, faces the challenge of having to develop batteries that will eliminate these obstacles of distance coverage. Other ways of tackling these challenges that are being considered include battery exchange and initiating an inductive energy transfer with the vehicle still in motion (SMMT 2011).

The Electric Vehicle Challenge

According to [9], for electric vehicles to offer CO2 emission savings, they must have covered a distance of about 129,000 km. However, because electric vehicles have distance coverage of about 145 km upon full charge, the possibility of achieving this distance is unlikely throughout their entire life cycle and even if they covered 160,000 km, the CO2 saving would be less significant. After a recent research into electric vehicles, conducted by the "Low Carbon Vehicle Partnership" (CVP), a scheme supported by the UK government and the automobile industry, it was discovered that throughout the electric vehicle's life cycle, it would have CO2 emissions of about 23.1 tonnes. However, its counterpart internal combustion vehicle will have CO2 emissions of about 24 tonnes. Moreover, when considering the fact that electric vehicle batteries are made from copper, zinc, silicon and so on, the amount of CO2 emissions tends to be even more because the process involved in their manufacture requires substantial amount of energy. In addition, considering the fact that the life span of a battery used in an electric vehicle has a life span of 2 years, a combined effect in terms of emissions of the 2 batteries takes emission levels even higher and comes to about 12.6 tonnes, as opposed to the 5.6 tonnes of the internal conventional engine. Other issues of concern include the increase in demand that would be placed on the power grid and the disposal of these batteries at end of life in terms of the energy used to recover and recycle the constituents of the battery. The Low CVP advocates the automobile industry to publish full vehicle lifecycle emissions instead of only the tailpipe emissions that provide just a fraction of the reality of the environmental impact of the electric vehicle [10].

Understanding the Metals under consideration

Rare Earth Metals

Elements of the periodic table with atomic numbers from 57-71 are called rare earth metals and they are shown in the table

Metal Symbol	Name	Metal Symbol	Name
La	Lanthanum	Tb	Terbium
Ce	Cerium	Dy	Dysprosium
Pr	Praseodymium	Ho	Holmium
Nd	Neodymium	Er	Erbium
Pm	Promethium	Tm	Thulium
Sm	Samarium	Yb	Ytterbium
Eu	Europium	Lu	Lutetium
Gd	Gadolinium	Y	Yttrium

Table 3 (Lifton 2010).

These elements have identical chemical characteristics, which make their extraction and separation a challenging and costly process. However, upon extraction and separation, they possess characteristics that make them a significant component for manufacturing applications which include electric vehicles, solar cells and so on. Two of these elements of importance are “dysprosium” and “terbium”; they are scarce and contribute significantly to the development of greener products. This is because they have characteristics that can make applications lighter and save energy as well. This makes them expensive and in high demand. China is the major geographic location of rare earth metals, this is where they are processed and China exports only very little amounts of its rare earth metals [11]. Heavy metals are in high demand and used in making batteries for electric vehicles because of their high density; however, they remain environmentally hazardous under certain conditions, upon accumulation. Some of them include
mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), thallium (Tl), copper (Cu), Selenium (Se), Nickel (Ni) and lead (Pb). They exist naturally in the earth and it is not possible to destroy them. Some heavy metals known as “trace elements” such as copper and zinc at low concentrations are necessary for metabolic activity in the body of human beings but become toxic at greater concentrations. With heavy metals, there is an inevitable tendency for their concentrations to increase after a while in the human body. Industrial applications involving metal processing like mining and smelting, disposal of waste, metal corrosion, and burning of fossil fuels are only a few amongst many sources of heavy metal pollution [12].

The process of Heavy Metal adsorption

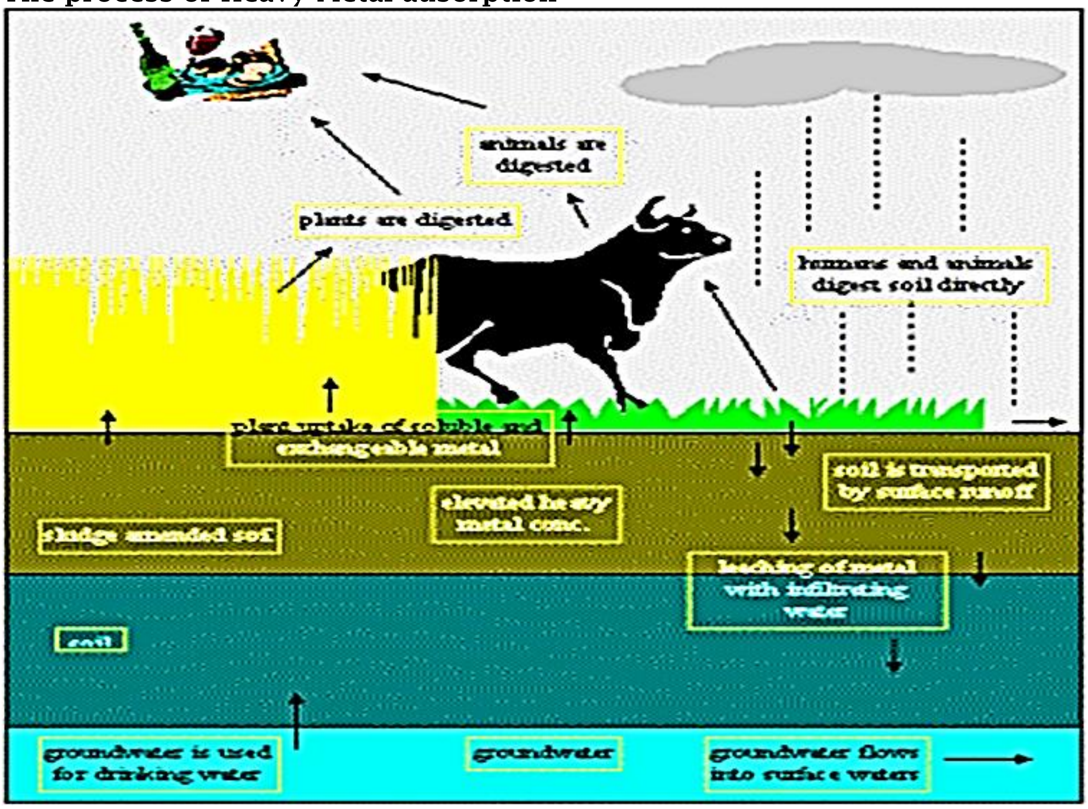


Figure 4 (Lenntech B.V 2011).

