Re-use and Re-cycling of Automobile Plastics – A step to manage plastic waste in Ghana.

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DEGREE THESIS
PLASTICS TECHNOLOGY
2012

DEGREE THESIS	
Arcada	
Degree Programme:	Plastics Technology
Identification number:	
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Title:	Re-use and re-cycling of automobile plastics – a step to manage plastic waste in Ghana.
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Commissioned by:	

Abstract:
The main aims of this thesis were to identify the disposal and management of cars plastics part after use, find out the effect plastic waste brings to the Ghanaian environment and to identify mesures of improving plastics waste management in the automotive sector, (end-of-life vehicle in accordance with European union deritives). Analysis the benefits of re-using or recycling of plastic waste in Ghana. This thesis done with a qualitative analysis by interviews and observations and was found that, most old plastics parts are usually re-used and that there were very little to do with recycling as Ghana did not have manufacturing car company plants. The plastics which are out of use and are beyond repairs are dumped at landfills. The thesis talks also of end of life vehicles legislation in the European Union and tried to find better ways of improving the waste in accordance with the EU directives. The internet has been main source for this thesis as most of the issues are global. The conclusion shows that, Ghana could solve plastic waste from automobiles if government bodies, companies and individuals adapt to change. As the main problem was found to be the attitude of the people and lack of education.

Keywords:	re-cycle, re-use, automobiles, plastics, end of life vehicle,
Number of pages:	70
Language:	English
Date of acceptance:	

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1 Introduction

The use of plastics has seen a tremendous increment from domestic household through agricultural to industrial application; one industrial application is in the automobile industry. The advancement seen in technology in the world today can be attributed to the evolution of plastics which has made most of these possible. Examples of such are credits cards, computers, modern range of television, compact disc not forgetting the countless contributions in the health sector like implants, capsules, dissolvable bags to wash infected and dirty clothes, respiratory machines and accessories.. There have been many concerns raised about the danger plastics imposed on our community from domestic, commercial and industry sectors.

1.1 Aims and Objectives

The main objectives of this thesis are to:

a) Identify the disposal and management of car plastics part after use.
b) Find out the effect plastic waste brings to the Ghanaian environment.
c) Identify mesures of improving plastics waste management in the automotive sector, (end-of-life vehicle in accordance with European union deritives).
d) Analysis the benefits of re-using or recycling of plastic waste in Ghana.

1.2 Scope of Studies

This thesis is to help identify better ways of controlling the waste generated in Ghana. As stated in the objectives, it is to concentrate only on plastic waste in automobiles. The studies is to be limited to main plastic parts of an average car.These parts includes batteries casing, dashbord, seat cushion,bumper, head lamps and wash-liquid tank and a mention is made of other parts chapter 2.

1.3 Literature Sources.

The main source of information has being the internet. Information were either collected from journals, technical reports on international research thesis on plastic waste recycling, pilot projects, press releases on recycling and findings of research centers.

1.4 Limitation of the Study

The major drawback to this thesis was non-availability of funds for the writer to spend ample time in Ghana. However, the writer was able to dedicate some hours during her practical training period to gather useful information though little on this thesis. In spite of visiting car shops and the Driver and Vehicle Licenses Authority (DVLA), there was not much information given as the DVLA needed much time to attend to the writer's request. The recycling of plastics is at the very beginning stage on the Ghanaian market thus not much information could be obtained and the few gathered could not be compared to any historical ideas, so it was basically the European standard used as the writer lived in Europe. Few points are also drawn from the Finnish car recycling system. The magazine association of Ghana has being the only informal group for car fitters and spare parts dealers and have operated not with any well documented information, thus most of the gathered information could not be well ascertained since they were given verbally by shop attendants. Plastic bags have been the major contributor of plastics waste and they are on high re-use and re-cycling scale.

1.5 Description and situation plastic waste of area

Ghana with a population of 24,223,431, is in the west of Africa. The main sources of plastic waste in Ghana include the following; food and beverages, furniture, automobile, agriculture, health; This thesis will be concentrated on Suame Magazine in Kumasi, Ashanti Region of Ghana, as the subject of automobile waste cannot be studied without taking Suame Magazine into account. Magazine is one of Africa's largest light-industrial areas and it forms the largest automobile land for Ghana. The area is filled with polluted industrial waste and noisy, auto-mechanical workshops; it also serves as resident for people.

Figure 1 shows maps Ghana, (pink area) and Kumasi, the second largest city in Ghana with the green color showing the area of study.

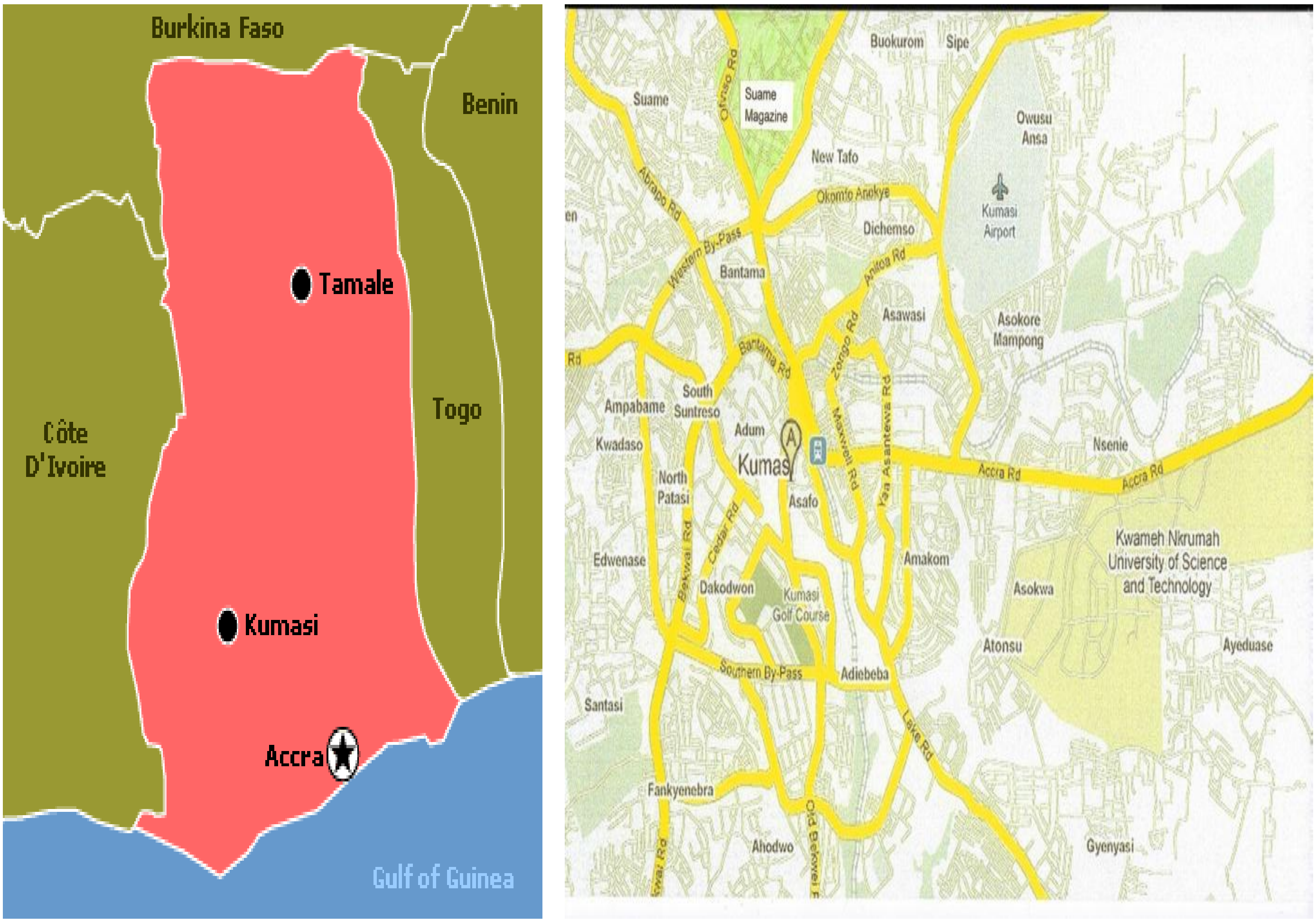

Figure 1: Maps of (a) Ghana and (b) Kumasi showing the location of Suame – Magazine, light-industrial area in Ghana. [40][41]

2 Literature Review

The introductions of plastics to replace the traditional materials in the vehicle industry do not only reduce product cost but also reduce production cost. Waste management has in recent years raised lots of concerns both in develop and developing countries and Ghana is of no exception. The European Union for example has in this view set up some laws to control waste generated in end of life vehicles (ELVs), and this thesis explains and outline few ideas about ELVs.

The introduction of plastics and composite materials into the vehicle industry has its own merits and demerits. In the 1950_S plastics used to be useful in the automobile sector only in the applications of seats, mirror cases and some other internal components of the automobiles in the 1950s, whereas about 260 pounds (118 kilograms) of plastics can be found in automobiles currently according to the Transportation Energy Data Book, 2005. With increased applications from chassis to roof and from head lamp to rear lamp. In a quest to overcome the adverse problems associated with its use in automobiles, many concerns have been raised with the paramount ones being about the high cost due to manufacturing and part cost as well as harmful emissions like carbon dioxide (CO_2) from petrol combustion. The introduction of electric cars or hybrid cars is one way to help overcome such problems but Ghana as a developing country has not yet been able to over electricity crisis and will not be able to embrace such noble invention open handedly. The replacement even if fully adopted in developed countries will not be able to erase the use of tons of oil used in the manufacturing of car plastic parts such as bumpers, engine components, seats, dashboards, head lamps, trims, and windshield. Studies have shown that plastics improve fuel economy by reducing weight, but they also require petroleum as a raw ingredient. Aafko Schanssema from PlasticsEurope defines Plastics as solidified oil. He also maintained that the high oil prices and strict CO_2 standards will accelerate the growth in plastic use. It is believed that these plastic may be recycled back into fuel in the near future. The average car is a mix of materials: steel body frame, glass windows, rubber tyres, lead batteries, copper wires, as well as traces of zinc, magnesium, tin, platinum and cobalt. The solution found rather seems to be posing more environmental harm than good as the major problem facing manufacturers, engineers, government bodies as well as other stake holders is the waste generated by these plastic car parts after their end of use seem to be uncontrollable. An average car is estimated to function at least 12-13 years before it comes to end of use. Paul Nieuwenhuis [1]

2.1 The history and growth trend of automobile plastics

The discovering and development of plastics can be seen as one of the most industrial achievement in the twentieth century. They have over the past fifty (50) to sixty (60) years gained attention in almost every aspect of daily life. Plastics seem not fully discovered as there is always new discovering in its properties and applications.

The invention of plastic composite is an example of such discovering which has made plastics more functional in the engineering field by the combination of two or more plastics. The success is based on their properties of resilience, good thermal properties, resistance to moisture, chemicals, stability, anti-corrosive, photo- and biodegradation low production and processing cost, manufacturing flexibility because they can be molded into different shapes.

The first semi synthetic plastic involved the modification of cellulose fibers with nitric acid in the 1950's.Cellulose nitrate, occurred in the late 1850s and Cellulose nitrate had many false starts following its invention by a Briton, Alexander Parkes, who exhibited it at the world's first plastics in 1862. [2]

The world's first plastics were produced at the turn of the twentieth century, and were based mainly on natural raw materials. Henry Ford is seen in records to be the first to patent plastic automobiles in the year 1942. The plastic car Ford patented used soy-based plastics and was 25% to 33% lighter than conventional cars of his day. Ford's vision was to create marketing opportunities for farmer to sell their produce.

Automobiles experts have predicted that the use of plastics will by 2020 be recognize as preferred material solution that will meet and set, automotive performance and sustainability requirements. [3]

2.1.1 Materials compositon

The composition of the car has changed considerably in recent years. The major reason for this is due to the fact that the concentration of ferrous metals has declined considerably as vehicle producers have opted for lighter and fuel efficient materials such as aluminum and engineering plastic in designing new vehicles. The amount of energy used in producing metals is very high as compared to that used in manufacturing of plastics. Aside the reduction in processing energy; we can also recover energy and material during recycling which will add value than seen as garbage.

As stated, the percentage of plastics used in vehicle production has risen considerably in recent years. Roughly, 11% of cars today are made up of plastics. This change occurred for reasons which include the fact that they are both impact and corrosion resistant, as well as low weight and low cost. One of the most defining features of the use of plastics in vehicle production involves the fact that it is cost efficient on fuel and energy sources. However, for domestic cars, the percentage of weight in steel and iron has dropped from 75 percent in 1977 to 63 percent in 2004, according to the Department of Energy's Transportation Energy Data Book. Some of the steel has been replaced by lightweight aluminum, whose percentage has grown from 2.6 percent in 1977 to 8.6 percent in 2004. Plastic has seen a similar rise in mass, going from 4.6 to 7.6 percent over the same 27-year period.

Metals such as steel, aluminum and metal alloys were the raw materials for the manufacturing of cars many years ago, but to overcome the release of CO_2 by reducing vehicles weight with the intension of cutting down the amount of fuel consumption. Ralf Zimnol laxness hopes that, CO_2 emission will be able to be reduced to about 13g for every 100kg saved if vehicle weights could be reduced. Mapleston [4]. Steel remain the single most important material in automobiles because of its toughness, durability and malleability, steel still remain very heavy, and for this reason manufacturers have been trimming down its use. PlasticsEurope studies showed that every pound of plastic in a car replaces roughly 0.7kg of traditional materials. Based on this weight reduction, the same studies calculated that plastics provide a fuel savings of about 3.8 percent. However, cars haven't improved their gas mileage by that much.

The weights of old cars have been greatly reduced with the replacement of traditional metals with lighter density metals or completely with plastic or other composite materials. An example of this is the replacement of cast iron (7.7Mgm) engine block with aluminum (2.7Mgm) or magnesium (1.8Mgm).This shows already about 4.9Mmg weight reduction. This may only be one of the few parts of automobiles that cannot be replaced with plastics. Plastics help to achieve the greatest weight saving with the body panels which form about 60% of the total weight of a car.

Graph 1 shows the average breakdown of materials found in cars in 1998. This year was used for this thesis since most of the cars coming to their end were manufactured around 90's.

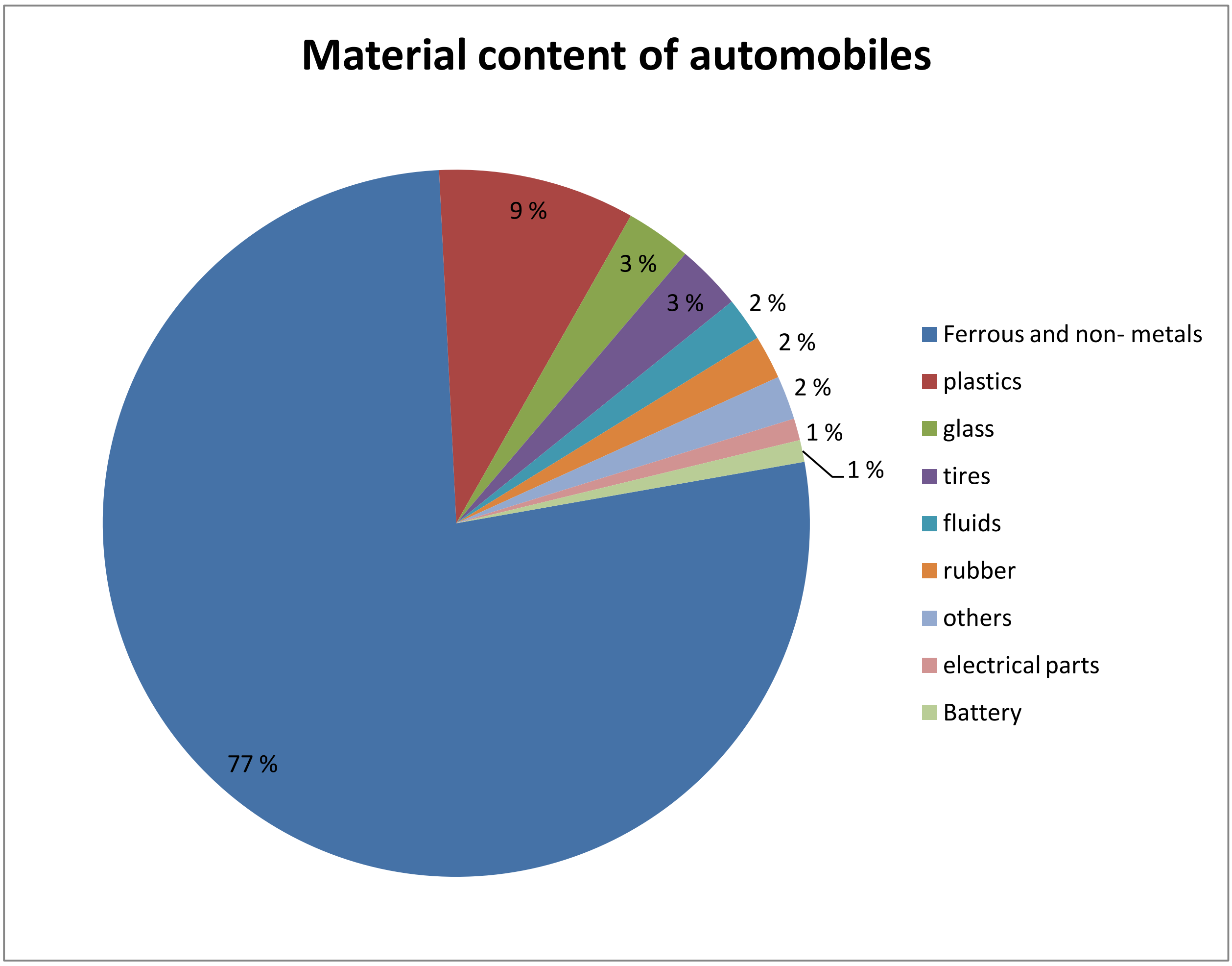

Figure 2: Material content of automobiles in 1998. [5]

Graph 2 below is a representation of plastics parts in an average car.

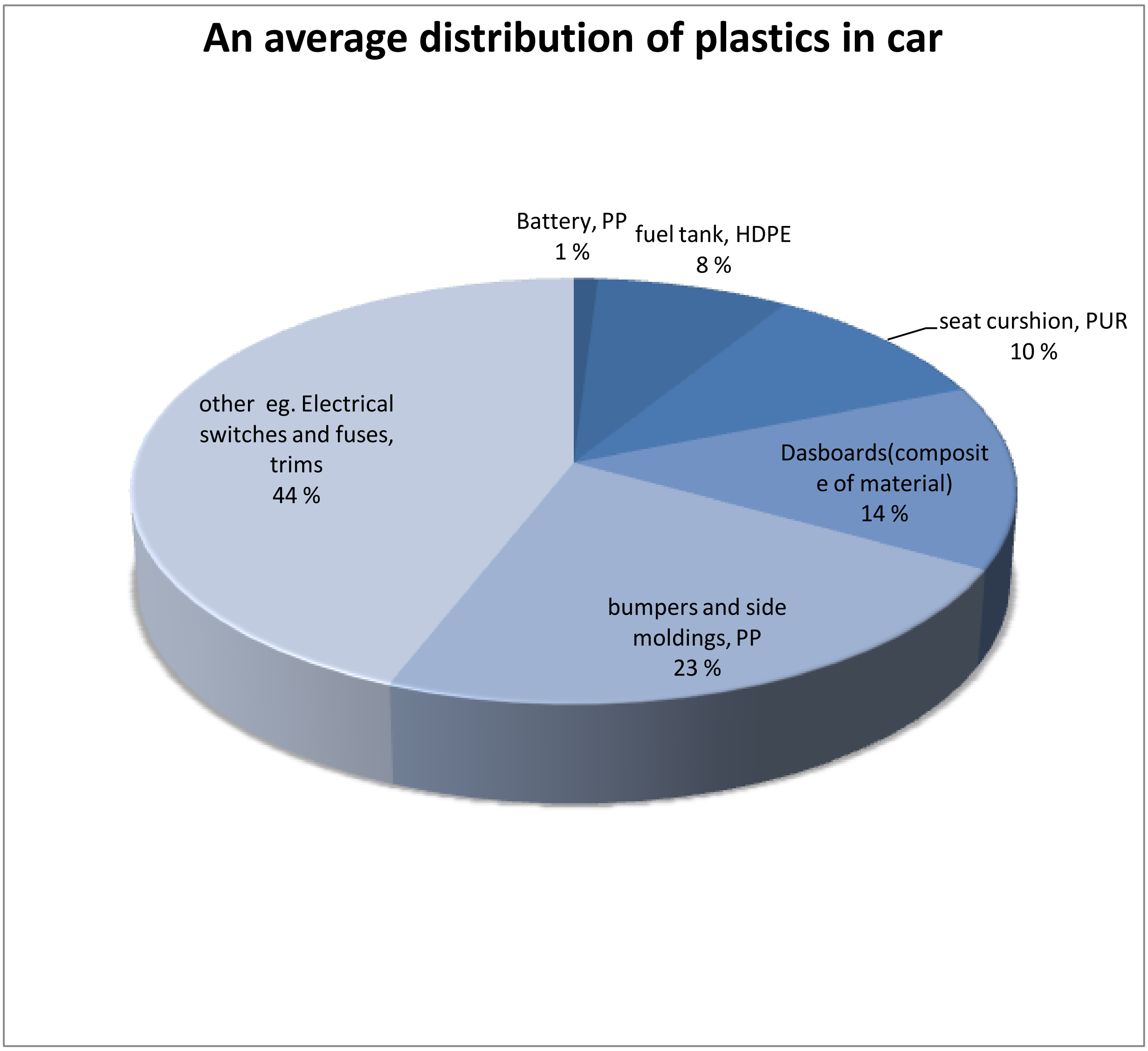

Figure 3: A representation of common plastics parts in cars.

The processing temperatures and weights of these plastics are shown in table. An example is with the glass fiber added to then PA for the application of inlet manifold to increase properties.

Table 1: Summary of average part weight of automobile plastic. Association of plastics manufacturing in Europe. [6]

Part	**Polymer**	**Maximum continuous use temperature °C**	**Weight kg/part**
bumper	polypropylene, PP	100	3,14
dashboard	Urethane,		
seat cushion	polyurethanes, PUR		1,20
mirror housing	acrylonitrile buta-diene styrene ABS	70	0,27
head lamp lens	polycarbonate (PC)	115	0,30
intake manifold	polyamide (PA)	80	0,72
wash tank & lid	polyethylene (PE)	50-55	0,43

2.1.2 Automobile polymers / plastics

Cars were entirely made of metals during the early ages of its development. Increment in oil during the 70's gave birth to the introduction of composite of automobile material. As engineers of that time sought for light weight cars with plastics. The Society looked for a better and efficient car in terms of reduction in mileage gallon of gas. According to Scribd Inc Plastic provides an average weight savings of 400 pounds, with 15 million cars manufactured each year, this translates to energy savings of about 5.25 million gallons of gas per year and about 10.5 billion pounds less CO_2 in air. (Scribd, 2011). Many thought of making cars entirely of plastics; but the cost of production at that time due to lack of technical knowhow and equipments did not make it a reality. However, a compromise was reached to make cars of different characteristics of material, hence the composites of cars. Reductions in gas mileage helps to not only manage natural resources such as gasoline, but also reduction in release of emission into the atmosphere. Plastic has become more competent in automobiles both internally and externally. Applications of such are electrical insulators, fuel tanks, engine compartment, chassis and power train.

The bumper is known to be the first plastic in automobiles and until present, bumpers still are made of plastics such as polypropylene (PP), polyesters (PS), thermoplastic olefins (TPO), or blends of these compounds reinforced with glass fibers. The bumper is one of the parts of automobiles that have seen a weight reduction of about 1.3kg eliminating about 13 metal parts. The horse power of vehicles is also increased by 33% with 2.3kg of engine manifold reduction.

The densities of main materials in an average car are given in the table 2. The values clearly explain why plastics have gained increase application in automobiles. Their low density values means that they are relatively light.

Table 2: Comparison of major automobiles materials densities. [7]

Material	**Density kg/m^3**
steel	7800
aluminum	2800
wood(pine)	550
polyamide(PA6)	1130
polycarbonate	1200
Acrylonitrile butadiene styrene ABS	1070
polypropylene PP	905

2.1.3 Importance of plastics in cars

Problems facing car manufacturers have been under some control since the introduction of light weight plastics in the automotive industry. Some of these problems have been in line with pricing, performance, safety, minimal environmental impact coupled with style and comfort.

The use of plastics in automobiles does not only reduce gasoline usage but also relief engineers from design limitations metals impose. One of such is the aerodynamic shape of modern cars due to flexibility in plastic shaping. Engine components are hotter than before due to this styling and this reduced space between parts, higher engine ratings and emission technology.(Mapleston)[4]

The constant exposure of both internal and external components of automobiles demands protection of some sort against corrosion caused by mud, salts, harmful chemicals as well as gravel, in order to increase the life span of vehicle some polymers are used to coat metal faces. Paints of polymers are used on some metal surfaces for this reason. An example of this is the application of High Density Polyethylene (HDPE) in gas tank as it is inert to corrosion and gives better anti corrosion effect than zinc coated products. Apart from all these, production and processing cost are relatively cheap compared to traditional materials. Energy consumption during processing is very economic as compared to that used in processing metals.

To every merit there is demerit and plastics for sure have their own demerits. Plastic as an engineering material must show its recyclability aside advantages of lighter and cost effectiveness. Thus automotive designers must not only meet customers' design, styling, cost and weight reduction and regulatory needs but also must prove to be able to sustain the environment. "Recycling" as being associated with the word" plastics" due to many concerns and education that has been going on with these two. The greatest problem posing greatest challenge to all plastics industries is recyclability and the car industry is not left out. Some of the major problems that oppose plastics application in automobiles include;

a. Insufficient technology for dismantlers to use to collect various plastics separately as plastics are usually collected and recycled with same kind and types.
b. Material wastage of raw materials during processing. example molding complex parts like the fuel tank.
c. Lack of plastic recycling infrastructure.
d. Loose of value of recycled plastics compared to newer plastics.
e. Expensive cost of recycling plastics with the few recycling possibilities.

Most of the above mentioned setbacks are however addressed in the EU directives on ELVs as shown later in this thesis.

2.1.4 Interior and Exterior applications of plastics in cars

Plastics used in cars can be given by percentage wise. Some parts of automobiles have seen much plastic usage than others. Few of these applications in the car industry includes bumpers, air intake systems, seat cushions, dash board, door panels, oil provisions, exhaust, valve covers, batteries cases, light housings, trims, seat belts, seat backs, engine torque rod air tubes, electrical cables and many more. The comfort and securities in automobiles are made better due to plastics. CD players, global positioning systems (GPS) and air bags are all examples of such.

The automobile parts listed in table 1 and graph 2 with other plastic parts is shown in the figures 1-6 below.

The bumper: seems to be the first identified part of a car and in reality is the first parts of vehicles in any head on collision. There are front and rear bumpers. They also protect both the front and back sides of a car against mud, corrosive fluids. Figure 1 below shows a front bumper.

Figure 4: a front bumper. [8]

Upholstery: Urethanes foam as said earlier best suit in auto upholstery cushioning. The ability to recycle, meet economic demands set forth by manufactures as well as flexibility makes them perfect choice. One application of recycled PUR foams carpets domestic and office use. PUR are used for seats and door panels. Figure 2 below shows a PUR door panel and seat.

Figure 5: A door panel and seat of PUR foam, [9]

Trims: The term trim is used to comprise mirror cases, wheels covers, door handles and radiator grilles. These parts in automobiles are largely made of plastics to increase usage and styling of car’s exteriors. Plastics such as PVC, PP,PC, PUR and PS are often used. The images in figure 3 are examples of such.

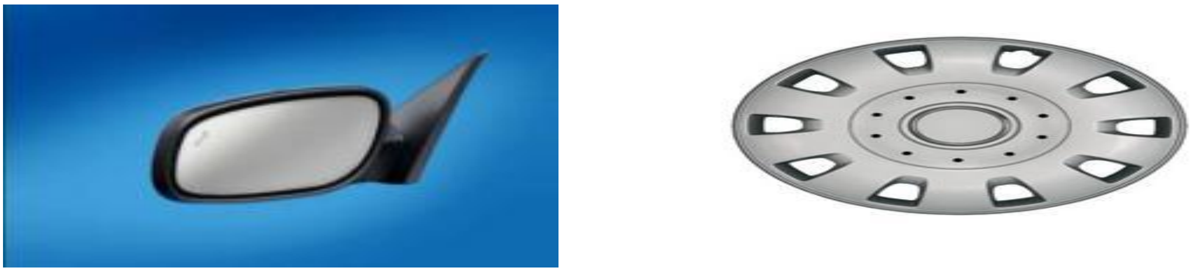

Figure 6: an ABS mirror housing and wheel rim, [9]

intake manifold: Figure 4 below is an example of PA intake manifold of the engine. The second image is a carbon fiber reinforced manifold.