Figure 4 above shows how heavy metals are transferred into the human body by the food taken in, from the initial stage to the final stage. That is, living organisms adsorb these metals through various processes in their environment and how this contamination is brought about via a series of processes from the leeching of the metal into the ground water and soil, to the consumption of this soil by animals and plants. With human beings being the final consumers of this heavy metal that leads to various toxic consequences.

Historic Harmful Effects of some heavy metals in the Environments

Year	Hazard	Nature of Hazard
1932 and 1952	Minamata and Minamata Syndrome	Mercury poisoning of aquatic life from sewages in Minamata Bay in Japan in 1932 came from Chisso's chemicals works. The mercury was then transferred to the populace of this area leading to several kinds of mercury related illnesses
1986	Sandoz	This mercury pollution came from water used to put out major fires and fungicide, which had mercury in it, contaminated the Upper Rhine. This led to the deaths of so many fish stretching as far as 100 km.
1998	Environmental disaster leads and the environmental consequences	Contaminated water in Coto de Donana reserve in Spain was caused by dam breakages of certain mines. This resulted in the damage of Europe's largest bird sanctuary and Spain's agriculture and fisheries.

Table 3 (Lenntech B.V 2011).

Government's Initiative
According to [13], various initiatives set up by the UK government include some of the following

- The UK government in 2009, formed the "New Automotive Innovation and Growth Team" (NAIGT) to create a platform for stakeholder dialogue to strategically outline and decide the way forward for the automotive sector from challenges through innovation and development. Part of the council's responsibility is to seek for investors for the UK automobile manufacturing industry to enhance efforts towards the development of alternatives to the vehicle emission dilemma and alternative sources of energy. This will help to further improve the supply chain and establish a platform for public opinion for the automotive sector in the UK.
- Another initiative by government was the establishment of the "Technology Strategy Board" (TSB), which deals with the promotion and provision of the necessary backing of research and development activities regarding technologies involved in introducing lower emitting alternatives. Electric vehicles with emissions less than 50 g/km were been put to test to determine how they will perform in real life scenarios. To achieve this, 340 electric vehicles were selected and this programme called the Ultra-low carbon demonstrator scheme benefited from a £25.5 million grant awarded by the technology strategy board.

- The other initiative established by government in 2009, was the “Office for Low Emission Vehicles” (OLEV), done with the objective of integrating policies and investments in the low carbon agenda so that the UK emerges as on the global font as a leader in this aspect of sustainable development. This initiative integrates policy and investment involving other schemes like the Department for Transport (DfT), Department for Business Innovation and Skills (BIS), the Department of Energy and Climate Change (DECC), and the Technology Strategy Board (TSB).

In 2010, the office for low emission vehicles put in place the plug-in vehicle grant, which was to take effect the following year. It was a £43 million grant which meant around a discount of £5,000 for the purchase of vehicles in the M1 class including the electric car that have CO_2 emissions lower than 75 g/km and a distance coverage of 70 miles. It was also saddled with the responsibility of putting in place recharging facilities in line with the plug-in places scheme, which covered areas such as London, Milton Keynes and the North East. This project was to last for 3 years and was aimed at achieving 11,000 recharge units in the UK. Other areas that were in line to benefit from the scheme include the Midlands, Great Manchester, East of England, Scotland and Northern Ireland and this aimed at achieving 4,000 more recharge units. However, other mediums through which government sought to be fully involved with were

- The establishment of a Green Investment Bank with an investment of around £1 billion in alternative carbon technologies
- To save £10 every day and an estimated £1,700 every year from implementing the London congestion charge for vehicles that have CO_2 emissions of less than 100 g/km
- Government loans were also given to programmes related to reducing carbon emissions by establishing the “automotive assistance project” (AAP) and the scrap incentive scheme (SIS) (SMMT 2011).

Relevant transport policies regarding the development of electric cars

[14], describes some other government regulations that deal with alternatively fuelled vehicles particularly the electric car. They include the following

- Renewable Energy Directive (RED) (EC, 2009c)
- Revised Fuel Quality Directive (FQD) (EC, 2009b)
- Regulation on CO_2 from cars (EC, 2009a) [15].

End of Life Vehicle Legislation (ELV)

This directive’s goal is to minimise the extent of waste from M1 and N1 vehicles at the time of disposal. In the annual sustainability report of society for motor manufacturers and traders (SMMT) and the Department of Business, innovation and skills (BIS), statistics representing how the environment performs is made available to the public, and this is done every 2 years. The past 5 years have seen the authorised treatment facilities (ATF) (about 1,800 of them) of car manufacturers in Europe surpass the goals set before them. The automobile sector had a rate of recovery of about 85% in 2008, and this was a lot more than what was obtainable the previous year. With present improvements in recycling programs, this figure is set to go up to about 95% in 2015 and further developments in automobile manufacturing techniques would ensure that at most just 10% of the automobile’s lifecycle carbon emission originate from production techniques (SMMT 2011).