 

Figure 7: A carbon fiber reinforced PA manifold, [10]

Wash lid and tank:

Figure 8: PE wash water tank and lid, [11]

Air duct and consoles: helps in supplying same amount as air or heat to rear passengers as that of front passengers. Plastics provide best flexibility in manufacturing despite its complicated shape.

 

Figure 9: PP+talc air ducts, [9]

The transmission and differential: for the two sets of power trains gears that transfer power to the drive wheels which consists of systems of bearings, shafts and gears. The application of plastics in this section has reduced the number of parts needed in effect reducing weight resulting in lower assembling cost while increasing fuel efficiency. Its complexity in manufacturing is reduced to great extent.

2.2 Engineering plastics applicable in automobiles.

There are many types of plastics use in the automobile industry. However, a mention of few major plastics are mentioned and discussed below.

The table 3 below shows a list of various plastics that have gained grounds in the automobile industry with applications. A comprehensive descriptions and properties are further given in this chapter.

Table 3: A list of engineering plastics in automobile industry, [13][14]

Chemical name	**Abbreviation**	**Application**
Polycarbonate	PC	bumper panels, radiator grilles
Polyurethanes	PUR	Arm rest, seat cushion,
Polyethylene (High and low)	PE (HD,LD)	bumper
Polypropylene	PP	Bumpers, battery case
Polyamide	PA	wheel covers, fuel tanks and filler flap, in fold manifold
Thermoplastic Poly urethane(Reinforced)	TPU,RTPU	
Polyphenylene oxides	PPO	body parts e.g. hatchbacks and mudguard
Acrylonitrile butadiene styrene copolymers	ABS	mirror housing, wheel covers, front and rear spoilers
Styrene acrylonitrile	SAN	radiator grilles
Polyurethane	PU	
Thermoplastic polyolefins	TPE,TPO	Bumpers, dashboard
Polybutylene terephthalate	PBT	plug connectors
Polymethyl Methacrylate	PMMA	window visor, taillights headlights
Polyvinyl chloride	PVC	

Plastics used in this industry are either reinforced or are used as composites of two or more kinds of materials for effective strength, heat, and other mechanical and physical properties. Each plastics type has a unique arrangement of the fundamental atoms thus unique characteristics and behavior. Their arrangement determines their crystallinity and thus makes it a bit difficult to know which kinds will form a uniform blend or mix. However, plastics like all engineering materials are possible to be investigated by laboratory test.

2.2.1 Polycarbonate PC

Polycarbonate PC**,** is one of the major plastics that has gained grounds in the automotive industry due to its versatility, toughness, transparency (optical), dimensional stability, impact and temperature resistance. It has ability to resists heat up to about 125°C PC is a polymer made up of carbonate groups and bisphenol A. It is a transparent polymer. Lighter polycarbonates materials can replace conventional gazing glass. PC are used for automotive headlamp lenses.

Chemical structure

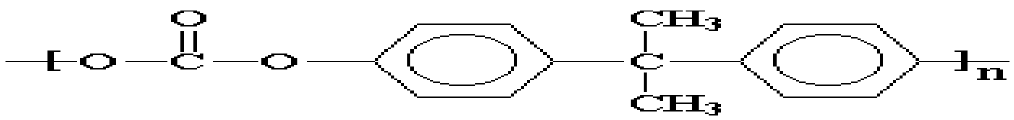

Figure 10: A representation of Polycarbonate structure.

PC is a thermoplastic material that has replaced most of glass applications in automotive industry. Its transparency makes it to function as headlight covers without affecting the visibility and transmission of light rays. PC materials are having high mechanical strength even at high temperatures thus serves as good resistance to weathering.

2.2.2 Polyurethanes, PUR

Polyurethanes forms are one of the best foam applicable in the automobile sector. All these plastics are structural foams, the hardness and flexibility of which can be varied extensively. Structural foams have a cellular core that becomes more and more compact the further it is from the centre and which is virtually sealed on the surface. Flexible PU foam has an extremely elastic core with very high resilience, i.e. the material will return to its original shape even after an extended period of deformation. Recyclability,

combined with their ability to fulfill design and economic demands set forth by a manufacturer, make them an ideal choice for car upholstery materials. They are normally referred to as urethanes because they are built on a urethane linkages.
The structure of urethanes can be best expressed with the figure 8 below. Eaves D [15]

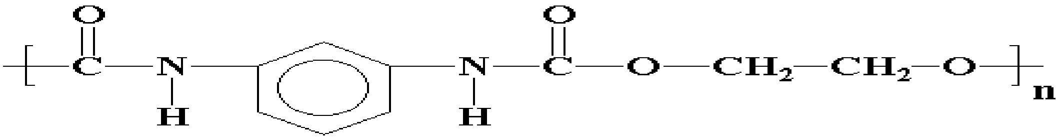

Figure 11: A representation of PUR structure

PUR are important plastics that have enormous applications in almost every aspect of human life. It is used as seats cushions, adhesives and also as insulators in the body of cars. They provide comfort, protection as well as conservation of energy. Polyurethane foams can also be found in armrests and headrests of most cars, better where cushioning properties eliminates or help reduce stress and fatigue during driving. Durability light weight and strength, of these materials have paved the numerous applications in the automobile industry. Their toughness and light-weight properties means that the overall weight of cars is reduced, resulting in greater fuel efficiency and improved environmental performance. [16]
Due to its water resistance, it serves as good flooring material. It flexibility is the reason for many complex shaped buildings.

2.2.3 High densityPolyethylene,(HD-PE)

The two main types of polyethylene are low-density polyethylene (LDPE) and high-density polyethylene (HDPE). They are made from the ethylene monomer and are named according to how the chains are formed. The structure is shown in 9 below.

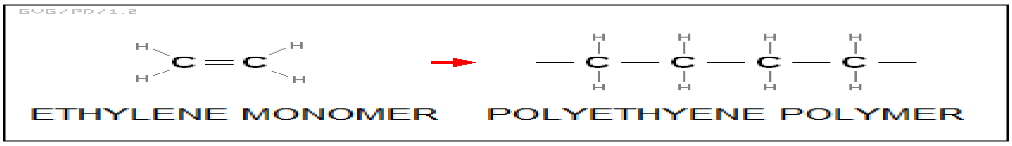

Figure 12: a representation of PE chains.

LDPE is soft, flexible and easy to cut, with the feel of candle wax. When very thin it is transparent, when thick it is milky white, unless a coloring agent is added. LDPE is used in the manufacture of automobile fittings, baby car seat, film bags, sacks and sheeting, blow-molded bottles, food boxes, flexible piping and hosepipes, household articles such as buckets and bowls, toys, telephone cable sheaths and many more.
HDPE is tougher and stiffer than LDPE, and is always milky white in colour, even when very thin. It is used for bags and industrial wrappings, soft drinks bottles, detergents and cosmetics containers, toys, jerry cans, crates, dustbins.

2.2.4 Polypropylene, PP

Polypropylene, PP**,** is a thermoplastic plastic that is formed as result of addition polymerization from the monomer propylene. Its chemical formula is built of three atoms of carbon bounded to six atoms of hydrogen. $\mathbf{C_3H_6}$**.** PP has many industrial and domestic applications due to it high melting temperature of about 160^{o}C. The length of the chain is dependent upon the number of C-C bonds or number of carbon. PP has gained many applications in the automobile industry because of its excellent impact balance, low density, fatigue resistance, chemical resistance, good tensile strength, anti scratch and toughness.
PP can exist in two main forms with each giving it unique properties and applications. There is an isotatic and atatic chains. The names are derived from the positioning to the methyl groups. PP has a density of about 0,946 g/cm^3 in the crystalline state. The isotatic PP has high chemical resistance, flow, creep resistance, tensile strength and modulus whereas its value of elongation is very minimal. The atatic arrangement of PP introduces certain amount of crystallinity into the PP chains thereby causing some changes in mechanical properties, like improved processability, low temperature performance and ability to elongate. The density of the atatic PP is thus lowered to about 0,855 g/cm.
Figure 10 shows two arrangement of PP. The first figure shows an alternating positing of the methyl groups whiles the second shows a uniform linear positioning of the methyl group, where x represents the length of chain.

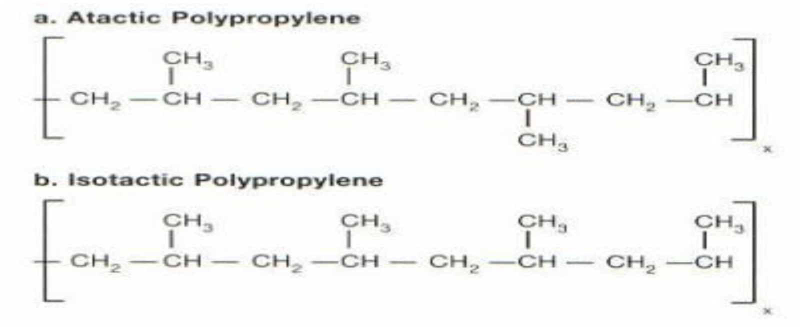

Figure 13: an actatic and isotactic representation of PP, Tripathi,D.[17]

PP in the automotive industry are used in the manufacturing of mudguards, tool boxes, wheel arch liners, steering wheel covers, brake fluids reservoir fittings, bumpers, body panel and battery cases. PP polymer at higher temperature during processing release very volatile organic compounds into the surroundings air which affect workers skins and breath, It however, does not pose any health hazard. However, it is advisable to use proper inhaler mask during it industrial processing. PP polymer is used in the manufacturing of bottles, bowls, and buckets, filament yarns, packaging sacks, artificial sport surfaces, door frames, tubs, iron body parts, stackable chairs, pressure pipes, domestic wastewater pipes to mention but a few.

Body parts made of this material are usually manufactured as blends. Complex injection-molding plants are required for manufacturing large parts. For this reason, they can be produced particularly cost-efficiently in the large numbers required by the automotive industry.

2.2.5 Polyamide, PA

PA can be said to be the largest group of engineering plastics. There are many parts of these plastics depending on the length of the chains. They are polymers that can exist natural or industrially. They are produced by condensation polymerization involving amide and acid which usually has water as a byproduct. Polyamides are classified as polymers which have an amide group recurring in the chain. (-CO-NH-). They are also called nylons. They have the ability to form fibers. Polyamide 6 6 is an example of these with extremely high melting point of about 265^{o}c making it suitable for high heat resistance appliance.

The structure below is a 6 carbons of amides and adipic acid respectively forming polyamide 6 6 atoms)

$$_{n}H_2N\text{-}(CH_2)_6\text{-}NH_2 + {}_{n}HOOC\text{-}\{CH_2\}_4\text{-}COOH \longrightarrow \left(\overset{H}{\overset{|}{N}} - (CH_2)_6 - \overset{H}{\overset{|}{N}} - \overset{O}{\overset{\|}{C}} - (CH_2)_4 - \overset{O}{\overset{\|}{C}} \right)_n$$

Figure 14: hexamethylene diamine adipic acid, Singh Jagdamba [18]

They are characteristically very resistant to wear and abrasion, have good mechanical properties even at elevated temperatures, have low permeability to gases and have good chemical resistance, they also have good toughness, high strength and are good flame retardant. Polyamides like most plastics are very sensitive to UV lights and thus need stabilizers, are affected by strong acids and bases, they stand the risk of losing mechanical properties at high moisture absorption rate. Care is needed during molding since shrinkage is very high. Many automotive companies are using this material for the wheel trims, airbags, gaskets, tyres, hoses, ropes and many other items out of the automobile section. These materials have a tough and resilient material with high rigidity and strength. They are resistant to most organic solvents. However, this is not entirely positive property since absorbed water may be dumped on surfaces of adhesions and coatings. Molecular water is reversibly bound within the molecular structure, i.e. it absorbs water from the ambient air and releases water to the ambient air.

2.2.6 Acrylonitrile butadiene styrene, ABS

Poly Acrylonitrile-Butadiene-Styrene, ABS is a copolymer made up the acrylonitrile, butadiene and styrene monomers. ABS is an amorphous blend that combines the strength and heat resistivity of acrylonitrile transparency and low cost of styrene coupled with the toughness, low temperature properties and elongation of natural butadiene rubber to form a shift, heat resistant, elastic and low temperature blend. The three monomers are apportioned depending on the required properties for the application of the final product. It can be in a ratio of 35% acrylonitrile, , 5- 30% butadiene and 40 -60% styrene resulting in a long chain of polybutadiene which is cross linked with polystyrene co acrylonitrile. Figure 15 is a presentation of ABS. It is stronger than styrene because of the strong polar holding forces from the nitrile groups in the chain from. They are used for electrical/electronic applications andinterior decorations.

ABS plastics are copolymer which derives their properties from each of the constituting components thus better mechanical rigidity and toughness. The rubber component (Butadiene) gives its toughness whiles the acrylonitrile equips it with rigidity. The structures of the forming monomers are represented in figure 12-14 below.

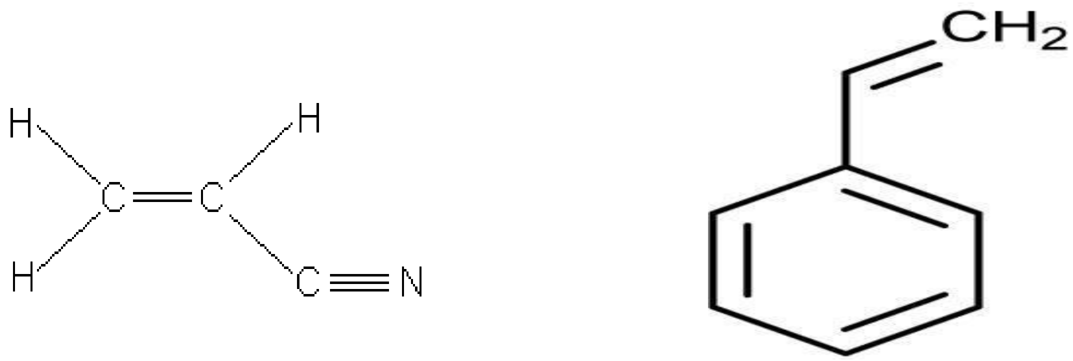

Figure 15: A view of acrylonitrile and styrene monomers respectively, [19].

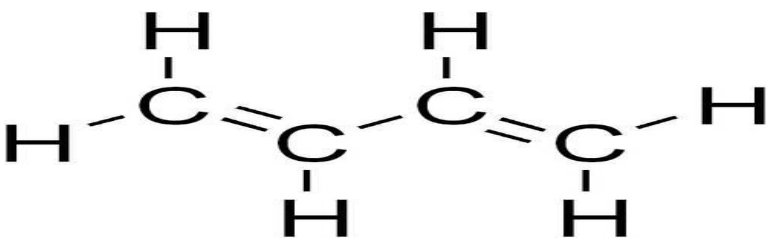

Figure 16: A view of butadiene rubber monomer, [20]

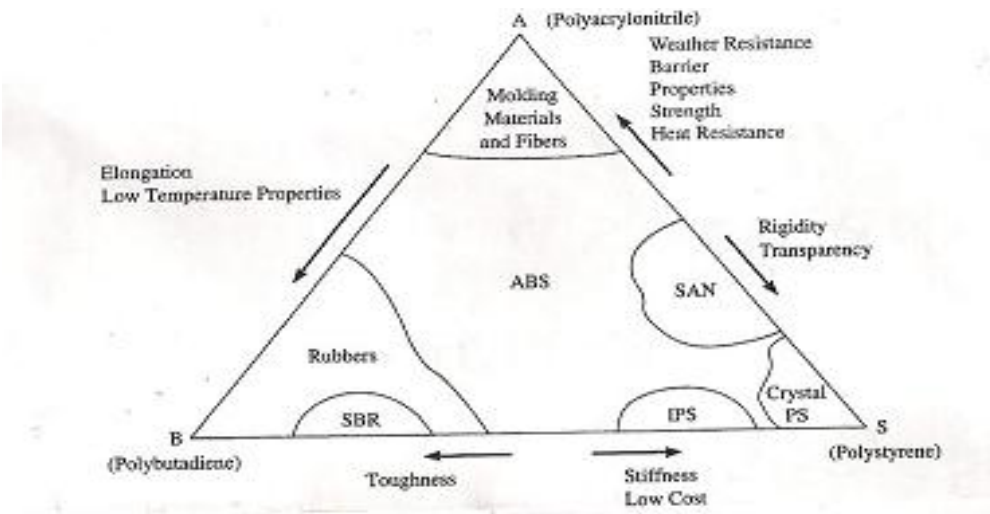

Figure 17: representation of ABS arrangement giving it unique properties.
Strong, A. B. [21]

The rubber makes it brittle when exposed to naked sunlight or UV radiation without any protection as they tend to lose their toughness, which result in aging.

2.2.7 Polymethyl methacrylate, PMMA

The problem of degradation in most amorphous plastics is minimized in PMMA materials. Mechanical and optical property is not affected in anyway by UV radiation as seen in PC plastics because PMMA transparency makes it possible to absorb only trace amount of light and UV radiation, these absorbed radiations lack the needed amount of energy necessary to break down the intermolecular bonds within the polymer chains making it suitable for long term weather resistance.

The structure of PMMA is given by $C_4H_8O_2$

The figure below accounts for the transparency in PMMA.

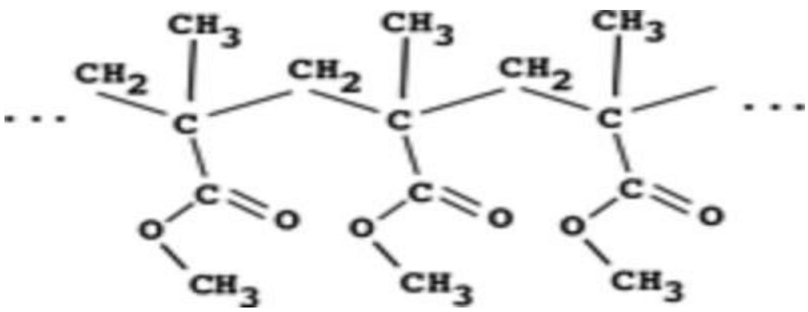

Figure 18: A representation of PMMA structure. The cyclic in this structure give its transparency.

PMMA has great scratch resistance when compared with PC but less when with glass. It remain glass substitute automobile due to its low density and toughness, it is relatively lightweight. PMMA unique properties has increased its application not only in engineering field but also in the medicine field since it is biocompatible with human body. Brydson [22]

2.2.8 Polyphenylene oxides, PPO

Poly(p-phenylene oxide) (PPO) or poly(p-phenylene ether) (PPE) are high-temperature thermoplastics. PPO are usually used as a blend with poly styrene(PS), High Impact Poly Styrene (HIPS) or polyamide in order to increase process ability as it does not remain as liquid like most thermoplastics during the processing. PPO has a high glass transition temperature of about 210^{o}c. It is formed by a condensation process involving the monomer 2,6-dimethylphenol with water as a byproduct. They are structured as phenylene rings linked by 1,4 or para position.

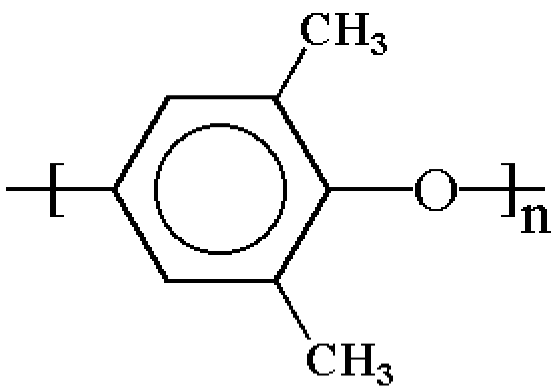

Figure 19: structure of PPO, [24]

2.2.9 Polybutylene terephthalate

Polybutylene terephthalate is a semi crystaline derived from 1,4 butanediol with either terephthalic acid or dimethyl terephthalate with esterification catalyst. The process involves two main reactions.

PBT has a chemical structure as:

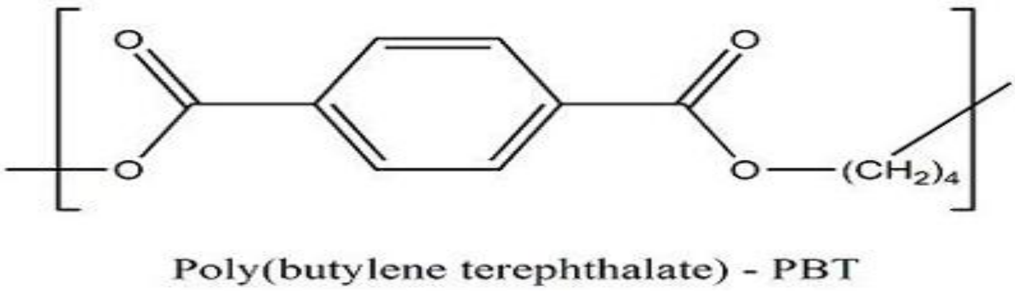

Figure 20: A PBT structure.

It is thermoplastic polyester. It fits as an engineering plastic as a result of its heat resistance, excellent electrical properties, stiffness, hardness and is very resistant to environmental influences. They are able to form blend with other polymers or blends such as polycarbonate (PBT/PC, PBT/PET, PBT/ABS). Their modulus, strength and heat deletion temperature under load could be increase by reinforcement. They can be used for the manufacturing of parts such as ignition coil, distributor cap, switch, head lamb garnish as well as other application aside automobile applications like oven handle, hair dryer, cooling fun and optical loose tubes. This reinforced PBT are not environmentally friendly because, they cannot be degraded or recycles because of the impurities added to reinforce them. [25]

2.2.10 PVC Polyvinyl chloride,PVC

PVC is a versatile plastic due, not least, to the fact that it can be produced with a wide variety of properties, from rigid to rubbery. Polyvinyl chloride is a hard, rigid material, unless plasticizers are added.

The chemical structure shows how Hydrogen atoms are bounded to Chlorine atom.

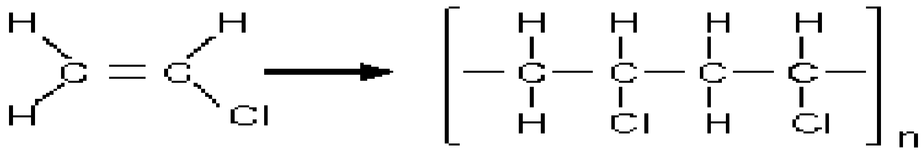

Figure 21: PVC structure, [25]

Common applications for PVC include bottles, thin sheeting, water and irrigation pipes, gutters, window frames, building panels, etc. Plasticizers improve flexibility making the material rather weak. Plastizied polyvinyl chloride PPVC are then able to be processed by other means and can be used for automobile linings, hosepipes and cable coverings, shoes, flooring, raincoats, shower curtains, furniture covers, bottles, etc.

2.2.11 Composites

As said earlier, two or more plastics or plastics and other engineering material like glass fiber, wood or even metals can be mixed in a right proportion to obtain a final advantageous material properties better than one type of constituting materials. They are serve as the only options most of the times to have the needed properties. These materials can be combined with particulate, fibers or be laminated. Thermoplastic composites made from polypropylene (PP) and long sisal fibres by using different processing techniques are thermoformed with small wall-thickness reductions to obtain a three-dimensional shape with very low forming energy, outstanding properties and excellent surface finish.

2.3 Methods of plastic waste management

Plastics like most material turns to be waste after serving their useful purpose, and plastics used in the automobiles cannot be isolated and thus the concept waste management has being employed by many city authorities, researchers, and other stake holders to address the waste generated from cars after their useful life or breakdown. Solid Waste management still poses a crucial treat to the environment. The question has been how to effectively manage and control the countless amount of waste generated in order to save the environment and health as well as to make the environment effectively and efficiently for the continuous existence of humankind. The best form of managing waste is to try as much as possible to avoid generating it. Minimal production of waste becomes an option when total avoidance is not possible. A final and problematic option to all nations which involves lots of finance and technical knowhow is to recycle the waste generated into other useful material of same or different kind or forms. Plastics in automobiles unfortunately happen to fall within the last group which means every society must aim at recycling plastics waste in automobiles which have come to end of life either through accident or old age. The avoidance of plastic waste is not achievable at this stage of advance technology when all and sundry yearn and hope for an efficient, economical, versatile, stylish, comfortable, and yet less expensive cars to drive.

2.3.1 Sources of plastics waste

The first step to solve a problem is to identify the source of it. As stated already, industrial waste is the main source of waste of interest under this studies and precisely the automobile industry. Plastic waste is becoming an increasing problem because of the rate at which they are replacing traditional metal and glass parts.

i. Industrial waste

A majority of these wastes are generated on factory floor thus not contaminated and can be recycled without much cost if there are reinforcers. They are usually defects or rejected materials. Industrial waste includes:

- **Electrical and electronic industries**: e.g. cable pipes, computer cases, mobile phone cases, electrical switches, compact disc to mention but a few.

The pictures in figures 20 and 21 are few examples of electrical and electronic waste.

Figure 22: plastic computers and mobile phones cases, [26]

Figure 23: plastics cable waste and end of life televisions collected as waste. [27]

- **airplanes and ships**: Light and efficient airplanes are possible because of light composites materials which are built by polymer resins enforced with glass fiber. Insulation and windows in aero planes and ships are safe, light and comfortable because of plastics. The figures 22 and 23 show waste of airplane and ship.

Figure 24: An example of airplane waste, [28]

Figure 25: A British ship under demolishment as after its useful life.

- **The automotive industries**: Cars are made lighter with new plastic dashboards, bumpers, inlet manifold, and door panels and most importantly safety, improved comforting media devices all made of plastics. Spare-parts for cars, such as fan blades, seat coverings, battery containers and front grills. (Which form the backbone of this thesis)

The pictures in figures 23, 24 and 25 below show some automobile wastes as they come to end of life. Figure 24 is a representation of how a plastic battery can be re-cycled and re-use.

Figure 26: End of life vehicle battery

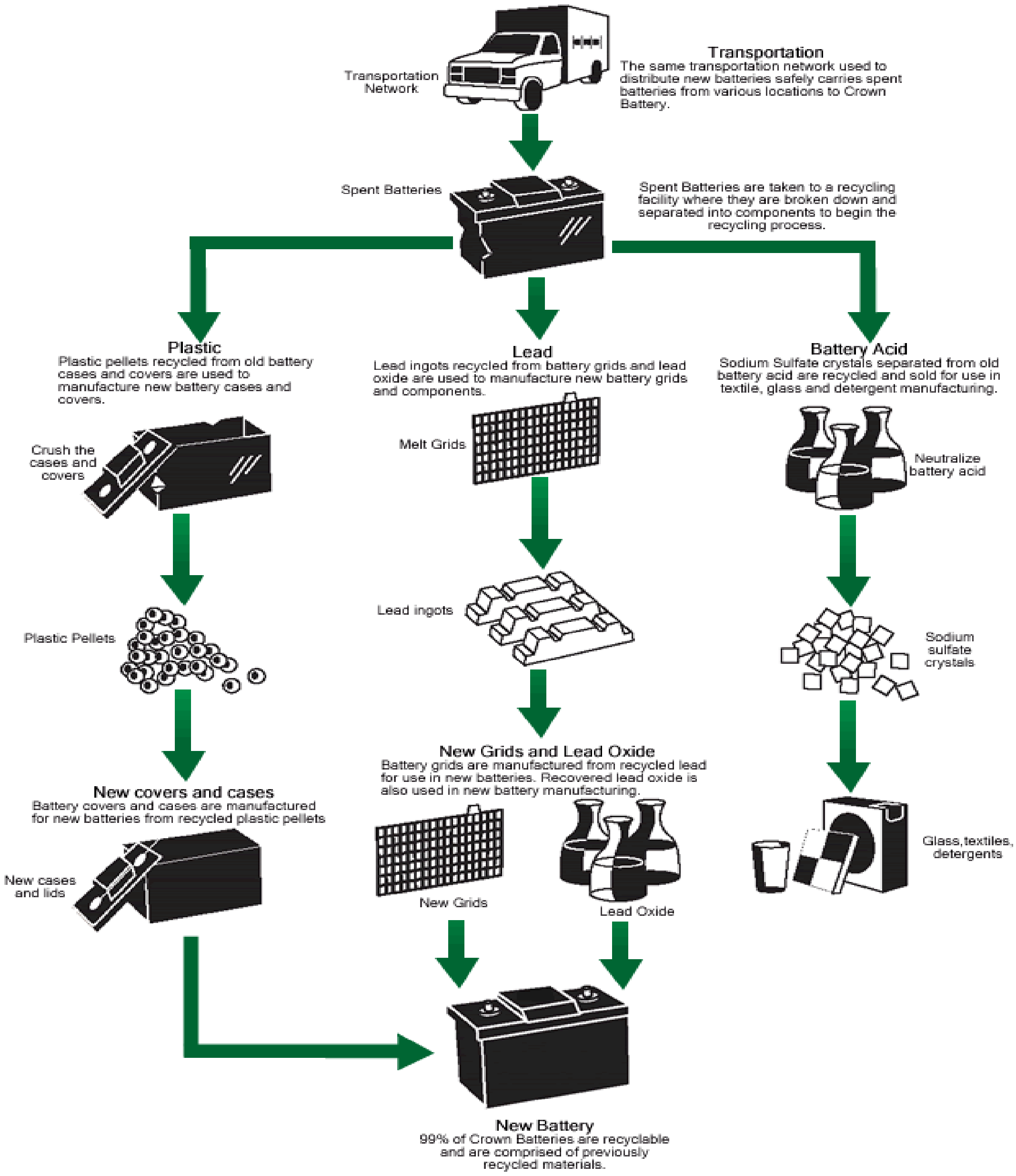

Figure 27: A systematic flow of plastic battery recycling, [29]

Figure 28: illustration of scrap car parts

These sources of waste are normally the used and not the rejected material since Ghana does not have many companies producing parts in automobiles, construction and electrical appliances but instead have lots of waste from the industry because of old and damaged products.