The End of Life Vehicle Legislation relevant to heavy metals regulation include the following

- The End-of-Life Vehicles Regulations 2003
- The End-of-Life Vehicles (Producer Responsibility) Regulations 2005
- The End-of-Life Vehicles (Amendment) Regulations 2010
- The End-of-Life Vehicles (Producer Responsibility) (Amendment) Regulations 2010

In the 2005 regulations, some amendments are made to the 2003 regulations; however, both of them are used as a compliment of each other to enforce the provisions of the European Union End of life vehicle directive (2000/53/EC). Moreover, the 2010 regulations were put in place to effect certain technical amendments to the 2003 and 2005 regulations. The End of life vehicle regulation 2005 translate into the UK law the provisions of the End of life directive (2000/53/EC) that encompasses the following

- From the 1st of January 2007, the "Free take-back" of end of life vehicles
- The responsibility of the manufacturer to carry out end of vehicle life take back by convenient chains of ATFs and units of where they can be collected
- The responsibility of the manufacturer and the ATF from 2006 and beyond, to deliver recycle and recovery goals for end of life vehicles

As found in Annex IIA of the council directive 70/156/EEC, these regulations are applicable to M1 or N1 class of vehicles. However, the regulations would not supersede the other EC regulations, national regulations, air emission standards, or environmental protection standards (BSI, 2010).

Alternatively Fuelled Vehicles

According to [16], recent research into the sustainability challenge of the internal combustion engine and the developments in alternatively fuelled options, which are based on the well to wheel emissions and the automobile life cycle, tend to point towards making use of renewable energy sources or fuels with low carbon content. How efficient these alternatives are can be evaluated in more depth and those ones, which will result in delivery of the highest level of energy savings and emission reduction, would be the industry's focus. However, the electric and hybrid vehicles seem to be emerging as the preferred alternative of focus, and to this effect, the industry invests hugely in research and development of aspects of this alternative. Electric vehicles and their hybrid counterparts have no tailpipe emissions hence they are referred to as "zero emission vehicles".

1. **Diesel**

With the recent improvements in diesel powered vehicles, consumer preferences well known in conventional type vehicles can be retained while achieving relatively low emitting statistics. Diesel powered engines are around 24% efficient as against the 20% efficient gasoline internal combustion engine and this means that the diesel powered automobile offers greater energy savings because the well to tank efficiency of the vehicle is better than its gasoline powered counterpart. This assessment in favour of the diesel fuel is this way because even though the carbon constituent of the diesel fuel is more than that of the gasoline-powered engine, the diesel manufacturing efficiency and automobile efficiency is greater contributing fewer greenhouse gas emissions. However, one challenge this alternative faces is the greater amounts of emissions of NOx and particulate matter (PM), posing a significant obstacle in the marketplace for diesel powered vehicles [17].

2. **Ethanol**

Petrol fuels used to power internal combustion engines can be combined with small quantities of ethanol, that is, 10%, E10 or in greater quantities of variable fuelled automobiles of 85%, E85 manufactured by most producers. However, understanding clearly the impact these alternatives have on the environment is by evaluating the well to tank aspect of their entire life cycle. A major setback in the alternative of using ethanol as a fuel for vehicles is how expensive it is in terms of energy consumption, about 2 times the cost of the petrol fuel used in the internal combustion engine. This is however; rather unfortunate because ethanol sourced from vegetation has a sound manufacturing and usage efficiency. Other setbacks include the fact that extensive cellulose-ethanol manufacturing plants do not exist and this generates a lack of confidence in the life cycle analysis. Other sources of ethanol such as fossil fuels are better options in terms of cost but in terms of sustainability rate low because of the quantity of greenhouse emissions that would be released [18].

3. Fuel Cell Vehicles

The option of using hydrogen fuel cells to power cars are generally seen as one of the best alternatives to the internal combustion engine, and this is because they have zero emissions, emitting just water and heat, and a great vehicle efficiency of 40% for the "proton exchange membrane" (PEM) fuel cell. There is a lot of on-going research and development into this technology alternative but they do not seem likely to produce a functional outcome in the near future. It also includes other challenges that involve the technologies of storing hydrogen and the economic implication of migrating to this alternative. There are several methods of obtaining hydrogen such as electrolysis, from natural gas and so on, and the efficiency with which it is manufactured and used afterwards, is greater than what is obtainable with the internal combustion engine. The alternative presented with the hydrogen vehicle will need to be analysed and offered in a more cost effective way to meet standards of economic sustainability, other analysis to be considered for re-evaluation will include the vehicles distance coverage, performance and so on [19].

4. Hybrid

These types of vehicles are powered by 2 or more different kinds of fuels, usually by both batteries and an internal combustion engine. Hybrid vehicles introduced into the marketplace like they have offered energy savings of about 40%, but the cost implication of owning a hybrid and their weight, which is greater than their internal combustion engine counterpart, are huge discouraging factors. Moreover, battery and disposal costs do not do much to help their course. The situation in developing countries and the switch to low emitting vehicles is also a case of concern, because in these parts of the world, the conventional type vehicles remain the less costly alternative since consumer preference will largely depend on cost [20].

CO2 Emissions From Vehicles and the Electric Car

When the electric car uses only batteries to function, it is referred to as the tank to wheel category of emission of the vehicle. Considering this category for electric vehicles, they do not have any tailpipe emissions. Another category of the vehicle emissions is the well to wheel, and in this category, the emissions at the time of electricity production is what is been considered. It is with the well to wheel evaluation that CO2 emissions from vehicles can be compared clearly. Table 4.1 represents the emissions category of a pure electric vehicle (EV) compared to that of small to medium sized internal combustion engine (ICE) vehicles

Emissions Category	Pure Electric Vehicle CO2/km	Internal Combustion Engine CO2/km
Tank to wheel average	0 g	133.1 g
Well to tank average	80 g	14.5 g
Well to wheel average	80 g	147.6 g

Table 4 (SMMT 2010).

The table shows the amount of emissions from every aspect of the vehicle life cycle and these values show that the pure electric vehicle emissions are considerably lower than that of the internal combustion vehicle.