The problem of plastic waste would have been less of a burden if biodegradable plastics could be incorporated into automobiles. But that notwithstanding, the petroleum based plastics could have some chemicals added that could increase the degradability after some years. The truth of the matter is that, automobiles plastic are often toughened and strengthen to increase their performance and these are usually done by adding reinforcers as fillers which make them less responsive to wear, UV radiation, and even more difficult to recycle even if it were possible.

ii. Commercial waste

Films of plastic seem to be the major waste contributor under commercial waste. The general method of managing this by most companies has been from the factory level by recycling their generated waste. Many educations are going on in almost every part of the world to help sensitized the people to help to sort waste generated either commercially or domestically. The health services are major sources of such commercial waste.

The images below are some examples of commercial waste.

Figure 29: A collection of mixed and hospital plastic waste .

iii. Municipal waste

A major contributor to the Ghanaian waste maniac is the littered plastics both on large or low scale. This attitude of leaving waste without any caution can also be seen in automobiles as people leave their accident cars or old cars which are beyond repairs at unauthorized locations or bushes. The sports stadia, airport, ship yards and other playing grounds are full of such waste as the people living in a community or other communities come together for the sake of games or travels and leave their waste behind. Water sachets and other soft drink plastic bottle are major contributors of this group of waste. Improper handling of these could form piles of wastes around vicinities. Some of such waste can be collected as shown in the pictures in figure 27.

Figure 30: A picture of collected plastic bottle waste on the large scale municipal level

Fortunately, the PE (water sachet) films which are ultraviolet (UV) degradable are already ageing and broken into smaller pieces before they are even collected from the streets. However, most of these plastic wastes remain as fresh as they are.

2.3.2 Identifying and sorting plastics

Plastic is one of the main engineering materials that need special care and attention so far as their waste management is concerned. Different grades of plastics cannot be mixed in the recycling process and few mixed types can result in a total break down or different chemical, mechanical and physical properties of new product. The situation can become worse if for example a Polyvinylchloride, PVC is mixed with other plastics. PVC emits hazardous chemicals like chlorine. Plastics are identified by unique code however, they are not always seen and when there are large volumes of waste to be sorted, it creates more problems. The density –based and selective dissolution are other methods aside manual sorting.

It is therefore essential that, the materials are correctly identified. It is usually difficult to tell exactly which type of plastic is present solely from the type of product. A simple burning test can be done; an infrared analysis may be carried out to help ease the problem of identifying types of plastics which usually happen to be the most problematic stage in the plastic recycling. In order to help ease the process of identifying and sorting plastics, there are numbers given globally to the often used plastics which help identify them even without knowing their names. The coding system is as shown in figure 31.

Figure 31: Plastic coding system for easy identification, [30]

The main separating techniques in sorting plastics include;

a. Manual sorting:

The process of identifying waste plastics of different materials by people with a "trained eye" while the materials are been moved by them is known as manual sorting. The materials are recognized by identification codes and by the different distinctiveness of the plastics that differentiates it for visual identification.

Figure 32: Manual sorting of mixed trash. [31]

b. Density based:

Density based technique form of sorting is carried out in a hydrocyclone or float sink tank. However this approach is not good for polyolefins as their densities are very similar. Since their specific gravities overlap, it is also not viable to disconnect PVC and PET . Tall (2002) presupposes that there is a possibility to alter the density by diverse fillers in the materials, which renders it difficult to have an absolute separation. In the float-sink severance, the plastics are positioned in a fluid that has a density in-between the materials making it probable for less dense materials to float and the heavier to sink. Common fluids used are: water for the separation of polyolefins from other plastics.

c. Selective dissolution:

Selective dissolution sorting is supported by batch dissolution of assorted plastics using solvents. To obtain a complete separation of the plastics a careful management of temperature and selection of solvent is needed. Identical solvent can be used for taking apart PS, LDPE, HDPE, PP and PVC, since these plastics melt at different hotness. PS dissolves almost immediately when the plastics are added to the solvent tank. The PS solution is drained and another hotter batch of about 750°C solvent is added dissolving LDPE. The temperature keeps increasing till about 1200°C. If PVC and PET are to be separated, a mixture of solvents is used in which PVC dissolves at a lower temperature than PET.

To identify plastics covered with paints is difficult just like in automobiles since most plastics look alike. One way to solving this in developed countries has been directions from stakeholders to manufacturers to visibly give the detailed material information before selling products out. To the Ghanaian community this does not give the impression that it is a solution because when almost all cars arriving are already over aged and the few which are not do not necessarily go into educated hands who have no knowledge of plastics and its handling. Many different types of plastics may look identical, or one type of plastic may appear to have several physical and chemical characteristics depending on the type of additive that has been used. Detailed chemical tests, such as infrared analysis, may be needed to make a definite identification of a polymer.

2.3.3 Plastic Waste Recycling Processes

Recycling or reprocessing of plastics is usually known as the process by which plastic waste material that would otherwise become solid waste are gathered, separated, developed and returned to use. [42]. According to the EU derivative the amount of waste in automobiles to the landfill must be reduced to 5% by 2015.

Table 4: EU utilization requirement in 2006, [32]

	2006	2015
Reuse and recycling	>80%	>85%
recovering	<5%	<10%
Utilization in total	>85%	>95%
Final disposal at a dump	<15%	<5%

Coming up with a resourceful and cost-effective approach to recycling of plastics waste that have accomplished their intended function, regaining them from the ravage stream and retrieving them back into the manufacturing procedures necessitates collection, categorization and cleaning and as a final point recovery. In support of identical plastic waste streams recycling by mechanical (or physical) processes the economically favored is a laudable option. Diverse plastic waste flows on the other hand are more treated or handled by chemical and thermal processes, for recycling of basic chemicals and /or energy. The processes are briefly elaborated underneath.

a. Mechanical Recycling

Mechanical recycling is the material reprocessing of waste plastics by physical means into plastics products. The sorted plastics are cleaned and developed straightforwardly into end products or into flakes or pellets of reliable quality suitable to producers. The ways used to reprocess post-consumer plastics may differ from process to process, but normally entail assessment for exclusion of contaminants or further arrangement, washing, grinding, drying and conversion into either flakes or pellets. Pellets are processed by softening of the flakes of the dry plastic and then extruding it into tiny filaments that are severed into minute, standardized pieces. The molten plastic is pushed and forced through a fine screen (filter) to get rid of any contaminants that may have escaped the washing cycle. The filaments are cooled, cut up into pellets and stored up for sale and shipment. Plastics of different nature may also under different transformation conditions such as different dispensation temperatures, the use of vacuum stripping, or other methods that could influence pollutant levels. During the grinding or melting levels, the recycled material may be blended with new polymer or with additives. Mechanical recycling is the ideal recovery direction for identical and relatively clean plastics waste flows, provided with the existence of end markets for the resultant recycled products.

b. Feedstock or Chemical Recycling

Chemical recycling or feedstock reprocessing means that a polymeric product could be broken down into its individual parts (plastics or hydrocarbon feedstock – synthesis gas) and that these mechanisms could then be fed back as raw material to regenerate the new product or others. Feedstock recycling include chemical depolymerisation (glycolysis, methanolysis, hydrolysis, ammonolysis etc), gasification and partial oxidation, thermal degradation (thermal cracking, pyrolisis, steam cracking, etc), catalytic furious and reforming, and hydrogenation. in addition to conventional handlings (pyrolisis, gasification), new technological methods for the dilapidation of plastics, such as conversion under supercritical surroundings and co processing with coal are being tested. This practice of recycling is nonetheless not suited for developing countries. This is because it demands a lot of know-how, intensive resources and is quite difficult. Even in industrialized countries, it is still under development and is being put into practice by only few companies. A number of industries have effectively developed and showed technologies many of which can recycle mixed plastics flows. There has been some interest shown in other areas of chemical recycling, such as the depolymerisation of PET or treatment of PVC to make chemicals which can then be used in the production of new plastics (APME, 2002-2003).

c. Energy Recovery

Plastics as petroleum based material are rich in oil content even as a waste product. Power recovered from plastic waste can make a major input to energy production. Plastics can be co-incinerated with other wastes or used as source of fuel (e.g. coal) in numerous manufacturing processes (cement kilns). The energy level of plastic waste can be reclaimed in other thermal and chemical processes such as pyrolisis. As plastic waste is incessantly being recycled, their physical and chemical properties are lost at their end-of-life cycle. Constant reprocessing could lead to second-rate and low quality products. Hence it would no longer be economically gainful to recycle any longer. Incineration with energy restoration would be the economically ideal option at this stage.

2.4 End of life vehicles (ELVs)

As the word, end, implies, something that has no meaningful use or lost its usefulness. All cars and light weight trucks which have served their stipulated number of years and can be classified as waste can be referred to as End of Life Vehicles (ELVs). However, the legal definition of "end-of-life vehicles" within the EU is defined as below.

"Vehicle' means any vehicle designated as category M1 or N1 defined in Annex IIA to Directive 70/156/EEC, and three wheel motor vehicles as defined in Directive 92/61/EEC, but excluding motor tricycles; 'End-of life vehicle' means a vehicle which is waste within the meaning of Article 1(a) of Directive 75/442/EEC;2" [35]

2.4.1 History of End of Life Vehicle

The end of vehicle life emerged in 1996 when various government agencies around Europe came up with a commission to make legislation of waste. In particular, the commission was instituted on End of Life Vehicles and generated important questions as who take responsibility for the generated waste by these vehicles. The body deduced that new law was required with respect to this kind of waste judging by its nature and eminent danger to the environment if not treated.[36]

The Organization for Economic Cooperation and Development (OECD) Working Party on waste streams also shared the same sentiment and took into consideration the suitable care of End of Life Vehicles as a significant approach toward curbing waste generated significantly by end of life vehicles and the danger associated with its by-products, whilst streamlining the end goal producing an environment for the next decades sustainably.

2.4.2 Principles and philosophy ELVs

The acceptance of product and closed-loop material reprocessing forms the basis of the accountable dealings with the environment, life cycle engineering and resources. End of life vehicles are retrieved in five significant levels according to the EU directive. The main steps are illustrated in figure 34. These are;

1. Draining the vehicle,
2. Dismantling,
3. Sorting
4. Processing reusable parts as well as
5. Grating the rest of the body.

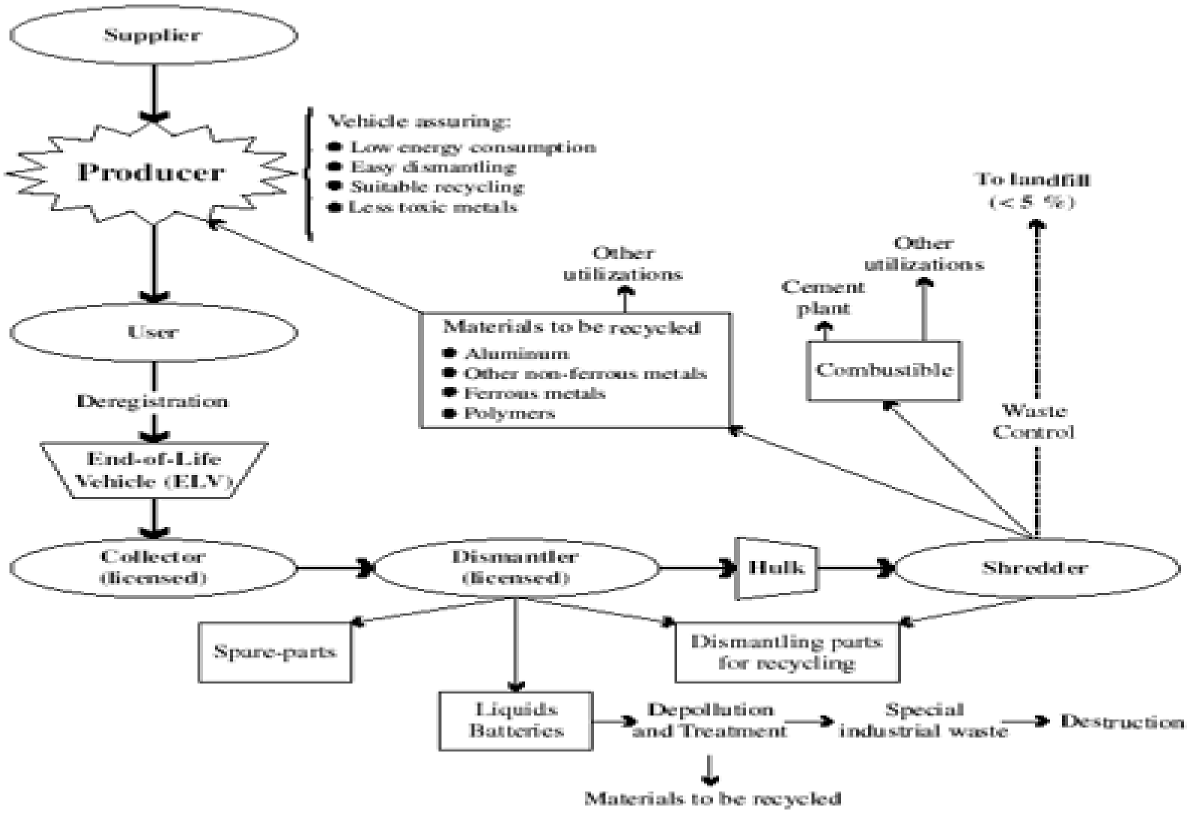

Figure 33: Major steps for ELV Recycling According to the E.U. Directive, [36]

Draining: this is the first thing done as cars come to ELV, the moment the outside and the engine area have been cleansed and the tyres removed, the automobile is drained by doing away with vehicle or automotive fluids and the parts surrounding fluids. Draining is important because of the danger involved in likely pollution as fluids finish on the storage area, together with the danger of subsequent soiling of remaining waste. The parts which are not difficult to access from the exterior are dismantled after draining, which includes body parts that can be retrieved, for example bumpers, plastic fuel tank and auxiliary compilations.