With improvements in energy generation from making use of more renewable energy sources, the CO2 emissions released by any stage in the production of an electric vehicle will continue to reduce. Recently, tailpipe emissions from internal combustion engines have improved immensely emitting as low as 88 g/km. However, an addition of the average well to tank value given in the table above of 14.5 g/km, it could bring the well to wheel emission of internal combustion engines to a small value of 102.5 g/km. Other tailpipe vehicle emissions that are harmful to the environment include nitrous oxide (NOx) and particulate matter, but industry emission analysis usually relates to only CO2 emissions. Having the knowledge of all these emissions in mind emphasises the significance of minimising vehicle tailpipe emissions with the electric vehicle set to be of immense importance [21].

Electric Vehicles Batteries

A description of the battery of the electric vehicle from Ehow.com (2011), describes them as being secondary type batteries because they have the capacity to save energy in the form of charges and can readily be recharged as opposed to primary type batteries that have shorter energy saving and rechargeable capacity. The batteries are placed in a T-format through the middle of the electric vehicle, and the head of the "T" facing the backend of the vehicle, which offers more distribution of weight and balance. The batteries are made from a variety of metallic materials that include nickel-iron, nickel-zinc, zinc-chloride, and lead-acid. Much of the weight of electric vehicles of about 40%, come from the batteries and the electric drive mechanism, compared to the conventional gasoline vehicle, the drive system and engine account for about 25% of the vehicle weight. A variety of electric vehicle battery metallic material combinations are in use at the moment, and those with lead-acid components are more widely used, however, others in the market with seemingly bright prospects are the nickel metal hydride (NiMH) types.

Disposing the Battery of an Electric Vehicle

The life span of an electric vehicle battery is 3 years, after which it would need to be changed and this would lead to the problem of getting rid of these batteries because of environmental concerns. However, there are several government regulations put in place to ensure these battery wastes and the threats they pose due to their constituent heavy metals are put away appropriately. Therefore, the metals contained in a battery have to be removed prior to the batteries been disposed of. After the metals have been removed, the batteries can be gotten rid of in landfills which help avoid leaking any other harmful components into the environment. The appropriate disposal of batteries increases the apparent cost of batteries that go for around £5,000. The environment can be affected directly by waste from batteries in the form of pollution to water-bodies and living organisms they contain that are close to production sites. Other effects include atmospheric pollution, which can lead to harmful effects on human beings and increase the cost of electricity supply in the area where they are manufactured [22].

Heavy Metals

From [23], the term "specific gravity" defines the density of a material in a particular quantity of solid as against an equal quantity of water. Metals are referred to as "heavy" because their specific gravity is about 5 times that of water, water's specific gravity being 1 at a temperature of 4 degrees Celsius. Heavy metals include the following: antimony, arsenic, bismuth, cadmium, cerium, chromium, cobalt, copper, gallium, gold, iron, lead, manganese, mercury, nickel, platinum, silver, tellurium, thallium, tin, uranium, vanadium, and zinc. Trace quantities of heavy metals can exist in the body and may be harmless to the living organism; however, increased quantities are harmful and hazardous to living bodies and their environment. There is a shortage of alternatives available to make automobiles more environmentally sustainable without forfeiting some of the most attractive and desired characteristics that the vehicle possesses. None of the alternatives been explored today has emerged as being completely green; nevertheless, some alternatives are discovered to be greener than others are [24].

Economic Aspects Of Sustainability

The Recent Technological Breakthrough in the automobile industry, which has led to the development of vehicles that have very high cost implications, contradicts the quest for sustainable development in terms of social issues. Moreover, the apparent much more affordable costs of conventional gasoline powered vehicles and their fuel creates an even bigger challenge for new technologically developed options to compete with. When considering economic sustainability, it is vital to evaluate the difference between social costs and private costs. It is based on this evaluation that virtually all vehicle producers operate, reducing the impact of their private costs by manufacturing automobiles that would generate maximum profits. On the other hand, customers make efforts to reduce their private costs as well by buying cheaper cars, with customers and automobile producers having little or no regard whatsoever for the social costs of their choices, which is what sustainability is based on [25].

Challenges For Green Design

According to [26], 3 vital setbacks in manufacturing alternatively fuelled vehicles include the following:

- Fundamental contrast in social objectives

For many years now, governments have provided legislations that govern the production of vehicles effectively setting standards for fuel economy, passenger safety and vehicle emissions. However, recent developments show that these government legislations have led to the introduction of more lightweight cars that use up less fuel but fail to meet other standard requirements such as the safety of the passenger

- Sustainable development can be achieved from improvements in technology and attempting to change consumer preference

Various attempts made to encourage customers to buy efficient and small lightweight cars have proven to be futile. The best efficient vehicles on the market today only account for a small portion of sales in the entire vehicle market, with most customers still having their purchasing preferences in big and heavy less fuel-efficient vehicles and in effect generating greater returns for automobile manufacturers.

- Challenges in outlining the exact impact of options in terms of cost and benefit

This relates to the fact that the exact extent of technology alternatives or environmentally threatening materials cannot be determined and comprehensively analysed. These inconsistencies are obvious with the introduction of alternatives that subsequently are discovered to do more harm than good, or more harm than even previous options would to the environment.

New efficient vehicles, when considering their entire life cycle would cost more and this contradicts the fundamentals of economic sustainability. In terms of social costs, these new technologies fail to meet even certain basic vehicle standards that consumers cherish, including distance coverage, safety and high performance. Present steps been taken by vehicle producers to introduce efficient vehicles should primarily include an analysis of what the consumer wants before assessing the technological know-how available to bring their desire to the marketplace [27].

COMPLETE AUTOMOBILE LIFE CYCLE

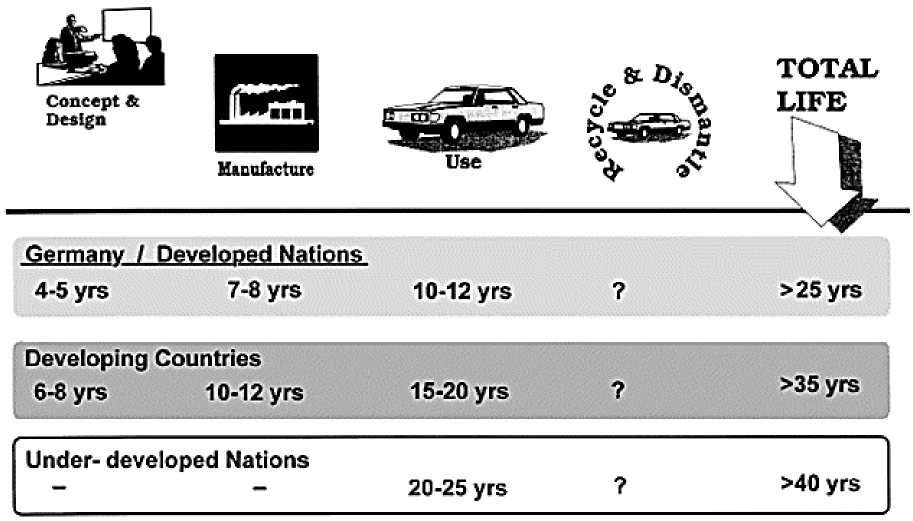


Figure 6 [28].

The diagram above shows how long it takes in different economies of the world to develop and design a vehicle from the concept and design stage to the recycling and disassembly stage. It is important to note the use stage here which has the highest number of years and the most significant because it is where vehicle emissions have been the most over the years. From the initial analysis above and the figure represented above, the amount of time it takes to bring automobile products to the marketplace can be seen and from this, it can be understood that their environmental effects may not have been determined at the time of design and manufacture.

Therefore, a framework can be developed that takes into cognisance the sustainability of the product, in terms of research and development and how these level up with the economic, environmental, and technological factors, upon which the whole system can be re-evaluated in terms of design, materials used, production processes, and performance. When considering the production of environmentally sustainable products, careful consideration is given to energy sources and whether they are renewable or not, due to

- The product's ability to be recyclable
- The extent of efficiency of energy been used
- The mandate of abstaining from using toxic components
- Lowest resource requirement during manufacturing activities
- Product life span [30].

Lack Of Consistent Policies

[31] opine that automobile legislation and policies that affect various aspects of the life cycle development of the vehicle in different parts of the world may not be the same, such as in European countries and in the United States of America (U. S.), and these inconsistencies deter the fight for sustainable development. Some of these inconsistencies include

- Petrol fuel taxes in the U. S. are less than the taxes on petrol in Europe, therefore, this is the reason why the cost of petrol in the U. S. is less than in Europe
- In the U. S., legislation is an instrument used to control the production and purchase of high emitting automobiles, and this dates as far back as in 1975, when the "Corporate average fuel economy" (CAFE) was established. CAFE was aimed at manufacturers of automobiles and a directive given to them about maintaining a particular average economy of fuel in their products

- Almost every country in Europe have implemented the End of Life Vehicle legislation, but in the U. S. there is no legislation for the vehicle end of life

In order to assess the direct and indirect or environmental costs of manufacturing a product, its useful stage and that leading to the product disposal, certain instruments are put in place to evaluate its life cycle cost throughout its entire life cycle. The instruments put in place can then regulate the product's efficiency, which is vital because it is in the design stage that environmental costs are evaluated [31].

A COMPARISON BETWEEN ELECTRIC VEHICLES AND CONVENTIONAL VEHICLES

The Weight of an Electric Car Battery

The batteries of the electric vehicle have a bigger responsibility than conventional type vehicle batteries because they are saddled with solely powering the vehicle unlike conventional vehicles that are powered by gasoline and the function of the batteries are reduced. For this reason, electric vehicle batteries are placed in combined fashion such as arrays or packs to generate more power for the vehicle; however, this offers a setback of making the battery very heavy reducing the vehicles ability to cover far distances. Lithium-ion battery arrays in electric vehicles weigh around 453.6 kg, and vehicle manufacturers would make efforts to reduce the collective weight of the vehicle in the vehicle design and use of materials. In the end, the vehicle may weigh a total of 1220.2 kg, which is a fair trade off having in mind that most of this weight comes from the battery [32].

Heavy Metals in the Conventional Car

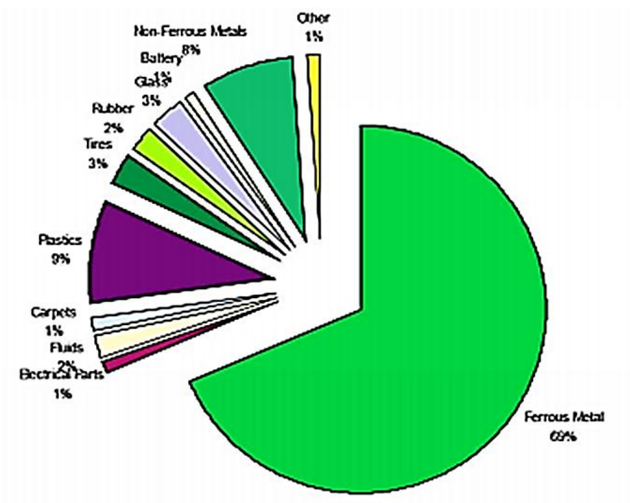


Figure 7 Average Material Distribution of Automobile in 1998 [33].