Dismantling and Sorting: In the dismantling process, it is necessary to make a decision concerning where the parts will definitely end up. Some electronic parts like electric motors are practically wear-free and therefore appropriate for use again or persisted use in related vehicle models. Plastics which are divided by kinds following taking to pieces are then passed on plastic reprocessing and the rest of the body is grated and the steel and nonferrous metals then reprocessed. (Bullinger, 2009). The picture in figure 35 gives a brief dismantling and sorting of a car.

Figure 34: dismantled car into single units,[37]

According to the Finnish Car Recycling, this process is not different but in Finland, the vehicles are dismantled and differentiated in three industry forms as follows:

- Magnetic steel, raw material for the steel industry
- NFR (Non-Ferrous Residue), different metals, which are further processed into raw materials of the metal industry
- Light components; part are recovered as energy and unrecoverable waste is disposed of at a dump.

In Finland, the pre-treatment of end-of-life vehicle is dried, for example all forms of liquids are eliminated. In addition, tyres, battery and catalyser are eliminated from the automobile and parts with eminent danger of explosion, like airbags are eradicated in some other form. growth.[32]

2.4.3 End-of-Life Issues

Within hybrid electric vehicles (HEV) and EVs, the subject of end-of-life is in connection with the life of the different parts and general management of life cycle. In connection with the mechanical aspects with regards the engine and transmission, it is equal or equivalent as in internal combustion engine (ICE) automobile. In a HEV, the battery is necessitated for about 10 years which is well-matched with the guaranteed life of the vehicle. Within the hybrid-specific parts the motor is deemed the more strong body. The life rate of the motor in itself is assumed to have a life span of ten or twelve years. The expectancy rate of all hybrid-specific items, which consist of the motor, battery and power electronics, is considerably influenced by ambient heat and the mode of operation. This means the difference that exists between the incessant drive cycle order and its climax has effects on the general life cycle. This pertains to power electronics, battery and motor and if there is an existence of extraordinarily high levels and valleys with correlated harmonics in the voltage and current, it will have consequences on the life anticipation in the future. In relation to the issue of life cycle, it ought to be noticed that certain items within the battery and motor have the potential of being reprocessed. For instance, the battery casing possibly will be straightforwardly be used again, and other objects or materials within can be recycled. The situation with the motor is not different as it potentially can be overhauled and if it is an everlasting magnet motor, the magnets could be changed if there are certain properties lost. Relating this to Ghana recycling or reprocessing of automobile components, the most common form is the reuse especially, the battery is chemically charged to extend the life rate which could then be used for certain period of time or years[38]

2.4.4 End-of-Life Vehicle Recycling in European Union(EU)

Vehicles are indispensable to humanity and continuous to grow in use, nonetheless, they during affect the atmosphere in different forms during their life cycle. Natural resources and energy are consumed as well as waste creation in production and use and discarding at the climax of their functional lives. Within the European Union (EU) nearly 75 percent of end-of-life automobiles predominantly metals, are eco-friendly whilst the remaining 25% of cars are deemed garbage and normally goes to landfills. The EU law on environment necessitates the lowering of this trash to a 5 percent by the year 2015. Production of vehicles has seen a major up surge in the last 20 years, with nearly 58 million units which do not take into account commercial automobiles in 2000. Figures by the Organization for Economic Cooperation and Development (OECD), the overall amount of cars in OECD nations were anticipated to rise by 32 percent from 1997 to 2020. Manufacturing of vehicle is fairly circulated between Europe, Asia and North and South America. Since 1998 over 14.5 million vehicles have been produced annually, with overall car manufacturing almost 17 million in 2002 (light commercial cars, trucks, passenger cars and buses). Available statistics shows that in 2001 more than 180 million units were in operation in the EU as compared to the 160 million in 1995. Over 80 percent of these vehicles were assembled in Germany, France, Spain, Italy and Great Britain. The rise in vehicle manufacturing and the use of statistics identifies the significance of the car manufacturing society. Nevertheless, that sector is confronted with series of serious problems connected in actual fact to its effect on the atmosphere. Automobiles have consequences on humanity via their whole life cycle. Problems such as using up of energy and resources, greenhouse gases, waste generation, hazardous substance emission and the dumping at the last part of their lives are challenges generated by vehicle manufacturing and use. [39]

2.4.5 Present ELV Reprocessing in the EU

Reprocessing of ELVs takes into account the recycling itself, reuse and recovery. The propelling force, method and process for reprocessing ELVs emanate from diverse reasons that have transformed with time. In this era globalization, reprocessing of ELV is urged not by technological and economic factors but in addition societal and concerns of the environment. This is to say that the vehicle sector is changing toward sustainable management of waste. Methods for recycling are connected to the equipments involved in the production of vehicle in addition to assembled parts. In recent years automobile constituents has been changing to materials which are light like polymeric components and aluminum. In the 1960s the overall mass of a European vehicle consisted almost 82 percent of ferrous and non-ferrous metals (2 percent aluminum) and 2% plastics whilst in the 80s the formation of ferrous and non-ferrous metals was around 74-75% with little over 4 percent aluminum whereas plastics were approximated at 8-10 % of weight of vehicles in Europe. The use of materials such as aluminum and plastics which are lighter enhanced the economization of fuel and decreased emissions. It is deemed that a 100kg weight decrease of automobile results in 0.7 L/100 km cutback in fuel. Instituting the use of lighter materials to cars also recompenses for rise in weight resulting from safety and modern comfortable features. The regular formation of vehicles in the EU depicts a rise in content of aluminum of 8% in the overall weight of automobile whereas the ferrous and non-ferrous metals account for nearly 67.5 percent of the car, and further shows that the use of plastics in average vehicles amount to 9.3 percent as the most common forms of and types of plastic used in their functions in the body of vehicles are polyvinyl chloride, polyurethane rubber, polypropylene to mention but only a few.

2.4.6 Expectations for ELV Recycling

Within the EU substantial strategies and agreements of voluntary nature by key vehicle producers have been established in relation to the environmental influence of automobiles over their life expectancy. Upon the directions of the European Parliament and of the council led to the organization of previous national strategies and agreement of voluntary nature. It was geared toward harmonizing these presented set of laws and to urge the EU governments and car sector to fully adhere to the directions and transform its major prerequisites into national legislation. [39]. A portion of the legislation states that by 2015, all end-of-life automobiles, the recuperation and reuse shall be raised to a least possible 95 percent by a standard weight of every car year and during the same time frame, the use again and reprocessing shall be augmented to a smallest possible percentage of 85 by a standard weight by automobile and year.

Waste avoidance, reprocessing, reuse and recovery of the ELV parts so as to minimize automobile shredder residue (ASR) waste disposal are the goals of the EU decree. The major player is the manufacturer, automobile producer or expert importer to a member state of the EU. The maker connects the main stream (supplier) and downward stream in the ELV sequence (collector, dismantler and shredder). According to the directive car manufactured has to meet at least the subsequent objectives, thus, low energy consumption, easy dismantling, suitable reprocessing and low toxic metals. In order to attain these objectives, the manufacturer has to have knowledge of technical and economical services, reprocessability rate and effectiveness of the ELV chain downstream. Subsequently, the manufacturer has to give information on dismantling for each innovative or new kind or form of automobile brought to the market. In order to considerably develop the support of the supplier – producer chain, cars should be aimed at appropriately for reprocessing, dismantling, reuse and free of some dangerous substances.

2.4.7 End of life vehicles in Finland

Finnish, an EU country has a well organized structure for the handling of ELVs and the Finnish Car Recycling Ltd is a so-called producer association, which coordinates the collection, treatment and recycling of end-of-life vehicles (ELVs) in accordance with the requirements laid down in the ELV Directive. The Parliament of Finland adopted Amendment 452/2004 to the Waste Act in June 4th 2004, which introduced producer responsibility to Finnish legislation. The Decree on End-of-Life Vehicles (581/2004) was adopted on 23 June 2004. These regulations enforced the ELV Directive (2000/53/EC) in Finland. The legislation came into force on 1 September 2004. The decree applies to passenger cars, vans and special vehicles such as recreational vehicles. There are currently 252 take-back points throughout the country for end users to send their cars in order to be given the certificate of destruction. The concept of car recycling has not been in Finland for long but can be seen from the table below that, it has grown tremendously because both the people and the laws takes it full course. A press release on the official site on 30th August 201, indicated a new record in car recycling in the month of July which represented a 28.6% year-on-year growth. A total of 6,859 vehicles, including 6,431 passenger cars, were scrapped in Finland in July. In 2011, recycling volumes have been increasing in other months, as well. A total of 33,937 vehicles have been scrapped in January–July 2011. The final owner of a vehicle has to do three main things in getting released of all responsibilities. Firstly, to choose the nearest take-back –point, to take car to take-back point and finally to obtain the certificate of destruction.

In Finland, the average scrapping age of passenger cars is 20.3 years, and the figure is growing each year the corresponding figure was 18.4 years in 2007. [32]

3 Methodology

A subject as new and or of no interest to the people was best handled with a qualitative interview and observations as there were not many facts and figures to support any given answers. On field trip were made to ascertain the reality and degree of the problem. A clearer picture of the where these waste ended up eventually was finally recovered through this survey. Four main questions formed the basis of the survey or interview. An interpretation has been made based on the data received from the interaction and observation made. There were a total of twenty five people forming the interview.

3.1 Obsservation

There were few visits to some automobile garages in order to have a practical experience of how waste was handled. There was no form of special collection for any waste. Everything was mixed up and empty car body frames were left at workshops without any attempt of recovery or recycling though few were re-assembled or recycled to other products. The metallic parts as they were used for cooking ports, coal ports or carrying carts. A night visit to the magazine showed flames from the garbage fires created a slight fear for the people as it was clear that poisonous substances were released into the human lungs. However, it was obviously clear in the day time that, most of the non-metallic parts like bumpers, rims, seats and tyres were re-used or stored in shops awaiting potential buyers. A visit to a spare parts shop in Accra, confirmed parts were sold to replace broken or old parts. The figure 35 below shows a spare parts shop with some head and tail lights, bumpers as well as switch and control boards all made of plastics or as a composite of them.

Figure 35: a picture of a spare parts shop, showing some plastic parts.

The pictures in figure 36 show some scenes from some mechanics shops visited. The seat has been in the vicinity for more than two years and remains to be there without any one identifying it as a source of energy or as a raw material for new seat.

Figure 36: Scenes from an automoble workshop in Mazagine

The figure below shows a land fill of automobile parts in Magazine. The serious aspect of it was that, there were children carrying both scrap metals, rims and other parts to the dump.

3.2 Interview

As stated earlier, the best way of finding better ways of handling automobile waste was to question people and interact with them. The issue of automobile waste is a broad field and does not cover only the plastic parts, but as this thesis is concerned, it was to do with only plastic parts.

3.2.1 The selection criteria

As recycling of plastic waste is a very new to the Ghanaian community, it was necessary to contact people who mattered or aim to become engineers in the automobile sector. It was therefore of importance to select people from the automobile workshops (mechanics), auto parts dealers, DVLA officials, car users, students (automobile and material science students) .

3.2.2 The process

The interview was more of informal interaction, there were no well organized meeting with the people as there was not enough days during the work practice to do it. Another underlying fact was that, most of these mechanics did not have any formal education so could not read and write. However, the little time and interaction was fruitful as the people were willing and ready to give answers and suggestions. The main questions in relation to this thesis were:

1. What materials make up a car?
2. How do we gather and handle waste from automobile?
3. How and whose is to take care of waste from cars?
4. How willing are you to welcome a move to handle plastic waste in automobile? (On a scale of 1 to 100%).

4 Results and Interpretation of interview and observation

After a careful interview and observations, data received were translated to a graph shown and explained below:

The first question was to enquire knowledge of plastics in cars.

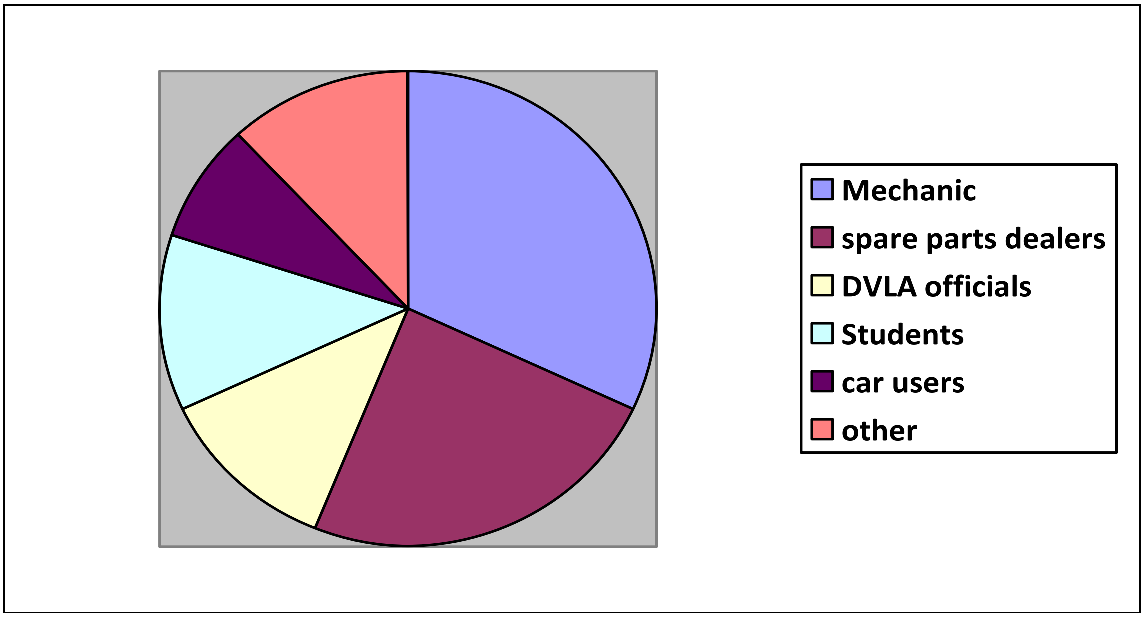

Figure 37: Area respondents represented.