Most ferrous metals are those that contain iron while non-ferrous metals are those that do not contain any iron. Heavy metals constitute both ferrous and non-ferrous metals and from the diagram above, we see that non-ferrous metals in conventional vehicles only constitute a small portion, while ferrous metals a large portion. Ferrous metals are alloys; therefore, they can be a combination of different metals including heavy metals. This shows that conventional vehicles have a considerable amount of heavy metal constituents; however, the manner in which these metals are applied goes a long way to determine their environmental toxicity. Most of the applications of toxic metals in conventional vehicles are the same when applied to electric vehicles, however, a significant difference in their application is the substantial quantity of heavy metals used in batteries of electric vehicles and this is why this is the application that is of greater concern. If this is the case, it is then is then vital to determine the exact criteria of preference in the development of the electric vehicle as a solution to the conventional automobile [34].

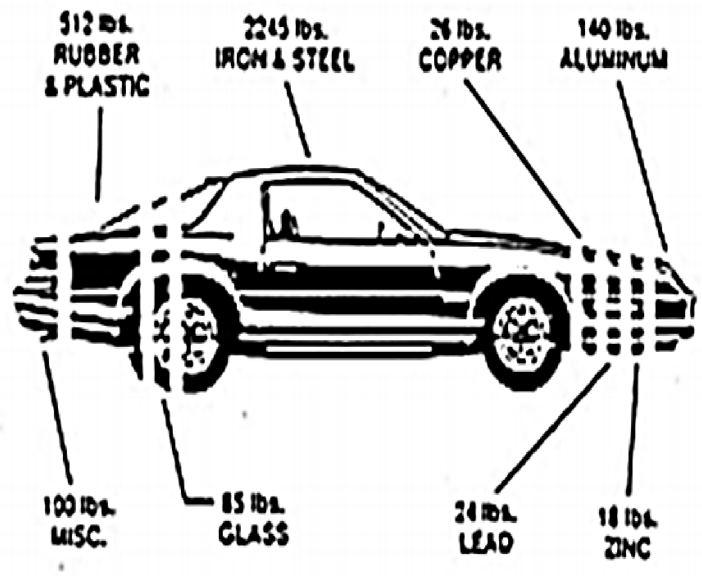
Weight of Fabricated and raw materials containing heavy metals on a conventional Vehicle

Fabricated Materials		Amount of Raw Materials Required	
Zinc	18 lbs.	Zinc ore	720 lbs.
Aluminium	140 lbs.	Bauxite	560 lbs.
Glass	85 lbs.	Silica sand	170 lbs.
Iron and steel	2,245 lbs.	Iron ore	4,600 lbs.
Rubber and Plastic	512 lbs.	Crude oil	980 lbs.
Lead	24 lbs.	Lead ore	960 lbs.
Copper	26 lbs.	Copper ore	2,600 lbs.
Upholstery	100 lbs. and so on	Misc. materials	250 lbs.
Total	3,150 lbs.	Total	11,200 lbs.

(The Automobile Industry)

In the diagram above, the weight of several heavy metals used in conventional vehicles are shown, this is because the energy consumption of the vehicle relates to its weight. This could be in terms of metals processing or direct emissions during usage.

Some of the parts where these heavy metals are used



(The Automobile Industry)

When comparing the weight of the electric vehicle and the internal combustion vehicle, it was found that the weight of an average electric vehicle was about 1385 kg and that of an average internal combustion vehicle in the same compact and medium category is around 1395 kg, which is only a small difference (The Automobile Industry).

Comparison between an Electric Car and a Conventional car (ICE)

Comparison category	Electric	Conventional
Vehicle efficiency	86%	13%
Vehicle Cost	£31,000	Between £10,000 and £49,000
Greenhouse emissions	No direct emissions	19.4 lbs. per gallon of petrol
Smog emissions	No direct emissions	14.9 lbs. of HC, NOx per 15,000 miles
Vehicle Speed	From 0-60 in 5.6 seconds	Differs

(McKinnon, 2009).

The table above shows the comparison between the electric vehicle and the conventional vehicle, and with the substantial difference in efficiency values, easily the preferred alternative would be the electric vehicle because this high efficiency value means it makes use of less energy to function. However, this efficiency value for the electric vehicle is only this high when the source of energy is from an efficient renewable source.

Comparison between the Engines of electric vehicles and internal combustion vehicles

Internal combustion Engine	Electric Motor
About 33% efficient and uses a radiator	Around 90% efficient and does not use a radiator
Emits greenhouse gases	No direct emissions
Loss of power when idle	No idle
Energy conversion is not reversible	Has regenerative braking
Big and heavyweight	Small and lightweight
They are noisy	They are silent

(The Automobile Industry).

The table above represent some advantages of the electric vehicle over the conventional type vehicles. But as was explained earlier, these advantages are conditional, and until those conditions are satisfied before the full benefits of the electric vehicle would be seen.

Analysis Using The Electric Car

From the table above, we see that averagely CO_2 emissions produced per kilowatt-hour from these sources gives a combined outcome of about 607 grams. With these figures, we can compute the amount of electricity required by an electric vehicle to cover 1 kilometre. According to [35], a modern electric car requires 0.2-0.3 kWh per kilometre. Therefore, the amount of electricity produced that would be required for every kWh necessary to power the vehicle is about 1.1 kWh from the energy producing plant, in addition to energy losses that would be deducted. However, the electric that needs energy of 0.2 kWh per kilometre is calculated thus

$$0.2 \times 1.1 \times 607 = 135 \text{ g } CO2/km$$

Using the technique above, an electric vehicle having an energy requirement of 0.3 kWh per kilometre would produce an outcome of 200 g CO2/km [36]. Therefore, pure electric vehicles averagely emit between 135 g CO2/km and 200 g CO2/km depending on the distance covered.

Analysis Using A Conventional Type Vehicle

CO_2 emissions for average new vehicles such as the BMW and the Citroen are from 195 g/km to 145 g/km respectively with the general average being about 162 g/km. However, because of energy losses that form part of the generation process, the upper limit of CO2 emitted could be up to 224 g/km. Values of between 162 to 224 g/km for the conventional type vehicle, against a value of 135 to 200 g/km for a pure electric vehicle are not very different emission levels. Therefore, suddenly moving from conventional vehicles to electric ones in most places in the U. S. does not have a significant influence on reducing emission levels, except the power grid is developed to make provision for more power generation from wind, tidal, nuclear and other lower emitting alternatives [37].

Energy Generation And Implications For Electric Vehicles In Places Like Canada

In places like Canada, sources of energy include more of hydro, nuclear and coal sources, and this means, there are fewer emissions realised from the electricity produced here compared to the U. S. This is illustrated below

Source of Energy	Generating Capacity percentage (from Energy Information Administration)	CO2 emissions in grams
Coal	18%	180
Hydro	58%	3
Nuclear	13%	1
Natural Gas	10%	50
Alternatives	1%	0
Total	100%	234

[38].

Given the same assumptions about electric vehicles as in the American analysis above, electric cars in Canada could expect on average to cause CO_2 emissions of

$$0.2 \times 1.1 \times 234 = 51 \text{ gCO2/km} \quad \text{To} \quad 0.3 \times 1.1 \times 234 = 77 \text{ gCO2/km}$$

Therefore, we compare the values above of between 51 g CO2/km and 77 g CO2/km with those of the internal combustion vehicle of between 162 and 224 g/km and this gives a clearer difference and advantage of using the electric vehicle. It shows that the source of energy is a significant factor in determining whether the electric vehicle emits more or less of CO2. In some locations in Canada like Ontario and Quebec, the electric vehicle CO2 emissions would be much lower, just between 45 g/km-70 g/km for Ontario and between 2 g/km-3 g/km for Quebec. This is because of the use of lower emitting sources of energy like nuclear, hydro and coal [39].

[40], suggests that alternatively fuelled vehicles present the possibility of a great chance for sustainable issues of the environment that have dubbed the automobile industry for many years to be solved or minimised. However, their success amongst other factors, depends on the nature of their entry into the marketplace, which includes the proper policies in place, appropriate technological readjustments made, and consumer needs being met. On entry, they would be seen to deliver lower emission vehicles and the efficient use of energy resources, however, emission reductions from their well to tank aspects would have to be improved on as well. Another important advantage that they offer would be the ability to save energy from renewable sources when supply is in excess, which would lead to more investments in renewable energy in the power sector. There would have to be significant improvements in many aspects of the uptake of electric vehicles before their success can be achieved. Some improvements in policies are necessary because the present government policies on offer, with the influx of alternatively fuelled vehicles into the market, would increase the electricity requirement from power stations. This increase may not have any reducing effect on petrol consumption for internal combustion vehicles, and if this happens then the aim of emission

reduction would be somewhat defeated. Government policies would then have to be put in place to make sure that this excess generation of electricity is balanced out [41].

End of Life Vehicle Legislation

The end of life vehicle directive (2000/53/EC) is meant to prevent the entry of wastes from automobiles at the reuse, recycle or other activities of recovery to the environment and every aspect of sustainable development. The directive is mandatory directly on automobile producers and indirectly their suppliers to minimise usage of toxic materials in vehicles at every stage in their manufacture to avoid entry into the environment on any account, which makes it convenient to recycle and dispose of any waste easily. The directive further points out specifically these toxic materials in question, which include cadmium or hexavalent chromium, mercury, and lead; it also outlines exceptions to this stipulation available in Annex II of the directive, of about 13 applications depending on their amounts [42].

Heavy Metal Substitution and Implications

Many efforts over the years have been directed into developing alternatives for toxic heavy metals and some of these efforts have yielded some success, however, the successful substitution of these metals in their applications would involve trade-offs in product purpose, characteristic and would involve cost implications. Some of these substitutes in applications include flashlights with lead components being replaced by soft zinc, mercury in thermometers and the change in colour of most applications from red and yellow colours to white and brown upon bans placed on cadmium. However, in achieving substitution, consumer preferences also play a key role and applying alternatives to products would need to demonstrate the fact that after application, the market demand for the product stays is enhanced or remain the same. With the processes involved in the automobile industry presently in developing technologies for vehicles and the framework that supports this set up, it difficult to ascertain the fact that a substitute would be cheaper or be more environmentally sustainable than its predecessor. Some of these circumstances include lead cable sheaths used in electric cables being substituted by aluminium sheaths. The aluminium sheaths also lead to high amounts of energy consumption and environmental pollution (European Commission, 2002).

Limitations Of Current Approach

In [43], some of the obstacles that lead to a company's inability to develop new strategies include the objective of profit maximization and the conventional systems of vehicle manufacture. The present pattern of the industry's set up compels it to mass vehicle production and the consequent effect of generating returns from the investment. This business approach operated in the automobile industry would easily lead to oversupply and subsequently generate waste. In other aspects of vehicle development, it is discovered that the development of alternatively fuelled automobiles would tend to lead to high consumption or usage trends. Considering all these scenarios, it is necessary that efforts are been made to develop more cohesive systems where economic and environmental strategies are integrated to bring about sustainable development. This would demand that all stakeholders are involved to make it a success. However, other areas that should be considered much more in the quest for sustainable development and the introduction of new technologies through innovation are the consumer preferences and system transformation.

From all the analysis of the current trends in the automobile industry and the efforts made to solve the issues of sustainability, the type of improvements sought after would only come when there is efficiency in the use of resources and a transformation of consumption habits. Therefore, there is a strong relationship between product manufacture and the manner in which it is consumed, an understanding of these aspects far beyond design and technological improvements is a step in the right direction to achieving sustainability. It should involve an approach from the dimension of the vehicle and its primary functions, and effectively making changes in the marketing and economic approach for automobile businesses and this change is difficult because it has huge cost implications which most automobile companies are not ready to undergo [19].