The graph above shows that, mechanics, students and license authorities were certain there were plastic parts in cars though some were not sure of exactly which parts were of plastics, whereas car users did not nor had little idea of plastics in cars.

The second question was to find out if there was a need to take care of plastic waste and how to. All respondents were positive about taking care of waste though their only knowledge of managing them was to burn them except the students who thought they could be energy recovering or recycling, which they had apparently being taught. It was clear that, waste was understood from all participants as something that had to go to the dump. Re-use of parts were common but to them they were not waste parts but instead second goods rather than waste. Figures 37 and 38 below are representation of question two.

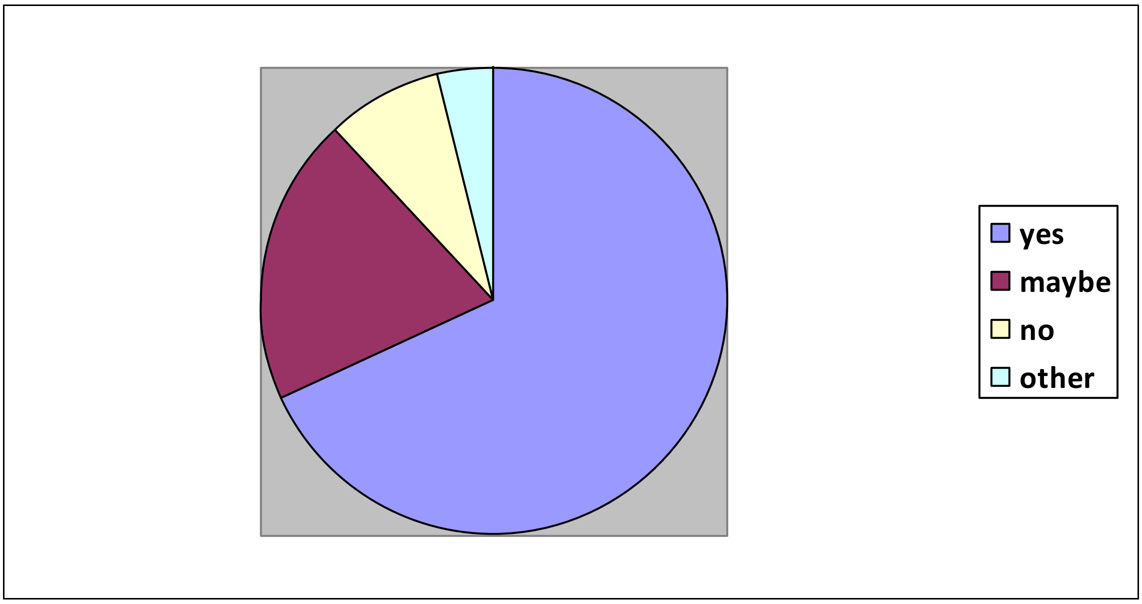

Figure 38: Reponses to the need to manage automobile plastic waste

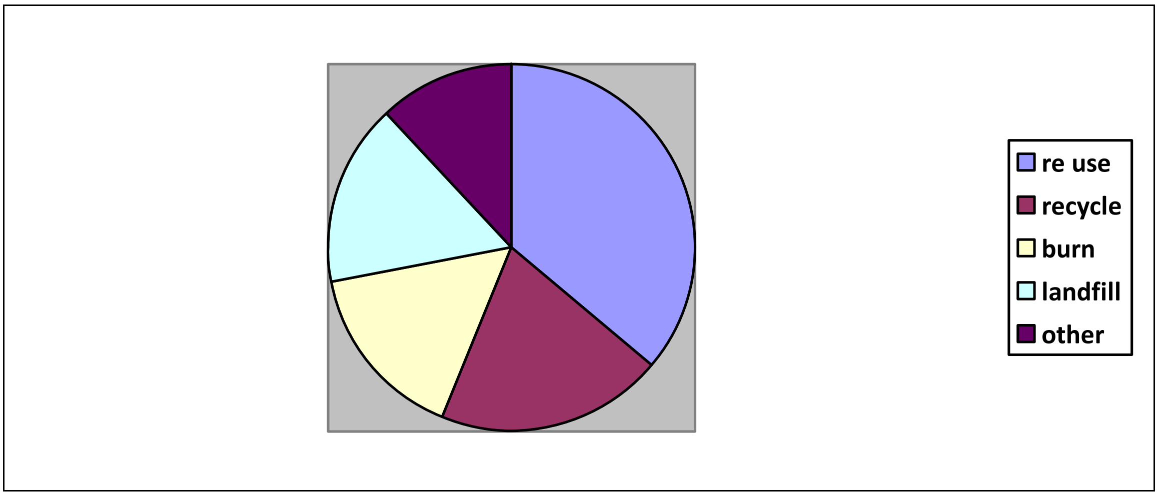

Figure 39: Possible suggestions given for managing plastic waste

The third and main issue was to do with how to gather the plastic waste from cars and whose responsibility it was. Respondents were of the view that, it was the duty of the government to take care of all waste since they were paying tax. However, there was a conflicting response from a student stating that all had to support to managing of waste.

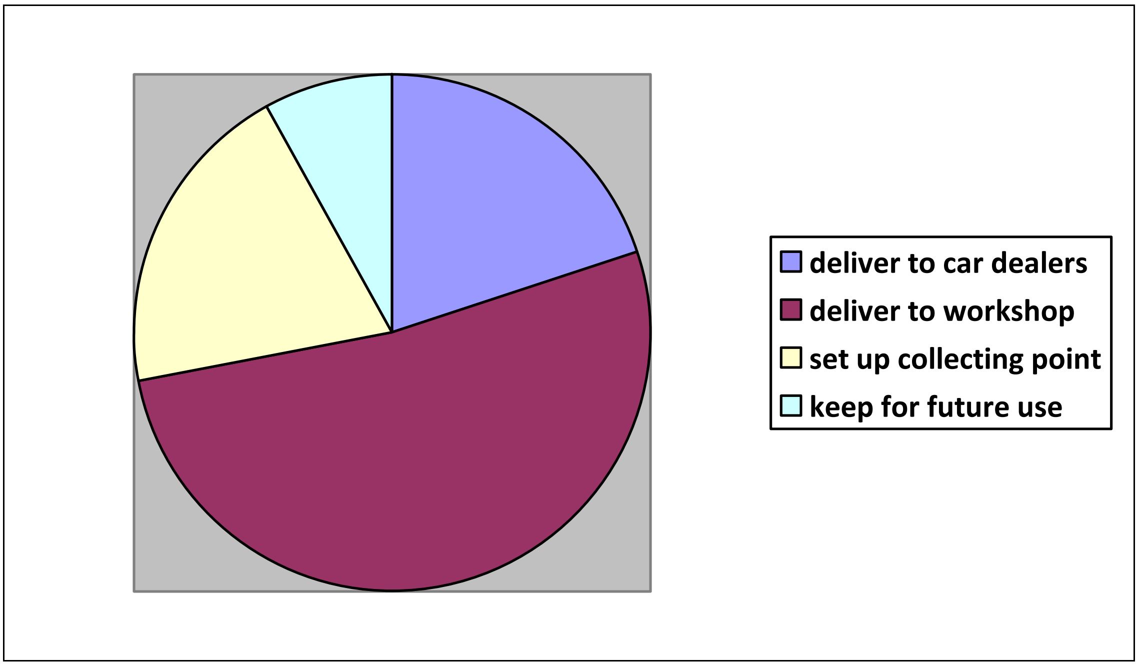

Figure 40: Possible answers for better ways for gathering plastic waste in automobiles

A final part of the questioning was to find out the willingness of how the people were willing to be involving themselves to the controlling and managing of automobile waste (plastics).

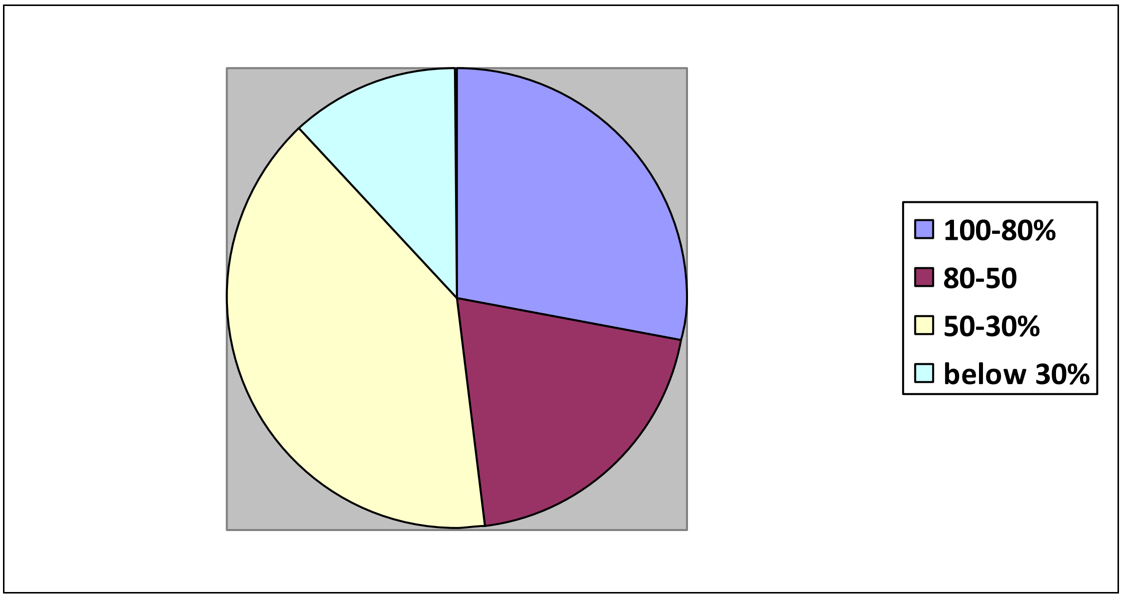

Figure 41: Williness off people toward plastic automobile waste management.

However, the observations showed the following:
The following methods were identified as the main means of handling automobile waste especially the plastics.
The following were identified as main ways of managing plastic automobile waste.

- Re-use – both old or broken parts were collected and use in same car or other cars. Broken parts are repaired to be used again either with welder or glue.
- Landfill (majority) - wastes are thrown to dump areas and are burnt periodically.

Parts such as bumpers, battery casing, head lights and wheel covers were mostly re-used or left to landfills if beyond repairs. A broken car tail light was welded or glued together to be reused or stored for a potential buyer.
It was also seen that, there were no organized set up recycling plant for cars parts especially the non-metal ones like plastics and rubbers. Instead, there is a great market

for these parts as there are no duplicate parts manufacturing company in Ghana as with the metals. The metal parts are machined, welded or screwed to make new parts or re-melted or assembled to make carrying carts, cooking ports, coal ports and other small parts for domestic or commercial use. The carrying carts are made with car axles and wooden boards. The image below show a self assembled carts made of axle, tyres, and wooden board and a coal port. there are also images of how they are used.

Figure 42: Representations of recycled and re-used automobile metal and tyres waste.

The results from the interview show that the people are willing to welcome any development on how to manage the waste that continue to be burnt almost every night, polluting the environment, but the lack of expertise and funds that can help run a recycling and or energy recovery company. The ministry of road and transport is responsible for automobiles and associating matters. A source from Toyota and Mercedes Benz (Silverstar) mentioned that, some amount of plastics is realized from their old cars which are ship to their manufacturing plants for recycling. The Kumasi and Accra metropolitan assemblies, spends lots of Ghanaian Cedi to get rid of abandoned cars which usually might have caused many fatal accidents already or serve as hide out for criminals.

5 Discussions

This thesis has shown that, there are better ways in which the Ghanaian community can control the amount of waste generated from automobile industry. The Ghanaian road is full of both old and modern cars. An average car in Ghana has a lifespan of about two decades before end of life. Road accidents, however, has been identified as the main factor that has brought most cars out of the road even before end of life. These cars are usually damaged beyond repairs and end up with parts removed leaving the body frame only. The cars are left unconcerned because no one cares about the remains simply because there are no laws governing the abandoned cars. Majority of accident or end of used cars are left in the automotive workshop with most repaired and the ones beyond repairs virtually left with just the chaises and frame.

In order to be able to handle automobile plastic waste, am attempt must be made to answer the following fundamental questions:

1. How long cars remain to be on road and how to get it off road after serving their useful time?
2. Who takes the responsibility of sending end of life cars for recycling and to where?
3. How will the sorting of plastic from other materials in the automobile be made?
4. How willing are car importers, repairer, engineers, end-users, government representative and all bodies concerned towards a move to manage the plastic waste in automobiles.
5. Who finance the managing of these waste and to which extent the nation will benefit?

The following could be said to be possible means of answering the above questions.
If compared to the European Union, a car serves for about twenty years before coming to end of life.

Most cars coming to Ghana are more than ten years thus a stipulated twenty years in addition will make it thirty years already. If and only if the Driver and Vehicle and license authority could be loyal to the road worthy rules, cars that do not pass test and fall beyond repairs could be mandated to be taken off-road.

Comparatively, the end user in the European Union is expected to take their cars to the recycling center, in order to have their deregistration certificate, thus, it could be applied in the Ghanaian context as this thesis compares Ghana to the EU directives.
The Government or the assembly must not incur the cost except in the cases of cars which have been involved in accident resulting in the death of owners.

The wiliness of the people could be high as there has already been some sort of campaign on plastic film waste. From the answers, received from mechanics at the Magazine shows they are ready to welcome any technology, infrastructure or finance in turning the plastic waste received into useful product.

The sorting of the parts can only be manually done in this case at least on the primary stage but there must be some sort of training for the people to sort them in the right way as plastics cannot be mixed for recycling except for energy recovery.