IMPROVING POLICIES AND DEVELOPING A PRODUCT SERVICE SYSTEM

Policy improvements

The extra electricity generated because of the introduction of new efficient vehicles such as the electric vehicle should be from renewable sources. Therefore to support this idea appropriate policies should be put in place to make sure that renewable energy generation is stepped up to compensate for the increase in demand imposed by the uptake of these new technologies that are powered by electricity. Other policies that would be important are those that would be put in place to encourage the customers to buy green electricity for use in the electric vehicle, while the supply of electric power to recharging units should be provided from these green electricity sources. It however seems likely that with the present government policies on CO2 emissions from vehicles, as people buy and use more of these more efficient vehicles, the policies associated with internal combustion vehicles would not be as strict anymore or be improved upon, which contradicts attempts to cut down vehicle emissions. Therefore, these legislations could be developed further using fiscal policies and getting rid of “super credits” and the electric vehicle culture of zero counting. Manufacturers use super credits to balance the manufacture of conventional vehicles when they sell electric vehicles [9].

Presently, the legislations available such as the directive on renewable energy (RED) and so on, do not provide enough concrete figures of the exact amount of electricity consumed from renewable sources that electric automobiles make use of, and the amounts of CO2 released. To achieve these, technologies such as smart metering could be employed, which would be beneficial now and for many years to come in the on-going battle to maintain a sustainable environment. There should be sufficient revision of relevant standards and technologies that are associated with the possibility of electric vehicle batteries retaining most of their energy for lengthy periods so that effective management in terms of energy requirement and supply can be practiced. This would however, help to take full advantage of the growing investments in renewable energy generation and supply. In the end, all these point to the fact that policies need to be developed and reviewed to support the influx of electric vehicles into the marketplace. On a small scale, the available policies may be sufficient, but on a large scale policies have to be put in place to make sure the full benefits of this initiative are achieved [20].

Developing service systems

[11] suggests that a system can be developed to take the connection between manufacturers and customers to a completely new level, which is the product service level. This system would include the development of services, products, facilities and value chain into a more customer oriented set up which supports environmental preservation as well as improve business performance. It is a system that is aimed at satisfying a particular function of the product by service on offer to the customer rather than the conventional methods of business that involve buying products and disposing them as waste. This system relates to the ability to sort out many challenges that arise from the use phase of the product life cycle, which is the most critical stage of the automobile life cycle. Therefore, if the manufacturer takes responsibility for the management of the product over its lifetime, more environmental savings can be done and avenues for business cash flows can be discovered.

For effective implementation of this system, certain factors have to be sorted; some of them include putting in place an ownership scheme. This involves product leasing or rental by the manufacturer to the customer as opposed to the customer buying and owning the product. The cost implication of the product usage would reduce and this eliminates the implication costs of purchase as well. As the system goes on, the relation between manufacturers and consumers would improve, because of this, appropriate design improvements can be made and product usage is enhanced making it easier for manufacturers to provide information and advice. This establishes a feedback system where information exchange is vital and would effectively lead to the development of more environmentally sustainable management systems [30].

CONCLUSION

In this project, a review and analysis of the need for stakeholders to adopt a different approach to achieving automobile sustainability by improving the legislation involved in the introduction of electric vehicles containing toxic heavy metals was conducted and the following were discovered

- A review of the current CO2 emission situation and greener alternatives, suggested that stakeholders in the automobile industry are in the process of seeking alternatively fuelled vehicles to tackle the sustainability issue in the transport sector
- A review of the Electric car and the implication of Heavy metals used in making their batteries showed that the electric vehicle presents a viable alternative to solving the sustainability issue in the vehicle industry. However, heavy metal legislation and environmental implication is an obstacle to the uptake of this initiative
- An analysis of the business implication of developing the electric car suggests that there is need to re-address available legislation, ensure that consumer's needs are met and improve power supply in the industry for the success entry of electric vehicles into the market
- An analysis of the comparison between the Electric vehicle and a Conventional car showed that the electric vehicles benefits are only delivered when the source of energy for electricity supply is from renewable energy sources
- A critical analysis of the current situation within the industry and suggestions on the way forward providing recommendations was done to suggest that policy adjustments have to made and a new approach needs to be adopted to integrate all the aspects of sustainability.

In addition,

- With the proper policy in place, consumers would be motivated to purchase the product, the power grid would be set up appropriately to cope with the inherent increase in energy demand, and facilities that support the electric vehicle would be properly installed from the right (renewable) sources.
- Toxic heavy metals used in most of the applications of the vehicle especially its batteries should be banned, substituted or continuously recycled in accordance with regulations. Reduced battery costs (purchase and replacement) and improved performance, which have been one of the main reasons why electric vehicles have not been well accepted in the markets have to be made through methods such as product service system, and car ownership scheme can help in this area.

LIMITATIONS

A few assumptions and limitations in this project include

- Using data containing information on Europe and the UK and using this to draw certain generalised conclusions
- Gathering data from mainly library based sources without necessarily contacting stakeholders involved
- Restricting the scope of analysis of the introduction of heavy

metals into the environment on heavy metals alone

- Due to the available data on the topic area, the scope of analysis and recommendations may not be as comprehensive as it should be

Questions For Further Research

On the global front, for under developed and developing countries, what are the economic, social and environmental implications of developing alternatively fuelled vehicles with the apparent staggering electricity supply and little or no substantial infrastructural or knowledge investment available to cope with these developments? This stands a chance of undermining the hard work been put in by other parts (developed) of the world when considering the fact that the environment (earth) is collectively and simultaneously affected by toxic gas emissions. In addition, would policy adjustments and developments, battery technology and costs, and solutions to renewable energy generation be sufficient to support the uptake of electric vehicles?

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