The cost of the recycling looks a bit debatable and will recommend a further discussion or studies as the benefit of recycling or reusing these plastic and how much volume there are will encourage anybody paying for it. However, companies who will be using these recycled parts could be paying a cost for the raw-material made from them and that means, there should be a ready market for them.
Another option would be for car dealers to export these parts as scraps to their manufacturing plants.

6 Conclusion

The concept of managing plastic waste to reduce automobile waste involves looks more in line with four parties; the dealer, engineer (mechanic), DVLA, and the end-user. However, how and the amount of plastic to be recovered is not clearly seen as there are not enough fact of end of life vehicles, in the system. There can only be reuse and recycling of plastics when there is ready market for it. The reuse has been seen as a better way of managing plastic waste, however, another method, and energy recovery could be included at this point when all these plastics could be burnt to recover energy. The fundamental aims of this thesis are given below with possible solutions and answers found.

a) Identify the disposal and management of cars plastics part after use.

The main way automobile plastics waste is been disposed in Ghana has been identified as re-using and land-filling.

b) Find out the effect plastic waste brings to the Ghanaian environment.

Automobile plastic wastes were identified to be polluting landfill and taking up lots of spaces like other plastic material.

c) Identify mesures of improving plastics waste management in the automotive sector, (end-of-life vehicle in accordance with European union deritives.)

A first step of improving the plastic waste in automobiles is to control the amount of imported parts into the country and instead re-used the old parts from end of life cars. Many car dealers import parts like bumpers, lights, dashbord to mention but a few in view of making profit but do not carefully consider how these parts will be disposed or managed after serving useful purposes.

Comparing the EU directives in solving automobile waste pointed out that the Ghanaian community is lucking out of three main methods of managing waste. The EU directives:

a) Reduction or prevention of waste generation
b) Reuse of the generated waste
c) Recycle of the generated waste into useful products of same or different kind

d) Recover energy from the plastic waste generated as plastics are petroleum based polycarbonates and have the potential of producing energy.
e) Landfills: The final option which all European countries are making effort to reduce to less than 5% by the year 2015 is the disposal of plastics waste in automobiles into landfills.

Energy recovery is a laudable idea as Ghana has recently discovered crude oil. These automobile plastics could be burnt with other plastics to generate energy for the plants in this area as Ghana's only source of electricity pose a trait.

d) Analysis the benefits of re-using or recycling of plastic waste in Ghana.

An effective and proper handling of plastic waste will benefit the Ghanaian society;

a) Socially

Socially, recycling plastics waste promotes tourism as most of the times potential tourist are scared from travelling to countries with high health hazards. Every country benefits from tourism as it boost a countries foreign exchange. Ghana as an African country will be able to limit the cost of curing malaria and diarrhea due to pollutions and contaminations.

b) Environmentally

The environment is safer with plastic waste recycling as the waste are made into new parts by reducing emission of harmful gases like carbon dioxide (CO_2) into the atmosphere. Natural resources are preserved when waste are re-cycled or re-use; as extracted raw material can be re-melted, grinded or molded into new forms. This phenomenon goes a long way to benefit the global world as gases know no boundary and petroleum globally will be reserved for the future if the little extracted are re-used or re-cycled again and again into new products.

c) Economically

Ghana as a nation that is undergoing development could create jobs for the ever growing unemployed labor by setting up recycling center. If automobile companies in the country could come together as the HDPE film producers have been able to do, in employing youths to collect film bags from the streets for a fee for each kilogram collected. There are many abandoned cars on the Ghanaian roads and bushes with plastic parts which can be reused or recycled into useful parts.

Figure 43: HDPE bags used for carrying bags and slippers (re-use).

These wastes bring air pollutions, greenhouse gas (GHGs) emissions which are harmful to both the human and natural ecosystem. The Ghanaians valuable resources are then not conserved.

The EU directive on End of life vehicles could and can improve the attitude of Ghanaian to a limited car waste abandonment if the governmental agencies like Ghana road and transport Agency could put up some of these to both private and commercial car importers. An article on EU Referendum highlights the idea of car manufactures to pay for disposal of private cars. One of the main reasons why people leave their cars without any care is that there are no laws or taxes paid for off-road cars not on roads, and even some cars on roads are not paying tax which does not help to check for old cars. That is to say there are unregistered cars on the roads. According to the article, car owners continue to pay licensing scheme and taxes until they have officially deregistered their cars from the system. Ghana or Africa in a way can be said to be a damping site for almost all the develop countries as most of accident and old cars are ship to be sold by their own citizens with the intention of making quick profit. These cars do not only pose as trait to the waste on the Ghanaian community but also as trait to human life as they give serious injuries in case of accident or even death. It would have been a great help from developed countries if they could restrict the cars that pass through their borders to such countries like Ghana. Finland for example has many cars sent to Africa when they have failed the yearly inspection. Though they cannot dictate to other countries, they could help limit the amount of these cars leaving the country depending on the level of damage. The end of the day it is the whole world being polluted not just Ghana or Africa. Ghana as a nation could set up a pilot project in the capital, Accra, where car owner would have to obtain a certificate of destruction from approved treatment center or Driver and Vehicle License Authority (DVLA), (responsible for issuing licenses). Most of the cars on the Ghanaian market are imported by individual so the directive for manufacturers to bear the cost of car disposal may not be applicable. However, these companies could ensure to set up shredding centers in at least the three big regions (Greater, Central and Ashanti regions) of the country where individuals could leave their old cars or parts for disposal. Most of the world car manufacturers like, BMW, Toyota, Mercedes (silver star), Volvo, Tata, Nissan and many more have service centers to sell and repair their cars but just few of them have plans for old cars that have come or yet to come to end of life.

The underlying factor is that the attitude of the people towards waste is a fundamental contributor to plastic waste in all sectors in Ghana. And until a better and comprehensive education has been given to the Ghanaians and with authorities ready to take up the responsibilities ought to be taken, the waste problem will persist. The End of Life Vehicle as shown from the European content shows a collective contribution from all levels from engineers to the consumer in helping to avoid waste. Ghana as a non-manufacturing automobile country really has less to do as the automobile plastic waste in Ghana is less as compared to the other manufacturing countries. Therefore trying to manage the waste generated will not be much of a problem.

Based on the finding and conclusions of this thesis, the following recommendations have been made.

6.1 Recommendations

After vigorous and comprehensive look at the subject matter with determination it was seen that Ghana as a nation will need to adapt to the recycling of plastic waste. This is taken on national, assembly, commercial dealers and individual dealers' levels as steps forward to control the landfills in Ghana. This thesis is to help Ghana as a growing nation to plan in advance before the problem of automobile waste will be on the rise. Soon the Ghanaian market will be full of manufacturing and assembling plants as the nation has just discovered petroleum.

6.1.1 On the national level:

The author recommends that, the plastics waste in cars are collected and recycled into newer parts or used as energy in the newly discovered oil in the central region of the country as the waste can be burnt with same grade plastics to recover energy. The nation must be prepared in the long term to have training program for students studying material science to further their studies in developed countries about starting, handling and maintaining a recycling plant or the recovering of energy from these waste. Based on my theological and practical knowledge, it can be said that plastics are not the worse and dangerous engineering material to human if and only if care and attention would be given to the waste generated by it.

At the end of this thesis, it can recommend that the ministry of roads and transport, driver and vehicle license authorities need to come to the drawing table to set up achievable objectives and plans to help the car dealers and private car owner in handling old and broken down cars especially the plastic parts.

Plastics saves life, saves energy and can be recycled would be my slogan for an education to the people.

6.1.2 The assembly level:

Teaching campaigns by the local governmental authorities like Accra and Kumasi metropolitan assemblies to their people will go a long way to help eradicate avoidable waste. It will take the effort of one man to get the whole nation to the realization of the potential in the tones of plastic waste left to landfills or on the road. The key to success is education and for lack of knowledge the people will perish, therefore it is essential that the nation makes conscious effort in the short term to educate her citizens.

6.1.3 The car dealers:

As the car companies in Ghana do not manufacture the parts of cars in Ghana, it will be worthwhile to reuse the old part from other cars instead of importing new parts in order to cut down cost and keep the exchange rate down. It will be of importance to have a pilot project with some car company to start rewarding private owners who bring their old plastic parts to be re-used or re-cycled.

6.1.4 Individual level:

A recommendation will be made that; the Ghanaian man will be ready to welcome the change with plastics. To have a safe and friendly society, all must help to take care of the waste generated. The author have on personal basis spoken to people the need to take care of plastics waste in Ghana last year during her practical training trip and hopes to do more of that as many times as the opportunity is given to travel back to Ghana. The Rome was not built in a day and it clear that, if all Ghanaians join in the campaign, it will pay off in the next decades for this thesis is more of the new generation cars that have been in existence for about ten years now.

There is hope for a safe and friendly environment if the little waste contributed by the automobile sector could be effectively managed and handled with care for their avoidance is not an option for now as plastics are gaining better grounds in automobiles due to their benefits mentioned earlier in chapters 1 and 2.

7 Refferences

1. .... Paul Nieuwenhuis, Peter E. Wells,2003)
2. [Online] Available http://www.ecologycenter.org/iptf/plasticinhistory.html [accessed; MAY 2011]
3. [Online] Available http://www.plastics-car.com/Todays-Automobiles/Auto-Interior/default.aspx; American Chemistry council .updated: 2010, [accessed19.
4. (Mapleston P., Plastic engineering journal. May 2008 Wiley Publisher)
5. graph 1: Material content of automobiles in 1998. [Online] Available http://www.greenvehicledisposal.com/environment/recyclable-materials/ [accessed 19.05.2011]
6. [Online] associates of plastics manufacturing in Europe.AMPE a Technical and Environmental center. Available http://www.docstoc.com/docs/80890696/Summary-report-on-Recovery-options-for-plastic-parts-from-end-of) [accessed; 19.05.2011]
7. [online] Available 2011 http://plastics.sabic.eu/technical/_media/polypropylenes_solutions_for_automotive_demands.pdf) update Jul 2005,[accessed; on 17Nov]
8. [Online] Available http://zhongyamould.com/Auto-Moulds/Auto-Bumper-Mould/Auto-Bumper-Mould-09.html [Accessed; 19.05.2011]
9. Society of Plastics Engineers International (SPE),Availablehttp://www.directcarparts.co.uk/product/393/indus/ring-indus-car-wheel-trims.htm [accessed19.05.2011]
10. [online]: http://www.reinforcedplastics.com/view/23643/michelman-carbon-fibre-sizing-offers-high-thermal-stability/ [accessed ; 15.03.2012]
11. [online] Available http://www.shopreckartperformancetuning.com/GM-LS6-Intake-Manifold_p_128.html#) [accessed ;17.Nov.2011]
12. [Online] Available http://polymerics.tripod.com/vs.htm
13. [On line] Available http://www.ets-corp.com/tradenames/pb.htm [accessed; 13th April 2011]

    Aetna Plastic corporation;

14. [Online] http://www.aetnaplastics.com/products/IndustrialPlastics/) http://www.bpf.co.uk/Innovation/Automotive.aspx [accessed; 13th April 2011,]
15. (Eaves, D., Handbook of polymer forms.2004, Smithers Rapra: Shrewsbury,GBR)
16. (American chemistry council Inc.2011)
17. (Tripathi,D., Practical guide to Polypropylene.2002. published by Smithers Rapra: Shrewsbury,GBR)
18. (Singh, Jagdamba; Dubey, R.C. 2009, Organic Polymer Chemistry.Meerut, IND: Global Media, p 133.)
19. [Online] Available http://www.inchem.org/documents/cicads/cicads/cicad39.htm [accessed; 29.03.2012]
20. http://chemistry.about.com/od/factsstructures/ig/Chemical-Structures---B/1-3-Butadiene.htm [accessed; 29.03.2012]
21. (Strong,A Brent. 2006, 3rd edition. , Plastics and Material processing,. Peason Prentice hall. p 255)
22. . (Brydson, Plastics Materials, Butterworths, 1989)
23. [Online] Available http://pslc.ws/macrog/ppo.htm) [accessed on 25.02.2012]
24. Margolis, James M. 2005, Engineering Plastics Handbook. Blacklick, OH, USA: McGraw-Hill Professional Publishing, p 132-150.)
25. ‘[Online] http://www.lenntech.com/polyvinyl-chloride-pvc.htm [accessed; 08.02.12]
26. [Online] Available http://recycleitproperly.wordpress.com [accessed; 19.03.2011]
27. [Online] Available http://www.richmaloof.com/TV-e-waste [accessed; 19.03.2012]
28. http://www.flightglobal.com/news/articles/aviation-industry-under-pressure-to-reduce-landfill-waste-from-scrapped [accessed; 15.03.2012]
29. [Online] Available http://www.admc.hct.ac.ae/hd1/english/process/proc_battery_ans.htm [accessed; 15.03.2012]

30. [Online] Available http://www.ljmu.ac.uk/Sustainability/84944.htm [Accesssed;15.03.2012]
31. [Online] Available http://www.green.uts.edu.au/initiatives/recycling/wastestreams/general-waste.html [Accessed; 30.03.2012]
32. [Online] Available http://www.autokierratys.fi/en/index.php?go=56;56;0;; [accessed; 03.01.2012]
33. [Online] Available http://www.businessguideghana.com/?p=3997 [accessed; 11 Nov.2011]
34. [Online] Available http://scp.eionet.europa.eu/definitions/elv) Updated; 2nd May,2005[Accessed 17 Nov,2011]
35. [Online] Available http://www.greenvehicledisposal.com/about/why-end-of-life/ [Accessed;18.10.2011]
36. [Online] Available http://www.tms.org/pubs/journals/jom/0308/kanari-0308.htmlA [Accessed; 10.08.2011]
37. [Online] Available (http://www.3-r.co.jp/contents/en/index.html) [Accessed; 15.03.2012]
38. (Mi, C., Masrur, M. A. & Gao, D.W. 2011. Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives. Sussex, John Wiley)
39. Kanari, N., Pineau, J.-L., & Shallari, S. 2003. Exploring traditional,Innovative and Revolutionary Issues in the Minerals, Metals and Materials Fields
40. [Online] Available (http://www.ghanabooksjwp.com/apps/photos/photo?photoid=113429022); [Accessed; 12.05.2012]
41. [Online] Available (http://news.bbc.co.uk/2/hi/programmes/from_our_own_correspondent/7450064.stm) [Accessed; 15.03.2012]
42. Lardinois, I. and Van de Klundert, A. 1995. Plastic Waste Options for Small-Scale Resource Recovery, Tool Publications, Amsterdam.(Online)